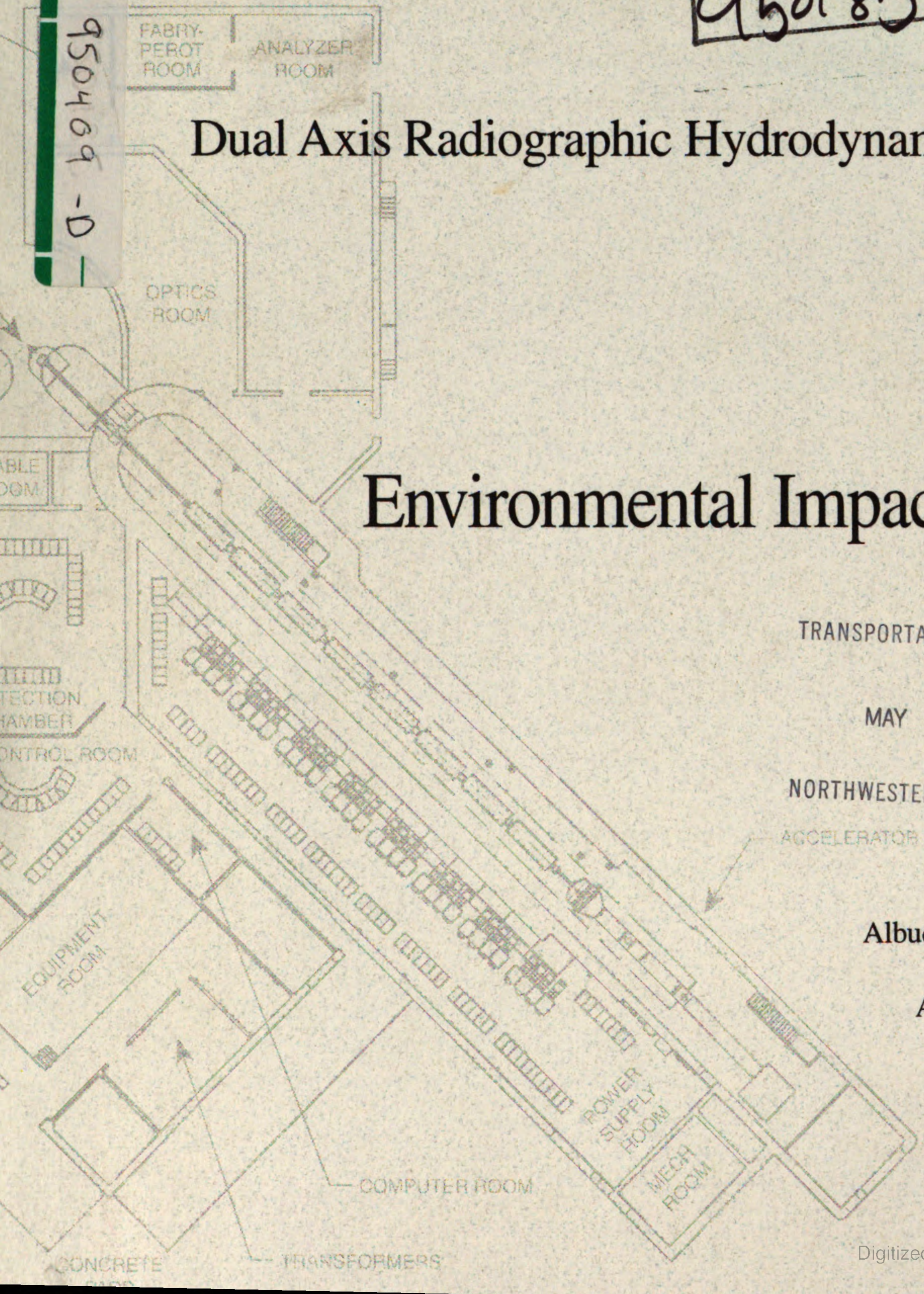
DOE/EIS-0228D

Dual Axis Radiographic Hydrodynamic Test Facility



Draft Environmental Impact Statement

Department of Energy
Albuquerque Operations Office
Los Alamos Area Office
Albuquerque, New Mexico

Los Alamos National Laboratory

Los Alamos National Laboratory (LANL) is a research and technology development facility of the Department of Energy (DOE), operated under contract by the University of California.

DOE coordinates and administers the energy functions of the Federal government. Among other things, DOE is responsible for the nuclear weapons program, research and development of energy technologies, and basic science research.

The origin of DOE and LANL was the Army's Manhattan Engineer District formed in August 1942. Known as the Manhattan Project, this organization developed the original laboratory and production facilities, including LANL, that created the nuclear weapons used in World War II. In 1946 the Atomic Energy Commission (AEC) assumed these responsibilities. In 1974 part of the AEC functions were transferred to the Energy Research and Development Administration (ERDA); in 1977 the DOE was formed from ERDA and other organizations.

LANL was established in 1943 to provide research, design, and testing of nuclear weapons and nuclear materials. Along with Lawrence Livermore National Laboratory in Livermore, California, and Sandia National Laboratories headquartered in Albuquerque, New Mexico, LANL remains one of the three research laboratories in the DOE nuclear weapons complex.

Over the past 50 years, LANL's mission has expanded to include research in energy, materials science, nuclear safeguards and security, biomedical science, computational science, environmental protection and cleanup, and other basic science research. In addition to work done in support of DOE programs, LANL provides research and science services for other Federal agencies, universities, foreign countries, and private industry.

LANL is one of the largest multiprogram research laboratories in the world with an annual budget of about $1 billion and employs about 10,000 contractor and subcontractor personnel. LANL is located in north-central New Mexico and covers about 43 square miles of Federal land in Los Alamos and Santa Fe counties.

The DOE Assistant Secretary for Defense Programs is responsible for policy, planning, and managing the DOE nuclear weapons complex, including research, experiments, and technology development work for nuclear weapons. The DOE Los Alamos Area Office and its parent Albuquerque Operations Office provide oversight of LANL operations.

DOE/EIS-0228D

Dual Axis Radiographic Hydrodynamic Test Facility

Draft
Environmental Impact Statement

Department of Energ
Albuquerque Operations Offic
Los Alamos Area Offic
Albuquerque, New Mexic

May 19

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COVER SHEET

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

TITLE:
Draft Environmental Impact Statement (DEIS), Dual Axis Radiographic Hydrodynamic Test DARHT) Facility (DOE/EIS-0228/D)

CONTACT:
For further information on this document, write or call:

Ms. M. Diana Webb, DARHT EIS Document Manager
U.S. Department of Energy
Los Alamos Area Office
528 35th Street
Los Alamos, New Mexico 87544
Telephone: (505) 665-6353
Fax: (505) 665-1506

Ms. Carol M. Borgstrom, Director
Office of NEPA Oversight (EH-25)
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:
DOE proposes to provide enhanced high-resolution radiographic capability for hydrodynamic tests and dynamic experiments to meet its mission to conduct a science-based stockpile stewardship program for the Nation's nuclear weapons. The DARHT Facility would include two electron accelerators to produce x-ray beams that intersect at a firing point. This document evaluates the potential environmental impacts of six alternatives: **No Action** (continue to operate the 30-year-old Pulsed High Energy Radiation Machine Emitting X-Rays (PHERMEX) at Los Alamos National Laboratories (LANL) and the Flash X-Ray at Lawrence Livermore National Laboratory; **Preferred Alternative** (complete and operate the DARHT Facility at LANL); **Upgrade PHERMEX** (upgrade PHERMEX with enhanced radiography technology instead of completing the DARHT Facility); **Enhanced Containment** (in addition to containing all experiments involving plutonium, enclose most or all experiments inside a containment vessel or structure); **Plutonium Exclusion** (exclude any applications involving experiments with plutonium at the DARHT Facility); and **Single-Axis** (complete and operate only a single axis of the DARHT Facility). The affected environment is primarily within LANL. Analyses indicate very little difference in the environmental impacts among the alternatives. The major discriminator would be contamination of soils near the firing points, health effects to workers, and amount of construction materials.

PUBLIC COMMENTS:
Comments on this Draft Environmental Impact Statement may be submitted during the public comment period, which extends through June 26, 1995, by writing to Ms. Webb at the above address, or by directing a telephone call or facsimile message at the numbers indicated. Comments may also be submitted at public meetings during the comment period. DOE will consider these public comments in its preparation of the Final Environmental Impact Statement.

Department of Energy
Washington, DC 20585
APR 2 8 1995

Dear Reader:

This is your copy of the draft Dual Axis Radiographic Hydrodynamic Test (DARHT) facility Environmental Impact Statement (EIS). The EIS analyzes the environmental impacts that might occur if the Department of Energy (DOE) were to complete and operate the proposed DARHT facility at the Department's Los Alamos National Laboratory (LANL) in New Mexico. The impacts which might occur from this proposal are weighed against the impacts of continuing to operate the Pulsed High Energy Radiation Machine Emitting X-Rays (PHERMEX) hydrodynamic testing facility at LANL. The Flash-X-Ray hydrodynamic testing facility at the Lawrence Livermore National Laboratory in California is also discussed. The draft EIS also analyzes four other alternative means to operate the DARHT or PHERMEX facilities.

We are asking you to review this draft and provide us with your comments. You may correct factual errors, if any, or share your ideas on how to improve any other aspect of this environmental review. We will use your comments to help us prepare the final version of this EIS. To be considered in preparing the final EIS, your comments must be postmarked by the date shown on the following page, although we will consider late comments to the extent possible. Comments are invited from the State, Native American tribal governments, local governments, other Federal agencies, and the general public.

We will be conducting two public hearings, one in Los Alamos and one in Santa Fe, where you may provide spoken comments or present written material. The dates, times, and locations of those public hearings are shown on the enclosed sheet. The meetings will use a workshop format and will provide opportunities for information exchange and open discussion as well as submitting prepared statements.

For additional copies of this document or for more information on this environmental review, please contact Diana Webb, DARHT EIS Project Manager, US DOE, 528 35th Street, Los Alamos, NM 87544, telephone (505) 665-6353, facsimile (505) 665-1506. Thank you for your interest in the DARHT EIS review process. We look forward to your continued participation.

Sincerely,

for

Victor H. Reis
Assistant Secretary
for Defense Programs

Enclosure

DUAL AXIS RADIOGRAPHIC HYDRODYNAMIC TEST (DARHT) FACILITY
ENVIRONMENTAL IMPACT STATEMENT (EIS)

DRAFT DARHT EIS PUBLIC COMMENT PERIOD

The Department of Energy invites comments on the draft DARHT EIS from the State, Native American tribal governments, local governments, other Federal agencies, and the general public. Comments may correct factual errors, if any, or share ideas on how to improve any other aspect of this environmental review. The Department will use the comments received to help prepare the final version of this EIS.

Comments must be postmarked by Monday, June 26, 1995.

Late comments will be considered to the extent possible.

Written comments should be sent to:

Diana Webb
DARHT EIS Project Manager
Los Alamos Area Office
U.S. Department of Energy
528 35th Street
Los Alamos, NM 87544
(505) 665-6353

Or fax comments to Ms. Webb at:

Facsimile (505) 665-1506

The Department will be conducting two public hearings to receive spoken or written comments. The meetings will use a workshop format and will provide opportunities for information exchange and open discussion as well as submitting prepared statements.

LOS ALAMOS PUBLIC HEARING
Wednesday, May 31, 1995
2:00 p.m. to 4:00 p.m. and 6:30 p.m. to 9:00 p.m.
Los Alamos Inn, 2201 Trinity Drive, Los Alamos, NM
(505) 662-7211

SANTA FE PUBLIC HEARING
Thursday, June 1, 1995
2:00 p.m. to 4:00 p.m. and 6:30 p.m. to 9:00 p.m.
High Mesa Inn, 3347 Cerrillos Road, Santa Fe, NM
(505) 473-2800

Executive Summary

EXECUTIVE SUMMARY

The U.S. Department of Energy (DOE) proposes to provide enhanced high-resolution radiography capability for the purpose of performing hydrodynamic tests and dynamic experiments in support of the Department's historical mission and near-term stewardship of the nuclear weapons stockpile. This Environmental Impact Statement (EIS) analyzes the environmental consequences of alternative ways to accomplish the proposed action. The DOE's preferred alternative for accomplishing the proposed action would be to complete and operate the Dual Axis Radiographic Hydrodynamic Test Facility (DARHT) at Los Alamos National Laboratory (LANL) in New Mexico. DOE has issued this draft EIS for review and invites comments from the State of New Mexico, affected American Indian tribes, county governments, other Federal agencies, and the general public.

PURPOSE AND NEED

DOE is responsible for ensuring that U.S. nuclear weapons remain safe, secure, and reliable. The DOE program that responds to the President's challenge to ensure confidence in the nuclear weapons stockpile in the absence of nuclear testing is science-based stockpile stewardship. This program plays a crucial role in accurately and effectively assessing the continued safety, performance, and reliability of nuclear weapons as they age.

> President Clinton, in the National Security Strategy, July 1994, stated:
>
> - "Even with the Cold War over, our nation must ... deter diverse threats."
> - "We will retain strategic nuclear forces sufficient to deter any future hostile foreign leadership ... Therefore we will continue to maintain nuclear forces of sufficient size and capability to hold at risk a broad range of assets valued by such political and military leaders."
> - "A critical priority for the United States is to stem the proliferation of nuclear weapons and other weapons of mass destruction and their missile delivery systems."

Hydrodynamic tests and dynamic experiments are essential elements of the evaluation and understanding of weapon performance under the science-based stockpile stewardship program. Dynamic experiments are used to gain information on the physical properties and dynamic behavior of materials used in nuclear weapons. Hydrodynamic tests are used to obtain diagnostic information on the behavior of a nuclear weapon primary and to evaluate the effects of aging on weapons. These tests are performed on mock-ups of nuclear weapons and do not result in nuclear detonation or nuclear yield.

DOE needs to improve its capability to perform radiographic hydrodynamic testing and dynamic experiments as soon as possible. Enhanced radiographic capability is needed to produce high-speed, high-resolution, deeply penetrating images to diagnose the condition and behavior of nuclear weapons. Uncertainty in the performance of the enduring stockpile will continue to increase with the passage of time, and DOE can no longer use nuclear testing to assess the safety, performance, and reliability of the weapons. DOE has determined that no other currently available advanced techniques exist which can provide a level of information comparable to that which can be obtained from enhanced radiographic hydrodynamic testing. Also, DOE needs to maintain or improve its radiographic testing capability to support other science missions.

Along with other stockpile stewardship responsibilities, DOE has assigned a hydrodynamic testing mission to its two nuclear weapons physics laboratories, LANL and Lawrence Livermore National Laboratory (LLNL). The Pulsed High Energy Radiation Machine Emitting X-Rays (PHERMEX) is the existing radiographic hydrodynamic testing facility at LANL and the Flash X-Ray (FXR) is the existing radiographic hydrodynamic testing facility at LLNL.

PHERMEX has been in continuous operation since 1963. In addition to major, full-scale hydrodynamic tests, PHERMEX is used for smaller types of experiments. Although PHERMEX was state of the art when it was designed, it is no longer adequate. It cannot provide the degree of resolution, depth of penetration, rapid time sequencing, or three-dimensional views that are needed to provide answers to current questions regarding weapons condition or performance.

FXR has been in continuous operation since 1983; it is DOE's most advanced radiographic hydrodynamic testing facility. At the time it was constructed, it represented a great improvement in capability over PHERMEX. However, FXR cannot provide the degree of resolution, depth of penetration, or three-dimensional views needed to address current questions. Additionally, DOE does not perform dynamic experiments with plutonium at LLNL. Neither PHERMEX nor FXR is adequate to provide the enhanced radiographic hydrodynamic testing capability that DOE now needs in the absence of nuclear testing.

DOE plans two other National Environmental Policy Act (NEPA) reviews regarding proposed actions at LANL related to the Dual Axis Radiographic Hydrodynamic Test (DARHT) Facility environmental impact statement (EIS) – the *LANL Sitewide Environmental Impact Statement* (SWEIS) and the *Stockpile Stewardship and Management Programmatic Environmental Impact Statement* (PEIS).

EIS	NOI	Draft EIS	Final EIS	ROD
DARHT EIS	Nov 94	May 95	Aug 95	Sep 95
LANL SWEIS	May 95	Apr 96	Dec 96	Mar 97
SS&M PEIS	Jun 95	Feb 96	Jul 96	Sep 96

Note: Dates are subject to change.

PROPOSED ACTION AND ALTERNATIVES

DOE is proposing to provide enhanced high-resolution radiographic capability to perform hydrodynamic tests and dynamic experiments in support of the Department's historical mission and near-term stewardship of the nuclear weapons stockpile. This EIS analyzes the following alternatives:

- **No Action Alternative:** DOE would continue to use PHERMEX at LANL and the FXR at LLNL in support of its stockpile stewardship mission. Construction of the DARHT Facility would not be completed although the building would be completed for other uses. DOE would perform some dynamic experiments; those using plutonium would be conducted in containment vessels.
- **Preferred Alternative:** DOE would complete and operate the DARHT Facility and phase out operations at PHERMEX. DOE may delay operation of the second axis of DARHT until the

accelerator equipment in the first axis is tested and proven. DOE would perform some dynamic experiments; those using plutonium would be conducted in containment vessels.

- **Upgrade PHERMEX Alternative:** Construction of the DARHT Facility would not be completed although the building would be completed and put to other uses. Major upgrades would be constructed at PHERMEX, and the high-resolution radiographic technology planned for DARHT would be installed at PHERMEX, including a second accelerator for two-axis imaging. DOE would perform some dynamic experiments; those involving plutonium would be conducted in containment vessels.
- **Enhanced Containment Alternative:** Similar to the Preferred Alternative except that most or all tests would be conducted in a containment vessel or containment structure. Most tests, including all dynamic experiments with plutonium, would be contained if containment vessels were used. All tests would be contained if a containment structure were used.
- **Plutonium Exclusion Alternative:** Similar to the Preferred Alternative except that plutonium would not be used in any of the experiments at DARHT. DOE would perform some dynamic experiments with plutonium at PHERMEX or other facilities.
- **Single-Axis Alternative:** Similar to the Preferred Alternative except that only one accelerator hall at DARHT would be completed and operated for hydrodynamic or dynamic experiments. The other hall would be completed for other uses.

AFFECTED ENVIRONMENT

LANL occupies an area of approximately 28,000 ac (11,300 ha) on the Pajarito Plateau, in Los Alamos County in north central New Mexico. The alternatives analyzed (including no action) would all occur within Area III of Technical Area 15 situated in the south central portion of LANL, an area that has been dedicated to high explosives testing for over 50 years. The PHERMEX site and the DARHT site are about 1/2 mi apart and are ecologically similar, set in a ponderosa pine plant community. The only discriminators between the two sites are resources that are point-specific, such as specific archeological sites or specific existing facilities.

ENVIRONMENTAL CONSEQUENCES

The analyses in this EIS indicate that there would be very little difference in the environmental impacts among the alternatives analyzed. The major discriminator among alternatives would be potential impacts from depleted uranium contamination to soils, which would be substantially less under the Enhanced Containment Alternative, and commitments of construction materials, which would be substantially greater under the Upgrade PHERMEX alternative. Also, there is a projected increase in the calculated worker dose from radioactive materials under the Enhanced Containment Alternative. This is a result of calculating the potential release in this alternative as a ground-level release, whereas the potential release in the other alternatives is calculated as an elevated release. Table S-1 presents a comparison of the environmental consequences for the six alternatives analyzed in this EIS based on the assessments contained in Chapter 5 of this DEIS. The table provides direct comparisons of expected consequences for each environmental factor across the alternatives.

REGULATORY REQUIREMENTS

DOE has obtained operating permits for PHERMEX and the DARHT Facility (Preferred Alternative). Permit modifications may be needed depending on the course of action selected in the Record of Decision.

DOE is in the process of consulting with Federal, State and Tribal agencies regarding wildlife habitat, threatened and endangered species, cultural resources protection, and other laws pertaining to Native American traditional use of land and resources. DOE does not expect any adverse effects to natural and cultural resources.

TABLE S-1.—*Summary of the Potential Environmental Impacts of the Alternatives*

Factor, Measure	No Action	Preferred Alternative	Upgrade PHERMEX Alternative	Enhanced Containment Alternative	Plutonium Exclusion Alternative	Single-Axis Alternative
Land Resources						
Acreage committed						
PHERMEX	11 ac	11 ac	11 ac	11 ac	11 ac	11 ac
DARHT (including RSL)	8 ac	8 ac	8 ac	9[a] ac	8 ac	8 ac
Air Quality						
Maximum percent of standard[b]						
NO_2	0.76	3.3	3.3	3.3	3.3	3.3
PM_{10}	2.1	12	12	12	12	12
SO_2	3.3×10^{-3}	2.2	2.2	2.2	2.2	2.2
Be	4.9×10^{-2}	4.9×10^{-2}	4.9×10^{-2}	3.3	4.9×10^{-2}	4.9×10^{-2}
Heavy Metal	5.3×10^{-3}	5.3×10^{-3}	5.3×10^{-3}	2.5	5.3×10^{-3}	5.3×10^{-3}
Lead	1.8×10^{-3}	1.8×10^{-3}	1.8×10^{-3}	2.7×10^{-3}	1.8×10^{-3}	1.8×10^{-3}
Noise (qualitative)	Possible nuisance	Possible nuisance	Possible nuisance	Nuisance unlikely	Possible nuisance	Possible nuisance
Water Resources						
Depleted uranium contamination, % Drinking Water Standards (after millennia)	<10%	<10%	<10%	<1%	<10%	<10%
Soils						
Depleted uranium contamination area	15 ac	15 ac	15 ac	15 ac	15 ac	15 ac
Max. concentration (approx.)	9,000 ppm	5,000 ppm	9,000 ppm	300 ppm	5,000 ppm	5,000 ppm
Biotic Resources						
Habitat reduction[c]	None	None	None	1 ac	None	None
Disturbance by noise	Some	Some	Some	~80% reduction	Some	Some

[a] Includes 1 ac (0.4 ha) for the recycling facility

[b] The values presented here represent the maximum pollutant concentrations as a percent of the respective standard. These values are reported in chapter 5 as impacts from either fugitive dust or emissions from construction equipment, the natural gas boiler or hydrodynamic testing.

[c] Habitat reduction refers to the change of habitat to another use. Only the Enhanced Containment Alternative would result in an additional use of land for the recycling facility (see footnote a).

[d] The calculated socioeconomic impacts are derived using PHERMEX operation figures as a baseline. Thus, under standard modeling procedures there are no additional impacts calculated.

[e] V = containment vessel scenario; B = containment building scenario

TABLE S-1.—*Summary of the Potential Environmental Impacts of the Alternatives – Continued*

Factor, Measure	No Action	Preferred Alternative	Upgrade PHERMEX Alternative	Enhanced Containment Alternative	Plutonium Exclusion Alternative	Single-Axis Alternative
Cultural Resources (qualitative)	None	If mitigated, None	None	None	If mitigated, None	If mitigatad, None
Socioeconomics						
Employment	—[d]	169 FTE	139 FTE	326 FTE (V)[e] 217 FTE (B)	169 FTE	87 FTE
Regional labor	—[d]	$ 3.6 million	$ 3.3 million	$ 6.9 million (V) $ 4.6 million (B)	$ 3.6 million	$ 1.8 million
Regional goods and services	—[d]	$ 6.2 million	$ 5.5 million	$ 12 million (V) $ 7.8 million (B)	$ 6.2 million	$ 3.3 million
Human Health						
Public (30-yr life of project)						
MEI Dose	7×10^{-4} rem	7×10^{-4} rem	7×10^{-4} rem	5×10^{-4} rem	7×10^{-4} rem	7×10^{-4} rem
Population dose	30 person-rem	30 person-rem	30 person-rem	13 person-rem (V) 8 person-rem (B)	30 person-rem	30 person-rem
Latent cancer fatalities	None	None	None	None	None	None
Workers (30-yr life of project)						
Average Dose	0.3 rem	0.3 rem	0.3 rem	0.6 rem	0.3 rem	0.3 rem
Collective dose	9 person-rem	9 person-rem	9 person-rem	60 person-rem	9 person-rem	9 person-rem
Latent cancer fatalities	None	None	None	None	None	None
Facility Accidents						
Involved workers, worst case explosion related fatalities	15	15	15	15	15	15
Public dose	6×10^{-4} rem	6×10^{-4} rem	6×10^{-4} rem	1×10^{-2} (V) rem 1×10^{-3} (B) rem	6×10^{-4} rem	6×10^{-4} rem
Latent cancer fatalities	None	None	None	None	None	None

[a] Includes 1 ac (0.4 ha) for the recycling facility
[b] The values presented here represent the maximum pollutant concentrations as a percent of the respective standard. These values are reported in chapter 5 as impacts from either fugitive dust or emissions from construction equipment, the natural gas boiler or hydrodynamic testing.
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[e] V = containment vessel scenario; B = containment building scenario

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c Habitat reduction refers to the change of habitat to another use. Only the Enhanced Containment Alternative would result in an additional use of land for the recycling facility (see footnote a).
d The calculated socioeconomic impacts are derived using PHERMEX operation figures as a baseline. Thus, under standard modeling procedures there are no additional impacts calculated.
e V = containment vessel scenario; B = containment building scenario

DARHT DEIS

TABLE S-1.—*Summary of the Potential Environmental Impacts of the Alternatives – Continued*

Factor, Measure	No Action	Preferred Alternative	Upgrade PHERMEX Alternative	Enhanced Containment Alternative	Plutonium Exclusion Alternative	Single-Axis Alternative
Transportation						
30-yr Worker dose	0.004 rem	0.004 rem	0.004 rem	0.004 rem	0.004 rem	0.004 rem
30-yr Public dose	3 x 10^{-9} person-rem	3 x 10^{-9} person-rem	3 x 10^{-9} person-rem	3 x 10^{-9} person-rem	3 x 10^{-9} person-rem	3 x 10^{-9} person-rem
30-yr Latent cancer fatalities	None	None	None	None	None	None
Unavoidable Adverse Impacts	See soils	See soils	See soils	See soils	See soils	See soils
Irreversible and/or Irretrievable Commitment of Resources						
Construction						
Concrete	15,000 yd^3	15,000 yd^3	28,000 yd^3	16,000 yd^3 (V) 22,000 yd^3 (B)	15,000 yd^3	15,000 yd^3
Diesel fuel	9,500 gal	11,500 gal	17,000 gal	12,500 gal (V) 18,200 gal (B)	11,500 gal	11,500 gal
Electricity	365 MWh	365 MWh	750 MWh	365 MWh (V) 450 MWh (B)	365 MWh	365 MWh
Operations						
Depleted uranium	1,540 lb/yr	1,540 lb/yr	1,540 lb/yr	90 lb/yr	1,540 lb/yr	1,540 lb/yr
Natural gas	8,700 ft^3/yr	10,400 ft^3/yr	13,000 ft^3/yr	13,300 ft^3/yr (V) 14,800 ft^3/yr (B)	10,400 ft^3/yr	10,400 ft^3/yr
Electricity	550 MWh/yr	2,250 MWh/yr	2,500 MWh/yr	2,800 MWh/yr (V) 2,900 MWh/yr (B)	2,250 MWh/yr	1,350 MWh/yr
Long-term Productivity (qualitative)	None	None	None	None	None	None

[a] Includes 1 ac (0.4 ha) for the recycling facility
[b] The values presented here represent the maximum pollutant concentrations as a percent of the respective standard. These values are reported in chapter 5 as impacts from either fugitive dust or emissions from construction equipment, the natural gas boiler or hydrodynamic testing.
[c] Habitat reduction refers to the change of habitat to another use. Only the Enhanced Containment Alternative would result in an additional use of land for the recycling facility (see footnote a).
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Helpful Information

Acronyms, Abbreviations, Conversions

ACRONYMS AND ABBREVIATIONS

ac	acre
ACO	Access Control Office
AHF	Advanced Hydrotest Facility
AIANAFP	American Indian and Alaska Native Area
ADM	action description memorandum
Am	americium
AMAD	activity median aerodynamic diameter
As	arsenic
Ba	barium
Be	beryllium
BEA	Bureau of Economic Analysis
CEQ	Council on Environmental Quality
CETC	Contained Explosives Test Complex
CFR	Code of Federal Regulations
CHIEF	Clearinghouse Inventory of Emission Factors
Ci	curie
Ci/g	curie per gram
cm	centimeter
cm^2	square centimeter
Co	cobalt
CO	carbon monoxide
CO_2	carbon dioxide
CPS	current population survey
Cr	chromium
Cs	cesium
Cu	copper
CX	categorical exclusion
D&D	decontamination and decommissioning
DAC	derived air concentrations
DARHT	Dual Axis Radiographic Hydrodynamic Test Facility, proposed to be operated at LANL
dB	decibel
dBA	A-weighted decibel
DCG	derived concentration guides
DFAIC	DARHT Feasibility Assessment Independent Consultants
DNAA	delayed neutron activation analysis
DOD	U.S. Department of Defense
DOE	U.S. Department of Energy
DOE/AL	DOE/Albuquerque Operations Office
DOL	U.S. Department of Labor
dose	unless otherwise specified, means effective dose equivalent
DOT	U.S. Department of Transportation
DU	depleted uranium
DX	dynamic experimentation
EDE	effective dose equivalent
EES	earth and environmental science
EIS	environmental impact statement

EM	environmental management
EPA	U.S. Environmental Protection Agency
ES	economic sectors
F	fluorine
Fe	iron
ft	foot
ft^2	square foot
ft^3/min	cubic feet per minute
ft^3	cubic foot
ft^3/s	cubic feet per second
FIPS	Federal Information Procedures System
FTE	full time equivalent personnel
FXR	Flash X-Ray Facility (located at LLNL)
FY	fiscal year
g/L	grams per liter
g	gram
G	acceleration due to gravity (seismology)
gal	gallon
gal/mo	gallon per month
gal/d-ft^2	gallons per day per square foot
gal/d-ft	gallons per day per foot
gal/min	gallons per minute
gal/min-ft	gallons per minute per foot
H-3	tritium
ha	hectare
HE	high explosive
He-Ne laser	helium-neon laser
HEPA	high-efficiency particulate air (filter)
HFS	hydrotest firing site
HI	hazard index
HMX	cyclotetramethylenetetranitramine
HNO_3	nitric acid
HPAIC	Hydrotest Program Assessment Independent Consultants
HTO	tritiated water
HVAC	heating, ventilation, and air conditioning
I	iodine
ICRP	International Commission on Radiological Protection
in	inch
in^2	square inch
in^3	cubic inch
INAA	instrument neutron activation analysis
ITS	Integrated Test Stand
kg/m^2	kilograms per square meter
kg	kilogram
kg/yr	kilograms per year
kJ	kilo Joule
km/h	kilometers per hour
km	kilometer

km^2	square kilometers
kPa	kilopascal
kV	kilovolt
kW	kilowatt
kWh	kilowatthour
kWh/gross ft^2	kilowatthour per gross square foot
kWh/gross m^2	kilowatthour per gross square meter
L	liter
LAMPF	Los Alamos Meson Physics Facility
LAAO	Los Alamos Area Office
lb	pound
lb/yr	pounds per year
lb/in^2	pounds per square inch
LCF	latent cancer fatalities
LiH	lithium hydride
LLNL	Lawrence Livermore National Laboratory
LLW	low-level radioactive waste
m	meter
m^2	square meter
m^3/s	cubic meters per second
m^3	cubic meter
MCL	maximum contaminant level
MEI	maximally exposed individual
MeV	million electron volt
mg	milligram
mg/L	milligram per liter
mi	mile
mi/h	miles per hour
mi^2	square miles
micron	micrometer (10^{-6} meter)
mL	milliliter
mrem	millirem (1/1000 rem)
mrem\yr	millirem per year
MSDS	material safety data sheets
MTF	memorandum to file
mV	millivolt
NA	not applicable
NAAQS	National Ambient Air Quality Standards
nCi/L	nanocurie per liter
NCRP	National Council on Radiation Protection and Measurements
Nd:YAG laser	neodymium:yttrium aluminum garnet laser
NEPA	National Environmental Policy Act
NESHAP	National Emission Standards for Hazardous Air Pollutants
ng/dry g	nanograms per gram of dry sample weight
ng/m^3	nanograms per cubic meter
Ni	nickel
NIPA	national income and product accounts
NMDGF	New Mexico Department of Game and Fish
NMED	New Mexico Environment Department

NO_2	nitrogen dioxide
NOI	notice of intent
NPDES	National Pollutant Discharge Elimination System
NRHP	National Register of Historic Places
nsec	nanosecond
NTS	Nevada Test Site
NTU	nominal turbidity units
ODS	ozone depleting substances
OSHA	Occupational Safety and Health Act or Occupational Safety and Health Administration
OU	operable unit
P	phosphorus
Pb	lead
PCB	polychlorinated biphenyls
pCi/dry g	picocuries per gram of dry sample
pCi/L	picocuries per liter
pCi/mL	picocuries per milliliter
PDL	public dose limit
PEIS	programmatic environmental impact statement
person-rem	unit collective population dose
PETN	pentaerythritoltetranitrate
PFS	PHERMEX Firing Site
pg/m^3	picograms per cubic meter
PHERMEX	Pulsed High Energy Radiation Machine Emitting X-Rays Facility (located at LANL)
PM	particulate matter
ppb	parts per billion
PPE	personal protective equipment
ppm	parts per million
Pu	plutonium
R/pulse	roentgen per pulse
R	roentgen
rad	unit of absorbed dose
RCRA	Resource Conservation and Recovery Act
RDX	cyclotrimethylenetrinitramine
rem/yr	common unit of effective dose equivalent rate
RF	radio frequency
ROD	Record of Decision
ROI	region-of-interest
RPC	regional purchasing coefficient
RSL	Radiographic Support Laboratory, located at LANL
Se	selenium
SF_6	sulfur hexaflouride
SIC	Standard Industrial Classification
SO_2	sulfur dioxide
Sr	strontium
SST	safe secure transports
SVOC	semivolatile organic compound
SVR	standard visual range
SWEIS	site-wide environmental impact statement

Ta	tantalum
TA	technical area
TATB	triaminotrinitrobenzene
TCLP	Toxicity Characteristics Leaching Procedure
Th	thorium
Tl	thallium
TLD	thermoluminescent dosimeters
TLV	threshold limit value
TNT	trinitrotoluene
TU	tritium units
U	uranium
USFWS	United States Fish and Wildlife Service
V	vanadium
W	tungsten
WCFS	Woodward-Clyde Federal Services
yd^3	cubic yard
yr	year

MEASUREMENTS AND CONVERSIONS

The following information is provided to assist the reader in understanding certain concepts in the environmental impact statement (EIS). Definitions of technical terms can be found in the Glossary.

Units of Measurement

The primary units used in this report are English with metric equivalents enclosed in parentheses. Table MC-1 summarizes and defines the terms for units of measure and corresponding symbols found throughout this report.

Radioactivity Units

Much of this report deals with levels of radioactivity in various environmental media. Radioactivity is a property; the amount of a radioactive material is usually expressed as "activity" in curies (Ci) (Table MC-2). The curie is the basic unit used to describe the amount of substance present, and concentrations are generally expressed in terms of curies per unit mass or volume. One curie is equivalent to 37 billion disintegrations per second or is a quantity of any radionuclide that decays at the rate of 37 billion disintegrations per second. Disintegrations generally include emissions of alpha or beta particles, gamma radiation, or combinations of these.

Radiation Dose Units

The amount of ionizing radiation energy received by a living organism is expressed in terms of radiation dose. Radiation dose in this report is usually written in terms of effective dose equivalent and reported numerically in units of rem (Table MC-3). Rem is a term that relates ionizing radiation and biological effect or risk. A dose of 1 millirem (0.001 rem) has a biological effect similar to the dose received from about a 1-day exposure to natural background radiation. A list of the radionuclides discussed in this document and their half-lives is included in Table MC-4.

Conversion Table

Multiply	By	To Obtain	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
acres	0.405	ha	ha	2.47	acres
mi^2	2.59	km^2	km^2	0.386	mi^2
ft^3	0.028	m^3	m^3	35.7	ft^3
nCi	0.001	pCi	pCi	1,000	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
ppb	0.001	ppm	ppm	1,000	ppb
°F	(°F - 32) ÷ 9/5	°C	°C	(°C x 9/5) + 32	°F
g	0.035	oz	oz	28.349	g

TABLE MC-1. —*Names and Symbols for Units of Measure*

Length

Symbol	Name
cm	centimeter (1 x 10^{-2} m)
ft	foot
in	inch
km	kilometer (1 x 10^{3} m)
m	meter
mi	mile
mm	millimeter (1 x 10^{-3} m)
µm	micrometer (1 x 10^{-6} m)

Time

Symbol	Name
d	day
h	hour
min	minute
nsec	nanosecond
s	second
yr	year

Area

Symbol	Name
ac	acre (640 mi^2)
cm^2	square centimeter
ft^2	square foot
ha	hectare (1 x 10^4 m^2)
in^2	square inch
km^2	square kilometer
mi^2	square mile

Volume

Symbol	Name
cm^3	cubic centimeter
ft^3	cubic foot
gal	gallon
in^3	cubic inch
L	liter
m^3	cubic meter
mL	milliliter (1 x 10^{-3} L)
ppb	parts per billion
ppm	parts per million
yd^3	cubic yard

Rate

Symbol	Name
cm^3/s	cubic meters per second
ft^3/s	cubic feet per second
ft^3/min	cubic feet per minute
gpm	gallons per minute
km/h	kilometers per hour
mi/h	miles per hour

Mass

Symbol	Name
g	gram
kg	kilogram (1 x 10^3 g)
mg	milligram (1 x 10^{-3} g)
µg	microgram (1 x 10^{-6} g)
ng	nanogram (1 x 10^{-9} g)
lb	pound
ton	ton (1 x 10^6 g)

Temperature

Symbol	Name
°C	degrees Centigrade
°F	degrees Fahrenheit
K	Kelvin

Sound

Symbol	Name
dB	decibel
dBA	A-weighted decibel

TABLE MC-2.—*Names and Symbols for Units of Radioactivity*

Radioactivity

Symbol	Name
Ci	curie
cpm	counts per minute
mCi	millicurie (1 x 10^{-3} Ci)
µCi	microcurie (1 x 10^{-6} Ci)
nCi	nanocurie (1 x 10^{-9} Ci)
pCi	picocurie (1 x 10^{-12} Ci)

TABLE MC-3.—*Names and Symbols for Units of Radiation Dose*

Radiation Dose

Symbol	Name
mrad	millirad (1 x 10^{-3} rad)
mrem	millirem (1 x 10^{-3} rem)
R	roentgen
mR	milliroentgen (1 x 10^{-3} R)
µR	microroentgen (1 x 10^{-6} R)

TABLE MC-4.—*Radionuclide Nomenclature*

Symbol	Radionuclide	Half-Life	Symbol	Radionuclide	Half-Life
Am-241	americium-241	432 yr	Pu-239	plutonium-239	2.4×10^4 yr
H-3	tritium	12.3 yr	Pu-240	plutonium-240	6.5×10^3 yr
Pa-234m	protactinium-234	1.17 min	Pu-241	plutonium-241	14.4 yr
Pa-234	protactinium-234	6.7 h	Th-231	thorium-231	25.5 h
Pu-236	plutonium-236	2.9 yr	Th-234	thorium-234	24.1 d
Pu-242	plutonium-242	3.8×10^5 yr	U-234	uranium-234	2.4×10^5 yr
Pu-244	plutonium-244	8.2×10^7 yr	U-235	uranium-235	7×10^8 yr
Pu-238	plutonium-238	87.7 yr	U-238	uranium-238	4.5×10^9 yr

Elemental and Chemical Constituent Nomenclature

Symbol	Constituent	Symbol	Constituent
Ag	silver	Pa	protactinium
Al	aluminum	Pb	lead
B	boron	Pu	plutonium
Be	beryllium	SF_6	sulfur hexafluoride
CO	carbon monoxide	Si	silicon
CO_2	carbon dioxide	SO_2	sulfur dioxide
Cu	copper	Ta	tantalum
F^-	fluoride	Th	thorium
Fe	iron	Ti	titanium
N	nitrogen	U	uranium
Ni	nickel	V	vanadium
NO_2^-	nitrite	W	tungsten
NO_3^-	nitrate	Zn	zinc

Numerical Relationships

Symbol	Meaning
<	less than
≤	less than or equal to
>	greater than
≥	greater than or equal to

Chapter 1
Introduction

CHAPTER 1
INTRODUCTION

This chapter outlines the environmental review for the Dual Axis Radiographic Hydrodynamic Test (DARHT) Facility environmental impact statement (EIS).

1.1 OVERVIEW

The United States Department of Energy (DOE) proposes to provide enhanced high-resolution radiography capability to perform hydrodynamic tests and dynamic experiments in support of its historical mission and near-term stewardship of the nuclear weapons stockpile. This EIS analyzes the environmental impacts of alternative ways to accomplish the proposed action. The DOE's preferred alternative would be to complete and operate the DARHT Facility at its Los Alamos National Laboratory (LANL) in northern New Mexico. An artists' concept of the Preferred Alternative is shown in figure 1-1.

This EIS has a classified supplement that provides additional information and analysis. Although the details of a nuclear weapon are classified, figure 1-2 provides an unclassified summary of a nuclear weapon.

DOE began the preliminary design for DARHT in the early 1980s and conducted a series of environmental reviews for the project between 1982 and 1989. DOE concluded that no significant environmental impact should result from constructing and operating the facility. Funding for DARHT was authorized and appropriated by Congress in 1988. Construction of the DARHT Radiographic Support Laboratory began in 1988 and was completed in 1990.

IMPORTANT TERMINOLOGY

Science-based Stockpile Stewardship – The DOE program to develop a new approach, based on scientific understanding and expert judgement, to ensure continued confidence in the safety, performance, and reliability of the nuclear weapons stockpile. This new approach is needed because DOE anticipates that nuclear testing will no longer be used to assess the condition of nuclear weapons.

Dynamic Experiment – An experiment to provide information regarding changes in materials under conditions caused by the detonation of high explosives.

Hydrodynamic Test – A dynamic, integrated systems test of a mock-up nuclear package (figure 1-2) during which the high explosives are detonated and the resulting motions and reactions of materials and components are observed and measured. The explosively generated high pressures and temperatures cause some of the materials to behave hydraulically (like a fluid).

Hydrodynamic Testing Facility – A facility in which to conduct dynamic and hydrodynamic testing for nuclear and conventional weapons research and assessment. Fast diagnostic systems that are available include radiographic, electrical, optical, laser, and microwave. The testing can provide both two- and three-dimensional information for performance evaluation.

Enhanced Radiography – A capability for producing extremely high resolution, time-phased, photographic images of an opaque object by transmitting a beam of x-rays (or gamma rays) through it onto an adjacent photographic film; the image(s) results from variations in thickness, density, and chemical composition of the object.

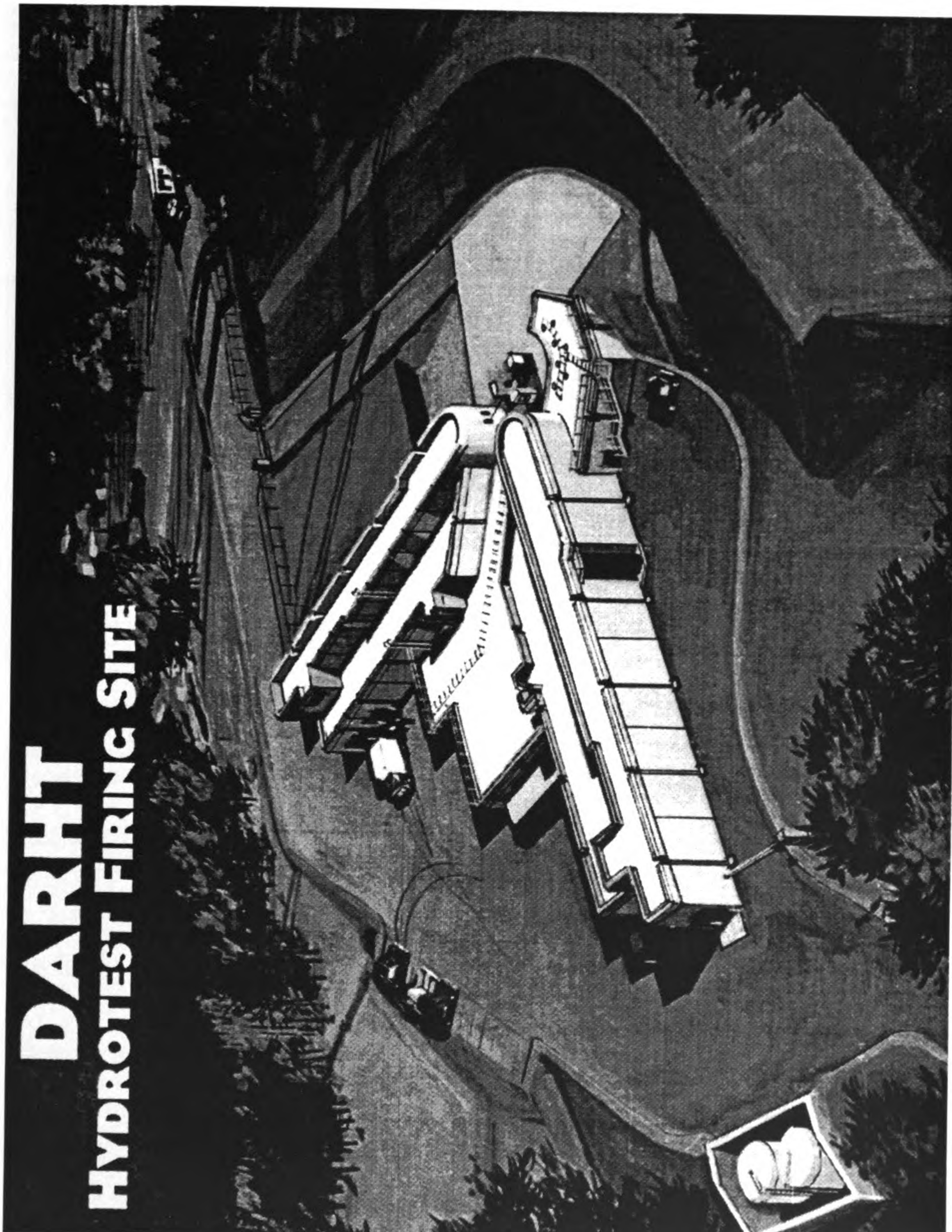
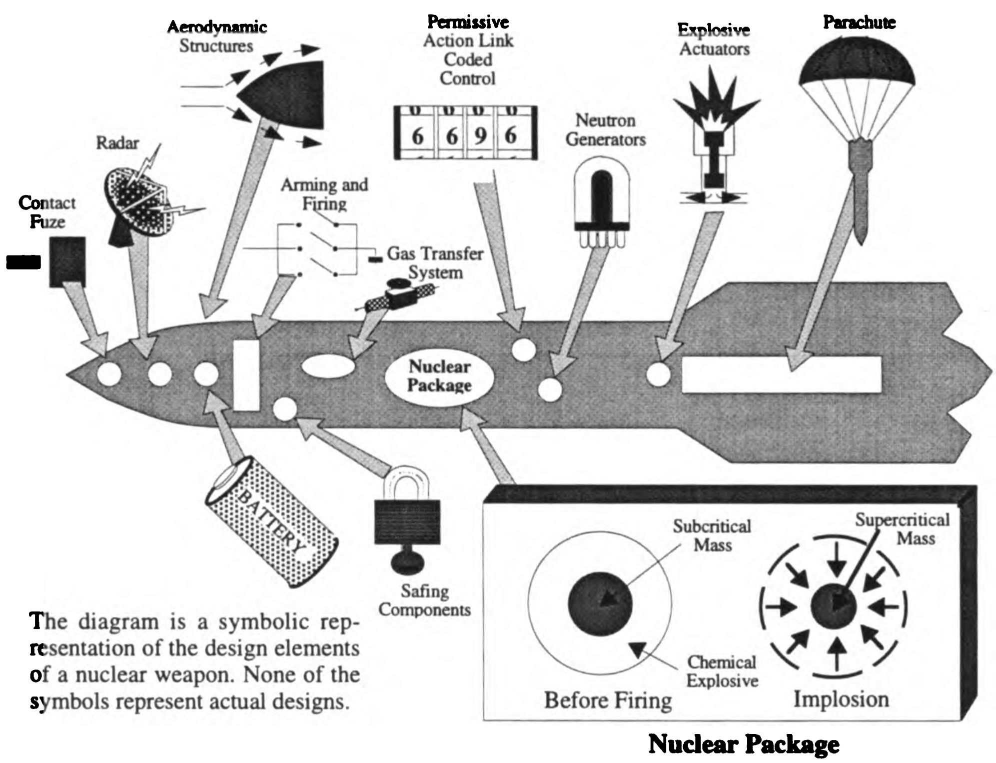


FIGURE 1-1.—*Architectural Rendering of the DARHT Facility.*

Nuclear explosions are produced by initiating and sustaining nuclear chain reactions in highly compressed material which can undergo both fission and fusion reactions. Modern strategic, and most tactical, nuclear weapons use a nuclear package with two assemblies: the primary assembly, which is used as the initial source of energy, and the secondary assembly, which provides additional explosive energy release. The primary assembly contains a central core, called the "pit," which is surrounded by a layer of high explosive. The "pit" is typically composed of plutonium-239 and/or highly enriched uranium (HEU), and other materials. HEU contains large fractions of the isotope uranium-235.



Primary Detonation

The primary nuclear explosion is initiated by detonating the layer of chemical high explosive that surrounds the "pit", which, in turn, drives the pit material into a compressed mass at the center of the primary assembly. This implosion process is illustrated in the inset of the diagram.

Boosting

In order to achieve higher explosive yields from primaries with relatively small quantities of pit material, a technique called "boosting" is used. Boosting is accomplished by injecting a mixture of tritium (T) and deuterium (D) gas into the pit. The deuterium and tritium are stored in high-pressure reservoirs until the gas transfer system is initiated. The implosion of the pit, along with the onset of the fissioning process, heats the D-T mixture to the point that the D-T atoms undergo fusion. The fusion reaction produces large quantities of very high energy neutrons which flow through the compressed pit material and produce additional fission reactions.

Secondary Activation

The energy released by the primary explosion activates the secondary assembly. The secondary assembly is composed of lithium deuteride and other materials. As the secondary implodes, the lithium, in the isotopic form lithium-6, is converted to tritium by neutron interactions, and the tritium product in turn undergoes fusion with the deuterium to create the thermonuclear explosion.

Nonnuclear Components

Nonnuclear components include contact fuzes, radar components, aerodynamic structures, arming and firing systems, gas transfer systems, permissive action link coded controls, neutron generators, explosive actuators, safing components, batteries, and parachutes.

FIGURE 1-2.—*Nuclear Weapons Design.*

In 1993, DOE decided to fund the accelerator and x-ray equipment for the second axis of DARHT under a separate budget line item. Construction of the DARHT firing-site facility began in April 1994.

In October 1994, three citizen groups wrote to the Secretary of Energy asking, among other things, that DOE prepare an EIS on the DARHT Facility. They also asked that further construction of the facility be halted until an EIS was completed. On November 16, 1994, two of these groups (the Los Alamos Study Group and the Concerned Citizens for Nuclear Safety) filed a lawsuit in U.S. District Court, Albuquerque, New Mexico, to enjoin DOE from proceeding with the DARHT project until completion of the EIS and issuance of the Record of Decision (ROD). On November 22, 1994, DOE published a Federal Register notice of its intent to prepare this DARHT EIS [59 FR 60134]; see appendix A. On January 27, 1995, the court issued a preliminary injunction enjoining DOE from further construction of the DARHT Facility and related activities, such as procuring special facility equipment, pending completion of this EIS and the related ROD. Figure 1-3 is a photograph of the DARHT site, showing construction, taken in January 1995. No further construction work has taken place.

Preparing an EIS at this time responds to public concern and allows for a full dialogue between DOE and the State, Tribal, county, and municipal governments; other Federal agencies; and the general public. The EIS will also provide the basis for appropriate mitigation measures if they are needed for the course of action selected.

1.2 ORGANIZATION OF THIS EIS

This EIS consists of six primary chapters.

- **Chapter 1 – Introduction**: DARHT background and the environmental analysis process.
- **Chapter 2 – Purpose and Need**: reasons why DOE needs to take action at this time.
- **Chapter 3 – Proposed Action and Alternatives**: the way DOE proposes to meet the specified need and alternative ways the specified need could be met. Includes a summary of expected environmental impacts if the Preferred Alternative or any of the other analyzed alternatives were to be implemented.
- **Chapter 4 – Affected Environment**: aspects of the human environment (natural, built, and social) that might be affected by the Preferred Alternative or one of the other alternatives.
- **Chapter 5 – Environmental Consequences**: comparative analyses of the changes or impacts that the Preferred Alternative or one of the other alternatives would be expected to have on the affected elements of the human environment. Impacts are compared to the human environment that would be expected to exist if no action were taken (the No Action Alternative).
- **Chapter 6 – Regulatory Requirements**: agencies and individuals consulted, and environmental regulations that would apply if the Preferred Alternative or one of the other alternatives were to be implemented.

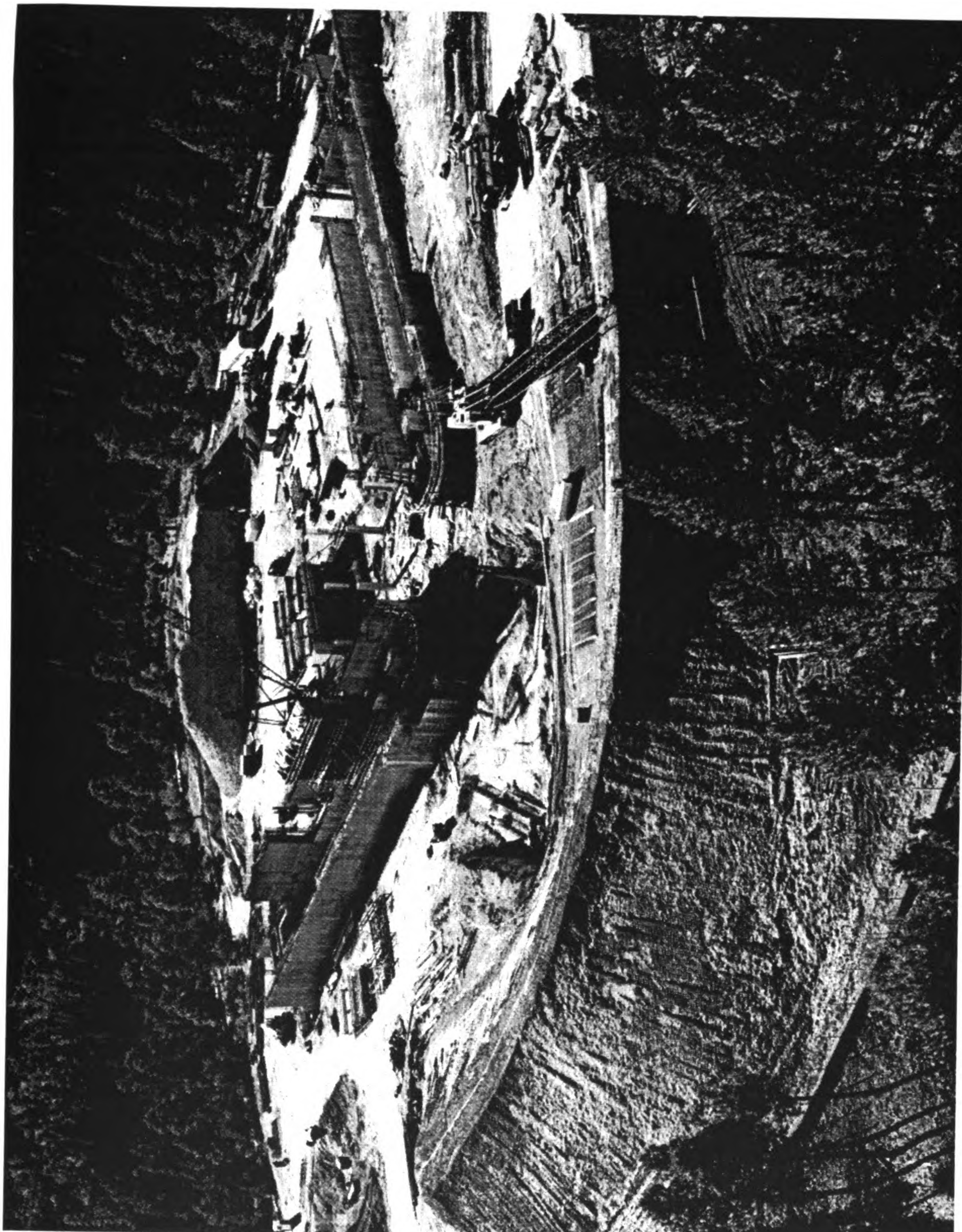


FIGURE 1-3.—*Aerial View of the DARHT Facility Construction Site, as of January 1995.*

1.3 ALTERNATIVES ANALYZED

This EIS analyzes the environmental impacts associated with constructing and operating a facility that would provide the needed enhanced capability for hydrodynamic testing and dynamic experiments. Radiographic hydrodynamic testing is now conducted in two existing facilities within the DOE complex – the Pulsed High Energy Radiation Machine Emitting X-Rays (PHERMEX) Facility at LANL and the Flash X-Ray (FXR) Facility at Lawrence Livermore National Laboratory (LLNL) in California. The potential impacts of five operational alternatives also are analyzed in the EIS and compared to the expected impacts of the No Action Alternative (see box). DOE considered, but did not analyze, several other alternatives (see section 3.10).

The Proposed Action

Provide enhanced high-resolution radiography capability to perform hydrodynamic tests and dynamic experiments.

DARHT EIS Alternatives

- **No Action:** Continue to operate PHERMEX at LANL and FXR at LLNL.
- **Preferred Alternative:** Complete and operate the DARHT Facility at LANL.
- **Upgrade PHERMEX:** Upgrade PHERMEX with the enhanced radiography technology instead of completing the DARHT Facility.
- **Enhanced Containment:** In addition to containing all experiments involving plutonium, enclose many or all experiments inside a containment vessel or containment structure.
- **Plutonium Exclusion:** Exclude any applications involving experiments with plutonium at the DARHT Facility.
- **Single-Axis:** Complete and operate only a single axis of the DARHT Facility.

1.4 LAWS AND REGULATIONS

This EIS is being prepared pursuant to the National Environmental Policy Act of 1969 (NEPA) [42 U.S.C. 4321 *et seq.*], the Council on Environmental Quality NEPA regulations [40 CFR 1500–1508], and the DOE NEPA regulations [10 CFR 1021].

1.5 INVITATION TO COMMENT

This draft EIS is being distributed to congressional members and committees; the State of New Mexico; the Tribal governments of Cochiti, Jemez, Santa Clara, and San Ildefonso Pueblos; Los Alamos, Rio Arriba, and Santa Fe county governments; other Federal agencies; and the general public for review and comment. DOE invites comments to correct factual errors or to provide insights on any other matter related to this environmental analysis. In addition to its invitation for written comments, DOE has scheduled public hearings to solicit spoken and written comments on the draft EIS. The dates for the formal/written public comment period, as well as the dates, times, and locations for public hearings on this draft EIS, are listed in the front of this document.

1.6 NEXT STEPS

After considering the comments received, DOE will revise the draft EIS as appropriate and publish a final EIS. The final EIS will be distributed to the State, Tribes, local governments, and other Federal agencies; all parties who commented on the draft EIS; and any other interested party. DOE intends to publish all comments received and a full comment response; however, if the number of comments proves to be too voluminous, DOE may publish only a comment summary in the final EIS. In that case, all comments and a full comment response would be available for public review in the LANL Community Reading Room and other locations.

Following completion of the final EIS (but at least 30 days after the final EIS is issued), the DOE Assistant Secretary for Defense Programs will issue a ROD. The ROD will explain all factors, including environmental impacts, that DOE considered in reaching its decision (see inside back cover). The ROD will specify the alternative or alternatives which are considered to be environmentally preferable. DOE anticipates that, in addition to environmental impacts, the ROD will be based on cost, national security, and infrastructure considerations. If mitigation measures, monitoring, or other conditions are adopted as part of the agency's decision, these will be summarized in the ROD as applicable, and included in a Mitigation Action Plan that would accompany the ROD. The Mitigation Action Plan would explain how and when mitigation measures would be implemented, and how DOE would monitor the mitigation measures over time to judge their effectiveness. The ROD and Mitigation Action Plan, if needed, also will be placed in the LANL Community Reading Room and will be available to interested parties upon request.

Chapter 2

Purpose and Need for DOE Action

CHAPTER 2
PURPOSE AND NEED FOR DOE ACTION

This chapter specifies the underlying purpose and need for the Proposed Action.

2.1 OVERVIEW

The Department of Energy (DOE) is responsible for ensuring that U.S. nuclear weapons remain safe, secure, and reliable. Although the details of nuclear weapons design are classified, figure 1-2 provides an unclassified summary of the parts of a nuclear weapon. Recent events and changes in U.S. policy that have affected the DOE need for hydrodynamic tests and dynamic experiments are summarized in the box. The discussion in this chapter is augmented by the classified supplement for this Environmental Impact Statement.

Date	Event/Policy Change
September 1991	President made the first of three announcements on significant reductions in the nuclear weapons stockpile.
September 1992	DOE performed last underground nuclear test.
October 1992	President signed nine-month moratorium stopping all nuclear testing until July 1993.
July 1993	President announced extension of moratorium on underground nuclear testing. Directed DOE to develop alternative means for a stockpile stewardship program.
November 1993	A Presidential Decision Directive established the scope of the stockpile stewardship program and emphasized increased importance of hydrodynamic testing in the absence of nuclear testing. Reaffirmed by Secretary of Defense.
November 1993	In the National Defense Authorization Act [P.L. 103-160], Congress instructed the Secretary of Energy to "establish a stewardship program to ensure the preservation of the core intellectual and technical competencies of the United States in nuclear weapons."
July 1994	In the National Security Strategy, the President stated that the Nation would retain nuclear forces sufficient to deter foreign hostility and would also stem proliferation of nuclear weapons.
September 1994	Secretary of Defense completed the Nuclear Posture Review and reaffirmed that nuclear weapons remain essential even though stockpiles will be reduced.

The DOE program that responds to the President's direction to ensure confidence in the nuclear weapons stockpile in the absence of nuclear testing is science-based stockpile stewardship and management. This is an ongoing program that has evolved from, and whose goals are redirected from, the former DOE weapons research, development and testing, and stockpile support programs. Stockpile stewardship plays a crucial role in accurately and effectively assessing the continued safety, performance, and reliability of nuclear weapons as they age; in identifying when a weapon or its components may need to be rebuilt;

and in assuring that the rebuilt components themselves do not compromise the safety, performance, and reliability of the weapons.

Hydrodynamic tests and dynamic experiments are essential elements of the evaluation and understanding of weapon performance under the science-based stockpile stewardship program. Dynamic experiments are used to gain information on the physical properties and dynamic behavior of materials used in nuclear weapons. Hydrodynamic tests are used to obtain diagnostic information on the behavior of a nuclear weapon primary and to evaluate the effects of aging on the weapons remaining in the greatly reduced nuclear weapons stockpile.

DOE needs to improve its hydrodynamic testing capability as soon as possible. Uncertainty in the performance of the enduring stockpile will continue to increase with the passage of time since DOE can no longer use nuclear testing to assess the safety, performance, and reliability of the weapons. DOE has determined that no other currently available advanced techniques exist which can provide a level of information comparable to that which can be obtained from enhanced radiographic hydrodynamic testing.

Also, DOE needs to maintain or improve its radiographic testing capability to support other science missions. Hydrodynamic tests and dynamic experiments are important tools for evaluating conventional munitions; studying hydrodynamics, materials physics, and high-speed impact phenomena; and for proliferation assessment and disablement.

2.2 POLICY CONSIDERATIONS

In responding to the Nation's need to ensure safety, security, and reliability of the nuclear weapons stockpile, DOE must consider national policy regarding nuclear deterrence and stockpile stewardship.

> President Clinton, in the National Security Strategy, July 1994, stated:
>
> - "Even with the Cold War over, our nation must ... deter diverse threats."
> - "We will retain strategic nuclear forces sufficient to deter any future hostile foreign leadership ... Therefore we will continue to maintain nuclear forces of sufficient size and capability to hold at risk a broad range of assets valued by such political and military leaders."
> - "A critical priority for the United States is to stem the proliferation of nuclear weapons and other weapons of mass destruction and their missile delivery systems."

2.2.1 Nuclear Deterrence

Nuclear deterrence remains a cornerstone of U.S. policy, and this Nation will continue to rely on DOE to maintain a safe, secure, and reliable nuclear weapons stockpile. In the past, DOE has been able to accomplish that mission by retiring weapons before the end of their design life and by upgrading or redesigning weapons if potential problems were detected through nuclear testing and hydrodynamic tests and dynamic experiments (see figure 2-1). However, the President has placed a moratorium on underground nuclear testing and has decided that the United States will not build new nuclear weapons for the foreseeable future (even to replace those past their design life). Now DOE must rely on the data from hydrodynamic tests and dynamic experiments to ensure the safety, security, and reliability of the weapons.

In the past, both hydrodynamic and nuclear testing were used to assess nuclear weapon safety, performance, and reliability. Computational models were verified by observing the results of both hydrodynamic tests and nuclear testing.

Without nuclear testing, DOE must rely on improved hydrodynamic testing to verify computational models and to assess weapon safety, performance, and reliability.

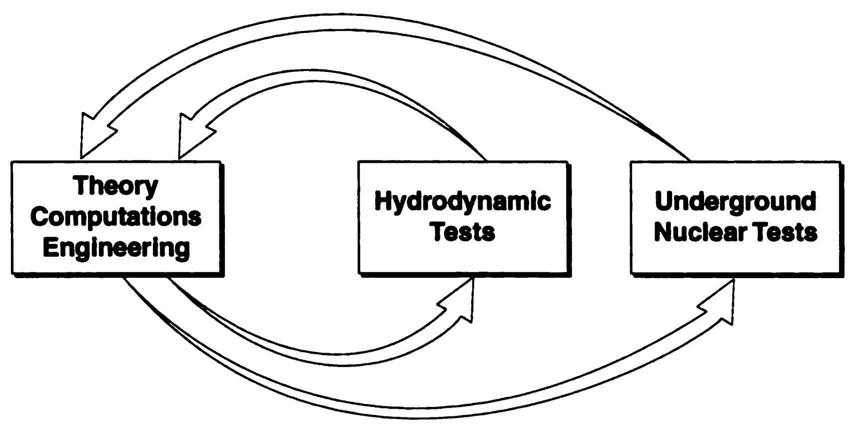


FIGURE 2-1.—***Prior Relationship of Hydrodynamic Tests and Underground Nuclear Tests to Nuclear Weapon Safety, Performance, and Reliability Assessments.***

2.2.2 Stockpile Stewardship

Since the 1940s, DOE and its predecessor agencies have been responsible for ensuring the safety, security, and reliability of the nuclear weapons in the stockpile. This assignment was included in the Atomic Energy Act [42 U.S.C. 2011 et seq.], along with the responsibility to design, manufacture, and certify nuclear weapons. DOE now accomplishes this mission through the science-based stockpile stewardship and management program. Stockpile stewardship includes those activities required to ensure a high level of confidence in the nuclear weapons stockpile, whereas stockpile management includes facilities and capability for maintenance, surveillance, repair or replacement of weapons in the stockpile.
DOE's three weapons laboratories [Los Alamos National Laboratory (LANL), Lawrence Livermore National Laboratory (LLNL), and Sandia National Laboratories] carry out the stockpile stewardship mission. The laboratories are asked to identify, develop, and implement selected tools – programs and facilities – needed to achieve their assigned responsibilities. Through the directors of the weapons laboratories, DOE must certify that nuclear weapons will not accidentally detonate during storage and handling (safety), that the weapons would thwart any attempts for unauthorized use (security), and that they would function as designed in the event of authorized use (performance and reliability).

For 50 years, nuclear tests were key to gathering data used for developing nuclear weapons and certifying their safety, reliability, and performance. Nuclear tests were also used to evaluate the effectiveness and certify performance of weapons that were redesigned. Since the 1992 moratorium on nuclear tests, DOE has recognized that a new approach, based on scientific understanding and expert judgment, is needed to ensure confidence in the nuclear deterrent and U.S. stockpile. Given the moratorium on nuclear testing, the termination of new weapons development and manufacturing, and the closure of DOE weapons production facilities, this confidence will depend on the competence of the people who must make the scientific and technical judgments related to the safety and reliability of U.S. nuclear weapons. Those people must have a fundamental understanding of the basic scientific phenomena associated with nuclear weapons.

To develop its science-based program, DOE identified five critical issues regarding stockpile stewardship and management and strategies to address them. Two of these strategies acknowledge DOE's need for improved hydrodynamic testing capability:

- Enhanced experimental and computational capabilities – high-resolution, multiple-time, multiple-view hydrodynamic tests using simulant materials to define implosion characteristics of weapons primaries and assess their safety, reliability, and performance.
- Enhanced weapon and materials surveillance technologies – hydrodynamic tests on test units built, when possible, with aged stockpile components (with simulant materials replacing the fissile pit materials) to provide important data on the effects of aging on weapons safety and performance. Data from experiments with these test units would augment the baseline data from hydrodynamic tests of stockpile weapons.

Confidence in the enduring nuclear stockpile is to some degree subjective, and in some cases the Nation might be willing to forego the means to ensure a higher degree of confidence in the condition of its nuclear weapons in favor of some other value, as was the case when the President decided to impose a moratorium on underground nuclear testing. However, the President continues to emphasize that DOE must maintain an effective nuclear deterrent, and DOE has determined that hydrodynamic testing programs are an essential means to develop baseline experimental data for the enduring stockpile, as a tool for stockpile sampling, and to determine the effects of aging.

> The Nuclear Posture Review completed by the Secretary of Defense in September 1994 reaffirmed that in today's security environment nuclear weapons remain essential even though nuclear weapons stockpiles will be reduced. The Review outlined:
>
> - A future nuclear posture with a focus on maintaining good stewardship of the weapons remaining in the national stockpile.
> - A continuing relationship between DOE and the Department of Defense under the aegis of the stockpile stewardship program to maintain a reliable, safe, and secure nuclear stockpile.
> - Actions to ensure a stockpile stewardship program within the bounds of a future comprehensive test ban treaty.
> - The Department of Defense requirements for DOE to, among other things, maintain nuclear weapons capability (without underground nuclear testing or fissile material production), while emphasizing that there is no foreseeable need for new-design nuclear warhead production.

2.3 NEED FOR ENHANCED RADIOGRAPHIC CAPABILITY

DOE has determined that it needs to obtain an enhanced capability to conduct radiographic hydrodynamic tests and dynamic experiments. The capability to obtain high-resolution, multiple-time, multiple-view information is needed to assess safety, performance and reliability of weapons; evaluate aging weapons; obtain information about plutonium through dynamic experiments; and for other uses.

The DOE's determination has been independently verified by a panel of technical experts who studied the requirements for the DOE science-based stockpile stewardship program (JASON 1994). DOE has determined that above-ground, radiographic diagnostics are the best means (and for some parameters, the only known means) to obtain the needed information, and that linear induction accelerators (the technology proposed for DARHT) represent the best available technology to produce the high-speed, high-resolution, deeply penetrating radiographs that are needed. In addition, DOE has determined that no other advanced technology is currently available that could provide a comparable level of information. DOE's conclusions have been independently verified by panels of consultants convened to consider these issues (JASON 1994; HPAIC 1992; DFAIC 1992; and DOE 1993).

President Clinton, in the Presidential Decision Directive of November 1993, stated:

- Stockpile stewardship will use past nuclear test data in combination with future nonnuclear test data, along with computational modeling, experimental facilities, and simulators to further comprehensive understanding of nuclear weapons.
- Stockpile stewardship will include stockpile surveillance, experimental research, development and engineering programs and maintaining a production capability to support stockpile requirements.
- Achieving stockpile stewardship objectives will require continued use of current facilities and programs, a limited set of new experimental facilities and computational facilities and programs, and periodic review and evaluation of program elements.
- In the absence of nuclear testing, hydrodynamic testing programs have increased in importance. These programs include developing baseline hydrodynamic experimental data for the enduring stockpile and increasing the number of hydrodynamic experiments as part of the stockpile sampling and aging evaluation programs.
- Hydrodynamic testing is also needed to support a development program necessary to help retain and exercise weapon design engineering skills and to examine safety modifications in existing nuclear warhead designs that could be introduced into the stockpile without nuclear testing in case they are needed in the future.
- The future hydrodynamic testing program requires ongoing support from the DOE and Department of Defense for research, development and testing activities; the program requires increased funding for constructing upgraded experimental facilities as well.

2.3.1 Assessing Weapons Safety, Performance, and Reliability

To ensure the continued viability of the smaller stockpile, DOE must improve its scientific understanding of the physics of a nuclear weapon, and develop a better understanding of how a nuclear weapon behaves during the complex interactions that occur in the brief interval between detonation and nuclear explosion. This information is needed to assure the continued safety, performance, and reliability of existing weapons.

DOE has not yet determined how to predict with sufficient accuracy from computer calculations alone the rapidly changing shape of a weapon primary during the last stages of implosion. However, this information is essential to predict the safety, performance, and reliability of a nuclear weapon. At this time, the highest priority issues for stockpiled primaries are those that affect the successful ignition of the deuterium-tritium boost gas. DOE needs to be able to predict the implosion movement of the three-dimensional weapons assembly to provide an integral measure of the expected performance of the fission drive, to assess nuclear safety in accidents, and for render-safe and disablement effectiveness. Current diagnostic capabilities are insufficient to make all of the necessary types of measurements of an imploding primary or to make refined measurements at the high level of detail needed. Therefore, DOE needs to establish an enhanced diagnostic capability to make the necessary types of measurements at the desired level of detail.

Prior to the President's moratorium on nuclear testing, the United States used both hydrodynamic and nuclear testing to obtain information needed to assess nuclear weapons safety, performance, and reliability. Nuclear testing at appropriate nuclear yields allowed DOE to maintain the stockpile and its nuclear expertise with very high confidence; the performance and safety of the enduring stockpile was validated by such tests. Because of the moratorium on nuclear testing, DOE did not complete all of the underground nuclear tests that had been planned. Certain types of data gaps, which the design laboratories expected to be partially filled in by analyzing the results of nuclear tests, remain unfilled.

Without nuclear testing, mathematical calculations based upon experimental data will be the only way to obtain needed information on weapons performance and reliability. Theoretical mathematical calculations alone cannot be relied upon to predict the behavior of a nuclear weapon primary; the calculations must be verified against actual experimental data. DOE considers enhanced radiographic hydrodynamic testing to be the best (and in some areas, the only known) tool to obtain certain types of information regarding weapons primaries. These data are needed to verify and refine predictive analytical models.

In an era during which nuclear testing will not be performed, DOE will have to assess weapons safety, performance, and reliability in other ways. Enhanced radiographic hydrodynamic testing would provide a powerful tool for implementing the science-based stockpile stewardship program. Whether or not this approach will fully satisfy the need for stockpile assurance without nuclear testing is not completely known, and it will not be known for several years after an enhanced hydrodynamic capability, among other tools, is put into place and test results are analyzed. The possibility exists that, without nuclear testing, the Nation cannot ensure the continued viability of a nuclear deterrent based on the existing weapons in the nuclear weapons stockpile. The sooner that DOE can obtain better diagnostic information, the sooner that the Nation can determine if its existing nuclear deterrent is sufficient. Conversely, the longer the Nation waits before an enhanced capability is achieved, the greater the chance that a problem will arise which cannot be addressed with the current capability in a manner which is sufficient to ensure the necessary level of confidence in the nuclear weapons stockpile.

2.3.2 Evaluating Aging Weapons

Although the U.S. nuclear weapons stockpile is presently safe and reliable, the nuclear weapons in today's U.S. stockpile are aging. Existing weapons, on the average, are about 15 years old, and in about five years, many weapons will begin exceeding their original design lifetime. In the past, individual weapons in the stockpile were replaced by new-design, upgraded or replacement weapons before they approached the end of their design life. However, because the United States is not producing new weapons, DOE does not anticipate replacing the weapons now in the stockpile before the end of their original design life. This creates uncertainty about the safety and performance capability of the remaining weapons as they continue to age because DOE does not know how the weapons will behave over the long term.

DOE believes that inventorying or benchmarking the condition of weapons and their expected performance characteristics, as soon as possible, is needed. This would provide a baseline for comparing future

> Secretary of Energy O'Leary, in April, 1995, stated to the U.S. Senate Committee on Armed Services:
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> - "In the past, our confidence in the stockpile was ensured through weapon research and development in the laboratories and underground nuclear testing at the Nevada Test Site. In July 1993, the President announced a moratorium on underground nuclear testing that he recently extended until September 1996..."
> - "The current stockpile is safe, secure, and reliable. However, the history of the stockpile has shown that continuous surveillance, repair, and replacement of components and subsystems is commonplace. In fact, the seven weapons that will be in the enduring START II stockpile have already been retrofitted to varying degrees and some have had major components of the nuclear system replaced. We cannot predict with any certainty whether or when such problems will arise in the future, but we must be equipped to respond effectively should they materialize."

surveillance observations and performance tests over the period of time that the weapons will eventually be called upon to serve in the stockpile. DOE would use hydrodynamic testing to assist with benchmarking. Enhanced hydrodynamic testing capability is needed to accurately benchmark weapon primaries. The sooner that benchmarking takes place, the sooner DOE would have more reliable data and could be more certain about the condition of the weapons remaining in the stockpile. DOE estimates that it will take several years to baseline each weapons system expected to remain in the stockpile.

As materials age, particularly the kinds of materials contained in nuclear weapons, they tend to change. DOE weapons personnel are able to predict some types of changes that would be expected to occur over time in the materials that make up the weapons. However, other effects that aging may bring about on the performance and reliability of these weapons, and on their behavior under certain postulated accident conditions, are largely unknown. DOE needs to be able to ensure that aging weapons remain safe and reliable. In the event that systems in aging weapons need to be reengineered or replaced, DOE needs a capability to validate that the replacement systems would not compromise weapons safety, reliability, or performance. DOE also needs to be able to predict the physics behavior that would be expected from an aging weapon under abnormal conditions, such as those that might occur in an accident or those that might occur in the material properties under routine or adverse conditions.

In the past, DOE has discovered several unanticipated problems in the weapons in the stockpile (Miller et al. 1987). DOE has considerable evidence to indicate that, as weapons age, problems related to the deterioration of weapon components can and do occur. Before the recent changes in policy, most weapons were replaced by newer systems before their design life had been exceeded. Therefore, most of the historical information on safety, reliability, or performance of stockpiled weapons was related to issues that arose unexpectedly before the end of their design lifetime. DOE has 50 years of experience in solving a wide diversity of issues, (e.g., the large number of ways that materials can crack, corrode, or otherwise degrade) and in increasing its understanding of plausible accident scenarios. This experience helps prevent exact recurrences of past problems, but it does not prevent new issues from arising.

DOE and its predecessor agencies have maintained a surveillance program since the 1940s; however, by itself, weapons surveillance is not adequate to predict and resolve performance or reliability problems. To certify a weapon system, prototype systems were tested extensively, using both nuclear testing and hydrodynamic tests, before any production of stockpile weapons was authorized. DOE relies on its stockpile surveillance program to observe post-production problems for weapons in the stockpile. Once a problem is discovered, DOE must determine the impact that the problem might have on weapons safety or performance reliability. The probable impact of an observed change is calculated based on known computer codes and then corroborated with experimental testing.

Although certain limited-life components were designed to be replaced (such as batteries) or replenished (such as tritium gas reservoirs), other essential components of weapons were presumed to last the life of the weapon. High explosives, primaries, secondaries, and radiation shields were not designed to be replaced unless testing programs indicated that a problem existed with a given component. However, the metals, plastic explosives and other materials that make up the weapons in the existing stockpile are known to have the possibility of becoming brittle, cracked, or otherwise show changes in material properties over extended periods of time. The question faced by weapons personnel is whether these changes, if they occur, would affect the safe handling characteristics or performance reliability of the weapons.

DOE cannot predict with certainty when safety or reliability concerns will arise in the future, but DOE anticipates that problems will be discovered more frequently as weapons become older and exceed their original design lifetime. Because the weapons will become older than any weapons with which DOE has had experience, there will be a need to address and correct problems not previously encountered. Of the weapon types introduced since 1970, nearly one-half required nuclear testing after their development was complete (either while they were deployed, or still being produced) to verify, resolve, or certify that problems relating to safety or reliability have been resolved. A majority of these problems involved the weapons' primary stage. Since 1970, several thousand weapons have been removed from the active stockpile for major modification, or have been accelerated on their path to retirement, to fully resolve such safety or performance reliability concerns.

One example is the now-retired W68 warhead for a submarine-launched ballistic missile. Routine surveillance disclosed a premature degradation of the warhead's high explosive. Without modification, the problem would have ultimately rendered the weapon inoperable. The weapons were disassembled and the high explosive replaced with a more chemically stable formulation. In addition, because some of the materials used in the original production were no longer available commercially, some additional changes were made in the rebuilt weapon. Nuclear test data were used to assure that the high explosive and other changes would not compromise adequate performance of the weapons. DOE performed a nuclear test to verify that the rebuilt weapons would perform as designed and was surprised to find that the weapon yield was degraded. However, DOE decided that the lower yield was acceptable. This example and others have been summarized in a 1987 unclassified report to Congress by Dr. George Miller, Dr. Carol Alonso, and Dr. Paul Brown (Miller et al. 1987).

In the absence of nuclear testing, DOE must rely more heavily on hydrodynamic testing to provide the same assurance of safety, performance, and reliability, particularly to verify, resolve, or validate fixes which modify existing systems. DOE considers enhanced radiographic hydrodynamic testing to be the best currently available tool to obtain information regarding the effects of aging on weapon primaries.

2.3.3 Dynamic Experiments with Plutonium

Some components of nuclear weapons contain plutonium, which is a material with unique behavioral characteristics. As part of its effort to better understand the materials science aspect of nuclear weapons aging and performance, DOE needs to develop a better understanding of the physical properties of plutonium. In metal form, plutonium is an extremely heavy, dense silvery metal. Plutonium is sometimes stored as an oxide or in solution. Any form of plutonium may react with water, plastics, metals, or other materials with which it comes into contact. It is important that the DOE weapons laboratories have the tools to study the various forms of plutonium and its physical properties, and to evaluate and predict plutonium behavior under dynamic conditions (that is, conditions involving very rapid motion).

Currently, the body of knowledge regarding the behavior of plutonium is inadequate. DOE needs:

- A better understanding of the properties of plutonium
- More accurate equations of state to predict the behavior of plutonium, especially at high pressures and temperatures
- More information regarding the behavior of the plutonium surface following a physical shock.

Since radiographic dynamic experiments are the best tool to obtain this information, DOE needs to have the capability to conduct dynamic experiments with plutonium using enhanced high-resolution radiography. As a matter of policy, in the event that DOE performed dynamic experiments involving plutonium, these experiments would always be conducted in double-walled containment vessels. Accordingly, DOE needs to have the capability to stage, maintain, and clean out the plutonium containment vessels.

2.3.4 Other Needs

DOE also needs more information on other issues related to nuclear deterrence and nuclear weapons materials science.

- The United States needs to be able to continue to assist other nations with evaluating the condition, safety, and expected performance of their weapons and weapons designs under current international agreements.
- The United States needs to be able to assess the condition, safety, security, and performance reliability of other nuclear weapons such as these designed by a nonfriendly nation or a terrorist.
- DOE needs to be able to continue to assist the Department of Defense with evaluation of conventional weapons and other military equipment.
- DOE needs to be able to study explosives-driven materials and high-velocity impact phenomena for nonweapons applications and other uses of interest to industry.
- The accelerator technology developed for high-resolution radiography may have other science and industry applications.

In 1991, the President stated that the United States would not design new nuclear weapons in the foreseeable future. However, in the event that this Nation decides, as a matter of policy, that new nuclear weapons should again be developed, DOE would use all appropriate means at our disposal to accomplish this. Hydrodynamic testing, along with many other tools, could be used to assist in weapons development. However, any decision to develop new nuclear weapons would be made by the President and be subject to Congressional review and approval.

2.4 LIMITATIONS OF EXISTING FACILITIES

Along with other stockpile stewardship responsibilities, DOE has assigned a hydrodynamic testing mission to its two nuclear weapons physics laboratories, LANL and LLNL. The Pulsed High Energy Radiation Machine Emitting X-Rays (PHERMEX) is the existing radiographic hydrodynamic testing facility at LANL and the Flash X-Ray (FXR) is the existing radiographic hydrodynamic testing facility at LLNL.

PHERMEX has been in continuous operation since 1963. In addition to major, full-scale hydrodynamic tests, PHERMEX is used for smaller types of experiments, such as high-explosive tests or static radiographs. Although PHERMEX was state of the art in the 1950s when it was designed, it is no longer adequate. It cannot provide the degree of resolution, depth of penetration, rapid time sequencing, or three-dimensional views that are needed to provide answers to current questions regarding weapons condition or performance. Even if these types of diagnostic information were not needed, PHERMEX would not remain a viable test facility over time without significant upgrades or replacement because of the increasing difficulty to maintain the facility. For example, the 30-year-old radio-frequency accelerator that powers PHERMEX uses eight large vacuum tubes; each tube costs about $90,000 and has to be replaced about every 18–24 months. While DOE has about a two to three year supply in stock, the sole manufacturer for the tubes does not manufacture this item in quantity because there are very few customers for the product.

FXR has been in continuous operation since 1983; it is DOE's most advanced radiographic hydrodynamic testing facility. At the time it was constructed, it represented a great improvement in capability over PHERMEX. Although FXR uses linear induction accelerator technology for high-speed radiography, it cannot provide the degree of resolution, depth of penetration, or three-dimensional views needed to address current questions. Additionally, DOE does not perform dynamic experiments with plutonium at LLNL.

Neither PHERMEX nor FXR are adequate to provide the enhanced radiographic hydrodynamic testing capability that DOE now needs in the absence of nuclear testing. At present, both PHERMEX and FXR can take only one image at a time. If planned upgrades are completed, PHERMEX and FXR may soon have the capability to make sequential radiographs up to 100 microseconds apart, but without improvement in x-ray dose or spot size. Neither PHERMEX nor FXR is capable of producing a high enough x-ray dose with a small enough beam spot size to provide the diagnostic capability that DOE now needs. Neither machine is capable of taking very high-resolution radiographs, which is dependent upon the accelerator beam spot size. Neither machine is capable of producing x-ray beams with the degree of penetration required, which is principally dependent upon x-ray dose strength. Neither machine has the capability to obtain three-dimensional information for one test event, which requires the ability to take pictures from more than one point of view. To obtain three-dimensional data at PHERMEX or FXR, the laboratory personnel must make up more than one test assembly and explode them, one at a time, rotating each subsequent device to obtain an additional point of view. Besides increasing costs – a full-scale hydrodynamic test costs $1.5 to $2 million, with the cost multiplied by the number of views tested – it is difficult to reproduce precise dimensions and alignments (within hundredths of an inch) to replicate test results for components in a series of tests. The confidence in the resulting data is also limited because of the uncertainties of using sequential tests. DOE's observations regarding the limitations of PHERMEX and FXR, even after planned upgrades have been incorporated, have also been reflected by independent researchers (JASON 1994).

2.5 NONPROLIFERATION

DOE has determined that enhanced hydrodynamic testing capability in support of the science-based stockpile stewardship program is consistent with the United States policy on nonproliferation.

The President is committed to curbing the proliferation of nuclear weapons. The DOE science-based stockpile stewardship and management program is a key component of the United States nonproliferation strategy. This Nation's commitment to nonproliferation is evident by our support for an indefinite extension of the Nonproliferation Treaty [in force 1970; 21 UST 483] and our goal of achieving a comprehensive test ban as soon as possible. In support of these goals, the stockpile stewardship program provides a means to assure the safety and reliability of the Nation's remaining stockpile of nuclear weapons under a continuing testing moratorium and a future comprehensive test ban.

One global benefit of science-based stockpile stewardship is to demonstrate the U.S. commitment to Nonproliferation Treaty goals; however, the U.S. nuclear posture is not the only factor that might affect whether or not other nations might develop nuclear weapons of their own. Some nations which are not declared nuclear states have the ability to develop nuclear weapons. Many of these nations rely on the U.S. nuclear deterrent for security assurance. The loss of confidence in the safety or reliability of the weapons in the U.S. stockpile could result in a corresponding loss of credibility of the Nation's ability to provide a nuclear deterrent, and could provide an incentive to other nations to develop their own nuclear weapons program.

The United States has halted the development of new nuclear weapons systems. The Nuclear Posture Review commits the United States to maintaining a safe and reliable nuclear deterrent. The hydrodynamic testing program, when used to assess the safety and reliability of the nuclear weapon primaries in the remaining stockpile, does not constitute proliferation. The results of such testing are classified and could not lead to proliferation without a breach of security. Because the United States is already a nuclear weapons state, and has had a hydrodynamic testing program for several decades, continuing to maintain a hydrodynamic testing capability does not change our Nation's status in regards to proliferation. Lack of hydrodynamic testing capability, while seriously impacting our ability to ensure the continued safety and reliability of the stockpile, also would not change the status of the United States in terms of proliferation – we would remain a nuclear weapons state. Proliferation drivers for other states, such as international competition or the desire to deter conventional armed forces, would remain unchanged regardless of whether DOE implemented the proposed action analyzed in this EIS.

Most of the component technology used for hydrodynamic testing is unclassified and is available in the open literature; many other nations have developed a considerable accelerator technology capability. Accelerator-based radiographic technology is currently used by other weapons states for many of the same reasons it is used by the United States.

2.6 RELATIONSHIP OF THE DARHT EIS TO OTHER DOE EIS'S

DOE plans two other National Environmental Policy Act (NEPA) reviews regarding proposed actions at LANL related to the Dual Axis Radiographic Hydrodynamic Test (DARHT) Facility environmental impact statement (EIS) – the *LANL Sitewide Environmental Impact Statement* (SWEIS) and the *Stockpile Stewardship and Management Programmatic Environmental Impact Statement* (PEIS).

EIS	NOI	Draft EIS	Final EIS	ROD
DARHT EIS	Nov 94	May 95	Aug 95	Sep 95
LANL SWEIS	May 95	Apr 96	Dec 96	Mar 97
SS&M PEIS	Jun 95	Feb 96	Jul 96	Sep 96

Note: Dates are subject to change.

DOE is in the process of preparing the SWEIS for LANL [Advance Notice of Intent, 59 FR 40889]. The purpose of the SWEIS is to provide DOE and its stakeholders a comprehensive look at the cumulative environmental impacts of ongoing and reasonably foreseeable future operations at LANL. The SWEIS will focus on impacts of current LANL activities and activities proposed or anticipated to occur 5 to 10 years into the future. It will replace the prior SWEIS that was completed in 1979. The SWEIS will include all activities at LANL and will incorporate the results of any related environmental impact analyses in any current NEPA documents, which will be combined with impact analyses performed specifically for the SWEIS. Under current schedules, the DOE plans to issue the Record of Decision (ROD) on the DARHT EIS prior to issuing the draft SWEIS. The information on environmental impacts of the course of action selected in the DARHT ROD will be included in the analysis of cumulative impacts for the SWEIS.

DOE will prepare a stockpile stewardship and management PEIS to support future decisions regarding DOE's responsibilities in connection with the nuclear weapons stockpile [59 FR 54175]. As discussed earlier in this section, the President and Congress have included within the definition of stockpile stewardship the actions needed to improve DOE's capability to conduct hydrodynamic tests. The environmental impact analysis of the course of action selected in the DARHT ROD will be incorporated into the PEIS.

The DOE proposal to provide enhanced high-resolution radiography capability responds to Presidential and Congressional direction, and is independently justified compared to the DOE stockpile stewardship and management program. Because enhanced hydrodynamic capability is needed in the near-term regardless of the alternatives analyzed in or the courses of action selected as a result of the stockpile stewardship and management PEIS, DOE believes that a decision on whether to implement the proposed action analyzed in this EIS would not prejudice any ultimate decision regarding the stockpile stewardship and management program. The No Action Alternative will not meet the purpose and need for the Proposed Action. Proceeding with the DARHT EIS in advance of the completion of either the SWEIS or the PEIS is necessary because a decision on whether to proceed with DARHT, or pursue an alternative, is needed as soon as possible to help ensure the continued safety and reliability of the nuclear weapons stockpile. As explained in chapter 3 of this EIS, DOE has considered alternative means to obtain the enhanced capability for hydrodynamic tests and dynamic experiments that it now needs, and has analyzed in detail in this EIS the range of alternatives that would meet the current need. Furthermore, as a matter of policy and Presidential and Congressional direction, DOE will continue to maintain and improve its hydrodynamic testing capability regardless of the outcome of either of the SWEIS or the PEIS. Thus, the alternatives analyzed in this DARHT EIS are not dependent on the decisions expected to flow from either the SWEIS or the PEIS. Accordingly, DOE does not believe that a decision on whether to proceed with DARHT would prejudice the outcome of either of these NEPA reviews.

2.7 REFERENCES CITED IN CHAPTER 2

DFAIC (DARHT Feasibility Assessment Independent Consultants), 1992, *DARHT Feasibility Assessment Independent Consultants DFAIC Panel, Final Report*, SAND92-2060, UC-700, September, Sandia National Laboratories, Albuquerque, New Mexico.

DOE (U.S. Department of Energy), 1993, *Report of Independent Consultants Reviewing Integrated Test Stands (ITS) Performance and Readiness of DARHT for Construction Start*, DOE/DP-0119, August, Washington, D.C.

HPAIC (Hydrotest Program Assessment Independent Consultants), 1992, *Hydrotest Program Assessment*, PSR Report 2320, October, Arlington, Virginia.

JASON/Mitre Corporation, 1994, *Science Based Stockpile Stewardship*, Report Number JSR-94-375, November, Washington, D.C.

Miller, G.H., et al., 1987, *Report to Congress on Stockpile Reliability, Weapon Remanufacture, and the Role of Nuclear Testing,* UCRL-53822, October, Lawrence Livermore National Laboratory, Livermore, California.

Chapter 3
Proposed Action and Alternatives

CHAPTER 3
PROPOSED ACTION AND ALTERNATIVES

This Chapter describes the proposed action and alternative ways to accomplish it. It also describes considerations that are common to all alternatives and alternatives that were considered but not analyzed.

3.1 OVERVIEW

The alternatives analyzed in this environmental impact statement (EIS) would implement all or part of the Proposed Action. The Proposed Action is to provide an enhanced high-resolution radiographic capability to perform hydrodynamic tests and dynamic experiments in support of DOE's historical mission and the near-term stewardship of the Nation's nuclear weapons stockpile. The aspects of the DOE hydrodynamic testing and dynamic experiment program that would not change regardless of the course of action selected are described in this chapter as considerations common to all alternatives. DOE considered, but did not analyze in detail, other alternatives, which are described here along with an explanation as to why they would not meet the DOE's purpose and need for enhanced testing capability. The environmental impacts of all analyzed alternatives, along with other decision factors, are summarized. The discussion in this chapter is augmented by the classified supplement for this Environmental Impact Statement.

The No Action Alternative would not meet the DOE's purpose and need for enhanced radiographic hydrodynamic testing but is provided as a basis of comparison. The next two alternatives address various ways to meet part or all of the purpose and need. The remaining alternatives would modify the Preferred Alternative to mitigate possible environmental impacts; these mitigation measures could also be applied to the other alternatives, but they are not expressly analyzed. For example, the Single-Axis Alternative could be constructed instead of the dual-axis facility under the Upgrade PHERMEX Alternative as well as the modification to the DARHT Facility analyzed under the Single-Axis Alternative. However, since the environmental impacts would be similar, and within the expected bounds of the alternative analyzed, this EIS does not specifically analyze that particular option.

The alternatives analyzed are:

- **No Action Alternative:** DOE would continue to use the Pulsed High Energy Radiation Machine Emitting X-Rays (PHERMEX) Facility at the Los Alamos National Laboratory (LANL) and the Flash X-Ray (FXR) Facility at the Lawrence Livermore National Laboratory (LLNL) in support of its stockpile stewardship mission. Construction of the Dual Axis Radiographic Hydrodynamic Test (DARHT) Facility would not be completed; the structure would be completed for other uses. DOE would perform some dynamic experiments; those using plutonium would be conducted in containment vessels.
- **Preferred Alternative:** DOE would complete and operate the DARHT Facility and phase out operations at PHERMEX. DOE may delay operation of the second axis of DARHT until the

accelerator equipment in the first axis is tested and proven. DOE would perform some dynamic experiments; those using plutonium would be conducted in containment vessels.

- **Upgrade PHERMEX Alternative:** Construction of the DARHT Facility would not be completed. Major upgrades would be constructed at PHERMEX, and the high-resolution radiographic technology planned for DARHT would be installed at PHERMEX, including a second accelerator for two-axis imaging. DOE would perform some dynamic experiments; those involving plutonium would be conducted in containment vessels.
- **Enhanced Containment Alternative:** Similar to the Preferred Alternative except that some or all tests would be conducted in a containment vessel or containment structure. Most tests would be contained if containment vessels were used. All tests would be contained if a containment structure were used.
- **Plutonium Exclusion Alternative:** Similar to the Preferred Alternative except that plutonium would not be used in any of the experiments at DARHT. DOE would conduct dynamic experiments with plutonium at PHERMEX or other facilities.
- **Single-Axis Alternative:** Similar to the Preferred Alternative except that only one accelerator hall would be completed and operated for hydrodynamic tests or dynamic experiments. The other hall would be completed for other uses.

3.2 PROPOSED ACTION

As discussed in chapter 2, DOE needs to ensure that the U.S. nuclear weapons stockpile remains safe, secure, and reliable. Science-based stockpile stewardship is DOE's program to gain the scientific understanding needed to assess the condition of nuclear weapons and to assure their continued safety, performance, and reliability. DOE has determined that, in the absence of nuclear testing, radiographic hydrodynamic testing and dynamic experiments are necessary to provide information regarding the condition and behavior of nuclear weapon primaries. DOE has determined that enhanced diagnostic capability is needed. DOE also has determined that no other currently available technique would provide a level of information comparable to that provided by enhanced high-resolution radiographic hydrodynamic testing and dynamic experiments. As discussed in chapter 2, these conclusions have been independently verified by panels of technical experts.

In response to the specified purpose and need, DOE proposes to provide an enhanced high-resolution radiographic capability to perform hydrodynamic tests and dynamic experiments in support of its historical mission and the near-term stewardship of the Nation's nuclear weapons stockpile. DOE's preferred approach would be to complete and operate the DARHT Facility.

3.3 CONSIDERATIONS COMMON TO ALL ALTERNATIVES

Certain aspects of the DOE's hydrodynamic test and dynamic experiments program would not change, regardless of which alternative would be implemented. The type of diagnostic experiment – e.g., optical, pin shot, or weapons geometry (explained below) – would not change even though the ability to obtain diagnostic information would vary among alternatives. The complex infrastructure needed to support hydrodynamic tests and dynamic experiments would not change. The operation of the FXR at LLNL and the Radiographic Support Laboratory (RSL) at LANL would not change.

3.3.1 Hydrodynamic Tests

For many years, DOE has relied upon hydrodynamic tests to obtain certain types of information about the behavior of nuclear weapon primaries during the complex interactions expected in an implosion (see figure 1-2). Hydrodynamic tests use full weapons geometry. The fissile material inside the weapon is replaced with another material. Hydrodynamic tests are used to measure material motions and compression by using pins, optics, and radiography. Hydrodynamic tests are supplemented with static, dynamic, or high-explosives experiments. The information obtained is then used to develop calculations to predict the safety, performance, or reliability of the weapons device.

Pin shot hydrodynamic tests involve replacing the fissile material of a weapon primary with another material and inserting a post, called a blast pipe, with various lengths of electrical sensors, called pins, which radiate from its end. The blast pipe is highly shielded to protect the diagnostic equipment. High explosives are placed around the outside of the inert material and pin assembly and used to detonate the mock device. The pins record the movement of the implosion. The information obtained is used to improve the understanding of how the pit surface moves during the short period of time up to a few microseconds before criticality would be achieved. Personnel extrapolate the pin shot data and estimate what would happen in an actual weapon up to the point of a nuclear explosion. These estimates become less certain as the estimated point of criticality is approached. After extrapolating the pin shot information, personnel calculate estimated changes in imploding shapes and stages of reactivity. The pin assembly and blast pipe affect the geometry of implosion, so this type of test does not exactly mimic the behavior expected during an actual weapons implosion. Pin shots do not provide information about the boost gas associated with a pit. Radiography is often used as an additional diagnostic with pin shots.

Radiographic hydrodynamic tests supply additional information needed to understand the behavior of an imploding pit, and information regarding boost gas. Unlike a pin shot, the entire shape of the weapon primary is replicated. These tests involve replacing the fissile material of a weapon with another material, detonating the mock device with high explosives, and taking very high-speed (60 to 200 nsec) x-ray photographs of the imploding device. Radiographic images of mock-up weapons can be taken at any point during an experiment, including up to the estimated point at which a nuclear explosion would occur in an actual weapon. They provide information about density and shape changes as the pit implodes. From this information, LANL personnel modify and improve calculations and infer more detailed information about an actual nuclear explosion.

To avoid risking security, health, and safety, weapons researchers use some surrogate materials for tests and experiments. Depleted uranium is often used to mock the weapons-grade plutonium. Depleted uranium has a higher density, greater strength, and a higher melting point than weapons-grade plutonium. Tantalum is used for some hydrodynamic tests. The density of tantalum is similar to that of weapons-grade plutonium, but, like depleted uranium, it has a higher strength and higher melting point. Lead is sometimes used, primarily to look at material ejected from the pit surface and joints. The density of lead is lower than weapons-grade plutonium, and lead has lower strength and melting point.

The certainty of information for radiographic hydrodynamic tests increases with the number of views that are obtained. This applies to both sequential images and images taken from different viewpoints. The amount of information obtained from radiographic hydrodynamic tests also depends on the clarity of the image. This, in turn, depends on the resolution provided by the x-ray beam spot size (a smaller beam spot size provides greater resolution) and the penetration provided by the x-ray intensity. The dense pit materials, typically represented by depleted uranium, inhibit the penetration of the x-rays and inhibit the ability to obtain images of the imploding pit. To obtain better penetration, hence better images, other surrogate materials are sometimes used, such as tantalum, which allows very good x-ray penetration.

Depleted uranium is also used for related mock-up components. For example, hydrodynamic tests are sometimes used to determine the effect that a large mass, such as a weapon secondary, would have on the physics of the imploding primary. The mock-ups of the weapon secondary are often made of depleted uranium.

Optical means are sometimes used to record information for a hydrodynamic test. Under this technique, light and conventional high-speed photography are used (instead of x-rays and radiography) to record the movement of materials in the weapons mock-up. Lasers are also used for high-speed photography and interferometry to provide additional diagnostic capability.

3.3.2 Dynamic Experiments

While hydrodynamic tests examine interactions among parts of the primary, dynamic experiments explore broader issues regarding materials science. Dynamic experiments involve a variety of techniques. Depending upon the properties being examined, a variety of different materials may be used. Dynamic motion is usually achieved by driving test materials with high explosives.

In the past, DOE has conducted dynamic experiments at PHERMEX using weapons-grade and other forms of plutonium metal. These experiments were conducted inside double-walled steel containment vessels. Plutonium is an extremely complex material, and DOE's understanding of its behavior is important to predict nuclear performance. In the future, DOE plans to conduct dynamic experiments to help understand the constitutive properties of plutonium, its equations-of-state (particularly under conditions involving high temperatures and pressures), and its surface behavior following shocks. Dynamic experiments may involve observing the effects that would occur on plutonium or other adjunct materials after being shocked by explosives-driven materials. As a matter of policy, dynamic experiments involving plutonium would always be conducted inside double-walled steel containment vessels.

3.3.3 Infrastructure Requirements

Hydrodynamic testing and dynamic experiment operations require considerable infrastructure – facilities, equipment, and personnel – in support of test events. Hydrodynamic testing and dynamic experiment operations at PHERMEX take advantage of the existing infrastructure at LANL. If DARHT were to be completed and operated as proposed, those operations would take advantage of the same infrastructure. However, hydrodynamic testing and dynamic experiment operations at LANL are only a small proportion of the total workload at the LANL support facilities; these facilities support many other DOE activities at LANL such as weapons research, science, and waste management.

Hydrodynamic testing and high-explosives experiments are conducted in several phases, each requiring extensive interactions among personnel. Any given test requires direct support from several organizations, as well as additional indirect support such as security, clerical, maintenance, or monitoring personnel.

To conduct a hydrodynamic test, weapons researchers decide what kind of information is needed, and test designers and engineers determine how the information can be obtained. Special parts are designed, engineered, and fabricated for each test. The test configuration is assembled and inspected. The test assembly is transported to the firing test facility, temporarily stored until the test can be conducted, and set up at the firing site. Firing-site personnel, such as accelerator specialists and radiograph technicians, must assure that the equipment is ready to record the diagnostic information. The final test assembly is inspected, the shot is fired, and the diagnostic information recorded. The test materials are collected, recycled or cleaned up, and the information obtained is analyzed. Computer projections are made to extrapolate the information, and the results are used to verify computational codes. Each part of the process is iterative; for example, a part manufactured for a hydrodynamic test first undergoes mechanical testing and inspection, and, if it appears inadequate, the parts designer and machinist may consult with both the weapons researchers and the test designers to develop a different part. The infrastructure requirements to support the different steps in the radiographic test experiments are summarized in table 3-1.

3.3.4 Flash X-Ray Facility

The FXR Facility (Building 801 at Site 300) at LLNL is included in this EIS baseline because the facility is an integral part of the DOE's capability for hydrodynamic testing. Under all alternatives analyzed in this EIS, DOE would continue to operate FXR. The continued operation of FXR would not be affected by any of the alternatives discussed in this EIS. However, the level and scope of the testing program at FXR could be affected by decisions resulting from this review.

The FXR is a key facility used by DOE to address physics issues associated with the primary stage of a nuclear weapon and other types of experiments. PHERMEX and FXR are the two DOE facilities that currently provide flash x-ray capability for the stockpile stewardship program. DOE anticipates maintaining and operating FXR into the next century to support LLNL's weapons stockpile stewardship mission. It is possible that in the future DOE could propose activities at LLNL which might affect operation of FXR, but at this time no such proposals are foreseen except those discussed below.

LLNL has operated the FXR Facility since 1983 at their Site 300, making it 20 years newer than PHERMEX. Currently, FXR represents the best hydrodynamic testing capability available to the DOE. The FXR Facility contains a linear induction accelerator with an array of diagnostic capabilities that have been used to provide a detailed understanding of the behavior of the implosion systems (HPAIC 1992). FXR is a single, linear induction accelerator operating at 17 MeV to provide an x-ray dose greater than 285 rad from a spot size that is approximately the same as PHERMEX (Baker 1995; JASON 1994).

FXR is being upgraded as part of a larger revitalization project at Site 300 valued at $27.4 million (Baker 1995). The upgrades at Site 300 include a high-speed optics maintenance facility, a bunker support facility, diagnostic equipment for the bunkers, road upgrades, central control post, and a new water supply. A $5.3 million segment of the upgrade is scheduled to begin October 1995 and be completed in October 1997 (Baker 1995). This latter segment will increase the capability of FXR by allowing for two pictures

TABLE 3-1.—*Infrastructure Requirements for Typical Radiographic Test Experiments*

Activity	Implementation Requirement	Infrastructure Capabilities and Resources
Experiment design and engineering	Weapons computer codes	Scientists and engineers experienced in weapons work
	Hardware engineering specifications	Component and assembly design engineers
	Test design	Hydrodynamic test engineers
Test materials and component fabrication	Parts design	Component and assembly design engineers
	High-precision parts fabrication	Precision manufacturing designers and facilities Facilities and operators for depleted uranium, beryllium, tantalum, tungsten, and high explosives
	High-precision quality inspection	Quality inspection instruments housed in controlled environment facilities
	High-explosives fabrication	High-explosives fabrication facilities Experienced fabrication engineers and safety engineers
	High-energy detonators	High-energy detonators design, fabrication, and testing facilities Experienced detonator designers, engineers, technicians, and safety engineers
	Pin dome precision assembly and quality inspection	Assembly facilities near test facility Inspection instrumentation near test facility Experienced assembly designers, engineers, and technicians
	Special materials: plastics, glues, foams, binders, organics	Chemistry laboratories, assembly facilities, technicians
	Salt mock-ups	High-explosives fabrication facilities, technicians
Test assembly and inspection	High-explosives handling facility	High-explosives facility Experienced high-explosives operators
	Precision mechanical inspection	Mechanical inspection instrumentation housed in controlled environment facility
	Penetrating x-ray nondestructive inspection and inspection	Static radiographic testing instrumentation Experienced radiographic technicians

TABLE 3-1.—*Infrastructure Requirements for Typical Radiographic Test Experiments – Continued*

Activity	Implementation Requirement	Infrastructure Capabilities and Resources
Transportation to firing site and integral storage area	Secure containment	Department of Transportation approved containers
	Secure transport	Department of Transportation approved vehicles; access via nonpublic roads or public road closures; Safe Secure Transport security vehicles used with special shipping containers
	Secure (classified) interim storage area	Approved secure storage facility in vicinity of firing site
Firing-site preparation	Perimeter control	Security and safety control systems in place Engineering and administrative controls for safety Security and safety personnel
	Multiple diagnostic capabilities	Flash radiography instrumentation High-speed electronic recording instrumentation High-speed optical diagnostic test equipment Laser diagnostics equipment Microwave diagnostics equipment Experienced diagnostic test engineers and equipment operators Specific temperature, environmental controls for inspection and diagnostic equipment Facility, instrumentation and equipment calibration, maintenance and repair support, and technicians
	Facility operations support	Machine shop Electronics calibration equipment Communication system and equipment Security support systems Plant operations support personnel Fire Suppression Personnel
	Small firing-site support	Equipment, personnel for qualifying detonations and characterizing high explosives
	Test set-up and take-down	Onsite mobile cranes, trucks, operators

TABLE 3-1.—*Infrastructure Requirements for Typical Radiographic Test Experiments – Continued*

Activity	Implementation Requirement	Infrastructure Capabilities and Resources
Uncontained testing	Materials recovery	Experienced recovery staff, equipment
	Materials recycle	Materials classifiers, materials characterization facility and equipment, materials storage
	Materials processing	Reprocessing facilities for depleted uranium, beryllium, tantalum, tungsten, and high explosives processing for reuse; technicians, transportation
	Waste management	Treatment, storage facilities, and staff for mixed waste, low-level radioactive waste, RCRA waste, sanitary waste Disposal facilities (offsite and onsite)
	Environmental monitoring	Environmental scientists, sampling and analytical technicians, chemistry laboratory facilities
	Worker health and safety monitoring	Health physicists, industrial hygienists, and industrial safety specialists, monitoring equipment, laboratory facilities
Contained experiments	Containment vessel support	Vessel design engineers Vessel test engineers, facilities Vessel cleanout Debris-handling capabilities Material recovery, reprocessing Waste treatment Vessel staging and storage
	Plutonium dynamic experiments	Plutonium fabrication, storage and handling Plutonium chemistry facilities Material processing and storage Specialized engineers, chemists, technicians, security, and worker safety personnel
Post-testing activities	Develop, digitize radiographs	Radiographic facilities and technicians
	Analyze images, signals	Custom computer analysis software
	Develop and refine analytic tools	Weapons components functional modeling capabilities, custom computer hardware and software, weapons personnel and technicians

to be taken along a single axis of the FXR accelerator; this is referred to as a double-pulse. However, the x-ray dose would be reduced to about 55 R per pulse. Following completion of the second upgrade, the replacement cost for FXR would be approximately $90 million.
All FXR explosive experiments are currently uncontained. In addition to the ongoing upgrades, DOE has funded studies to examine the option of using a containment facility at LLNL that would be capable of containing an explosion of up to 172 lb (80 kg) of high explosives (DOE 1992; HPAIC 1992). This potential containment facility is in the conceptual design stage. Design funding is included in DOE's FY 1996 budget. An environmental assessment for the proposed Contained Firing Facility is in progress. During the construction period, DOE could not use FXR for hydrodynamic testing. Although the firing site is in compliance with current environmental regulations and does not adversely impact upon residential areas near Site 300, a containment facility would provide LLNL with additional flexibility to continue hydrodynamic tests and dynamic experiments, particularly in the event that future environmental regulations in California would restrict uncontained operations. Even with the planned upgrades and the inclusion of the proposed containment system, DOE has no plans to conduct experiments with plutonium at Site 300 (Multhauf 1995). In the event that in the future DOE proposes other major modifications to the FXR facility or its operations, DOE would conduct appropriate studies [including National Environmental Policy Act (NEPA) review if required] at that time.

3.3.5 Radiographic Support Laboratory

The RSL was the first part of the DARHT project at LANL. Construction started in 1988 and was completed in 1990. Under all alternatives analyzed in this EIS, DOE would continue to operate the RSL to support radiographic operations undertaken at LANL. The RSL is a 21,000-ft^2 (1,950-m^2) building located in Technical Area 15 (TA-15). The main functions of the RSL are development, calibration, testing, and repair of high-energy flash x-ray machines. The facility includes a radiographic machine room, control room, mechanical and electronics room, machine shop, and offices. In addition to supporting ongoing radiographic testing at the PHERMEX Facility, the RSL has been serving as a staging area for development of accelerator technology and the Integrated Test Stand that DOE proposes to use to achieve an enhanced radiographic hydrodynamic test capability.

Two separate panels of independent consultants convened by DOE studied the linear induction accelerator technology that DOE proposed to use, and they agreed that DOE needed to design and test the Integrated Test Stand as the front-end of the linear induction accelerator proposed to be installed at DARHT (DFAIC 1995, DOE 1993a). The same linear induction accelerator would be used under all alternatives analyzed in this EIS except that under the No Action Alternative an enhanced accelerator capability would not be installed in PHERMEX. However, under all alternatives, including the No Action Alternative, DOE would continue to perform accelerator research in support of flash x-ray technology and use the RSL facility in the same way it is used now.

3.3.6 Site Description

All of the alternatives analyzed in this EIS refer to the PHERMEX site and/or the DARHT site (figure 3-1). These sites are located in the southeastern part of LANL TA-15 on Threemile Mesa. TA-15 is located in the center of the high-explosives research, development, and testing area, in the southwestern part of LANL, which makes up about 20 mi^2 (52 km^2), or about half of the area of LANL (LANL 1994).

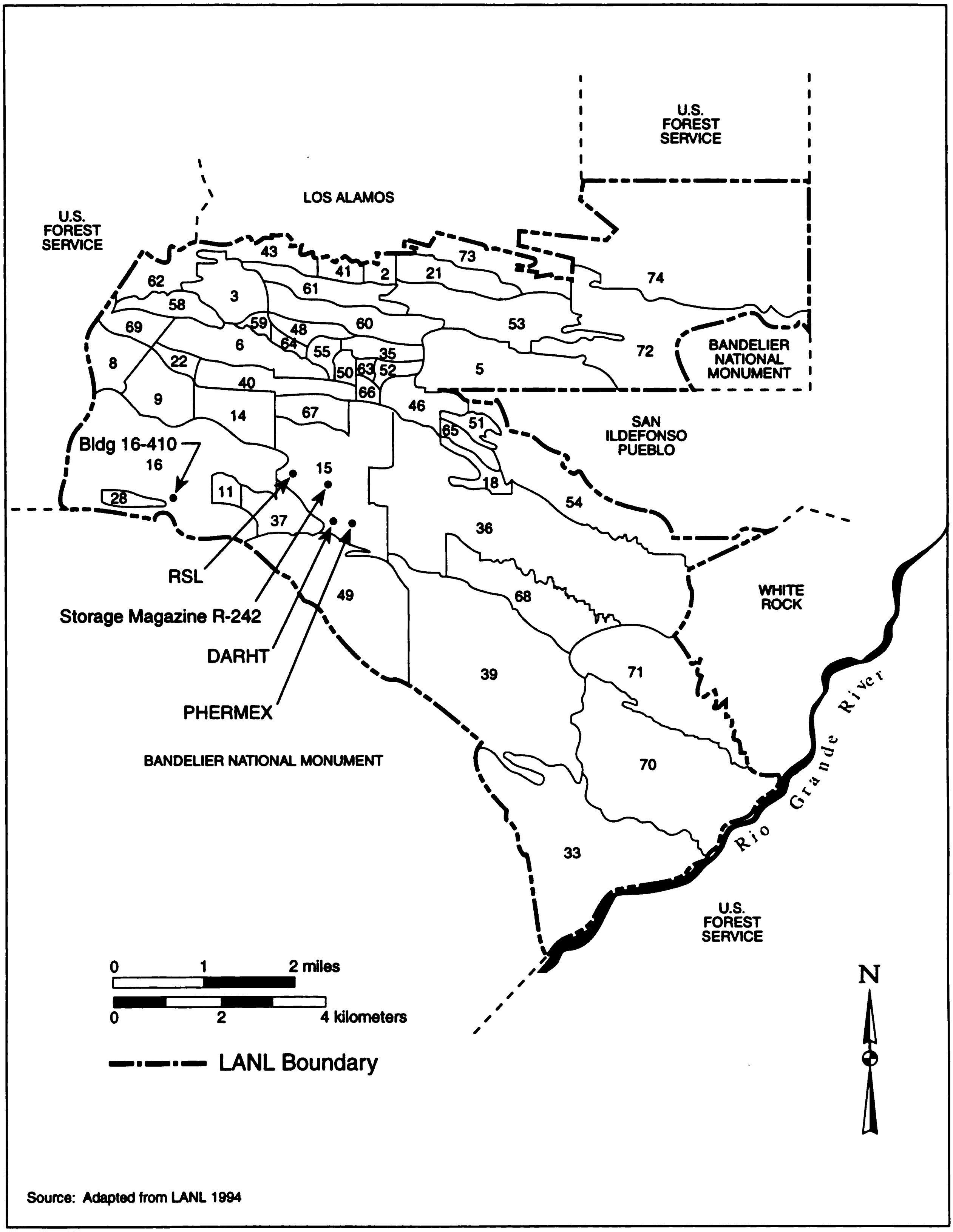

FIGURE 3-1.—*The Relationship of the LANL Technical Areas to the Location of PHERMEX and the DARHT Facility.*

The PHERMEX site and the DARHT site are about 2,000 ft (600 m) apart. These locations constitute a single site for many of the environmental impacts. For the purpose of analysis, the combined sites are considered to be Area III in TA-15, as defined by LANL for safety, security, and control of the firing sites at PHERMEX and the DARHT Facility. Area III includes the mesa top from the southeast boundary of TA-15 extending northwestward a little over 1 mi (about 2 km) to a fence line near R-183 (see figure 3-2).

The PHERMEX site, shown in figure 3-1, is a small complex of buildings and structures which have been used for hydrodynamic testing and dynamic experiments at LANL. The buildings, structures, and roadways at the PHERMEX site occupy about 11 ac (4 ha). About 120 ac (48 ha) of the mesa top lie behind the safety fence for PHERMEX and within TA-15. At PHERMEX, the mesa is about 1,500 to 2,000 ft (460 to 610 m) wide, bounded on the north by Potrillo Canyon, and on the south by Water Canyon.

The DARHT site is located to the west of the PHERMEX site, also in TA-15 on Threemile Mesa. The total area for the DARHT Facility is about 8 ac (2.3 ha). This area includes about 1 ac (0.4 ha) previously disturbed under the RSL contract for the DARHT Facility access road and utilities and 7 ac (2.3 ha) disturbed by the DARHT construction. Previous DARHT construction activities through 1994 account for the clearing of 14,000 board-feet of lumber. Potential impacts related to the future construction of the DARHT site are discussed in section 5.2.2.1.1 and section 5.2.5.1.1. At this site, the mesa is about 1,600 ft (490 m) wide. It is bounded on the north by the upper reaches of Potrillo Canyon and on the south by Water Canyon. The site lies only a few hundred feet from the mesa rim for Water Canyon.

The elevation on the mesa top in Area III is about 7,180 ft (2,190 m). In the vicinity of Area III, vegetation is mainly the Ponderosa pine plant community. This plant community within the 8 ac (2.3 ha) associated with DARHT has been altered due to construction. Any reptile, amphibian, bird, and large mammal population have been displaced by these activities. Small mammals such as rodents would have been displaced temporarily and would likely return to the disturbed area. Soils on the nearby portions of the mesa top include the Pogna fine sandy loam, rock outcrop, and Seaby loam (LANL 1993). The surface is well drained, and the main aquifer lies approximately 1,200 ft (370 m) below the surface (Broxton et al. 1994). Beneath the site, the Bandelier Tuff is likely to be more than 700 ft (215 m) thick, and the underlying Puye formation makes up the remaining interval to the water table.

3.3.7 Development of Operating Procedures

Operating procedures are already in place at PHERMEX and would be used under the No Action Alternative. Under all of the other alternatives analyzed, DOE would develop operating procedures to assist with safe, secure operation of the facility.

LANL policy provides general safety guidance and requires that procedures more specific to actual operations be developed within the operating group. The operating group would also prepare a plan for emergency response. To foster a general safety awareness within the operating group, periodic meetings would be held to emphasize the aspects and consequences of safety and emergency planning. Safety considerations would take precedence over operational necessity of the operating group.

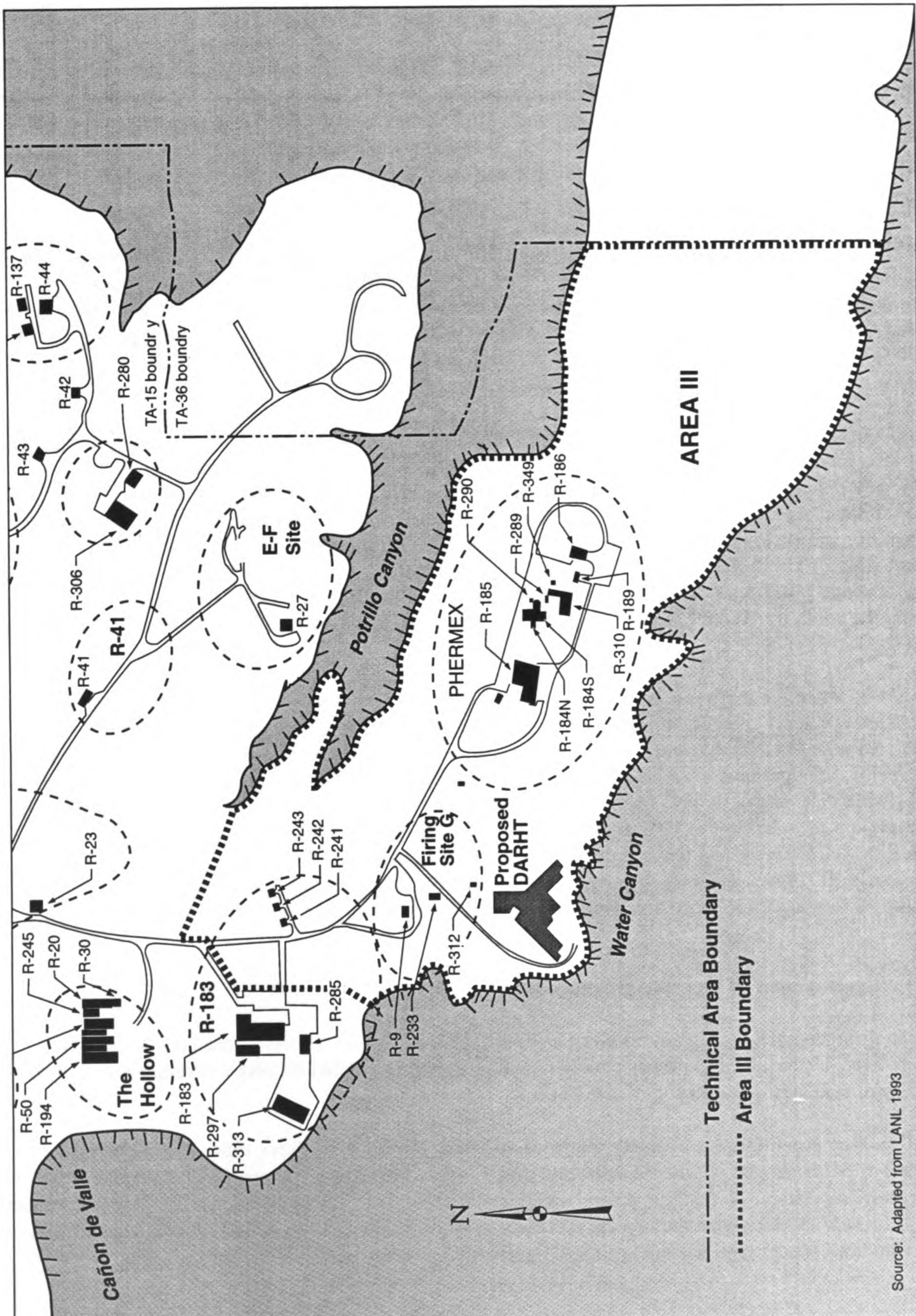

FIGURE 3-2.—*Site Map of Area III in TA-15, LANL, Showing Building Numbers (generalized schematic representation).*

3.3.8. Decontamination and Decommissioning

Under all alternatives analyzed in this EIS, eventually DOE would no longer need PHERMEX or the DARHT Facility and would decontaminate and decommission (D&D) the structures. The structures would eventually be demolished as well.

The only difference among alternatives would be the timing of the eventual D&D. For example, under the No Action Alternative and Upgrade PHERMEX Alternative, DOE would continue to operate PHERMEX indefinitely, while under the Preferred Alternative DOE would phase out operations at PHERMEX over a four-year transition period. DOE would then proceed with D&D and demolition of the structure when it is no longer needed for any purpose. DOE estimates that the DARHT Facility has a 30-year design life, regardless of whether the structure is used for hydrodynamic tests and dynamic experiments, as under the Preferred Alternative, or for other uses, as under the No Action Alternative.

At the end of the useful life of either PHERMEX or DARHT, DOE would evaluate options for disposal of the facility. At that time DOE would perform engineering evaluation, environmental studies, and a NEPA review to assess the consequences of different potential courses of action.

D&D activities would result in the generation of mixed waste, radiological waste, and solid waste. Demolition would result in solid waste in the form of construction rubble and possibly other types of waste. These wastes would be treated and disposed.

DOE anticipates that alternatives for disposition of the two facilities would include:

- D&D and demolish the structures and release the site for unrestricted use
- D&D and demolish the structures and restrict use of the site
- Partial D&D and retain structures for unrestricted use
- Partial D&D and retain structures for modified or restricted use
- No D&D and retain structures for similar or modified use

DOE cannot anticipate which options may be considered reasonable in the future and so cannot assess these alternatives in this EIS.

3.4 NO ACTION ALTERNATIVE

The No Action Alternative describes the continuation of the current situation (status quo) that would be expected in the future if DOE did not implement the Preferred Alternative or any other alternative analyzed in this EIS. The No Action Alternative serves as a basis of comparison for all other alternatives analyzed. For this EIS, the No Action Alternative would be to continue to operate PHERMEX at LANL and FXR at LLNL and not acquire an enhanced radiographic hydrodynamic testing capability. However, the No Action Alternative is not static. DOE would use these facilities to support its science-based stockpile stewardship and management program to the greatest extent possible. Accordingly, the type and number of hydrodynamic tests and dynamic experiments could vary from the type and number used in the past, as program needs change.

Under the No Action Alternative, the following would occur:

- PHERMEX and FXR would continue to provide hydrodynamic test capability
- The partially constructed DARHT Facility would be mothballed, and construction would not resume until another use for the structure could be determined (e.g., office space or accelerator applications), and appropriate reviews, including design and NEPA review as appropriate, were completed
- The RSL would continue to support radiography technology and operations at LANL
- Three-dimensional or time-dependent information would be partially obtained at PHERMEX by conducting sequential tests of nominally the same design
- DOE would perform some dynamic experiments; those using plutonium would be conducted in double-walled containment vessels

Under this alternative, DOE would continue to operate PHERMEX well into the next century. As discussed in chapter 2, over time, maintenance of the facility would be increasingly difficult in the event that replacement parts become unavailable to maintain and operate the vintage accelerator.

Under this alternative, DOE would determine another use for the partially constructed DARHT Facility, and would complete the structure following redesign and other appropriate reviews. This may require additional NEPA review. For the purposes of this EIS, in order to serve as basis of comparison for other alternatives, DOE has assumed that completing the structure would involve completing a concrete shell similar to the DARHT Facility; DOE recognizes that other types of uses may require modification to the structure and different construction materials or techniques, compatible with other requirements for structures within TA-15 or the larger explosives testing area.

3.4.1 Facility

PHERMEX was constructed in the 1960s and first operated in 1963; the north and south amplifier rooms were added in 1980 and the R-310 Multidiagnostics Operations Center in 1988. The PHERMEX Facility includes three major buildings and several other support buildings and structures (see figure 3-2).

Table 3-2 lists some of the PHERMEX buildings and their functions. PHERMEX uses a radio-frequency accelerator (instead of a linear induction accelerator, like that at FXR) that was designed and built at LANL specifically for radiography. The accelerator is unique in that it was designed for a maximum charge per pulse by using a very low frequency (50 Mhz) to provide maximum stored energy per pulse. Although PHERMEX is able to obtain several hundred amperes peak beam current, the voltage quickly drops, resulting in a beam energy spread that limits beam spot size (DFAIC 1995).

No new construction or site modification at PHERMEX is included in the No Action Alternative, with the exception of DOE's proposal to relocate the Ector machine. In 1991, DOE proposed moving Ector from Site R-306, TA-15, to the PHERMEX site. Site preparations to receive the Ector machine have been ongoing since 1992 and have consisted of installing a concrete pad and an above-ground oil tank. Ector is an existing 30-year-old x-ray diagnostic machine that is scheduled to be moved to the PHERMEX site in 1995 or 1996 for experiments in which a wide-field-of-view, medium-resolution radiograph of an entire

TABLE 3-2.—*PHERMEX Buildings and Their Functions*

Building	Function
R-185	Power Control Building for PHERMEX (two-story). Contains equipment for regular site power and heating, ventilation, and air conditioning (HVAC), and special equipment to generate and control high voltages, store electrical energy, generate and control radio-frequency energy, and control PHERMEX functions during a test shot. One of only two buildings at the facility that personnel are allowed to occupy during a test shot.
R-184	Houses the linear accelerator, PHERMEX, and its ancillary equipment that produce the x-rays for imaging a test shot. Accelerator's 25 to 30 MeV electron beam impinges on a tungsten target which then emits the x-ray beam. Has high voltage power supplies and radio-frequency equipment. Personnel are not allowed in the building when the accelerator is operating.
R-310	Multidiagnostics Operations Center, built in 1988. Has a control room for firing explosive tests independently or in conjunction with PHERMEX radiography. Houses diagnostic equipment associated with firing control and data collection from test shots. Second of the two buildings that may be occupied during a test shot.
Firing Area and R-349	Contains detonator firing equipment. Firing site can handle 150 lb[a] (70 kg) of explosives on the pad in front of the Building R-184 bullnose which protects the x-ray converter. Larger explosive charges, up to about 1,000 lb (454 kg), can be accommodated by moving the firing point up to a distance of 160 ft (48 m) to the east away from Building R-184.

[a] Throughout this EIS, quantities of explosives are mentioned. Although different explosive compounds may be used, quantities are always given as an equivalent amount of TNT, which serves as a standard reference.

assembly being tested is needed simultaneously with a high-resolution radiograph of the same test. Ector could be used to image the large-scale motion of the lower-density region of an experiment while PHERMEX images a smaller high-density region of the same test. Ector would not require a separate building. DOE has completed NEPA review of certain site preparation activities that could be used for Ector and will complete all required NEPA review before the proposed relocation of Ector to the PHERMEX site is done. Use of Ector at PHERMEX would eventually be phased out.

Under the No Action Alternative, a double-walled steel containment vessel would be used at the firing-site facility to contain emissions and debris from selected dynamic experiments, particularly those involving plutonium.

3.4.2 Operations

The historic operational baseline for PHERMEX is described in appendix B. The PHERMEX Facility can detonate high-explosive charges up to 150 lb (70 kg) located at the principal firing point. If larger high-explosive charges are necessary, such charges up to about 1,000 lb (454 kg) would be located at firing points to the east along the accelerator axis. For such experiments, a temporary expendable blast shield would be constructed as necessary to mitigate blast effects. Both uncontained and contained shots are fired at PHERMEX.

Typical requirements to conduct a radiographic test are listed in table 3-1. Operations specific to PHERMEX can be divided into six steps: planning, assembly, placement, diagnostic verifications, firing, and post firing. Typically, the need and the initial planning for a test shot involve several LANL organizations (see section 3.3.3). Experts within the division that operates PHERMEX often participate in the planning aspects related to mechanical support, placement, and diagnostics. Completed assemblies are usually prepared elsewhere and delivered to the firing site. The Access Control Office (ACO) monitors transportation activities within the PHERMEX controlled area. A limited number of assembly operations, such as electrical connections at the firing point, may be performed at the TA-15 site.

Before a shot is fired, the firing supervisor clears the firing point of personnel and makes the final connections to the high-explosive assembly. The firing supervisor contacts the ACO for a list of personnel in the PHERMEX area and accounts for each one. No one is allowed to enter or exit the area until the shot is fired. Clearance patrolmen make a sweep from the PHERMEX site out to the designated control point and set up a roadblock. The roadblock remains in place until the shot is fired and the area is declared safe by the firing supervisor. The firing supervisor, clearance patrolmen, and the ACO maintain radio contact during the firing procedure. Fire suppression personnel and equipment remain in standby at the designated control point during the firing procedures.

Activation of the detonators occurs just before the PHERMEX x-ray machine is pulsed and is controlled by the facility safety system. Operation of the PHERMEX radiographic beam is controlled by physical interlocks and a machine visual disconnect terminal. The system includes an explosives visual disconnect terminal. For pin test assemblies, the pins are connected to their power supply just prior to firing and comprise the pin diagnostic network. The pin diagnostic network connections are protected in a manner similar to connections for the detonator circuit.

Prior to use, all simulated weapon assemblies are monitored for the presence of fissile material according to pit verification procedures. This monitoring is performed and verified by the firing supervisor and a member of the firing crew.

After the shot has been fired and the site declared safe, the clearance patrolmen remove the roadblocks and fireman on standby enter the area to control fires. The operating crew enters the firing area, collects any diagnostic data, and moves the film cassette to another building for dismantling. Film cassettes are heavily armored containers that protect the x-ray film from the explosive blast. Post-firing activities include cleaning up the firing site and collecting firing-site debris. Cleanup and debris removal are often scheduled only after a sequence of shots. If a containment vessel has been used, the vessel is moved by truck to another LANL facility for opening, cleaning, and refurbishing.

Personnel who are engaged in recovery or cleanup activities typically are required to wear protective clothing as deemed necessary by the LANL Environment, Safety, and Health radiation control technician. Contamination of the firing point by undetonated explosives is highly unlikely, but remotely possible. If such contamination occurs, cleanup under a Special Work Permit is required before the firing point may be used again.

The PHERMEX operating crew includes personnel to field an experiment and support personnel to maintain the PHERMEX accelerator and all of the site's ancillary equipment. The number of workers with radiation safety training and available to be assigned to tasks at or near the PHERMEX firing area currently ranges from 67 to 77. Only nine radiation workers are required at one time. Some of the support personnel for a test typically include two electronics technicians for the diagnostic chamber, two or more PHERMEX operators, two staff members to provide physics support, one or more mechanical technicians for maintenance and upgrades, two clearance personnel, a firing crew of three technicians, a photographic technician to handle and process the x-ray films, and additional personnel depending on the diagnostics fielded for a test shot. Most of these people also support other programmatic efforts unrelated to PHERMEX.

3.5 PREFERRED ALTERNATIVE

Under the Preferred Alternative, DOE would complete construction and operate both axes of the DARHT Facility. An artists' conception of the DARHT Facility is shown in figure 1-1. If the DARHT Facility becomes operational, DOE would phase out operation of PHERMEX over approximately four years. The Preferred Alternative is not expected to affect future operations of the RSL at LANL, the FXR at LLNL, or other smaller explosive test facilities at LANL and LLNL. Under the Preferred Alternative, a steel containment vessel could be used at the firing site facility to contain emissions and debris from selected dynamic experiments; experiments involving plutonium would be conducted inside a double-walled steel vessel.

The DARHT Facility responds to DOE's need to obtain enhanced hydrodynamic testing capability. Through its weapons research and design expertise at LANL, DOE developed DARHT to provide enhanced diagnostic capability to study the behavior of nuclear weapons. DARHT was designed specifically to provide three-dimensional information and to obtain deeply penetrating, high-resolution radiographic images.

DARHT would be used to study the three-dimensional implosion of mock nuclear weapon primaries. DARHT would enable imaging through very thick, dense materials; take multiple, very brief, snapshots from two different lines of sight; and provide images of very high resolution. Completion and operation of the first axis of DARHT would produce radiographic images with significantly higher spatial resolution and penetration than is now possible at either PHERMEX or FXR. With completion and operation of the second axis, DOE would be able to obtain three-dimensional data as well as time-sequenced images taken within millionths of a second or at arbitrary times.

Compared to the present capability at PHERMEX and FXR, the DARHT Facility would:

- Provide higher resolution of the entire imploded primary area
- Provide more information content in each radiographic image because of the reduction in beam size proposed for DARHT and the corresponding increase in resolution
- Provide two independent views, taken at right angles to each other, of the systems being tested; this capability could be used to provide either three-dimensional data or provide information at two slightly different times, whichever would be more important in observing a particular system
- Provide this increased information content over the full field of view of the machine, which would encompass a full-scale mockup of the system to be tested
- Provide a 100 percent increase in x-ray strength, compared to PHERMEX

DARHT was first proposed in the early 1980s as a diagnostic facility to be used as part of LANL's ongoing weapons research and development mission. DARHT was intended, then as now, to assist in evaluating the safety, performance, and reliability of existing weapons. In addition, at that time hydrodynamic testing at DARHT, in conjunction with underground nuclear testing, was intended to assist in designing new nuclear weapons and replacement parts.

The DARHT Facility would provide a flash radiographic capability for the testing of high explosives systems and components. Other types of electronic, optical, and photographic diagnostics would also be available at the site. Timing options would allow triggering of the two x-ray beams either simultaneously or with slight delays. Simultaneous images from the two axes would provide for three-dimensional data while sequential images would aid in studying the time history of a test assembly.

DOE may install, test, and prove the linear induction accelerator equipment in the first axis (the southeast accelerator hall) before purchasing, assembling, and installing the accelerator equipment in the second axis. This would be to ensure that the accelerator technology will perform as anticipated before incurring the expense of equipment for the second axis. Accordingly, DOE has split the expenditure for the second axis equipment into a separate budget line item for the remainder of the project. This is in keeping with the recommendations of independent panels of consultants convened by DOE to review technology plans (HPAIC 1992; DFAIC 1995; DOE 1993a). Although the two 1992 reports suggested delaying construction of the second axis until the first axis was tested and proven, in 1992 DOE approved funding for construction of accelerator halls for both axes. DOE allowed for site preparation and construction for both accelerator halls to proceed at the same time to avoid undue disruption to operation of the first axis while the second accelerator hall was constructed. The accelerator halls and associated diagnostic areas were modified to accommodate the recommendations of the various panels and to ensure that the DARHT facility could provide diagnostics used by LLNL, and thereby function as a shared user facility (DOE 1993a).

Hydrodynamic and explosives operations proposed for the DARHT firing-site facility are similar to those currently undertaken at the PHERMEX facility, which is located approximately 2,000 ft (610 m) to the east of the DARHT site. The DARHT Facility would provide increased information and improved radiographic diagnostic capability over PHERMEX because of the increased temporal and spatial resolution and two lines of sight. Although the DARHT Facility is designed to provide more and better data for each shot, the total number of shots per year would remain about the same as for the No Action Alternative.

Hydrodynamic testing at the DARHT Facility would consist of observations of explosive systems in combination with surrogate materials, such as depleted uranium or tantalum, which simulate the behavior of weapons materials but are physically incapable of producing energy from nuclear reactions during testing. In addition, the facility could be used for testing systems such as high-velocity impacts and explosive forming of metals.

3.5.1 Facility

The DARHT Facility would consist of a new accelerator building, with two accelerator halls, firing point, and the associated support and diagnostic facilities at the DARHT site (see figure 3-3). The proposed firing point would be at the juncture of x-ray beams produced by two electron beam accelerators oriented at right angles to each other to provide dual-axis, line-of-sight radiographs. The accelerators would be housed in halls about 225 ft (70 m) long by 50 ft (15 m) wide. The existing RSL, which supports all radiographic machines at TA-15, would be used to support the DARHT Facility.

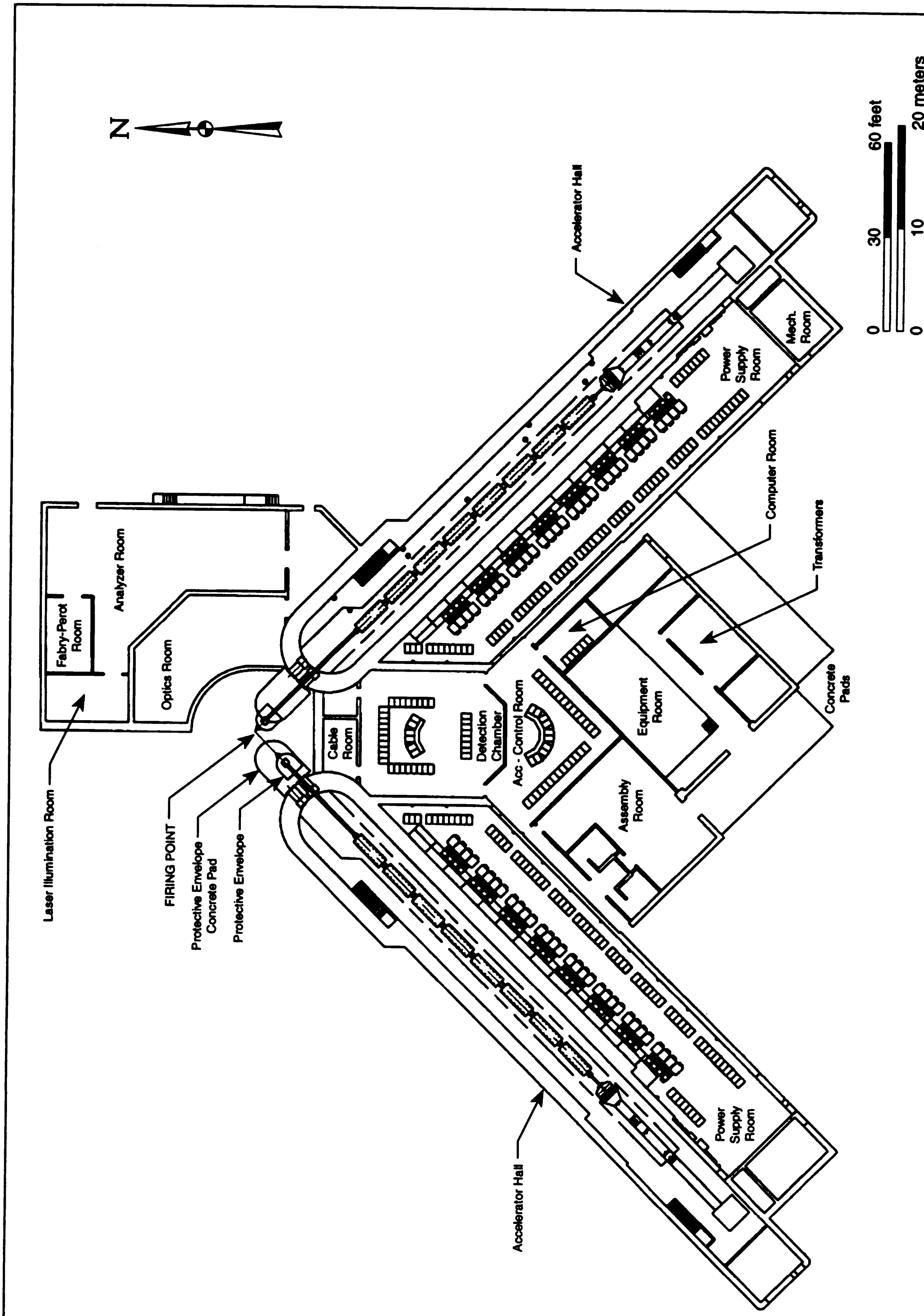

FIGURE 3-3.—*Proposed DARHT Facility Plan.*

Construction of the DARHT Hydrotest Firing Site (HFS) began in May 1994, and construction was halted on January 27, 1995, by preliminary injunction from the U.S. District Court, Albuquerque, New Mexico. At that time, approximately 34 percent of the construction of the HFS was complete. It is estimated that construction, installation, and testing activities for the first axis would take an additional 38 months, and for both axes 66 months, if this alternative were to be implemented.

3.5.2 Operations

The steps necessary to conduct a radiographic test are shown in table 3-1. The DARHT Facility would be able, by design, to detonate high explosives charges up to 150 lb (70 kg) located at the dual axis firing point. If larger high explosives charges were necessary, charges up to 500 lb (230 kg) would be located at a firing point to the northwest along the axis of the southeast accelerator to provide sufficient distance between the firing site and the building. For such experiments, a temporary expendable blast shield would be constructed to mitigate blast effects.

The operations to be performed at the proposed facility would be similar to those currently performed at, and proposed for, the PHERMEX facility. Some differences arise because there would be two x-ray machines to coordinate with a test detonation, and the DARHT x-ray machines would not be identical in their operating parameters to the PHERMEX machine. The operational tasks include design; assembly and placement of the test assembly at the firing point; setting up and checking out the diagnostic apparatus; executing the experiment from a remote control room; and completing post-firing tasks associated with securing the firing pad and cleanup. Preliminary data reduction is usually done onsite to determine the success of the experiment.

One of the few differences between operations at the DARHT and existing PHERMEX Facilities would be the operation of two accelerators from the remote control room in the two-axis mode of operation. Since there would be two buildings containing accelerators, only minor upgrades to most existing operating procedures and administrative controls would be needed. However, the new technology of DARHT would result in changes to electronic operation and control of the facility.

Accelerators at the DARHT Facility would produce a sharply focused x-ray beam that would be much narrower than that of PHERMEX or FXR (approximately 60 nsec pulse width) and with a much stronger x-ray dose rate [at least 350 R/pulse at 3.3 ft (1 m) from the exit of each machine on the beam axis]. The electron beam energy would be in the range of 16 to 20 MeV. The electron beam would be converted into an intense x-ray beam emanating from a spot size that is approximately one-third that of PHERMEX. The initial dose strength of the x-ray beam would be about double that of PHERMEX. The performance history of electron accelerators for flash radiography shows that the machine performance improves considerably in a few years from the original start up. Such improvements are expected for DARHT, and a dose strength of up to 2000 R could be achievable, which is about 10 times that of PHERMEX. The DARHT pulse width would be approximately one-third of the existing situation at PHERMEX and would result in improved radiographic resolution.

The accelerator could also be operated in a second mode without the production of x-ray beams. In this mode of operation, the electron beam would be stopped within a graphite target (beam stop) placed within the building near the exit of the accelerator. Tantalum shielding would be used to enclose x-ray production in the beam stop. This mode would be used during testing and beam-tuning operations in preparation for beam production for an actual test. Operational procedures in this mode would be essentially the same as in the x-ray production mode.

Explosives would not be stored, handled, or processed inside any DARHT building. Explosives operations would be performed in accordance with approved procedures and at other locations on the site. Conventional high explosives consisting of bare charges and clad devices would be positioned outside the DARHT structure and detonated at the firing point. Several kinds of test and x-ray preparation activities, identical to those conducted at PHERMEX, would be conducted at the firing point prior to detonation. These include positioning and mechanical alignment of the test assembly relative to the x-ray beam, establishing and verifying the cabling for diagnostics, and resistance measurement testing of the detonators to be used in the hydrodynamic test.

During preparations for a test, repetitively pulsing the accelerators would be necessary to focus and adjust the electron and/or x-ray beams. Tuning of the accelerator components is expected to account for a very large fraction of the estimated 25,000 pulses per year.

The proposed facility would use lasers both for lining up radiographic tests and for diagnostic purposes in optical tests. Operation of both the helium-neon laser and the solid state lasers (Neodymium: yttrium aluminum garnet with harmonic generator) to be employed in the accelerator rooms at the DARHT Facility would be performed in accordance with standard industrial safety practices. Further administrative and engineering controls in accordance with LANL procedures would be used for laser operation. Only operators who have been trained and certified in laser operation would be allowed to operate the lasers when used for alignment and checkout. When used as a diagnostic in an experiment, the lasers would be operated from the control room.

When containment would be used for a test shot, the blast products would remain in the containment vessel that would be taken to another LANL facility for cleaning and refurbishing. The contained blast debris would be taken to appropriate processing or disposal facilities according to the nature of the debris.

In 1988, a U.S. Environmental Protection Agency (EPA) radiological air emissions approval to construct the DARHT Facility under 40 CFR Part 61, the National Emission Standards for Hazardous Air Pollutants regulations, was obtained for the Preferred Alternative. This approval limits the annual expenditure of uranium to 440 lb (200 kg). This limit was based on the amount of depleted uranium used at PHERMEX during the mid-1980s. However, since that time, underground nuclear testing has ceased, programmatic objectives have changed, and a limit of 1,540 lb (700 kg) would be required to meet all objectives under this alternative. For example, safety tests of full-scale systems involving accident scenarios with stockpiled systems in sympathetic detonation would expend more depleted uranium per test than a single system test of the type envisioned at the time the permit was obtained. During a hydrodynamic test, ascertaining the proper function of certain stockpiled components that contain tritium could also be needed. These tests would be expected to release a small amount of tritium, and the maximum annual release would be less than 0.06 in^3 (1 mL, 3 Ci) of tritium. A new EPA approval would be needed in order for DARHT to operate at these new limits, and unless it could be obtained, operations at the DARHT Facility would be bounded by the current approval.

Sanitary wastes from the DARHT Facility would be handled by a septic system at the facility.

3.6 UPGRADE PHERMEX ALTERNATIVE

Under the Upgrade PHERMEX Alternative, DOE would upgrade PHERMEX with the new high-resolution radiographic technology developed for DARHT (see figure 3-4). (The existing PHERMEX x-ray machine is not technically capable of meeting DOE's need for enhanced high-resolution radiography.) PHERMEX would be remodeled and enlarged to accept the new equipment. Under this alternative, DOE would obtain improved high-resolution capability, as compared to the present capability at PHERMEX and FXR, and would construct a second accelerator hall to provide the capability to obtain three-dimensional and time-sequence data. As in the Preferred Alternative, the accelerator equipment for the second axis may be procured and installed after the equipment in the first axis was installed, tested, and proven. As in the Preferred Alternative, a steel containment vessel could be used at this firing site facility to contain emissions and debris from selected dynamic experiments; experiments involving plutonium would be conducted inside a double-walled steel vessel.

As discussed earlier in this chapter, some of the potential measures discussed for the Preferred Alternative could be applied to this alternative; however, they are not expressly analyzed. For example, DOE could decide to enlarge the existing single axis at PHERMEX and equip it with the enhanced radiographic capability originally planned for the DARHT Facility. Although this would not meet all of the DOE's programmatic objectives, the environmental impacts of such an approach would be within the range of impacts expected from the alternatives analyzed in this EIS.

The DARHT Facility would not be completed, but the partially constructed concrete shell of the firing site facility would be put to other uses, as described in the No Action Alternative. The Upgrade PHERMEX Alternative is not expected to affect future operations of the RSL at LANL, the FXR at LLNL, or other smaller explosive test facilities at LANL and LLNL. During the upgrade construction, expected to last a little over four years, DOE would suspend its hydrodynamic testing program at LANL.

3.6.1 Facility

Under the Upgrade PHERMEX Alternative, DOE would install the proposed enhanced hydrodynamic capabilities at the present PHERMEX Facility site. The PHERMEX structures and equipment would be used to the extent possible, but extensive replacements of and modifications to the present PHERMEX Facility would be required. Because only the enhanced radiographic technology developed for DARHT is currently available to provide the capability needed, and because the linear induction accelerator planned for DARHT is the only currently available technology to provide the needed capability, the radio-frequency accelerator now at PHERMEX would be removed and replaced with a linear induction accelerator. The new accelerator is physically larger than the existing accelerator, and would not fit in the existing accelerator hall. The existing hall would have to be extensively remodeled.

Under the conceptual design for this upgrade, the two accelerator halls and other buildings for the firing site would be sized and laid out similarly to the plans for the DARHT Facility. Orientation of the complex would be consistent with the existing accelerator hall at the PHERMEX site, with the first upgraded accelerator hall being an extension of the existing hall and the second hall constructed at a right angle to the first. The demolition of several existing structures and cleanup of existing debris would be necessary before construction could begin on facilities under the Upgrade PHERMEX Alternative.

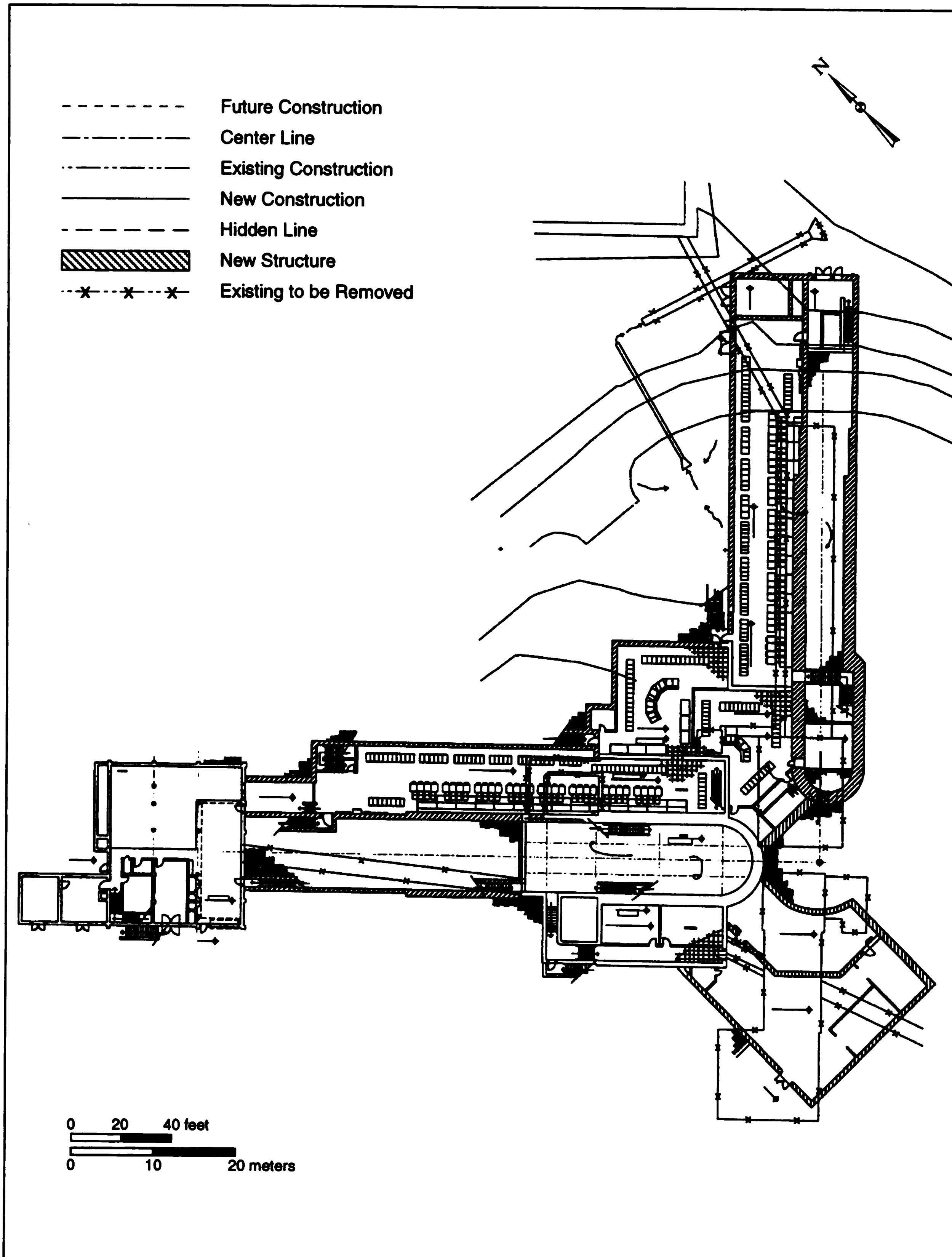

FIGURE 3-4.—*Conceptual Design of the PHERMEX Upgrade Facility.*

The existing PHERMEX building would be used under the Upgrade PHERMEX Alternative, but the structure would require substantial modification. The current PHERMEX diagnostic buildings are not appropriately configured for the Upgrade PHERMEX Alternative and would be demolished and replaced. The underground tunnels, which interconnect buildings, would be removed where necessary and abandoned in place if no longer needed. The mechanical and electrical systems at PHERMEX are inappropriate for DARHT technology and would be replaced. Cleanup, demolition, construction, installation, and testing activities associated with the Upgrade PHERMEX Alternative would require approximately 51 months to complete.

No new transmission lines would be required for the upgraded PHERMEX Facility; however, new water, fire protection, and gas lines would be installed to meet the requirements of the upgraded facility. A new sanitary sewer would also be required.

3.6.2 Operations

The operations to be performed at the upgraded PHERMEX Facility would be identical to those planned for the DARHT Facility. These operational tasks are described in section 3.5.2.

3.7 ENHANCED CONTAINMENT ALTERNATIVE

The Enhanced Containment Alternative is similar to the Preferred Alternative, but with the addition of a means (i.e., containment) to prevent the release of most or all airborne emissions, metal fragments, and other debris resulting from firing-site operations. The containment could be either portable steel vessels or a permanent building. DOE currently uses steel containment vessels at LANL facilities for some dynamic experiments. Under this alternative, using the containment vessel approach, DOE would conduct most hydrodynamic tests and dynamic experiments using containment vessels. On a case-by-case basis, DOE might opt to conduct certain types of tests as uncontained, such as those using a very large explosives charge (larger than the containment vessel rating); those requiring complex diagnostics (such as certain optics or laser tests) that cannot be achieved using a containment vessel; those requiring measurement of material movement beyond the confines of the vessel; or those using a very small explosives charge or small amounts of hazardous materials where use of the vessel would not be practical or cost-effective. For the purpose of this EIS analysis, DOE estimates that up to about 25 percent of all tests might be uncontained. Under this alternative, using the containment building approach, all hydrodynamic tests and dynamic experiments would be contained. Dynamic experiments involving plutonium would always be conducted in a double-walled steel containment vessel under either approach.

Under this alternative, using the containment vessel approach, DOE would expect to use containment for any experiment with materials made from beryllium, depleted uranium, or Resource Conservation and Recovery Act (RCRA) characteristic metals. At least 99 percent by mass of these materials would be retained as a result of using a single-walled containment vessel. Although DOE expects that any such vessel system would be designed to be highly effective, for the purpose of this EIS, DOE has made a conservative assumption that the single-walled containment vessel system might fail and allow a release of material to the outside environment up to 5 percent of the time. Such a failure would be expected to release gaseous by-products of the detonation and possibly small fragments. To simplify the analysis of impacts of such a release, for this EIS DOE has made a conservative assumption to equate the effects of such a release to a standard uncontained experiment. Experiments using plutonium would always be done within double-walled vessels that have been demonstrated to fully contain these types of tests and would not lead to environmental release.

For the Enhanced Containment Alternative, the DARHT Facility, as described in section 3.5.1, would be augmented by either the portable steel containment vessels or the addition of a permanent containment building to the DARHT structure. Either of these would require construction of a separate recycling facility, in addition to the construction for the Preferred Alternative. Compared to the Preferred Alternative, DOE would have to acquire several additional portable single-walled containment vessel systems under the containment vessel approach. Under this alternative, DOE would obtain greatly improved high-resolution capability, as compared to the present capability at PHERMEX and FXR, but would forego some degree of image resolution due to some loss of x-ray penetration through the containment vessel or structure.

3.7.1 Facility

This section describes the facility that would be constructed at the DARHT site to implement the Enhanced Containment Alternative. Under this alternative, if single-wall steel vessels were used, a separate recycling facility would be built near the DARHT site to recycle the vessels after each use. Double-wall vessels would be handled the same as under the No Action Alternative. The recycling facility would include a vessel and debris recycling area and handling equipment to minimize secondary waste generation and personnel exposure during recycling operations. Any secondary waste would then be transferred to a LANL disposal area. Under this approach, several new containment vessels would be purchased or fabricated. If a permanent building for containment were added to the current DARHT plans, the separate recycling facility for shot debris would still be needed and would be built near the containment building. The proposed site of such a facility is yet to be determined, but it would be somewhere within TA-15 and probably within 1 mi (1.6 km) of the DARHT Facility. Appropriate NEPA reviews will be conducted if this facility is required.

A containment structure would add about 13,000 ft^2 (1,210 m^2) to the DARHT building, but all of this additional area would be within the original DARHT Facility area. Portions of the earthen berm around the northern side of the site would have to be removed to build the containment structure and provide access to the building, but the berm would no longer be needed for its original purpose, which was to provide radiation shielding. A recycling facility, about 12,000 ft^2 (1,115 m^2), would be built at the DARHT site for the containment building approach. The specific location has not been determined (pending more detailed design of the containment building); it might sightly enlarge the DARHT site. For the vessel containment approach, the recycling facility would be located in TA-15 outside the DARHT hazard zone.

3.7.1.1 Containment Vessels

LANL is experienced in using containment vessels for explosives tests up to 44 lb (20 kg) of high explosives and is presently developing modern, reusable, transportable vessels for use with higher explosive loadings and a full suite of diagnostic capabilities. A prototype containment vessel for a 110 lb

(50 kg) high explosive load is in the design stage (see figure 3-5). This single-walled vessel would be modular in design to allow users to modify the vessel geometry to accommodate different experiments and shot configurations. The vessel would consist of a 12-ft (4-m) cylindrical shell with four ports for extension modules and a removable hemispherical top shell. The extension modules would be 6 ft (2 m) in diameter, 8 ft (2.5 m) long, and could be specifically configured to accommodate a particular experiment or diagnostic. Each extension module would have five ports: one on top for placing diagnostic equipment in the module and two ports on each side that can accommodate optical windows. The vessels would be fabricated from a state-of-the-art military steel so that field repairs and modifications would be possible. A support and alignment system would provide adjustments to align experiments for radiography or other diagnostics.

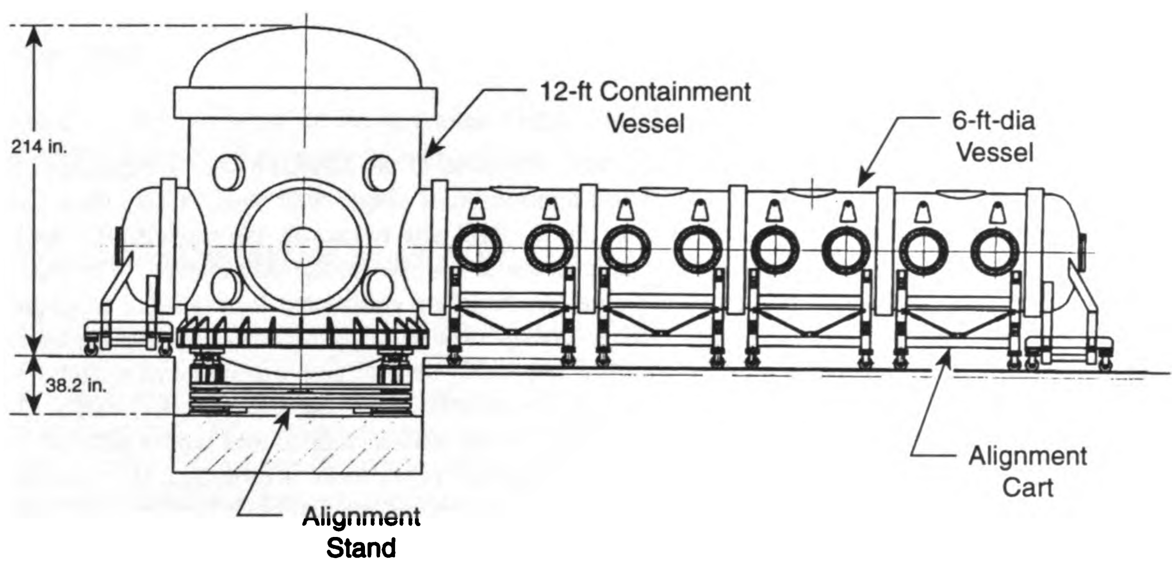

FIGURE 3-5.—***Conceptual Design of a 110-lb (50-kg) Containment Vessel*.**

DOE has considered proposing a Contained Explosives Test Complex, which would expand DOE's current capabilities for contained experiments. The Test Complex would provide for 15-ft (5-m) diameter vessels for firing capability up to 440 lb (200 kg) in addition to the 110-lb (50-kg) vessels described above and the support complex for containment vessels.

3.7.1.2 Containment Building

A containment building would be attached to the planned DARHT structure at its north end; it would enclose the firing point and extend to the northwest aligned with the axis of the southeast accelerator hall. This addition would extend to approximately the center line of the existing earthen berm. A concept for such a building, designed to contain a 185-lb (85-kg) test explosion at the DARHT firing point is shown in figure 3-6 (LANL 1995). A 625-lb (285-kg) test explosion could be accommodated in this building at

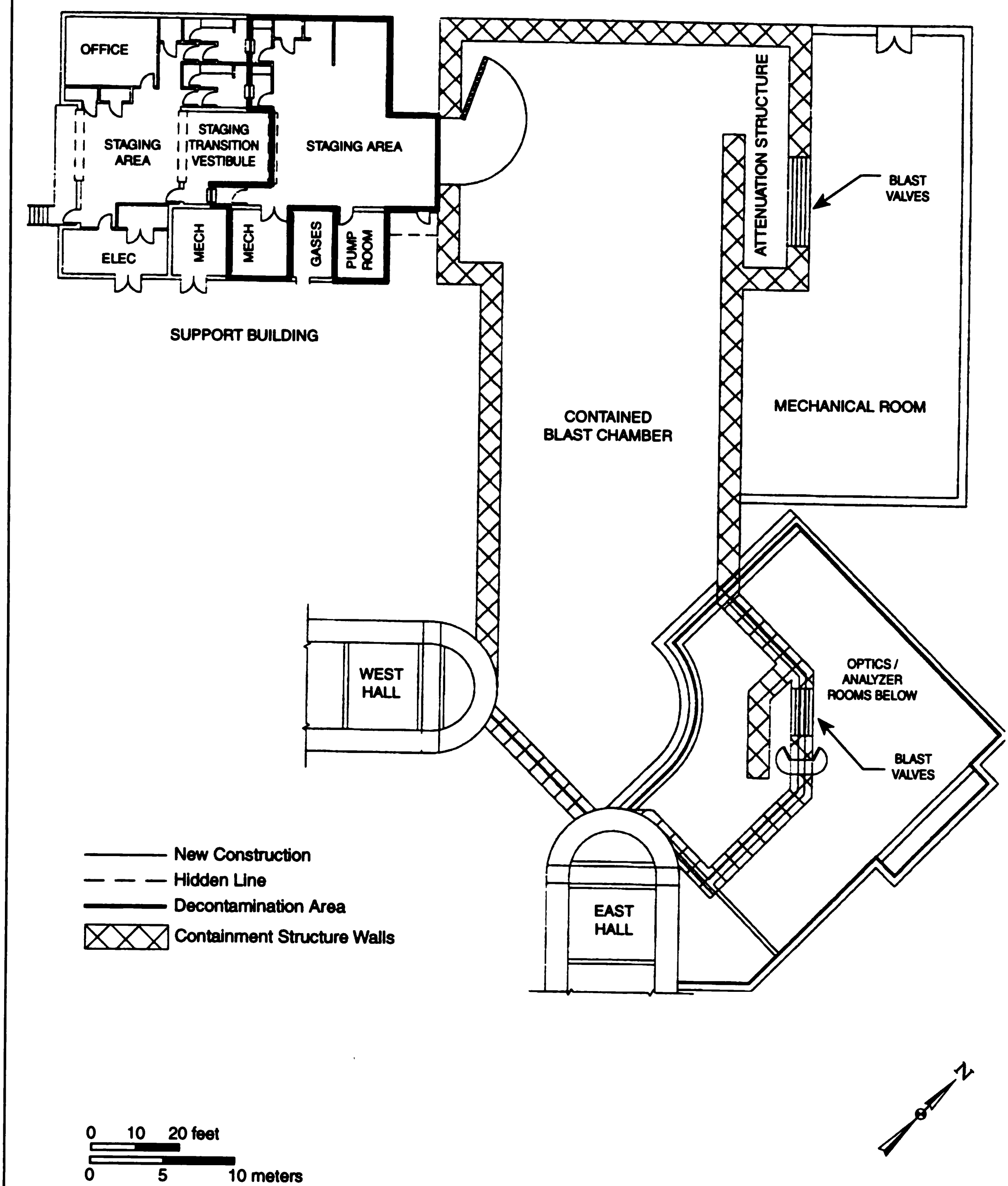

FIGURE 3-6.—*Conceptual Design of the Containment Building.*

the firing point shown about 40 ft (12 m) northwest of the dual-axis firing point, but only one accelerator could be used for imaging a test there. Preconceptual design is used to assist general layout and analyses of tradeoffs between chamber volume and resulting maximums for internal temperatures and pressures.

The walls, floor, and roof of the chamber that would contain a test explosion would be reinforced concrete 5 to 6 ft (1.5 to 1.8 m) thick. The roof would also have 6 ft (2 m) of gravel above the concrete to prestress the roof against explosive pressure. Replaceable fragment shielding would protect the inside surfaces of the chamber. In the design shown, the containment area within the building would be about 10,400 ft^2 (970 m^2), and its volume would be about 260,000 ft^3 (7,360 m^3) as fixed by the maximum charge of 625 lb (285 kg). If a maximum of only 185 lb (85 kg) of high explosives is to be fired, the building could be sized down by shortening its length in the northwest direction. The need to vent the resultant hot atmosphere, up to 650°F (343°C), would require a large robust mechanical cleanup system. A support area within the containment building would also be necessary to provide decontamination for personnel and other services during cleanup and shot preparation. Construction of the containment building would add at a minimum about one year to the DARHT construction schedule (LANL 1995).

3.7.1.3 Recycling Facility

A conceptual sketch of the proposed recycling facility is shown in figure 3-7. The facility would be constructed at TA-15 if portable single-wall steel vessels were used for containment, or near the containment building if such a building were used. The approximate size of the building would be 12,000 ft^2 (1,115 m^2). The main components of this facility would be two large bays, a debris processing room, and an analytical laboratory.

3.7.2 Operations

Under the Enhanced Containment Alternative, operations at the DARHT Facility would be the same as for the Preferred Alternative for the accelerators and their ancillary equipment. However, differences in operations would arise for setting up a test assembly and for post-shot operations to clean up the test shot products. Two operations scenarios would be possible depending on whether the approach to containment would be to use portable steel vessels or a containment building. With steel vessels or a containment building, there would be an exclusion area as for uncontained shots, but it would be reduced appropriately.

3.7.2.1 Containment Vessels

To set up a shot, a new or refurbished single-wall steel vessel would be delivered to the firing area by a heavy-duty tractor-trailer unit. The facility set-up crew would transfer the vessel to the firing point using a crane. The crew would also attach tested extension modules (figure 3-5) to the vessel if needed to accommodate the test assembly for a particular test. The main vessel and its attached extension modules would then constitute the containment vessel. Removing the hemispherical top to the vessel would provide access so the test assembly could be placed or assembled in the vessel. The containment vessel would have an electrical pass through and optical ports for the test assembly and diagnostics to communicate with the outside world.

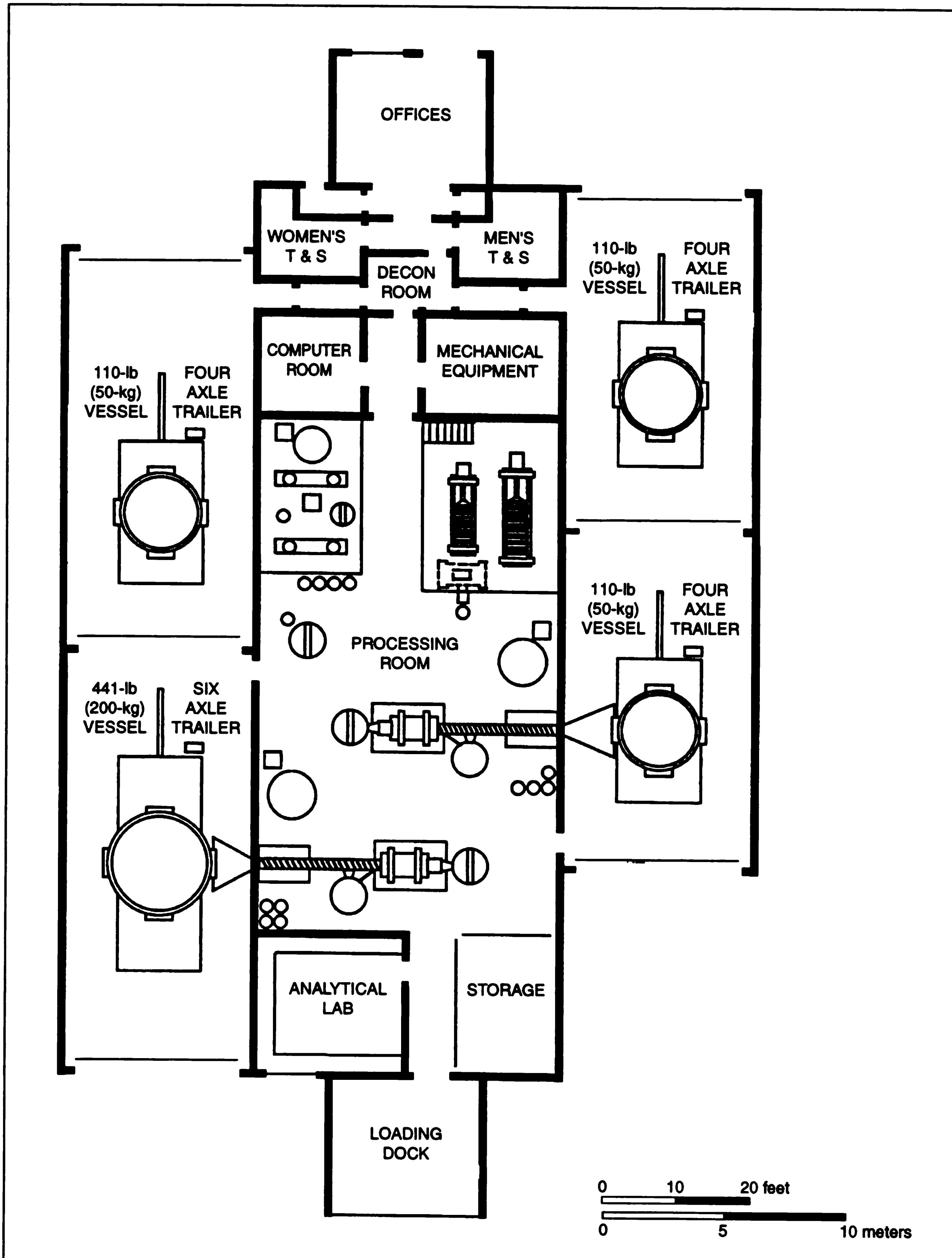

FIGURE 3-7.—*Conceptual Design of the Recycling Facility.*

Following a shot, the containment vessel would pass through several steps to render it safe, remove internal debris, and prepare it for subsequent reuse. First, the vessel's post-shot atmosphere would be vented and pumped out through high-efficiency particulate (HEPA) filters. A crane would be used to place the vessel on a trailer, and the vessel would be transported away from the DARHT Facility to adjacent recycling and test refurbishment facilities. The vessel would remain on the trailer during the cleanout and preparation process by using a mechanism to rotate the vessel-trailer assembly 90 degrees to facilitate cleanout.

Operations at the recycling facility would include single-wall vessel cleanout, debris recovery/ decontamination/recycling, vessel decontamination, recovery of process fluids for reuse and solidification of nonrecoverable materials from the process for disposal. Debris would be emptied from the vessel and separated by size. Large pieces of debris would be decontaminated in a cleaning tray using a polymeric extractant solution that binds and solubilizes radioactive and toxic metals. The cleaned debris would be stored for recycling. Fine debris not suitable for recovery would be transferred into a reaction tank where it would be agitated with the polymer extractant and the resulting slurry would subsequently be filtered to collect the solids. Following cleanout, the emptied vessel would be moved to secondary containment in the wet bay, sprayed for further decontamination using polymeric extractant, and finally rinsed. Metal-loaded polymer from the extraction and wash processes would be collected in a tank for extraction of the metal and regeneration of the polymer.

Cleaned vessels would be moved on their trailers to an existing building (R-285) for refurbishing. The refurbishing operations might include detection and repair of damaged areas, painting the interior, installation of shot supporting fixtures and diagnostics, and pressure tests.

3.7.2.2 Containment Building

The blast chamber in the containment building would be approximately 48 ft (15 m) wide by 160 ft (49 m) long (see figure 3-6); walls would be no closer than 17 ft (5.1 m) to the dual-axis firing point; and the chamber would have a 25-ft (8-m) floor-to-ceiling interval. However, access to the chamber, proximity of the inner surfaces, and the need for portable lighting affect the efficiency of experiment setup compared to uncontained testing.

Before a shot, the firing crew would verify that no personnel were in any portion of the containment building and that the mechanical systems affecting containment were functional. Following the detonation of a maximum charge, gases and aerosols would fill the blast chamber, increasing the pressure to about 20 psi (14,060 kg/m^2) and temperature to 650° F (343° C). This pressure would bleed off through blast valves into the treatment area where the gases would be mixed with sufficient ambient air to allow filtration through HEPA filters. The process of venting and purging gases would take about two hours. Following purging, an automated wash system using three ceiling-mounted, retractable water cannons would spray the walls and ceiling with water or other solutions. Wash-down water or solutions would be collected in floor drains connected to a collection tank, filtered, and stored for reprocessing. Following the wash down, a decontamination team wearing protective clothing would enter and clean the chamber to make it safe for minimally protected personnel to enter. Venting, purging, cleanup, and testing of the chamber are estimated to take approximately two days using four workers. In addition, replacement of damaged fragment shielding would be an ongoing activity.

The processes for recovering debris from the containment building would be similar to those described for the portable steel vessels. The recycling facility would be sited near the containment building. Debris resulting from detonations within the blast chamber would be segregated and reclaimed. Polymer extractant solutions would be used for decontaminating chamber surfaces.

3.8 PLUTONIUM EXCLUSION ALTERNATIVE

Under the Plutonium Exclusion Alternative (referred to in the Notice of Intent as the "Institutional Control Alternative"), DOE would complete and operate DARHT as described in the Preferred Alternative but would limit use of the facility to exclude any applications involving experiments with plutonium. This alternative is analyzed to provide a basis of comparison between the environmental impacts expected to occur if the DARHT Facility were used to conduct contained dynamic experiments with plutonium (the Preferred Alternative) or not used for contained dynamic experiments with plutonium. DOE would conduct dynamic experiments with plutonium at PHERMEX or other facilities. This alternative would not be expected to affect future operations at the RSL at LANL, the FXR at LLNL, or other smaller explosive test facilities.

3.8.1 Facility

The facilities required under the Plutonium Exclusion Alternative are identical to those described for the Preferred Alternative at the DARHT site.

3.8.2 Operations

Operations at the DARHT Facility under the Plutonium Exclusion Alternative would be the same as those described for the Preferred Alternative except that DOE would not incorporate plutonium into any of the experiments at DARHT. The Preferred Alternative specifies containment for experiments that incorporate plutonium. Under the Plutonium Exclusion Alternative, containment vessels would be used for selected experiments involving hazardous materials. There would be no differences in facility operations for uncontained tests and no differences in the explosion products that might be deposited on the firing site or the surrounding area.

3.9 SINGLE-AXIS ALTERNATIVE

Under the Single-Axis Alternative, DOE would complete construction of the DARHT Facility with one accelerator hall and would operate only a single axis of DARHT with one accelerator. The second hall (second axis) would not be completed as an accelerator hall for DARHT but could be put to other uses such as office space. Under this alternative, DOE would obtain greatly improved high-resolution capability, as compared to the present capability at PHERMEX and FXR, but would forego the capability to obtain three-dimensional, rapid-time-sequenced data.

Under the Single-Axis Alternative, operation of PHERMEX would be phased out. This alternative is not expected to affect future operations of the RSL at LANL, the FXR at LLNL, or other smaller explosive test facilities at LANL and LLNL.

3.9.1 Facility

The facility for the Single-Axis Alternative would be identical to that for the Preferred Alternative at the DARHT site except that DOE would not install an accelerator and its ancillary equipment in the southwest accelerator hall. Figure 3-3 shows the layout of the DARHT Facility. The southeast accelerator hall would be completed as planned to provide the single-axis, x-ray radiographic capability. The DARHT firing site, associated support and diagnostic facilities, and the RSL would all be considered part of the single-axis facility.

Construction at the DARHT site would be nearly the same for the Single-Axis Alternative as for the Preferred Alternative. The entire firing-site complex would be completed under this alternative, but only the basic structure of the southwest accelerator hall would be finished as planned. The interior finish would depend on how that space might best be used, and that determination would be made at a later date. Possible uses for the southwest wing include storage, office space, or laboratory space for research efforts.

3.9.2 Operations

Operations under the Single-Axis Alternative would be similar to those under the Preferred Alternative, but they would be somewhat simplified by the need to coordinate only one x-ray machine with the test assembly detonation. Operation of the single x-ray machine would be the same as its operation as part of a dual x-ray system. Under the Single-Axis Alternative, some tasks might be reduced in number or scope, but all of the activities described as part of the Preferred Alternative would remain. The high-explosive testing program would be modified to single-axis capabilities and would be similar to that for the No Action Alternative.

More emphasis would be placed on studying the late stages of hydrodynamic phenomena under the Single-Axis Alternative, resulting in less use of blast-protected, electronic-position-indicating diagnostics compared to the No Action Alternative. However, more total shots would be required to synthesize three-dimensional and time-sequence data and to address reproducibility among shots. Therefore, the cost and yearly progress of the testing program would be similar to the No Action Alternative.

For this alternative, use of heavy equipment inside the accelerator hall, such as overhead cranes, would be about half of that needed for the Preferred Alternative. On the other hand, use of heavy equipment on the firing point would be the same as for the Preferred Alternative.

3.10 ALTERNATIVES CONSIDERED BUT NOT ANALYZED IN DETAIL

A NEPA review specifies the purpose and need for an agency to take action, describes the action that the agency proposes to meet that purpose and need, and identifies reasonable alternatives to meet part or all of the purpose and need. A potential alternative may be dismissed from a NEPA review as unreasonable if it would not meet part or all of the agency's purpose and need to take action, or for such reasons as taking too long to implement, being prohibitively expensive, or being too speculative in nature. An agency does not need to analyze an alternative that would not be responsive to the specified purpose and need.

The DOE considered, but did not analyze in detail, several alternatives in addition to those discussed above. None of the following would meet DOE's need for enhanced radiographic hydrodynamic test capability. These include:

- Alternative sites
- Alternative location at LANL
- Alternative facilities
- Consolidation
- Use of FXR
- Alternative types of tests
- Relinquishing reliability of the nuclear stockpile
- Weapons design
- No hydrodynamic testing
- Other programmatic alternatives
- Other mission alternatives

3.10.1 Alternative Sites

> ***As an alternative to constructing and operating the DARHT Facility at LANL, construct and operate the facility at an alternative site.***

DOE considered, but dismissed as unreasonable, the alternative of locating, constructing, and operating the DARHT Facility at a site other than LANL. DOE's need for hydrodynamic test facilities for weapons work is limited to those needed to support testing programs for LANL and LLNL. DOE has no need to construct hydrodynamic test facilities at non-DOE sites.

As discussed in section 3.3.3, LANL already has infrastructure in place to support its dynamic experiments and hydrodynamic testing program. This infrastructure supports operations at the PHERMEX Facility and other smaller LANL firing sites. The same infrastructure would be needed to support hydrodynamic testing and dynamic experiments at the DARHT Facility. Although other DOE sites have some of this infrastructure in place, no other DOE site currently has all the infrastructure in place to support all aspects of hydrodynamic tests and dynamic experiments being done at PHERMEX or proposed to be done at DARHT. DOE considers that this would represent an unreasonably expensive option to replicate some or all the infrastructure at another DOE site to support a facility with the same capability as the proposed DARHT Facility. It would not be cost-effective for DOE to replicate support facilities solely to support hydrodynamic testing or dynamic experiments.

In the future, DOE may choose to change facilities or operations at LANL or other DOE sites for other reasons. However, any such changes would be the result of separate DOE proposals in response to a different Departmental need and would be subject to appropriate reviews, including a NEPA review.

DOE considered two alternative means of conducting LANL's hydrodynamic testing at a site other than LANL:

- Single Site – Locate and construct the proposed radiographic hydrodynamic test facility at another site, make use of existing infrastructure at that site, and construct the remaining infrastructure at that site
- Multi Site – Locate and construct the proposed radiographic hydrodynamic test facility at another site and make use of existing infrastructure at that site, supplemented by existing infrastructure at LANL or other sites

Neither alternative was considered to be reasonable for reasons described in the following sections.

3.10.1.1 Single Site

Replicating all the infrastructure needed to support a hydrodynamic test program or dynamic experiments at a single site other than LANL would be unreasonably expensive. Although theoretically all of the support facilities could be constructed and operated at another site, depending on the infrastructure already in place at the site, this could increase the cost of the DARHT Facility several times.

Depending on the location of the alternative site, DOE could incur extensive travel costs because LANL personnel would have to oversee the LANL testing program at another site, which would involve travel of several people at least once a week. If the other site had a hydrodynamic test or dynamic experiment program of its own (as does LLNL), the number of shots that could be scheduled to support both programs could be limited; this could be detrimental to both. In the event that the radiographic hydrodynamic test or dynamic experiment capability were to be located elsewhere, DOE would have to continue to operate and maintain PHERMEX to support smaller tests or dynamic experiments at LANL that would not be cost-effective to transport to the other site. DOE would therefore have to invest substantial capital to repair the facility to keep it viable over the long term, in addition to constructing and maintaining the enhanced radiographic test facility. This would not meet the need to replace PHERMEX.

Besides LANL, LLNL, NTS, and Pantex have some hydrodynamic testing infrastructure in place. However, they are considered to be unreasonable alternatives to LANL for siting a testing facility to support the proposed action because they would require expensive additional specialized infrastructure to support the hydrodynamic tests and dynamic experiments under the Proposed Action. In addition, as discussed above, DOE would need to continue to operate and maintain PHERMEX, which does not meet the need to replace the existing PHERMEX radiographic capability.

- **LLNL.** LLNL is the only DOE site, besides LANL, which has the capability currently in place to support hydrodynamic tests. However, LLNL is considered unreasonable to support a LANL hydrodynamic testing facility for two reasons. First, the type, size, and number of shots that LANL would require in addition to the number of shots that LLNL already conducts could unduly burden the support infrastructure that currently exists at LLNL, unless personnel and equipment were replicated. This would be considerably more costly than the Preferred Alternative. Second, without a major additional investment, LLNL could not provide the material recovery/recycle capability and waste treatment, storage, and disposal to support LANL's program in addition to its own. In addition, DOE does not conduct dynamic experiments with plutonium at LLNL. It would be unreasonably expensive to replicate the required infrastructure needs at LLNL for the sole purpose of supporting a facility as small as the Preferred Alternative.

- **NTS.** NTS has supported a testing program with experiments similar to hydrodynamic tests. However, NTS is considered unreasonable to support a radiographic hydrodynamic testing facility in the near term because NTS does not now have the required material recovery/recycle capability. It would be unreasonably expensive to replicate the required infrastructure needs at NTS for the sole purpose of supporting a facility as small as the Preferred Alternative.
- **Pantex.** Pantex has supported high explosives testing. However, Pantex is considered unreasonable to support a radiographic hydrodynamic testing facility in the near term because Pantex does not currently have any of the required infrastructure other than instrumented firing sites. In addition, currently the site could not support dynamic experiments with plutonium. It would be unreasonably expensive to replicate the required infrastructure needs at Pantex for the sole purpose of supporting a facility as small as the Preferred Alternative.

3.10.1.2 Multi-Site

Making use of multiple sites presents logistical problems that would be unreasonably inefficient and expensive to overcome. DOE believes that the quality of the hydrodynamic testing program would be degraded by splitting among multiple sites the testing functions for the improved capability needed. Collocated personnel achieve a certain synergism and efficiency in their interactions; this would be lost if personnel involved in different stages of a test event were located at different sites. Depending on the split, the ability to fix in-process mistakes or to iterate a design feature could be slowed to the point that test schedules could not reliably be met. Splitting the mission responsibility among sites would dilute the focus achieved by consolidating at a single institution, and would also blur lines of funding and responsibility. DOE would incur significant costs for transporting equipment, materials, and personnel among multiple sites and LANL. As described for a single site, travel costs would increase, the number of shots could be limited, and LANL would have to continue to operate and maintain PHERMEX, which does not meet the need to replace the existing PHERMEX radiographic capability.

DOE has considered whether each of the different steps of the hydrodynamic testing process could take place at a location other than LANL. Although some aspects could take place at various DOE sites, transportation, firing-site support, and materials management (materials reprocessing and recycling, and waste treatment and disposal) are limiting factors. Sites with some infrastructure in place include LLNL, at Livermore, California; the Nevada Test Site (NTS), near Las Vegas, Nevada; and the Pantex Plant, near Amarillo, Texas.

- **Transportation of test assemblies.** Shipping assembled hydrodynamic test assemblies is difficult. An assembled pin shot cannot be transported for more than a short distance because the diagnostic sensors must be very precisely located and are very susceptible to dislocation when moved. If transported, they must be moved only under controlled conditions (secure transport, very stable shipping container, very slow speeds). If public roads were used, either the road would have to be closed to the public (as is now the case at LANL), or safe, secure, transport vehicles would have to be used.

- **Firing site.** High explosive testing areas require a large buffer zone for safety reasons and perimeter-limited access for security and safety reasons. Several DOE sites are large enough to provide adequate secure buffer zones for a hydrodynamic test or dynamic experiment firing site. However, to operate a radiographic hydrodynamic test or dynamic experiment facility would require that several collocated support functions be available at the firing site. This would be a limiting factor for an alternative site because it would be difficult and expensive to replicate all the support facilities that would have to be located in the vicinity of the firing site. The site would have to have appropriate permits and licenses to allow for high explosives work. Other than LANL, LLNL is the only DOE site with in-place, firing-site support capability sufficient to support radiographic hydrodynamic tests or dynamic experiments. LLNL facilities are sized and scheduled to handle their own testing program, and the additional shots sufficient to support LANL's testing program could unreasonably burden the existing LLNL facilities. The NTS has firing sites and is currently qualifying a firing site to conduct radiographic hydrodynamic tests, which would use large charges of high explosives. Pantex has instrumented firing sites used to test high explosives, but these firing sites are not currently configured to support the required radiographic hydrodynamic testing and dynamic experiments, and to do so, besides being very expensive, would conflict with the current use of these sites.
- **Materials Management.** Materials management includes materials reprocessing and recycling, waste treatment, and disposal. Waste processing and disposal are limiting factors. Cleanup and recycling operations for hydrodynamic tests and dynamic experiments require specialized handling techniques. An alternative site would have to have the means to treat and dispose of debris and other waste hardware after a test is complete, and to collect, process and recycle reusable materials. This would include the ability to clean out and, if necessary, dispose of large containment vessels. LANL is the only site with the requisite facilities in place. Although LLNL has waste processing, disposal, and recycling facilities in place that are sufficient to handle their own hydrodynamic testing program, it does not have facilities in place to handle containment vessels or sufficient capability to handle LANL's waste stream in addition to its own. NTS has a waste disposal capacity that is used by other DOE sites, but does not have in place the specialized facilities required to support the Proposed Action.

3.10.2 Alternative Location at LANL

As an alternative to constructing DARHT at the proposed sites, construct DARHT at an alternative site at LANL.

In the 1980s, DOE considered different locations at LANL for the DARHT Facility, and determined that the proposed site was preferable. The proposed site is within the explosives testing area and makes use of existing infrastructure such as access roads and utilities. Replicating the proposed facility at another location at LANL would result in duplicating infrastructure and related construction that has already occurred, with no programmatic gain, increase in onsite safety.

3.10.3 Alternative Types of Facilities

As an alternative to constructing a hydrodynamic testing facility, use an alternative type of facility to conduct diagnostic experiments.

The DARHT Facility responds to DOE's need for enhanced capability for hydrodynamic testing and dynamic experiments. No other type of facility provides hydrodynamic testing capability other than a hydrodynamic testing facility. An alternative type of hydrodynamic testing facility that could produce the needed capability in the near-term would be essentially a replication of the DARHT Facility. DOE and LANL have spent more than 10 years optimizing the design of DARHT; DOE does not consider it reasonable to spend additional time and expense to develop additional design studies for alternative facilities that would not meet the specified need nor add programmatic value.

DOE proposes to install a linear induction accelerator to operate the radiography equipment at the DARHT Facility. Other types of accelerators are available, such as radio-frequency, pulsed-power, or inductive-voltage-adder accelerators, and theoretically they could be used to power a radiography machine. The equipment proposed to be installed in DARHT, if the facility is completed and operated as proposed, was designed to improve on the technology and equipment used at FXR (which is also a linear induction accelerator). The technology proposed for the DARHT Facility has been reviewed by two independent technical panels, DARHT Feasibility Assessment Independent Consultants (DFAIC) and Independent Consultants Reviewing Integrated Test Stands (ITS); both have concurred with the technology proposed (DFAIC 1992; DOE 1993 MDW2). DOE does not consider it reasonable to revisit the technical evaluation of the currently available technology for the enhanced capability proposed, or to await possible development of future technologies that are now considered either speculative or inferior to the proposed technology for the intended use.

DOE has conceptualized a multi-axis, multi-time Advanced Hydrotest Facility (AHF) for the next generation of advanced hydrotesting capability. The AHF would be based on new and developing accelerator technology, drawing partially on the rapidly advancing state of the art in high-power, high-speed, solid-state components. This conceptualized facility has not yet reached the stage of a firm Departmental proposal. The DARHT facility would provide information useful for the design of the AHF, and experience gained from its operation would be important in optimizing the operations of this advanced facility. AHF is not considered to be a reasonable alternative to the DARHT Facility for the following reasons: it is still only a concept, the technology to support AHF is not yet developed or proven, and the conceptual design and development of the technology for AHF would take several years to complete, as would siting studies and construction design.

3.10.4 Consolidation

As an alternative to operating more than one hydrodynamic test facility, consolidate hydrodynamic testing capability at one site.

The DOE has historically maintained hydrodynamic testing capability at both LANL and LLNL; it would not be advantageous to fulfilling the mission of the DOE to maintain hydrodynamic testing facilities at only one site. DOE has proposed DARHT to be a shared user facility but has not proposed shutting down hydrodynamic testing capability at either LLNL or LANL. Consolidating LANL's testing program with

LLNL's at LLNL is discussed section 3.10.1.3., and is dismissed as unreasonable. DOE has not identified any need to consolidate LLNL's testing program with LANL's at LANL. Consolidation at one site is therefore not considered as a reasonable alternative to the Preferred Alternative.

3.10.5 FXR

As an alternative to operating DARHT, modify and upgrade the FXR facility at LLNL to provide the capabilities proposed for DARHT.

DOE is in the process of upgrading the FXR Facility under a separate proposal. Under this type of alternative, in addition to the already proposed upgrades, FXR would be remodeled and enlarged to construct a second accelerator hall to accept the new technology developed for DARHT, and PHERMEX would continue to operate at LANL. This is considered unreasonable as an alternative for the Proposed Action because DOE does not conduct dynamic experiments with plutonium at LLNL. In the event that in the future DOE would propose to provide three-dimensional capability at LLNL, a separate NEPA review would be prepared at that time if required.

3.10.6 Alternative Types of Tests

As an alternative to operating DARHT, use an alternative type of test to conduct diagnostic experiments.

Although hydrodynamic testing is used in conjunction with other types of testing capability, such as computer modeling or nuclear testing, no other type of experimental facility will produce the diagnostic results of a hydrodynamic testing facility. The President, Congress, and the Secretaries of Energy and Defense have determined that the Nation needs to maintain and improve its hydrodynamic test capabilities that reside with DOE. The purpose of the Proposed Action is to provide improved hydrodynamic test capability. Other types of tests would not meet the agency and National need for the type of information that can only be obtained from hydrodynamic tests. DOE will continue to use other diagnostic tools, such as computer modeling, in conjunction with hydrodynamic testing, as has been done for more than 30 years.

3.10.7 Relinquishing Reliability of the Nuclear Stockpile

As an alternative to operating DARHT, relinquishing the goal of maintaining the reliability of nuclear weapons would mean that hydrodynamic testing (hence the DARHT Facility) would not be needed.

The alternative of not maintaining the integrity of the nuclear weapons stockpile does not meet the direction from the President and Congress to maintain a safe, secure, and reliable nuclear deterrent as a cornerstone of National defense. Thus this alternative is not considered to be reasonable.

3.10.8 Weapons Design

As an alternative to operating DARHT to ensure weapons safety and reliability, operate DARHT to design prototype weapons, and study impacts on the Nation's nonproliferation objectives and the impact of fabricating prototype weapons.

As discussed in section 3.5, in the 1980s, DOE proposed to operate DARHT to provide enhanced hydrodynamic testing capability in support of the Nation's nuclear weapons design program, as well as in support of ensuring safety and reliability of stockpiled nuclear weapons. As stated in section 2.3.4, in the event that this Nation decides as a matter of policy that new nuclear weapons should again be developed, we would use all appropriate means at our disposal to accomplish this. Hydrodynamic testing, along with many other tools, could be used to assist in weapons development. However, in 1991, the President stated that the United States would not design new nuclear weapons in the foreseeable future; any decision to reverse this policy would come from the President and Congress. Accordingly, DOE does not at this time need to propose, design, or construct new facilities to assist with new weapons design. In any event, the environmental impacts of hydrodynamic tests at the DARHT Facility, the existing hydrodynamic testing facilities, or other alternatives analyzed in this EIS would vary by the number of test shots, size of explosive charge, materials used, and the design of the facility, not the intended application of test results.

3.10.9 No Hydrodynamic Testing Alternative

As an alternative to operating DARHT, do not construct or operate any hydrodynamic testing facility, and do not conduct hydrodynamic tests.

As discussed in chapter 2, the President and Congress have directed DOE to ensure the safety, performance, and reliability of the weapons stockpile, and to maintain and enhance its hydrodynamic testing capability in order to perform this task. A proposal not to conduct hydrodynamic testing would not meet this purpose.

3.10.10 Other Programmatic Alternatives

As an alternative to operating DARHT, use alternative means to conduct the Nation's stockpile stewardship program.

As discussed in chapter 2, the *Stockpile Stewardship and Management Programmatic Environmental Impact Statement* (PEIS) will analyze alternative means to conduct the Nation's stockpile stewardship program. The relationship of the DARHT EIS to that PEIS is discussed in that chapter. The President and Congress have determined that, as one aspect of conducting stockpile stewardship, the Nation needs to maintain and improve its hydrodynamic test capabilities that reside with DOE. The DARHT Facility responds to that purpose and need.

3.10.11 Other Mission Alternatives

As an alternative to operating DARHT as part of the DOE weapons program, consider an alternative nonweapons mission for DOE or LANL.

The nuclear weapons mission of DOE is established by law. Alternative missions for LANL do not respond to the purpose and need specified in this EIS. Accordingly, nonweapons missions are not considered to be reasonable alternatives to the Preferred Alternative.

DOE anticipates that the *LANL Sitewide EIS* discussed in chapter 2, will examine the cumulative impacts of facility operations in support of the mission assignments at LANL and that the PEIS discussed in chapter 2 will examine the impacts of alternative ways to carry out the stockpile stewardship program. If, in the future, DOE would eliminate weapons research at LANL, including hydrodynamic testing, the Department would examine the need for additional NEPA review. This review would be used to determine the disposition of existing weapons research facilities at LANL, including any hydrodynamic test facilities existing at that time. DOE currently has no plans to withdraw weapons research work from LANL.

3.11 COMPARISON OF ALTERNATIVES

The following tables comparatively summarize the alternatives analyzed in this EIS in terms of their expected environmental impacts and other possible decision factors. Table 3-3 compares the environmental impacts of the alternatives as discussed in detail in chapter 5; for the most part, environmental impacts would be expected to be similar among the alternatives analyzed.

Table 3-4 summarizes facility construction and operations factors. The entries in this table are self explanatory for the most part. However, the material releases information needs explanation. These entries represent estimated annual material releases to the environment immediately after high-explosive tests conducted at PHERMEX, or the DARHT Facility. Subsequent cleanups are not considered in the estimated amounts. As discussed in section 3.7, under the Enhanced Containment Alternative, for the containment vessel approach, this EIS conservatively assumes that the vessels would be used for most, but not all, tests, and that the single-wall containment vessels may have a leak rate of one percent and a maximum failure rate of five percent. The gaseous products from the detonation of high explosives (90 percent) would not be contained, and the remaining products would consist of carbon soot. For all alternatives, any future dynamic experiments using plutonium would be conducted within double-walled vessels that have been demonstrated to fully contain the tests and yield no measurable releases.

Table 3-5 compares the hydrodynamic testing capabilities that would be expected under the alternatives analyzed.

TABLE 3-3.—*Summary of the Potential Environmental Impacts of the Alternatives*

Factor, Measure	No Action	Preferred Alternative	Upgrade PHERMEX Alternative	Enhanced Containment Alternative	Plutonium Exclusion Alternative	Single-Axis Alternative
Land Resources						
Acreage committed						
PHERMEX	11 ac	11 ac	11 ac	11 ac	11 ac	11 ac
DARHT (including RSL)	8 ac	8 ac	8 ac	9[a] ac	8 ac	8 ac
Air Quality						
Maximum percent of standard[b]						
NO_2	0.76	3.3	3.3	3.3	3.3	3.3
PM_{10}	2.1	12	12	12	12	12
SO_2	3.3×10^{-3}	2.2	2.2	2.2	2.2	2.2
Be	4.9×10^{-2}	4.9×10^{-2}	4.9×10^{-2}	3.3	4.9×10^{-2}	4.9×10^{-2}
Heavy Metal	5.3×10^{-3}	5.3×10^{-3}	5.3×10^{-3}	2.5	5.3×10^{-3}	5.3×10^{-3}
Lead	1.8×10^{-3}	1.8×10^{-3}	1.8×10^{-3}	2.7×10^{-3}	1.8×10^{-3}	1.8×10^{-3}
Noise (qualitative)	Possible nuisance	Possible nuisance	Possible nuisance	Nuisance unlikely	Possible nuisance	Possible nuisance
Water Resources						
Depleted uranium contamination, % Drinking Water Standards (after millennia)	<10%	<10%	<10%	<1%	<10%	<10%
Soils						
Depleted uranium contamination area	15 ac	15 ac	15 ac	15 ac	15 ac	15 ac
Max. concentration (approx.)	9,000 ppm	5,000 ppm	9,000 ppm	300 ppm	5,000 ppm	5,000 ppm
Biotic Resources						
Habitat reduction[c]	None	None	None	1 ac	None	None
Disturbance by noise	Some	Some	Some	~80% reduction	Some	Some

[a] Includes 1 ac (0.4 ha) for the recycling facility

[b] The values presented here represent the maximum pollutant concentrations as a percent of the respective standard. These values are reported in chapter 5 as impacts from either fugitive dust or emissions from construction equipment, the natural gas boiler or hydrodynamic testing.

[c] Habitat reduction refers to the change of habitat to another use. Only the Enhanced Containment Alternative would result in an additional use of land for the recycling facility (see footnote a).

[d] The calculated socioeconomic impacts are derived using PHERMEX operation figures as a baseline. Thus, under standard modeling procedures there are no additional impacts calculated.

[e] V = containment vessel scenario; B = containment building scenario

TABLE 3-3.—*Summary of the Potential Environmental Impacts of the Alternatives – Continued*

Factor, Measure	No Action	Preferred Alternative	Upgrade PHERMEX Alternative	Enhanced Containment Alternative	Plutonium Exclusion Alternative	Single-Axis Alternative
Cultural Resources (qualitative)	None	If mitigated, None	None	None	If mitigated, None	If mitigated, None
Socioeconomics						
Employment	—[d]	169 FTE	139 FTE	326 FTE (V)[e] 217 FTE (B)	169 FTE	87 FTE
Regional labor	—[d]	$ 3.6 million	$ 3.3 million	$ 6.9 million (V) $ 4.6 million (B)	$ 3.6 million	$ 1.8 million
Regional goods and services	—[d]	$ 6.2 million	$ 5.5 million	$ 12 million (V) $ 7.8 million (B)	$ 6.2 million	$ 3.3 million
Human Health						
Public (30-yr life of project)						
MEI Dose	7×10^{-4} rem	7×10^{-4} rem	7×10^{-4} rem	5×10^{-4} rem	7×10^{-4} rem	7×10^{-4} rem
Population dose	30 person-rem	30 person-rem	30 person-rem	13 person-rem (V) 8 person-rem (B)	30 person-rem	30 person-rem
Latent cancer fatalities	None	None	None	None	None	None
Workers (30-yr life of project)						
Average Dose	0.3 rem	0.3 rem	0.3 rem	0.6 rem	0.3 rem	0.3 rem
Collective dose	9 person-rem	9 person-rem	9 person-rem	60 person-rem	9 person-rem	9 person-rem
Latent cancer fatalities	None	None	None	None	None	None
Facility Accidents						
Involved workers, worst case explosion related fatalities	15	15	15	15	15	15
Public dose	6×10^{-4} rem	6×10^{-4} rem	6×10^{-4} rem	1×10^{-2} (V) rem 1×10^{-3} (B) rem	6×10^{-4} rem	6×10^{-4} rem
Latent cancer fatalities	None	None	None	None	None	None

[a] Includes 1 ac (0.4 ha) for the recycling facility
[b] The values presented hare represent the maximum pollutant concentrations as a percent of the respective standard. These values are reported in chapter 5 as impacts from either fugitive dust or emissions from construction equipment, the natural gas boiler or hydrodynamic testing.
[c] Habitat reduction refers to the change of habitat to another use. Only the Enhanced Containment Alternative would result in an additional use of land for the recycling facility (see footnote a).
[d] The calculated socioeconomic impacts are derived using PHERMEX operation figures as a baseline. Thus, under standard modeling procedures there are no additional impacts calculated.
[e] V = containment vessel scenario; B = containment building scenario

TABLE 3-3.—*Summary of the Potential Environmental Impacts of the Alternatives – Continued*

Factor, Measure	No Action	Preferred Alternative	Upgrade PHERMEX Alternative	Enhanced Containment Alternative	Plutonium Exclusion Alternative	Single-Axis Alternative
Transportation						
30-yr Worker dose	0.004 rem	0.004 rem	0.004 rem	0.004 rem	0.004 rem	0.004 rem
30-yr Public dose	3 x 10^{-9} person-rem	3 x 10^{-9} person-rem	3 x 10^{-9} person-rem	3 x 10^{-9} person-rem	3 x 10^{-9} person-rem	3 x 10^{-9} person-rem
30-yr Latent cancer fatalities	None	None	None	None	None	None
Unavoidable Adverse Impacts	See soils	See soils	See soils	See soils	See soils	See soils
Irreversible and/or Irretrievable Commitment of Resources						
Construction						
Concrete	15,000 yd^3	15,000 yd^3	28,000 yd^3	16,000 yd^3 (V) 22,000 yd^3 (B)	15,000 yd^3	15,000 yd^3
Diesel fuel	9,500 gal	11,500 gal	17,000 gal	12,500 gal (V) 18,200 gal (B)	11,500 gal	11,500 gal
Electricity	365 MWh	365 MWh	750 MWh	365 MWh (V) 450 MWh (B)	365 MWh	365 MWh
Operations						
Depleted uranium	1,540 lb/yr	1,540 lb/yr	1,540 lb/yr	90 lb/yr	1,540 lb/yr	1,540 lb/yr
Natural gas	8,700 ft^3/yr	10,400 ft^3/yr	13,000 ft^3/yr	13,300 ft^3/yr (V) 14,800 ft^3/yr (B)	10,400 ft^3/yr	10,400 ft^3/yr
Electricity	550 MWh/yr	2,250 MWh/yr	2,500 MWh/yr	2,800 MWh/yr (V) 2,900 MWh/yr (B)	2,250 MWh/yr	1,350 MWh/yr
Long-term Productivity (qualitative)	None	None	None	None	None	None

[a] Includes 1 ac (0.4 ha) for the recycling facility
[b] The values presented here represent the maximum pollutant concentrations as a percent of the respective standard. These values are reported in chapter 5 as impacts from either fugitive dust or emissions from construction equipment, the natural gas boiler or hydrodynamic testing.
[c] Habitat reduction refers to the change of habitat to another use. Only the Enhanced Containment Alternative would result in an additional use of land for the recycling facility (see footnote a).
[d] The calculated socioeconomic impacts are derived using PHERMEX operation figures as a baseline. Thus, under standard modeling procedures there are no additional impacts calculated.
[e] V = containment vessel scenario; B = containment building scenario

TABLE 3-4.—*Summary Comparison of the Alternatives*

Factor	No Action[a] Alternative	Preferred Alternative	Upgrade PHERMEX[b] Alternative	Enhanced Containment Alternative (Vessels)[c]	Enhanced Containment Alternative (Building)[d]	Plutonium Exclusion Alternative	Single-Axis Alternative
CONSTRUCTION							
Facility Footprint (ft^2)	36,000	36,000	45,600	49,300	72,500	36,000	36,000
Laydown Area (ac)	2.5	2.5	2.5	3.5	3.5	2.5	2.5
Added Roadway (ft)	1,200	1,200	1,200	1,200	1,200	1,200	1,200
Construction Materials							
Concrete (yd^3)	15,000	15,000	28,000	16,000	22,000	15,000	15,000
Cement (lb)	9,800,000	9,800,000	18,100,000	10,300,000	14,300,000	9,800,000	9,800,000
Steel (tons)	640	950	1,500	1,000	1,300	950	900
Copper (tons)	15	85	100	90	100	60	60
Stainless Steel (tons)	15	100	105	105	110	100	60
Aluminum (tons)	2	15	15	15	15	15	8
Glycol (gal)	0	3,800	3,800	3,800	3,800	3,800	1,900
Non-PCB mineral oil (gal)	0	30,000	30,000	30,000	30,000	30,000	15,000
Excavation (yd^3)	25,000	25,000[e]	40,000	25,000	30,000	25,000	25,000
Backfill (yd^3)	25,000	25,000	40,000	25,000	28,000	25,000	25,000
Rebar (tons)	600	600	1,000	600	900	600	600
Fuel							
Diesel (gal)	9,500	11,500	17,000	12,500	18,500	11,500	11,500
Gasoline (gal)	9,500	11,500	17,000	12,500	18,500	11,500	11,500
Propane (lb)	9,500	11,500	17,000	12,500	18,500	11,500	11,500
Electricity (kWh)	365,000	365,000	750,000	365,000	450,000	365,000	365,000
Work Force							
Craft (hr)	100,000	118,000	248,000	148,000	278,000	118,000	118,000
Noncraft (hr)	25,000	28,000	58,000	36,000	52,000	28,000	28,000
Project Management (people)	max. 15/day	max. 15/day	max. 15/day	max. 15/day	max. 15/day	max. 15/day	max. 15/day
Noise Levels Generated (dBA)	93	93	93	93	93	93	93
Waste Disposal Costs ($ thousands)	14.5	14.5	41.5	14.5	30.0	14.5	14.5
TOTAL COSTS ($ millions) (construction and equipment)	49	123	145	154	159	123	85
OPERATIONS							
Materials Used (Annual)							
Water (gal)	40,000	70,000	70,000	110,000	110,000	100,000	60,000
Helium (ft^3)	6,000	36,000	36,000	36,000	36,000	36,000	36,000

TABLE 3-4.—*Summary Comparison of the Alternatives - Continued*

Factor	No Action[a] Alternative	Preferred Alternative	Upgrade PHERMEX[b] Altsrnative	Enhanced Containment Alternative (Vessels)[c]	Enhanced Containment Alternative (Building)[d]	Plutonium Exclusion Alternative	Single-Axis Alternative
Operations (continued)							
Materials Used (continued)							
Sulfur Hexafluoride (ft^3)[f]	3,100	0	0	0	0	0	0
Acetone (gal)	3	3	3	3	3	3	2
Ethanol (gal)	6	6	6	6	6	6	3
Polymer (lb)	0	0	0	50	50	0	0
Energy (Annual)							
Natural Gas (ft^3)	8,700	10,400	13,000	13,300	14,700	10,400	10,400
Electricity (kWh)	550,000	2,250,000	2,500,000	2,600,000	2,900,000	2,250,000	1,350,000
Work Force							
Radiation-trained workers	9	15	15	24	24	20	13
Support staff	5	5	5	5	5	5	5
Noise Levels Generated, dBA, at nearest community by 150-lb explosion	65	65	65	not audible[g]	not audible	65	65
Operating Costs per Year	$4.2 million	$6.5 million	$6.5 million	$10.4 million	$10.4 million	$6.5 million	$5.4 million
Material Releases[h]							
Depleted Uranium (lb)	1,540	1,540	1,540	90	90	1,540	1,540
Beryllium (lb)	20	20	20	2	2	20	20
Lead (lb)	30	30	30	2	2	30	30
Copper (lb)	220	220	220	13	13	220	220
Other Metals (lb)	440	440	440	25	25	440	440
High Explosive (lb)	3,300	3,300	3,100	3,100	3,100	3,300	3,300
Tritium (Ci)	3	3	3	0.3	0.3	3	3
Lithium Hydride (lb)	220	220	220	13	13	220	220

[a] No construction at PHERMEX; however, construction at proposed DARHT site to complete building for nonhydrodynamic testing purposes.
[b] New construction at PHERMEX plus DARHT construction to complete building for nonhydrodynamic testing purposes.
[c] DARHT Facility plus recycling facility.
[d] DARHT Facility plus recycling facility and containment building.
[e] Excavation for DARHT is complete.
[f] Sulfur hexaflouride is used as an insulator at PHERMEX.
[g] When vessel is used for containment.
[h] For all alternatives, the annual materials used in this group are the same as the table entries for No Action.

TABLE 3-5. —*Comparison of Facility Attributes*

Attribute	No Action Alternative (Baseline)	Preferred Alternative	Upgrade PHERMEX Alternative	Enhanced Containment Alternative (Vessels)	Enhanced Containment Alternative (Building)	Plutonium Exclusion Alternative	Single-Axis Alternative
Image Quality	Baseline for comparison, does not meet needs	Best resolution, penetration meets needs	Best resolution, penetration meets needs	Better resolution, penetration meets most needs	Better resolution, penetration meets most needs	Best resolution, penetration meets needs	Best resolution, penetration meets needs
3-D Capability	Only with multiple shots that introduce inconsistency and increase costs	Better quality and available with single shot	Better quality and available with single shot	Better quality and available with single shot	Better quality and available with single shot	Better quality and available with single shot	Only with multiple shots that introduce inconsistency and increase costs
Time-sequence Capability	Only with multiple shots that introduce inconsistency and increase costs	Better quality and available with single shot	Better quality and available with single shot	Better quality and available with single shot	Better quality and available with single shot	Better quality and available with single shot	Only with multiple shots that introduce inconsistency and increase costs
Testing Efficiency	Baseline for comparison	Best, fewer tests and lower cost to obtain same data	Best, fewer tests and lower cost to obtain same data	Worst, more time to cycle tests	Worst, more time to cycle tests	Best, fewer tests and lower cost to obtain same data	Best, fewer tests and lower cost to obtain same data
Firing Point Materials Released	Baseline for Comparison	Reduced 15 percent	Reduced 15 percent	Reduced 75 to 95 percent	Reduced 95 percent	Reduced 15 percent	Reduced 15 percent
Time Frame for Operation	Currently available	Single axis ready 38 months after ROD, dual axis in 66 months	Dual axis ready 71 months after ROD	Single axis ready 38 months after ROD, dual axis in 66 months	Dual axis ready 77 months after ROD	Single axis ready 38 months after ROD, dual axis in 66 months	Single axis ready 38 months after ROD

TABLE 3-5. —*Comparison of Facility Attributes – Continued*

Attribute	No Action Alternative (Baseline)	Preferred Alternative	Upgrade PHERMEX Alternative	Enhanced Containment Alternative (Vessels)	Enhanced Containment Alternative (Building)	Plutonium Exclusion Alternative	Single-Axis Alternative
Miscellaneous	High-power RF tubes may become unavailable		No testing at LANL for 51 months	New recycling center, costs may discourage small experiments, no overhead diagnostics	New recycling center, costs may discourage small experiments, no overhead diagnostics		One accelerator hall available for a secondary use

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Chapter 4
Affected Environment

CHAPTER 4
AFFECTED ENVIRONMENT

This chapter describes the environments that may be affected by the Proposed Action, whether the Preferred Alternative, No Action Alternative, or another analyzed alternative is chosen by DOE for implementation.

The Los Alamos National Laboratory (LANL) is located in north-central New Mexico in Los Alamos and Santa Fe counties. Most of LANL and the surrounding community development is situated on mesa tops. The areas that may be impacted by the Proposed Action include land use, air quality and noise, water resources, geology and soils, biotic resources, cultural and paleontological resources, socioeconomic environment, and radiological and hazardous chemical environment. The scope of the affected environment differs from discipline to discipline, and the approach in this chapter is to describe the portion of the geographic area that is relevant to each resource type. Sufficient detail is presented for assessing the consequences of the analyzed alternatives for each area of the affected environment. The discussion in this chapter is augmented by the classified supplement for this EIS.

The PHERMEX site and the DARHT site, which are about 2,000 ft (600 m) apart, essentially constitute a single site for many of the environmental impact analyses. For the impact analyses, the combined sites are considered to be Area III (shown in figure 3-2) in Technical Area 15 (TA-15), as defined by LANL for safety, security, and control of the firing sites at PHERMEX and the DARHT Facility. In order to maintain clarity, the following terminology conventions are used in this chapter:

- "Site" refers to Area III containing both the PHERMEX and DARHT facilities.
- "PHERMEX site" or "DARHT site" refers to the area at, and immediately around, each respective facility.

This chapter describes the affected environment using information drawn from existing data on the specific technical areas (TAs), facilities and projects conducted in these areas, and LANL environmental protection/monitoring programs supporting compliance objectives. The data used to characterize the affected environment, while not all from the same calendar year(s), are the most recent and relevant published data available. These data are presented as representative of the conditions of the affected environment.

4.1 LAND RESOURCES

The study area for Land Resources is limited to Los Alamos National Laboratory (LANL) and its adjacent lands. LANL is located in north-central New Mexico, 60 mi (97 km) north-northeast of Albuquerque, 25 mi (40 km) northwest of Santa Fe, and 20 mi (32 km) southwest of Española in Los Alamos and Santa Fe counties. The associated communities of Los Alamos and White Rock are in Los Alamos County. Figure 4-1 shows the geographical location of LANL. The 28,000 ac (11,300 ha) LANL site and adjacent

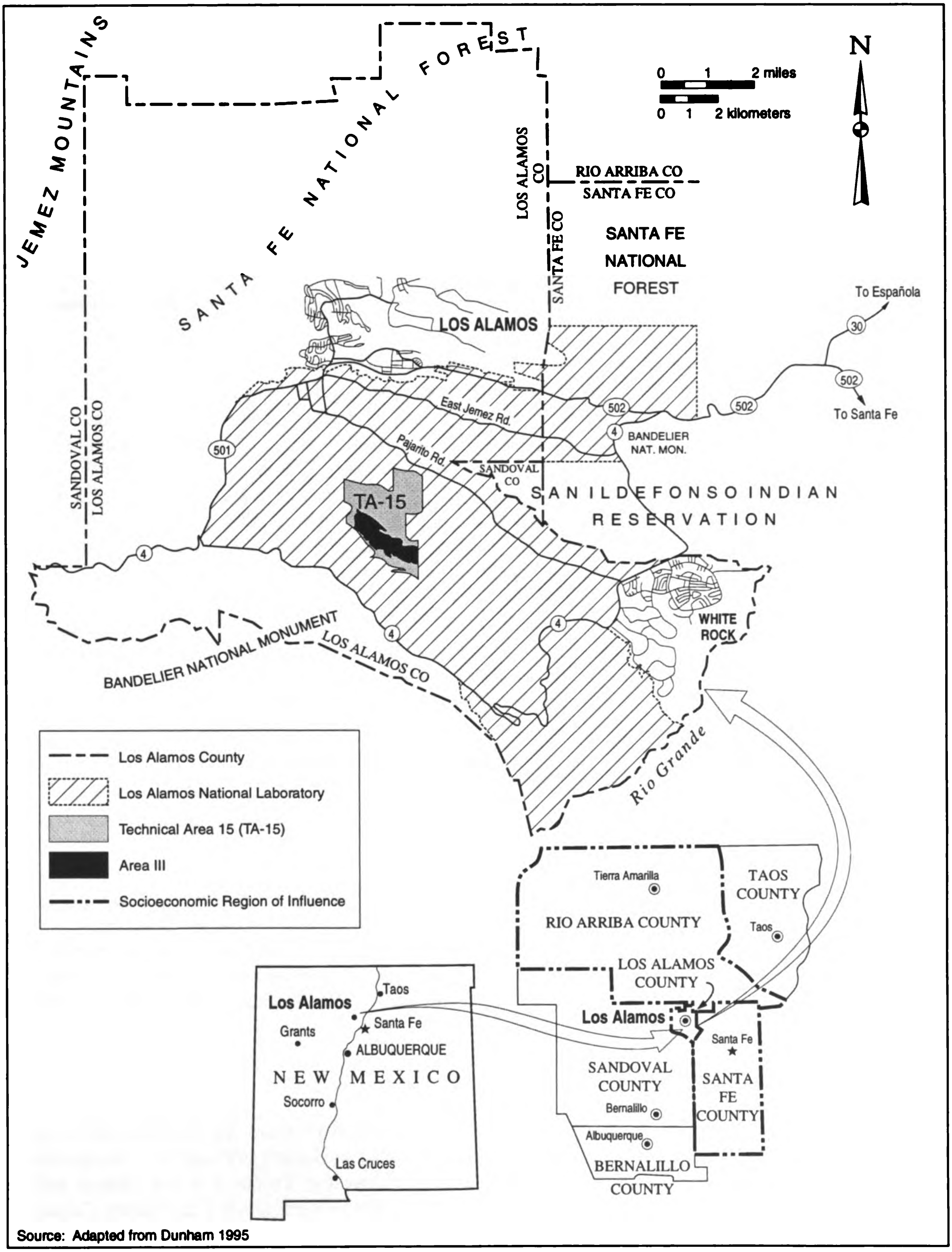


FIGURE 4-1.—*The Regional Location of LANL Showing the Geographical Relationship to Adjacent Communities and the State of New Mexico.*

communities are situated on the Pajarito Plateau, which consists of a series of finger-like mesas separated by deep canyons that run from the Jemez Mountains on the west toward the Rio Grande Valley on the east. Mesa tops range in elevation from approximately 7,800 ft (2,400 m) on the west to about 6,200 ft (1,900 m) on the east (LANL 1994a). The developed acreage of LANL consists of 30 active Technical Areas (TAs) (see figure 3-1).

4.1.1 Land Use

Most developments within Los Alamos County are confined to mesa tops. The surrounding land is largely undeveloped with large tracts north, west, and south of the LANL site administered by the U.S. Forest Service (Santa Fe National Forest) the National Park Service (Bandelier National Monument), and Los Alamos County (figure 4-2). The San Ildefonso Pueblo borders the LANL site to the east (LANL 1994a).

Area III [approximately 1,400 ac (567 ha)] is located within TA-15 on Threemile Mesa, with Cañon de Valle to the southwest, Potrillo Canyon to the southeast, and Threemile Canyon to the northeast. The topography in the vicinity is varied, ranging from steep, precipitous canyon walls to gently sloping mesa tops. The elevation of Threemile Mesa ranges from 7,100 to 7,300 ft (2,165 to 2,225 m). The Pulsed High Energy Radiation Machine Emitting X-Rays (PHERMEX) Facility and the Radiographic Support Laboratory (RSL) lie within Area III (as shown in figure 3-2). Eight ac (3 ha) of land at Area III has been disturbed for DARHT construction (Chastain 1995).

PHERMEX has a 4,100-ft (1,250-m) radius exclusion zone available, but typically a 2,460-ft (750-m) radius zone is used (shown in figure 4-3). The areas of these zones are 1,212 and 436 ac (490 and 176 ha), respectively. These exclusion zones are the areas surrounding the firing point that are cleared of all personnel for a test shot; they are concentric and are partially shared with exclusion areas for other test shot facilities. Facilities and development in this exclusion zone are limited to those needed in direct support of the firing site or which have use restrictions to ensure compatibility in the firing site. The *LANL Site Development Plan* (LANL 1994) defines a larger area, about 20 mi^2 (50 km^2), as the High Explosives Research and Development and Testing area; it separates explosives activity from noncompatible uses.

The major public roads that are used at LANL include State Road 501, State Road 4, and Pajarito Road. State Roads 501 and 4 are the closest to TA-15 (figure 4-1). Threemile Mesa is limited to Federal use, with no plans to release any portion of this mesa for public use.

4.1.2 Visual Resources

The topography of LANL affords spectacular views of the surrounding landscape of forested mountains, deep canyons, and the Rio Grande Valley. The mountain scenery, unusual geology, and archeological heritage create a diverse visual environment. The scenery contrasts greatly with the functional industrial facilities of LANL. A majority of LANL's parking lots, security gates, and service and storage yards are highly visible to employees and visitors using public roads (LANL 1990). Most structures are cinderblock, frame, or metal, painted various shades of tan. Many of these buildings were constructed in the 1940s, 1950s, and 1960s.

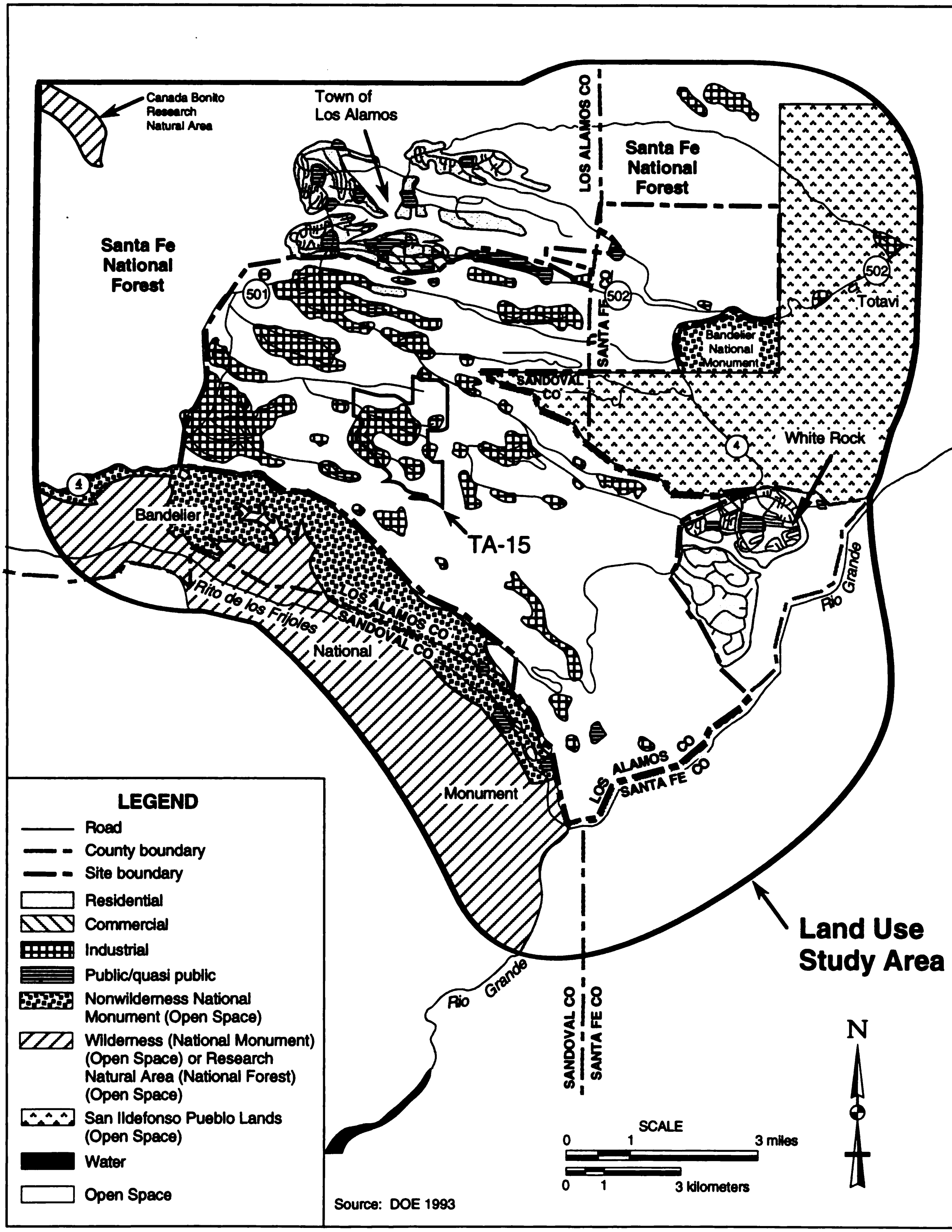


FIGURE 4-2.—*Generalized Land Use at LANL and Vicinity.*

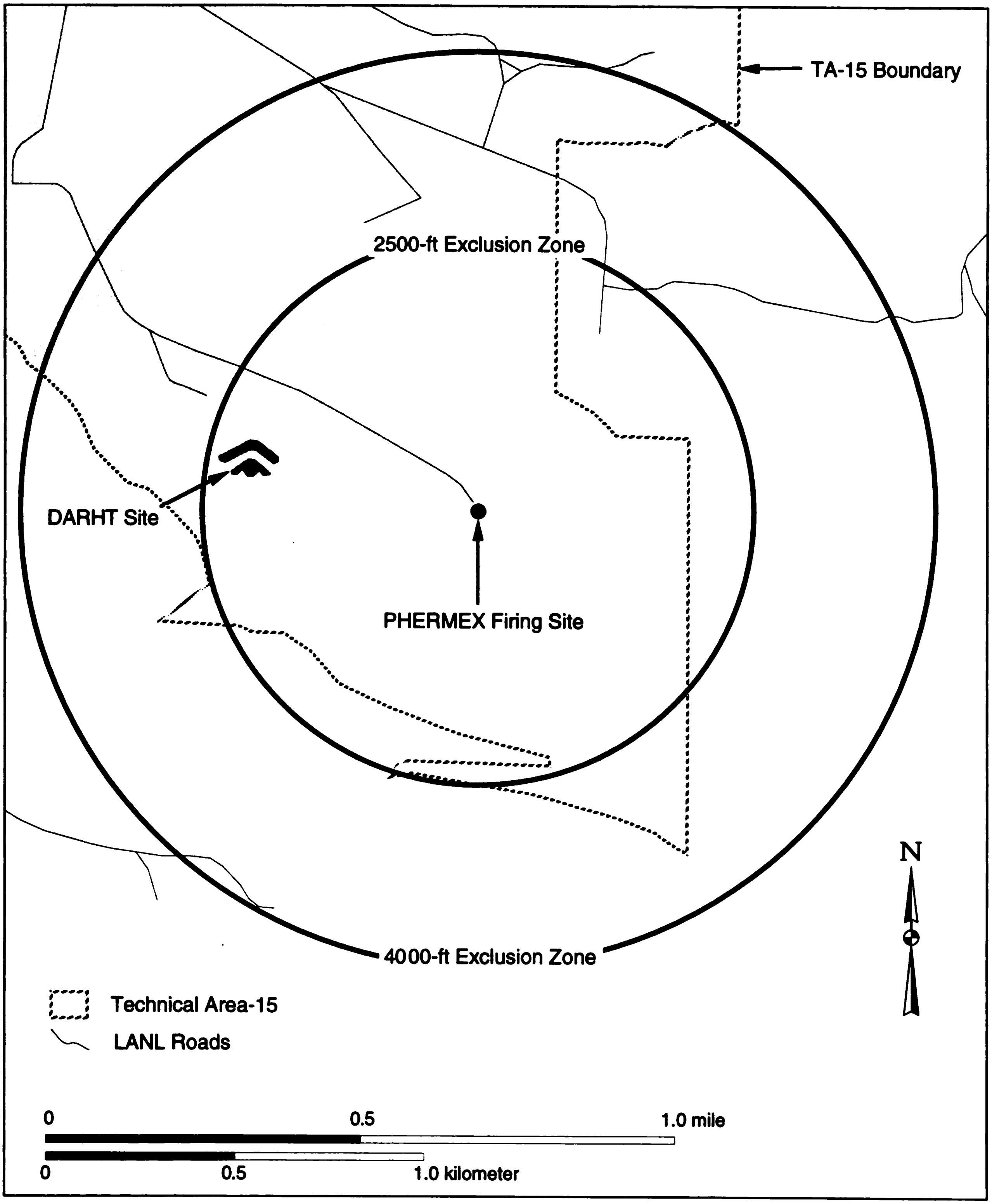


FIGURE 4-3.—*Exclusion Zones [2500 ft (760 m) and 4000 ft (1200 m)] Surrounding the PHERMEX Firing Site.*

Area III, which is not visible from public roads, contains the same visual resources as LANL. However, at Area III, the facilities are widely separated, so that vistas include canyons, mesas, and forests with occasional buildings. Immediately following a large test at Area III, the smoke plume may be briefly visible offsite.

4.1.3 Regional Recreation

The public is allowed limited access to certain areas of LANL. An area north of Ancho Canyon between the Rio Grande and State Road 4 is open to the public for selected recreation activities such as hunting and hiking. Vehicles and activities, such as woodcutting, are prohibited. Portions of Mortandad and Pueblo Canyons are also open to the public. TA-15, including Area III, is restricted to the public, except for specially permitted activities. An archeological site (the Otowi tract), northwest of State Road 502 near White Rock, is open to the public, subject to restrictions imposed by regulations that protect cultural resources (LANL 1993a).

Although they are not on the LANL site, other recreational areas are nearby. Located immediately south of LANL (figure 4-2), Bandelier National Monument is a popular public attraction. Natural beauty, Indian ruins, abundant wildlife, and historic structures are present. It has 65 mi (105 km) of maintained hiking trails that range from easy to strenuous (Los Alamos County Chamber of Commerce 1995). Another portion of Bandelier National Monument, located north of White Rock and south of State Road 502, is open to the public. 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.

4.2 AIR QUALITY AND NOISE

The study area for this section includes LANL and the surrounding areas where affected air may move or where noise may be perceived. This section describes the climate, air quality, noise, and air monitoring at LANL and TA-15. LANL quantifies and assesses the radiologic and nonradiologic air emissions to determine compliance with the Federal standards set by the U.S. Environmental Protection Agency (EPA) and State standards set by the New Mexico Environmental Improvement Board. All of the areas within LANL and its surrounding counties are designated as attainment areas with respect to the National Ambient Air Quality Standards (NAAQS). These standards define levels of air quality that are necessary, with an adequate margin of safety, to protect the public health (primary standards) and the public welfare (secondary standards).

4.2.1 Meteorology and Climatology

Los Alamos has a semiarid, temperate mountain climate. The climate averages for atmospheric variables such as temperature, pressure, moisture, and precipitation are based on observations made at the official LANL weather station at TA-59 from 1961 through 1990. The meteorological conditions described here are representative of conditions on the Pajarito Plateau at an elevation of approximately 7,200 ft (2,190 m) above sea level (LANL 1994a). The TA-59 weather station is approximately 2 mi (3 km) north of TA-15 and is considered representative of the weather conditions at that location.

In July, the average daily high temperature is 81 °F (27 °C), and the average nighttime low temperature is 55 °F (13 °C). The average January daily high is 40 °F (4 °C), and the average nighttime low is 17 °F (-8 °C). The highest recorded temperature is 95 °F (35 °C), and the lowest recorded temperature is -18 °F (-28 °C). The large daily range in temperature of approximately 23 °F (13 °C) results from the site's relatively high elevation and dry, clear atmosphere, which allows high insolation during the day and rapid radiative losses at night (LANL 1994a).

The average annual precipitation is 18.7 in (48 cm) but is quite variable from year to year. The lowest recorded annual precipitation is 6.8 in (17 cm), and the highest is 30.3 in (77 cm). The maximum precipitation recorded for a 24-hour period is 3.5 in (9 cm). Because of the eastward slope of the terrain, there is a large east-to-west gradient in precipitation across the plateau. White Rock often receives about 5 in (13 cm) less annual precipitation than the official weather station at TA-59, and the eastern flanks of the Jemez Mountains often receive about 5 in (13 cm) more (Bowen 1992).

Approximately 36 percent of the annual precipitation normally occurs from thundershowers during July and August. Winter precipitation falls primarily as snow, with accumulations of about 59 in (150 cm) seasonally (LANL 1993a). The highest recorded snowfall for one season is 153 in (389 cm), and the highest recorded snowfall for a 24-hour period is 22 in (56 cm). In a typical winter season, snowfall equal to or exceeding 1 in (2.5 cm) will occur on 14 days, and snowfall equal to or exceeding 4 in (10 cm) will occur on 4 days. The snow is generally dry; on the average, 20 units of snow at LANL are equivalent to 1 unit of water (LANL 1994a).

Los Alamos winds are generally light, averaging 6.3 mi/h (10 km/h). Strong winds are most frequent during the spring when peak gusts during this season often exceed 50 mi/h (80 km/h). The highest recorded wind gust is 77 mi/h (124 km/h). The semiarid climate promotes strong surface heating by day and strong radiative cooling by night. Because the terrain is complex, heating and cooling rates are uneven over the LANL area, which results in local thermally generated winds. The distributions of wind direction and wind speed for the four measurement stations (located at TA-6, TA-49, TA-53, and TA-54) on the plateau are shown in figures 4-4 and 4-5 (LANL 1994a). The wind roses presented in these figures provide general information of the daytime and nighttime wind conditions surrounding TA-15.

During sunny, light-wind days, an upslope air flow often develops over the plateau in the morning hours. This flow is more pronounced along the western edge of the plateau, where the flow is 650 to 1,650 ft (200 to 500 m) deep. By noon, southerly flow usually prevails over the entire plateau.

At measurement sites closer to the eastern edge of the plateau, wind roses show a weak secondary peak in the daytime wind direction in the northeast sector. These northeasterlies also show up in the wind roses for observations made at 300 ft (92 m) and 1,670 ft (510 m) above the ground. They are thought to result from cold air drainage down the Rio Grande Valley that persists into the early morning hours (LANL 1994a).

The prevailing nighttime flow along the western edge of the plateau is west-southwesterly to northwesterly. These nighttime westerlies result from cold air drainage off the Jemez Mountains and the Pajarito Plateau; the drainage layer is typically 165 ft (50 m) deep in the vicinity of TA-3. At sites farther from the mountains, the nighttime direction is more variable but usually has a relatively strong westerly component. Just above the drainage layer, the prevailing nighttime flow is southwesterly, with minor

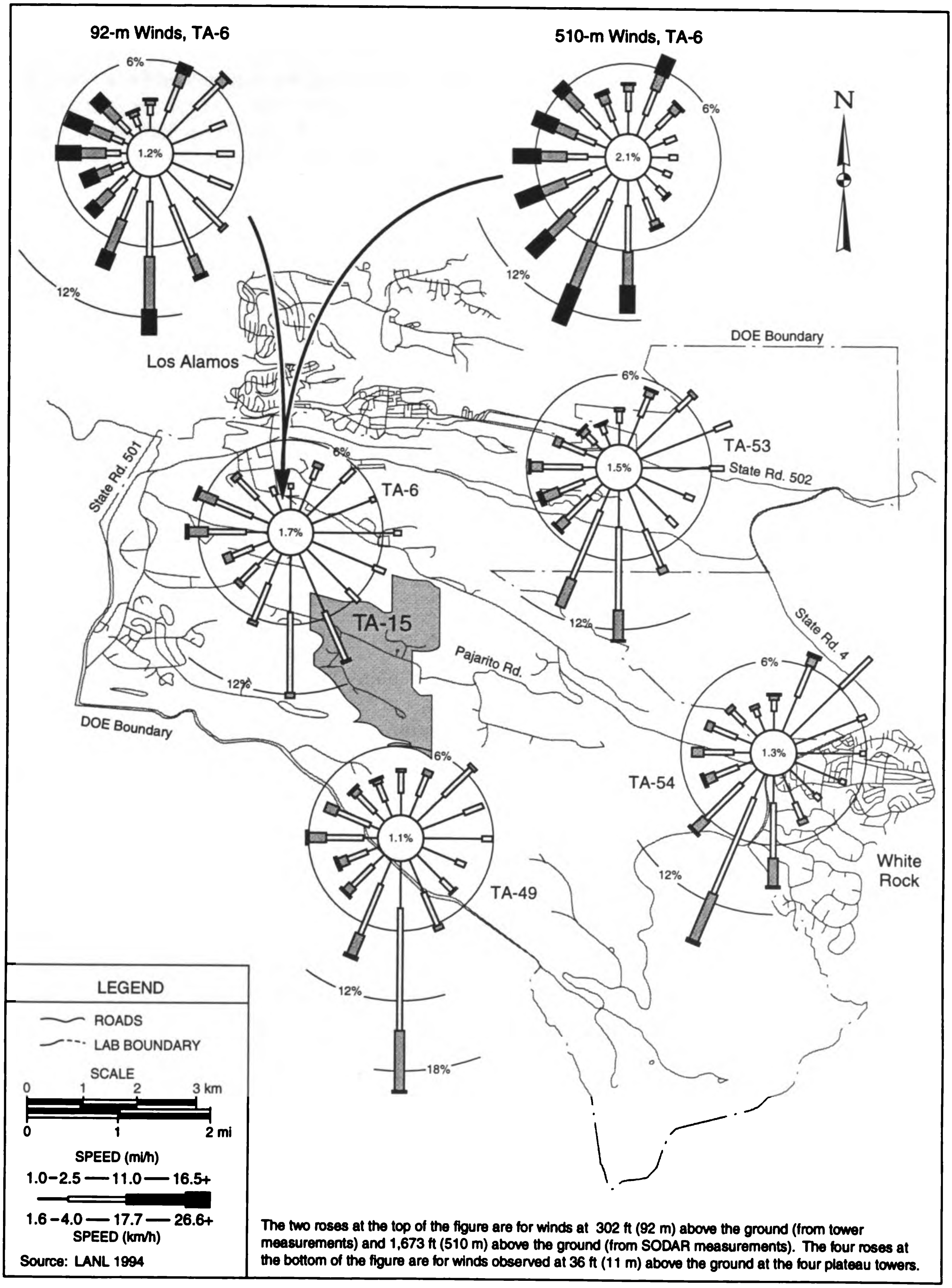


FIGURE 4-4.—*Wind Roses at LANL Monitoring Sites for Daytime Winds in 1992.*

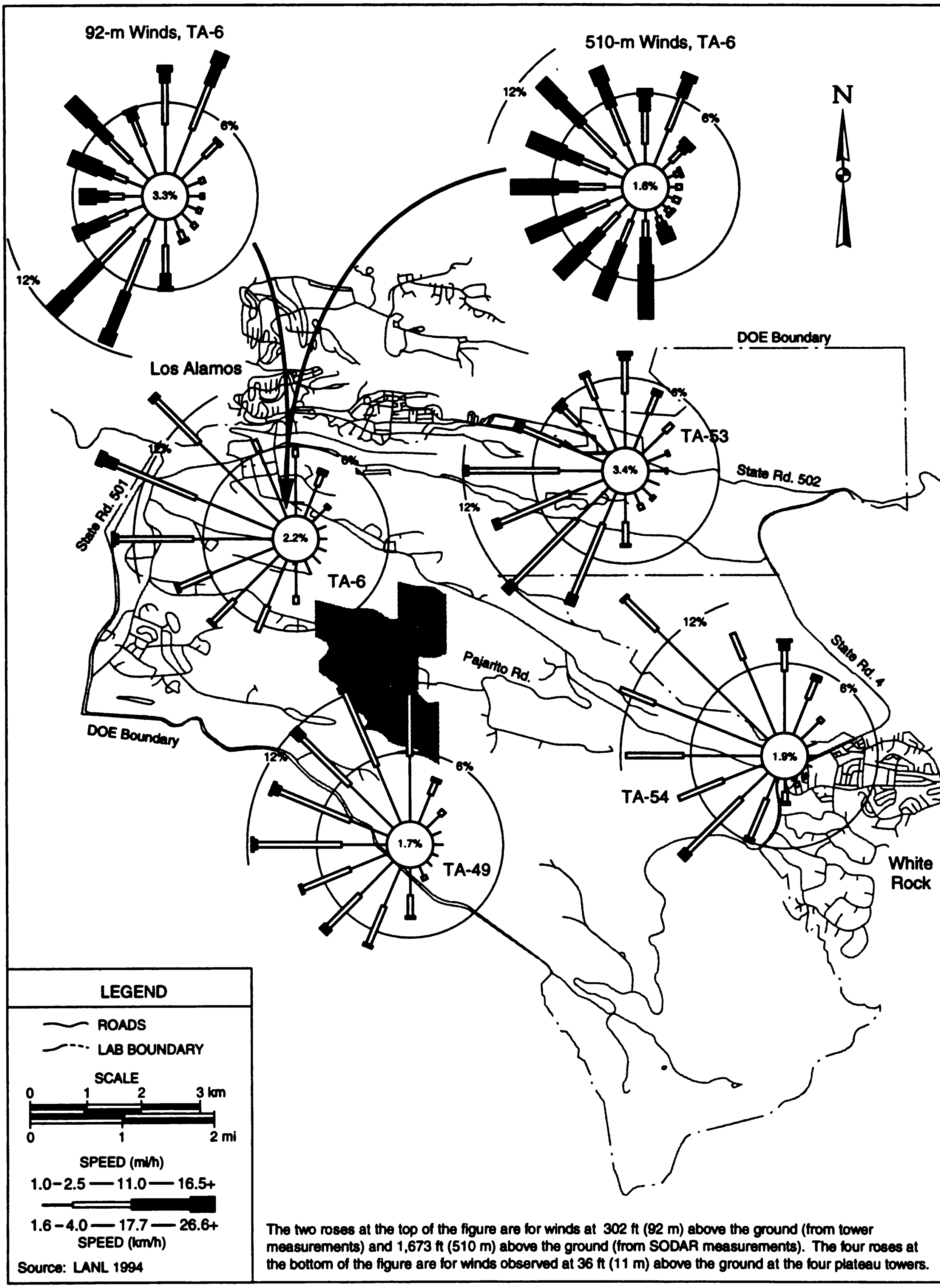


FIGURE 4-5. ***Wind Roses at LANL Monitoring Sites for Nighttime Winds in 1992.***

peaks in the distribution around northwest and northeast. At 1,673 ft (510 m) above the ground, the wind direction distribution exhibits a broad, flat peak covering the whole western half of the compass (LANL 1994a).

Atmospheric flow in the canyons is quite different than over the plateau. Data collected from Los Alamos Canyon suggest that at night a cold air drainage fills the lower portion of the canyon more than 75 percent of the time. The flow is steady and continues for about an hour after sunrise when it ceases abruptly and is followed by an unsteady up-canyon flow for a couple of hours. Down-canyon flow begins again around sunset, but the onset time appears to be more variable than cessation time in the morning (LANL 1994a).

4.2.2 Severe Weather

Thunderstorms are common at LANL, with 61 occurring in an average year. A thunderstorm day is defined as a day in which either a thunderstorm occurs or thunder is heard nearby. Most thunderstorm days occur during July and August, the so-called monsoon season. During this time of year, large-scale southerly and southeasterly winds bring moist air into New Mexico from the Gulf of Mexico and the Pacific Ocean. The combination of moist air, strong sunshine, and warm surface temperatures encourages the formation of afternoon and evening thundershowers, especially over the Jemez Mountains. Upper air winds often move the thunderstorms over TA-15. The resultant drainage patterns are discussed in section 4.4.1. No tornadoes have been reported to have touched down in Los Alamos County.

Lightning in LANL can be frequent and intense during some thunderstorms. Because lightning can cause occasional brief power outages, lightning protection is an important design factor for most facilities at LANL and the surrounding area. Lightning protection is used at PHERMEX and has been designed into the alternatives.

Hail is also very common at LANL. In fact, the area around Los Alamos has the most frequent hailstorms in New Mexico. Typically, the hailstones have diameters of about 0.25 in. (0.6 cm), with a few somewhat larger. Some storms produce measurable accumulation on the ground. Rarely, hailstorms cause significant damage to property and plants. Very little hail damage is expected on hydrodynamic testing operations.

Large-scale flooding is not common in New Mexico. However, flash floods from heavy thunderstorms are possible in susceptible areas, such as arroyos, canyons, and low spots. Severe flooding has never been observed in Los Alamos, but heavy downpour combined with already saturated soil caused flash flooding in Los Alamos on August 4, 1991. Flooding washed out sewer lines in Pueblo Canyon, with extensive flooding of streets and basements. This type of flooding is possible at TA-15 and could serve as a mechanism to transport contaminants.

Flooding is possible in the spring from snowmelt, although snowmelt flooding is usually confined to the larger rivers in the state. However, snowmelt can cause muddy conditions in the LANL area, along with minor flooding of streams in the Jemez Mountains (Bowen 1992). Flooding from snowmelt is not expected to impact TA-15.

4.2.3 Atmospheric Dispersion

The irregular and complex terrain at LANL affects the atmospheric dispersion. The terrain and forests create an aerodynamically rough surface, forcing increased horizontal and vertical turbulence and dispersion. The dispersion generally decreases at lower elevations where the terrain becomes smoother and less vegetated, and canyons also limit dispersion by channeling air flow. The frequent clear skies and light winds cause good daytime vertical dispersion, especially during the warm season.

Clear skies and light winds have a negative effect on dispersion at night, creating strong, shallow surface inversions. The inversions are especially strong during the winter. Overall dispersion is greater in the spring during strong winds. However, vertical dispersion is the greatest during summer afternoons (Bowen 1992).

4.2.4 Air Quality

The criteria pollutants – nitrogen dioxide (NO_2), carbon monoxide (CO), hydrocarbons, particulate matter, and sulfur dioxide (SO_2) – make up approximately 79 percent of the stationary source emissions at LANL. The source of these criteria pollutants is combustion in power plants, steam plants, asphalt plants, and local space heaters. Toxic and other hazardous pollutants represent the remaining 21 percent of emissions from stationary sources at LANL. These emissions include equipment surface cleaning, coating, acid gases, metals, and miscellaneous emissions such as wood dust, hazardous gases, and plastics (LANL 1994a).

Table 4-1 shows the results of two studies that estimated emissions of nonradioactive chemicals. The 1987 emissions inventories were designed to collect information on emissions of these chemicals for the state's toxic air pollutant registration regulation. The 1990 inventory expanded the list of chemicals and sources and was designed to give LANL an estimate of its overall emissions. Data from the 1987 and 1990 inventories represent the only available listings of chemical emissions for LANL. The main difference between the two inventories is that the 1990 estimates included the emissions from the boilers, which accounts for the large emissions of nitrogen dioxide, carbon monoxide, and particulate matter. The amount and type of nonradioactive chemical emissions will also change from year to year as experiments change (LANL 1994a).

Natural atmospheric and fallout radioactivity levels fluctuate and affect measurements made during LANL's air sampling program. Worldwide background airborne radioactivity is largely composed of fallout from past atmospheric nuclear weapons tests, natural radioactive constituents from the decay of thorium and uranium attached to dust particles, and materials resulting from interactions with cosmic radiation (for example, natural tritiated water vapor produced by interactions of cosmic radiation and stable water). Levels of background radioactivity in the atmosphere are summarized in table 4-2. Note that the measurements taken in Santa Fe on the roof of the Public Employment Retirement Association Building by the EPA are similar to those taken by LANL as regional background values (LANL 1994a).

The annual air emissions reports for CY 1992 (DOE 1993b) and CY 1993 (DOE 1994) have estimated the radiological dose assessment from nonpoint sources, as defined by the Clean Air Act, such as the experiments conducted at TA-15. In 1992, the contribution from TA-15 operations to the Effective Dose Equivalent from all LANL operations for the maximally exposed individual [located approximately

TABLE 4-1.—*Summary of Total LANL Estimated Emissions of Nonradioactive Air Pollutants[a] in 1987and 1990[b] that may be Associated with Area III at TA-15[c]*

Pollutant	1987 Emissions (lb/yr)[d]	1990 Emissions (lb/yr)	Pollutant	1987 Emissions (lb/yr)	1990 Emissions (lb/yr)
Nitrogen dioxide	—[e]	118,772	Hydrogen fluoride as Fluorine	6	534
Nonmethane hydrocarbons	10,872	6,377	Trichlorethylene	1,229	463
Particulate Matter	—	5,629	Aluminum welding fumes	—	271
Ammonia	3,816	1,761			
Nitric acid	1,674	1,457	Heavy metals	—	251
Hydrogen chloride	1,832	1,407	Tungsten (insoluble)	—	241
Methyl alcohol	4,437	1,298	Ethylene glycol	50	159
Isopropyl alcohol	829	1,188	Nickel metal	—	122
Acetic acid	96	1,184	Aluminum (metal and oxide)	5	89
Welding fumes (not otherwise listed)	253	1,127	Softwood	525	88
Wood dust (certain hard woods)	—	1,003	Mineral oil mist	13	76
			Cyclohexane	9	62
Nitrogen oxide	1,049	944	Lead	—	57
Stoddard solvent	941	583	Hydrogen peroxide	17	43
Kerosene	15,265	574	Chlorine	29	29

[a] Only pollutants with 1990 emissions of 25 lb/yr or more are reported here.
[b] Data for these two years are not adjusted for changes in LANL activities. Only those materials likely to be used at a hydrodynamic testing facility are listed here.
[c] This table represents pollutants associated with Area III operations. Emissions stated in this table are for the entire LANL Site. For a complete listing of LANL emissions see the 1992 LANL Environmental Surveillance Report.
[d] Conversion factor: 1 lb/yr = 0.454 kg/yr.
[e] Data not collected for these pollutants.

Source: Adapted from LANL 1994.

2,600 ft (800 m) north-northeast of the Los Alamos Meson Physics Facility stock in TA-53] was 9 x 10^{-6} rem of the total of 7.9 x 10^{-3} rem (DOE 1993b). In 1993, the estimated dose from TA-15 operations was 6.6 x 10^{-5} rem (DOE 1994), which was higher for TA-15 but still very small. These values are approximately 1 percent of the total annual LANL dose to the public.

Particulate radionuclide matter in the atmosphere is primarily caused by the resuspension of soil, which is dependent on current meteorological conditions and human disturbance. Windy, dry days can increase the soil resuspension, whereas precipitation (rain or snow) can wash particulate matter out of the air. Consequently, there are often large daily and seasonal fluctuations in airborne radioactivity concentrations caused by changing meteorological conditions.

Construction of the DARHT Facility, which is 34 percent complete, affected the air quality of the area. Dust and auto emissions increased during the period of construction because of the increase in vehicles and construction machinery in the area.

TABLE 4-2.—*Average Background Concentrations of Radioactivity in the Regional Atmosphere*

Radioactive Constituent	Units	Santa Fe[a] 1988-1991	New Mexico[b] 1992	DOE Guideline 5400.5 for Uncontrolled Area
Tritium	10^{-12} µCi/mL	—	0.3 (0.8)[c]	200,000
Uranium (natural)	pg/m^3	58.2 (19.5)	92.0 (15.0)	100,000
Uranium-234	10^{-18} µCi/mL	22.5 (7.5)	30.6 (9.0)	90,000
Uranium-235	10^{-18} µCi/mL	0.8 (0.4)	2.6 (0.7)	100,000
Uranium-238	10^{-18} µCi/mL	22.5 (7.5)	28.8 (8.0)	100,000
Plutonium-238	10^{-18} µCi/mL	0.3 (0.2)	0.6 (3.8)	30,000
Plutonium-239,240	10^{-18} µCi/mL	0.2 (0.1)	1.5 (2.2)	20,000
Americium-241	10^{-18} µCi/mL	—	1.3 (4.1)	20,000

[a] EPA (1989-1993), Reports 53 through 68. Data are from the EPA, Santa Fe, New Mexico, sampling location and were taken from January 1988 through December 1991. Data for 1992 were not available at time of publication.
[b] Data are annual averages from the regional stations (Española, Pojoaque, Santa Fe) and were taken by LANL during 1992.
[c] Uncertainties (± 2σ) are in parentheses.

Source: LANL 1994.

4.2.5 Air Monitoring

The visibility at and near LANL has been monitored since 1988 at the Bandelier National Monument southwest of LANL off of State Road 4 (see figure 4-1). Visibility monitoring quantifies how well the visible information (i.e., images) is transmitted through the atmosphere to an observer some distance away.

The data are measured according to the Standard Visual Range (SVR), which can be interpreted as the farthest distance that a large black feature can be seen on the horizon. From summer 1993 to spring 1994, the SVR was measured during a four-hour average variation in visual air quality (excluding weather-affected data) at Bandelier National Monument. The SVR ranged from approximately 48 to 103 mi (77 to 166 km). This is a typical visibility range for the area according to data collected since 1988 (Air Resource Specialists 1994).

LANL operates or accesses a network of nonradiological ambient air monitors to routinely measure criteria pollutants, beryllium, acid precipitation, and visibility (see table 4-3). The nonradiological monitoring network consists of a variety of monitoring stations: 1 onsite criteria pollutant monitoring station, 17 beryllium monitors, 1 perimeter acid rain monitor, and 1 perimeter visibility monitoring station (LANL 1994a). Beginning in FY 1995, no measurements of the criteria pollutants are being made by

TABLE 4-3.—*Nonradiological Ambient Air Monitoring Results in the LANL Region 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 hours	ppm	0.10	0.14		
	3 hours	ppm			0.05	
	1 hour	ppm				0.009
Total suspended particulate matter	Annual Geometric Mean	μg/m³	60			
	30 days	μg/m³	90			
	7 days	μg/m³	110			
	24 hours[c]	μg/m³	150			
PM_{10}[a]	Annual arithmetic mean	μg/m³		50	50	8
	24 hours	μg/m³		150	150	21
Ozone[a]	1 hour	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 hours	ppm	0.10			
	1 hour	ppm				0.02
Lead	Calendar quarter	μg/m³		1.5	1.5	
Beryllium[b]	30 day	μg/m³	10			0.02
Heavy Metals	30 days	μg/m³	10			

[a] Measurements made at Bandelier Monitoring Compound
[b] Measurement made at TA-52
[c] Maximum concentration, not to exceed more than once per year.

Source: LANL 1994.

LANL on a continuing basis because past observed values were low relative to standards. Measurements are made on an as-needed basis for activities with potential for pollution (Jardine 1995).

The 1992 sampling network for ambient airborne radioactivity consists of 55 continuously operating air sampling stations, including 17 offsite locations (3 regional and 14 perimeter), 14 onsite stations, and 5 onsite waste site stations. One station at TA-18 is inactive. The regional monitoring stations, 18 to 28 mi (29 to 45 km) from LANL, are located in Española, Pojoaque, and Santa Fe (figure 4-6). The data from these stations are used as reference points for determining regional background levels of atmospheric radioactivity. Ambient air is routinely sampled for beryllium, tritium, isotopic plutonium and uranium americium, iodine, gross alpha, beta and gamma activity. Table 4-4 presents 1992 radionuclide releases from LANL operations (LANL 1994a).

Later in 1993, three air monitoring stations (76, 77, and 78 in figure 4-6) were added downward of the firing site for PHERMEX and DARHT. The monitoring stations are about 320 to 3,300 ft (100 to 1,000 m) northeast of the firing site. Samples collected at these stations are analyzed for isotopic uranium, isotopic plutonium, gross alpha, beta, gamma, and beryllium (Jacobson 1995).

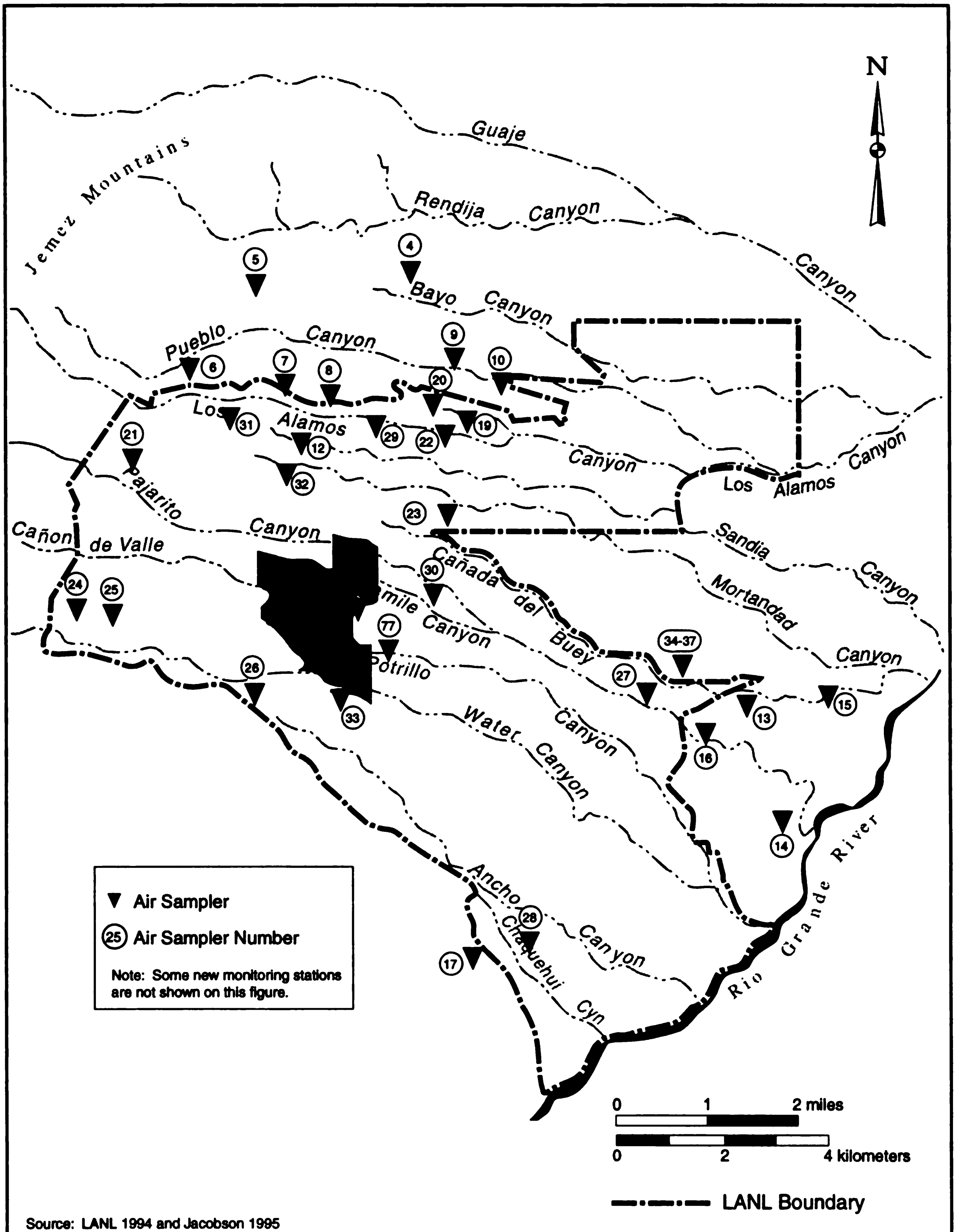


FIGURE 4-6.—*Approximate Locations for Offsite Perimeter and Onsite LANL Stations for Sampling Airborne Radionuclides in 1992 and TA-15 Stations added in Late 1993.*

TABLE 4-4.—*1992 Airborne Releases of Radionuclides from LANL Operations*

Radionuclide	Units	Activity Released 1992
Tritium	Ci	1,298
Phosphorus-32	µCi	9
Uranium	µCi	242[a]
Plutonium	µCi	12
Gaseous mixed activation products	Ci	71,950
Mixed fission products	µCi	275
Particulate/vapor activation products	Ci	0.73
Spallation products	Ci	< 0.1
TOTAL	Ci	73,248

[a] Does not include uncontained hydrodynamic testing. Reported releases are measured at 88 LANL discharge locations.

Source: LANL 1994.

4.2.6 Noise

Noise measurements have been made in the standard unit for measuring noise levels in the A-weighted decibel (dBA) scale. Two kinds of noise are emitted from TA-15 – peak (or impact), which is high level and short duration noise, and continuous, which is of moderate level and relatively lengthy duration.

Continuous noise at TA-15 results from background noise and from construction activities (such as the construction of DARHT which is currently halted). Background noise levels range from 31 to 35 dBA at the vicinity of the Bandelier National Monument entrance and State Road 4 (Vigil 1995). Background noise levels at White Rock range from 38 to 51 dBA (Burns 1995). The higher background noise levels at White Rock result from a greater amount of traffic.

The sources of peak noise are explosive experiments in the PHERMEX and surrounding TAs. Peak noise measurements of a test using 20 lb (9 kg) of trinitrotoluene (TNT) at TA-14 (northeast of TA-15) at a distance of 750 ft (230 m) from the source ranged from 140-148 dBA. Noise measurements on March 11, 1995, from 150 lb (70 kg) of TNT at PHERMEX showed levels of 71 dBA at State Highway 4 [closest public approach, 1.3 mi (2 km)], 60 dBA near the state highway entrance to Bandelier National Monument [closest permanent residences, 2.6 mi (4.3 km)], and about 70 dBA in White Rock [a nearby residential community, 4 mi (6.4 km)].

When recent construction was underway at the DARHT site, it included use of heavy equipment such as dozers, loaders, backhoes, and generators. While actual noise measurements were not made during the use of the heavy equipment, existing data are available to quantify the range of noise levels. The mean level of noise from these equipment types ranges from 81 to 85 dBA (Chastain 1995 and Wyle Labs 1981).

4.3 GEOLOGY AND SOILS

The geology of the affected environment includes consideration of two perspectives:

- The broad area that is the source of geologic phenomena (such as earthquakes) that could affect the proposed facility

- The immediate area where the hydrodynamic test facility would be located and might subsequently impact the environment.

This section of the EIS first describes the geologic setting of the broader area and then progresses toward the greater specificity of local geologic pressures and features of the Pajarito Plateau, where the site is located.

4.3.1 Geology

The broad geological area described here is in north-central New Mexico (see figure 4-1). The Pajarito Plateau lies between the Jemez Mountains on the west and the Rio Grande on the east (figure 4-7). Although Precambrian rocks more than a billion years in age are found in deep drill holes in the LANL region, the most important geologic events for understanding the environment occurred during the past 32 million years, particularly the last million years.

The primary, controlling feature in the region is the Rio Grande rift that begins in northern Mexico, trends northward across central New Mexico, and ends in central Colorado. The rift owes its origins to tension along the crest of a broad, gentle crustal uplift some 32 million years ago. The rift now comprises a series of basins formed by faulting that dropped the basin rocks relative to the uplift, usually much more deeply on either the east or west margins. These basins are filled with sediments derived from highlands to the east and west as well as occasional lake deposits and lava flows. The rift basin in the Los Alamos and Santa Fe area is the Española Basin.

Faulting associated with the rifting provided conduits for volcanic activity such as the basaltic lavas that are interbedded with the basin-filling sediments. In addition, the deep faulting helped localize the expression of some major trends in volcanic activity. The volcanic vents in and near the Jemez Mountains lie at the intersection of a northeast trend of volcanic centers and the western edge of the Española Basin of the Rio Grande rift (Seager and Morgan 1979). Deposits from these Jemez Mountains vents buried the basin-filling sediments and the adjacent uplands over an area of more than 800 mi^2 (2100 km^2).

The climactic eruptions occurred about 1.5 to 1.1 million years ago; during this time the Bandelier Tuff was laid down in a sequence of ash falls from individual eruptions in the series. Also, during these eruptions, the crater, Valles Caldera, formed by collapse when a great volume of magma was ejected along the ring-shaped fractures that now define the caldera structure.

The Rio Grande rift, along with its faulting and volcanism, is complicated in detail and is the subject of both extensive literature and ongoing research. This is evident in descriptive documents with extensive bibliographies that have been published by Turin and Rosenburg (1994), Woodward-Clyde Federal Services (Wong et al. 1995), LANL (1993a), and Gardner and House (1987). The geologic summary provided here is generalized to the level of information needed for environmental assessment.

The major portion of LANL is underlain by the Tshirege member of the Bandelier Tuff, a sequence of ashfall strata dipping slightly to the south-southeast. Along the eastern portion of LANL, canyons have exposed underlying strata within the Bandelier Tuff and older, deeper formations.

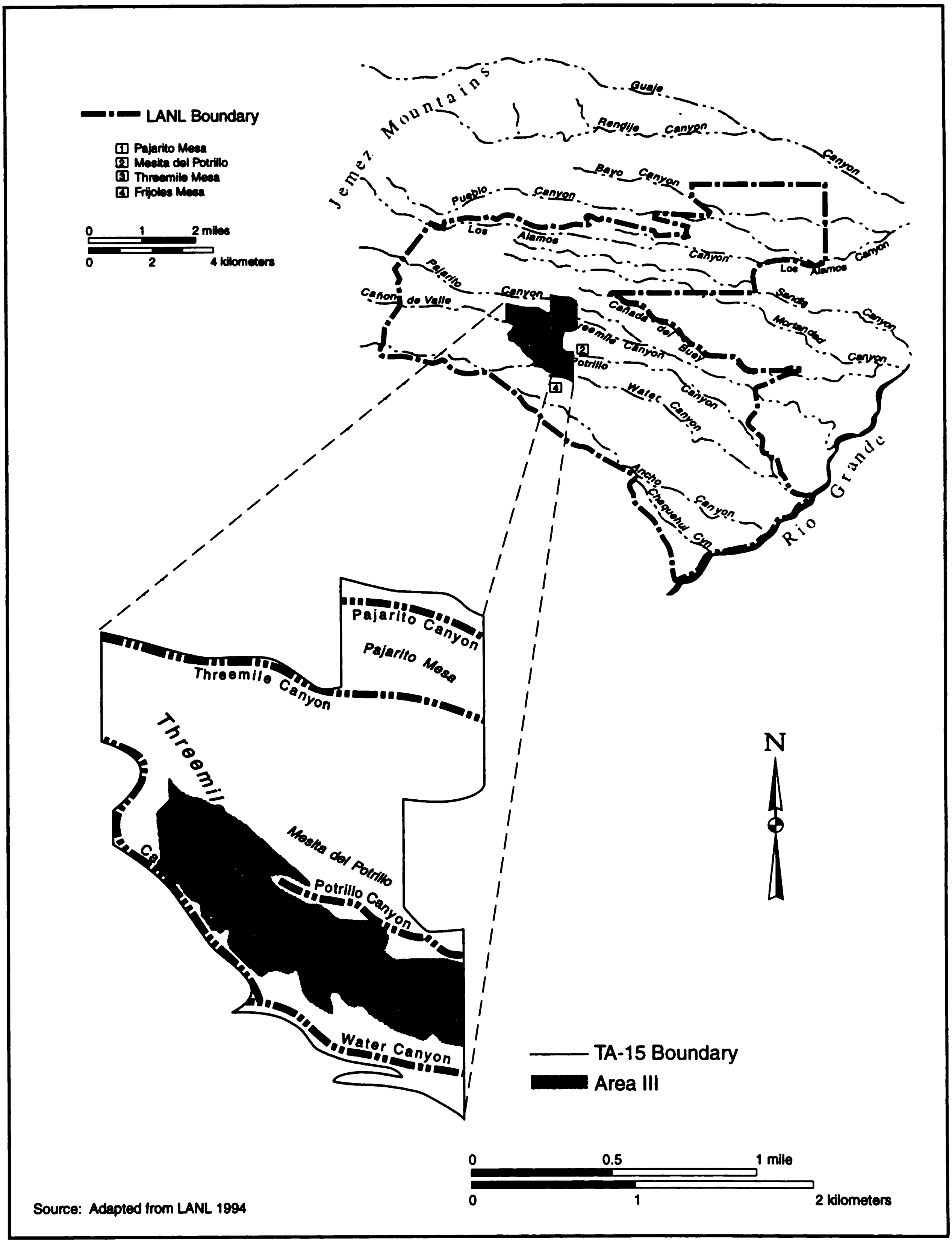


FIGURE 4-7.—*Mesas and Canyons on the LANL Site.*

4.3.2 Structure and Stratigraphy

Structure and stratigraphy are the key elements of the local geologic environment. The geologic structure at the site is dominated by three fault zones: the Pajarito, Rendija Canyon, and Guaje Mountain faults. These faults are clearly expressed by surface offsets at some locations and inferred from geologic evidence at others. Figure 4-8 shows the results of recent mapping of faults, including the young faulting that is significant to LANL in general and the proposed site in particular (Wong et al. 1995). The figure distinguishes between clearly observable faulting and photo lineaments that may indicate connections or extensions of the faults. Other geologic maps often show simpler and more continuous faults.

The Pajarito fault is thought to mark the currently active western boundary of the Española Basin (Wong et al. 1995). Prior to the Jemez Mountains volcanism, the basin boundary may have been farther west and under the present Valles Caldera. The Rendija Canyon and Guaje Mountain faults are shorter and secondary to the Pajarito fault. However, a recent investigation determined that all three faults are geologically young and are capable of producing future earthquakes (see table 4-5) (Wong et al. 1995).

Earthquakes in the region are not always well correlated with faults that are expressed in the surface geology. Figure 4-8 shows the epicenters for reported earthquakes near LANL from 1873 through 1992 (Wong et al. 1995). A few of these epicenters are near the Pajarito and Rendija Canyon faults. However, the epicenter determinations necessarily have some uncertainties, and the true locations may be somewhat different. The important conclusion from both the geologic and seismic evidence is that faulting in the region is an ongoing process.

Figure 4-9 is a general cross section of the area from the east edge of the Jemez Mountains across the Pajarito Plateau to the Rio Grande (DOE 1979). This cross section shows the Pajarito fault, the Precambrian basement rocks, the basin-filling sediments, volcanic rocks of the Jemez Mountains, and the volcanic Bandelier Tuff that forms the Pajarito Plateau.

A stratigraphic section for TA-67, about 1 mi (1.6 km) north of the proposed site is shown in figure 4-10 (adapted from Broxton et al. 1994). The Tshirege member of the Bandelier Tuff is divided into several distinct units. Units 4 and 3 are important as contributors to the mesa-top soils. Unit 3, because of its welding, is a comparatively strong rock and resists erosion sufficiently to form the mesa topography. Units 2 and 3, as well as the nonwelded bed between them, contribute to the soils in the canyons.

The main aquifer below the proposed site is estimated to be in the Puye formation some 1,100 to 1,200 ft (335 to 365 m) below the mesa top. The porosity, permeability, and fracture flow (if present) for these formations are described in section 4.4 on water resources.

4.3.3 Soils

Several distinct soils have developed on the Pajarito Plateau as the result of interactions among the bedrock, surface morphology, and local climate. Nyhan et al. (1978) mapped these soils as shown in figure 4-11. The mineral components of the soils on Threemile Mesa are in large part derived from the Bandelier Tuff, but other underlying formations are locally important elsewhere on the Pajarito Plateau. Alluvium derived from the plateau, the Jemez Mountains, and windblown deposits contributes to soils in the canyons and also on some of the mesa tops. Layers of pumice from the El Cajete eruption in the

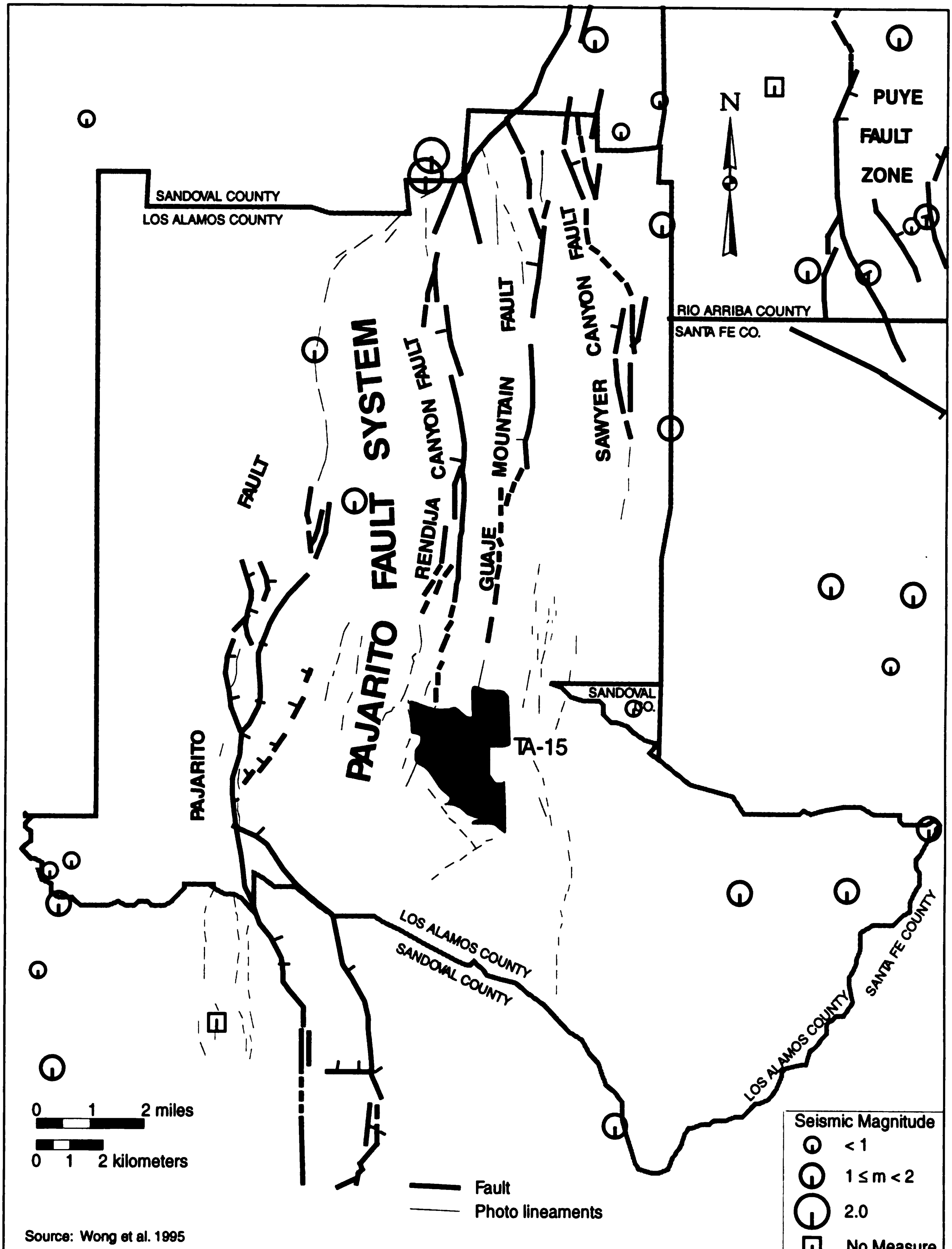


FIGURE 4-8.—*Recent Mapping of Faults, Photo Lineaments, and Earthquake Epicenters at LANL.*

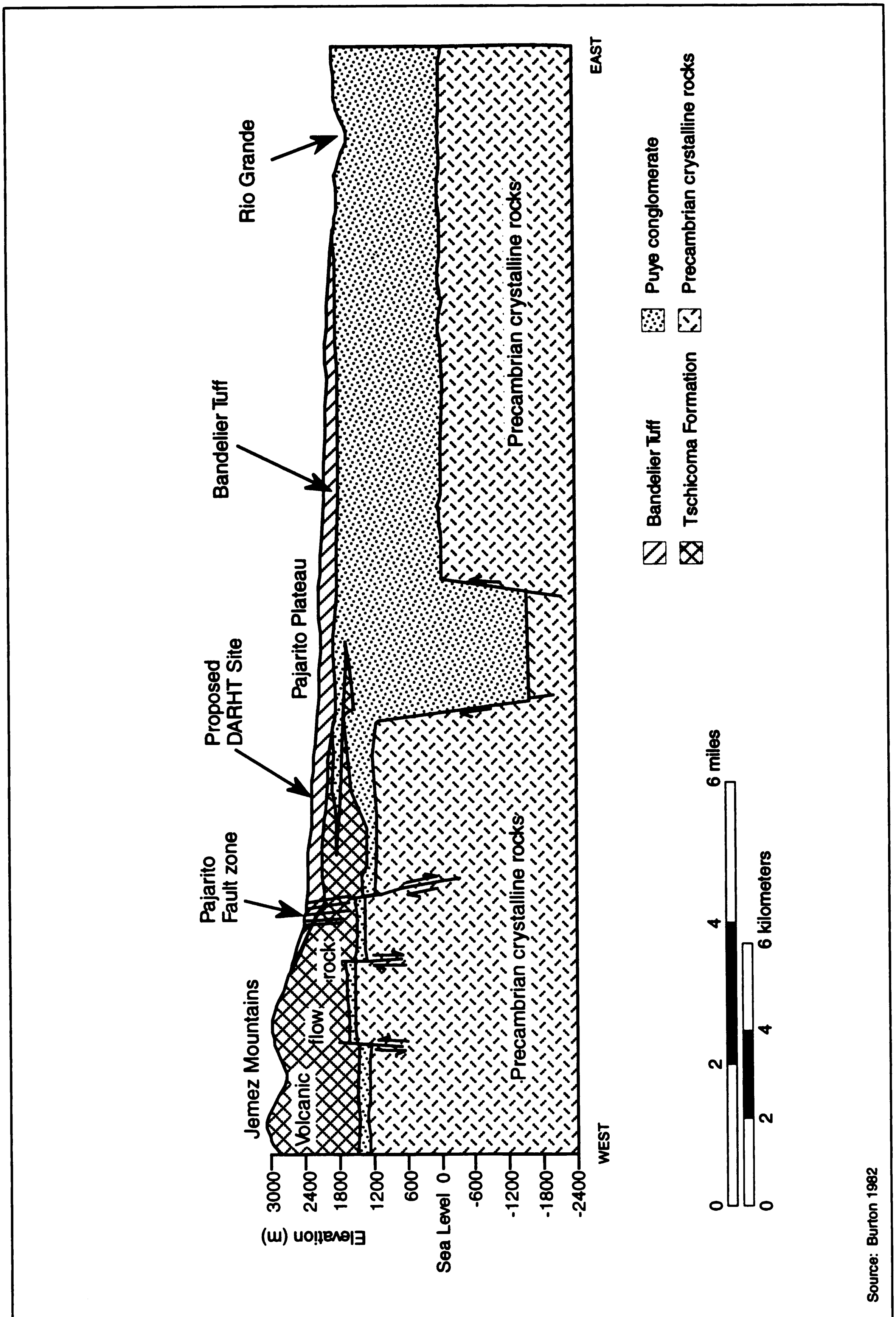


FIGURE 4-9.—*Geologic Stratigraphic Relationships at LANL.*

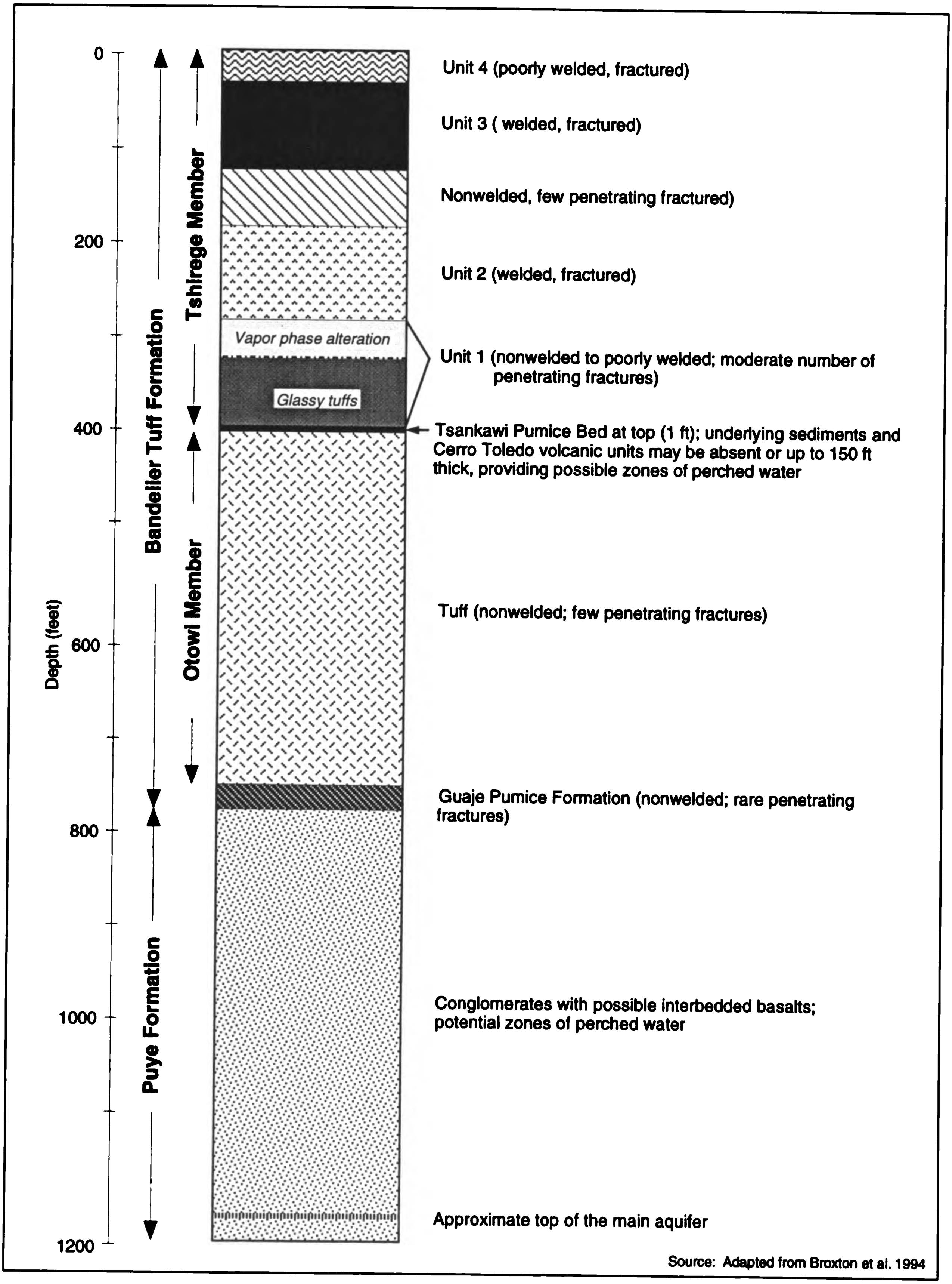
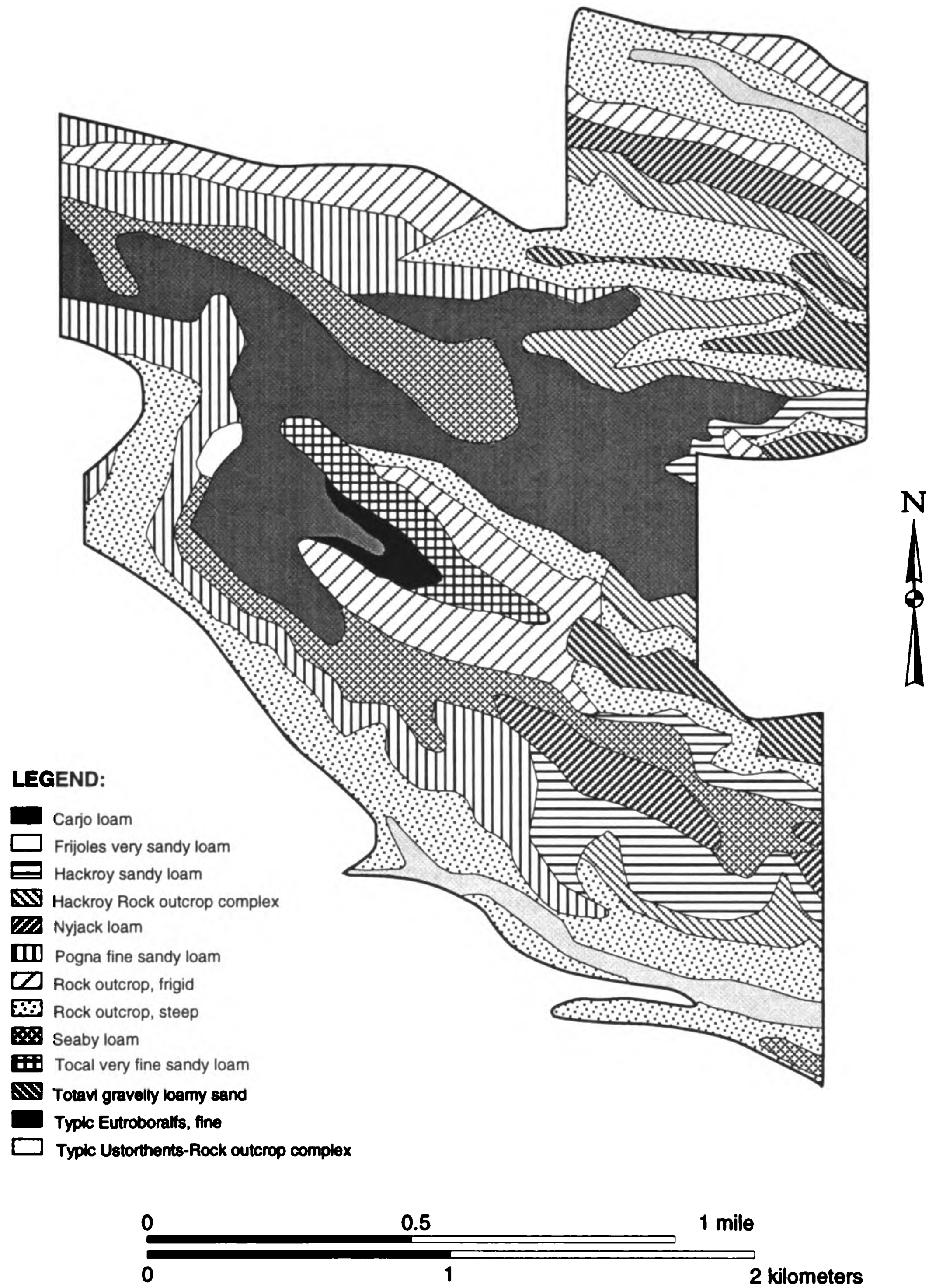


FIGURE 4-10.—*Stratigraphic Column at Threemile Mesa, TA-15.*



Source: Adapted from LANL 1990

FIGURE 4-11.—***Soil Types in TA-15.***

TABLE 4-5.—*Major Faults at LANL*

Name	Approximate Length (mi)	Type[a]	Most Recent Movement	Maximum Earthquake[b] (Mw)
Pajarito	29	Normal, East Side Down	multiple in past 100,000 to 200,000 years	7
Rendija Canyon	6	Normal, West Side Down	8,000 to 9,000 years ago	6.5
Guaje Mountain	8	Normal, West Side Down	4,000 to 6,000 years ago	6.5

[a] Normal Fault: a steep to moderately steep fault for which the movement is downward for the rocks above the fault zone.
[b] Mw denotes the moment magnitude scale (Katsuyuki 1995), which is physically based and calibrated to the Richter local magnitude scale at the lower values.

Source: Wong et al. 1995.

Jemez Mountains and windblown sediment from beyond the Pajarito Plateau are also significant components of many soils on the plateau.

Soils on the mesas can vary widely in thickness and are typically thinnest near the edges of the mesas, where bedrock is often exposed. The walls of the canyons often consist of steep rock outcrops and patches of shallow, undeveloped colluvial soils. South-facing canyon walls are steep and usually have little or no soil material or vegetation. In contrast, the north-facing walls generally have areas of very shallow, dark-colored soils and are more heavily vegetated (LANL 1993a).

Soils at the proposed site on Threemile Mesa have been mapped but not studied in detail (Nyhan et al. 1978). These soils at the proposed site are mapped as the Pogna fine sandy loam, rock outcrop, and sandy loam that formed in material weathered from tuff on gently to strongly sloping mesa tops. Typically, these soils are light brownish grey, fine sandy loam, or sandy loam, over tuff bedrock at 10 to 20 in (25 to 51 cm).

Detailed soil studies at Pajarito Mesa, about a mile north of the DARHT site, can provide general expectations for the origin of both the surface and buried soils at the proposed site. The two localities have similar bedrock, topography, and local climate. Near-surface stratigraphic units on Pajarito Mesa include two general soil-stratigraphic units (pre- and post-60,000 years old) and an older consolidated alluvium (perhaps greater than 1 million years old) (Broxton et al. 1994).

The uppermost soil-stratigraphic unit at Pajarito Mesa includes the El Cajete pumice (about 60,000 years old) and overlying deposits. These deposits comprise the loosest material at Pajarito Mesa and are the deposits most susceptible to collapse. The average thickness of these deposits in mesa-top trenches is about 3 ft (0.9 m), although the deposits are probably thinner away from the mesa top. Pure deposits of El Cajete pumice generally occur as small patches beneath the mesa top. The pumice deposit reaches a maximum of 2.8 ft (0.85 m) thick. Elsewhere, the pumice is mixed into the fine-grained mesa-top soils (Broxton et al. 1994). A patch of El Cajete pumice is visible in an excavation for the DARHT site.

Beneath the El Cajete pumice are older, consolidated soils that have thicknesses ranging from 0.2 to 6.7 ft (0.06 to 2.04 m), with their base typically occurring 4 to 6 ft (1 to 2 m) below the surface. This unit typically has a relatively high clay content and holds vertical walls (Broxton et al. 1994).

On Pajarito Mesa, some deposits of old, consolidated alluvium and associated pumice beds were found. These deposits may exceed 1 million years in age. They are up to 7 ft (2 m) thick, with their base up to 11 ft (3 m) below the surface. This unit is very cohesive and holds vertical walls.

The soil around PHERMEX is contaminated with materials which were part of the experiments exposed to high explosives. DOE has conducted studies, including aerial surveys using helicopters and soil-sampling surveys, that indicate that elevated levels of depleted uranium are found on the firing point (Fresquez 1995). These studies indicate that gamma radiation levels decrease uniformly until only natural background levels are detected at about 460 ft (140 m) from the firing point. Another study (not radiological) indicated that approximately 90 percent of the depleted uranium remains within 490 ft (150 m) of the firing point (McClure 1995). No depleted uranium has been observed in samples obtained outside LANL.

4.3.4 Site Stability

Site stability could be affected by natural and engineered slopes near the hydrodynamic test facilities, erosional retreat of cliffs forming the mesa rims, and shaking from seismic ground motion. Engineering geology studies did not identify any slope stability problems at the DARHT site nor did they report any near-surface materials that would fail to support the buildings during seismic shaking (Korecki 1988). The PHERMEX site has similar near-surface geology, and has not experienced any slope stability problems during its operations since 1963. Geology studies of the stability of rocks near the rim of nearby Pajarito Mesa concluded that placing disposal facilities more than 200 ft (60 m) from the mesa rim would be adequate to ensure the integrity of such facilities for periods exceeding 10,000 yr (Reneau 1994). PHERMEX is, and the DARHT Facility would be, more than 200 ft (60 m) from the mesa edge. Seismic shaking may be an important triggering mechanism for major rock falls.

The three faults listed in table 4-5 control the estimates of seismic hazard at TA-15 because of their lengths, proximity, and evidence of geologically young movement. The maximum earthquakes could cause damage to structures not designed to resist such large earthquakes. It's important to note that the maximum earthquake on any of these faults would be a rare event. The WCFS report infers annual probabilities on the order of 10^{-4}, which corresponds to a return period of 10,000 yr. Even moderate earthquakes on these faults would have return periods of hundreds to thousands of years.

The firing-site facilities are engineered to withstand the blast wave and ground motion from detonating high explosives. However, vibratory ground motion from blasts has been raised as a possible concern for other structures, specifically for standing walls at cultural resources such as the Nake'muu ruin. Vibratory ground motion from detonation of high explosives was measured in conjunction with noise measurements (Vibronics 1995). Peak ground motion (particle velocity) for the energy transmitted through the ground was found to be less than the ground motion caused by the air wave pulse when it arrived. This result is reasonable because the high explosives are placed above ground and their energy does not couple into the ground as efficiently as it would in blasting for construction or mining. These measurements indicate that ground motion from test shots would have less effect on structures than the corresponding air-wave pulse.

4.4 WATER RESOURCES

This section describes the surface and ground water resources at LANL. LANL continuously monitors these resources for primary pollutants and radionuclides. Area III has no streams or surface water bodies, but there are ground water resources; a portion of the main aquifer is present below the site.

4.4.1 Surface Water

The Rio Grande is the major source of surface water in north-central New Mexico. All surface water drainage and ground water discharge from the Pajarito Plateau ultimately arrives at the Rio Grande. The Rio Grande at Otowi, just east of Los Alamos, has a drainage area of 14,300 mi^2 (37,037 km^2) in southern Colorado and northern New Mexico. The flow at Otowi has ranged from a minimum of 60 ft^3/s (1.7 m^3/s) in 1902 to 24,400 ft^3/s (691 m^3/s) in 1920. The river transports about 1 million tons of suspended sediments past Otowi annually (LANL 1993a).

The major canyons that contain reaches of perennial streams inside LANL are Pajarito, Water, Ancho, and Chaquehui Canyons. Los Alamos, Water, and Pajarito Canyons, and perennial streams originate upstream of LANL facilities or effluent discharge points (see figure 4-7) (LANL 1993a).

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 yards long, followed by intermittent flows for varying distances, depending on climate conditions (LANL 1993a).

Springs between 7,900 and 8,900 ft (2,408 and 2,713 m) elevation on the eastern slope of the Jemez Mountains supply base flow throughout the year to the upper reaches of Cañon de Valle, Los Alamos, Pajarito, and Water Canyons. These springs discharge water perched in the Bandelier Tuff and Tschicoma Formation at rates from .0045 to .30 ft^3/s (.0001 to .0085 m^3/s). The volume of flow from the springs is insufficient to maintain surface flow within more than the western third of the canyons before it is depleted by evaporation, transpiration, and infiltration into the underlying alluvium (LANL 1993a).

Eleven drainage areas, with a total area of 82 mi^2 (212 km^2), pass through the eastern boundary of LANL. Runoff from heavy thunderstorms and heavy snowmelt reaches the Rio Grande several times a year from some drainages. Los Alamos, Pajarito, and Water Canyons have drainage areas greater than 10 mi^2 (26 km^2). Pueblo Canyon has 8 mi^2 (21 km^2), and all others have less than 5 mi^2 (13 km^2). Theoretical maximum flood peaks range from 24 ft^3/s (0.7 m^3/s) for a 2-year recurrence to 686 ft^3/s (19 m^3/s) for a 50-year recurrence. The overall flood risk to LANL and TA-15 buildings is low because nearly all the structures are located on the mesa tops, from which runoff drains rapidly into the deep canyons (LANL 1993a).

4.4.2 Ground Water

Ground water in the LANL area occurs in four modes – in shallow alluvium in canyons, perched water, in the unsaturated zone between the surface and the main aquifer, and the main aquifer (LANL 1994a).

Threemile Canyon has a small drainage area that heads on the Pajarito Plateau, and ephemeral streamflow occurs in response to snowmelt runoff and from seasonal storms. The presence of a permanent perched or alluvial water body in this canyon is considered unlikely. Potrillo Canyon heads on the Pajarito Plateau at TA-15. Streamflow in the channel results from snowmelt and runoff from seasonal storms. The stream channel in the upper reaches of the watershed in TA-15 is cut directly into the Bandelier Tuff. There is little to no alluvial fill in this reach; therefore, it is unlikely that a permanent alluvial deposit exists in this canyon. No alluvial aquifers were found in the watershed further downstream where streamflow discharge is greater due to a larger contributing area (LANL 1993b).

Cañon de Valle heads on the flanks of the Sierra de los Valles. Cañon de Valle receives small amounts of recharge from springs in its uppermost reaches, but because of evapotranspiration and infiltration, streamflow from this source does not reach West Jemez Road. Cañon de Valle receives effluent from permitted wastewater discharge in the reaches below West Jemez Road but above TA-15.

Water Canyon is a large canyon that heads on the flanks of Sierra de Los Valles. Several springs discharge from perched aquifers in the tuff in upper Water Canyon. A short distance downstream from the confluence of Water Canyon and Cañon de Valle is Beta Hole, a dry well extending 187 ft (57 m) into the Bandelier Tuff. Two other shallow wells were drilled into the alluvium in Water Canyon, one of which is located at TA-15. These wells are also dry, which confirms that Water Canyon in the vicinity of TA-15 contains no permanent perched or alluvial aquifers. There is a possibility of perched water zones lying above basalt flows that interfinger with sediment beds at intermediate depth.

The main aquifer in the LANL area is the only aquifer in the area capable of serving as a municipal water supply. The surface of the aquifer rises westward from the Rio Grande within the Santa Fe Group, a sequence of basin-filling sediments, passing into the lower part of the Puye Formation beneath the central and western part of the Pajarito Plateau (LANL 1994a). Based on the regional water table contour map presented in figure 4-10, the depth of the main aquifer beneath TA-15 is estimated to vary from about 1,150 to >1,200 ft (350 to >365 m below the mesa tops), with depths increasing to the west and from valley bottoms to mesa tops (figure 4-12). Aquifer hydrologic characteristics vary (LANL 1993b). Recent drilling results suggest that the main aquifer may be as shallow as 650 ft (198 m) (Gardner et al. 1993).

The aquifer beneath TA-15 is located within the layers of rock known as the Chino Mesa basalts, Puye conglomerate, and the Santa Fe Group, as shown in figure 4-13. These units are composed of various rock types – basalts, interflow breccias, conglomerates, sandstones, and siltstones. Not all of these rocks transmit water equally well. Thick basalts, siltstones, and fine-grained sandstones will not yield water as readily as coarse-grained conglomerates, sandstones, highly jointed basalts, and coarse sediments. To maximize production, supply and test wells are completed within a thick section of the aquifer to draw from multiple, highly permeable layers (figures 4-13 and 4-9) (LANL 1993a). The water in the aquifer moves from the main recharge area in the Valles Grande in the Jemez Mountains eastward towards the Rio Grande, where there is some discharge into the river through seeps and springs.

LANL, the nearby communities of Los Alamos and White Rock, and Bandelier National Monument are entirely dependent on ground water for their water supply. The water supply is primarily obtained from well fields. About 4.1 million gal/day (16 million L/day) are used by these communities (DOE 1993a).

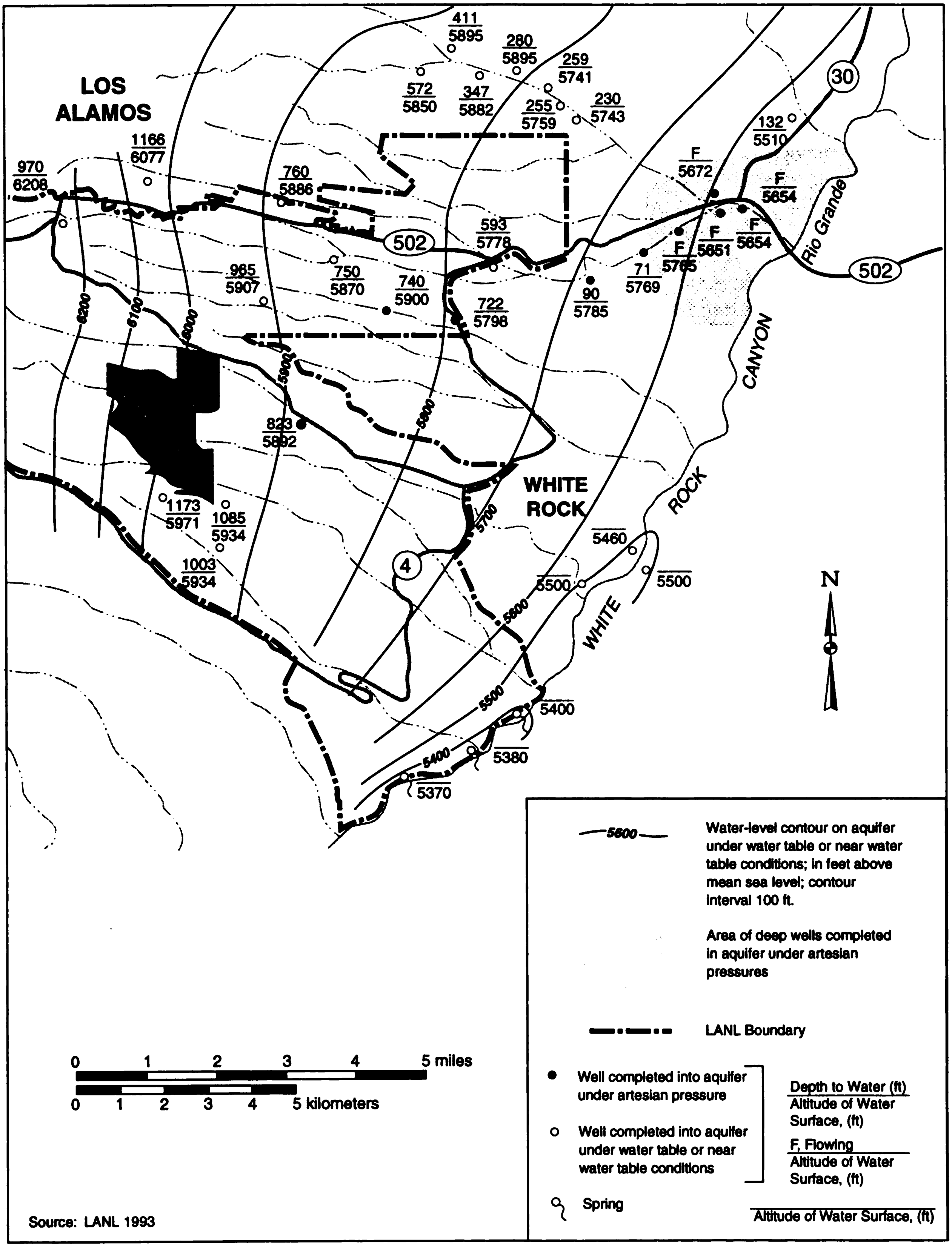


FIGURE 4-12.—*Generalized Contours on Top of the Main Aquifer in the LANL Area.*

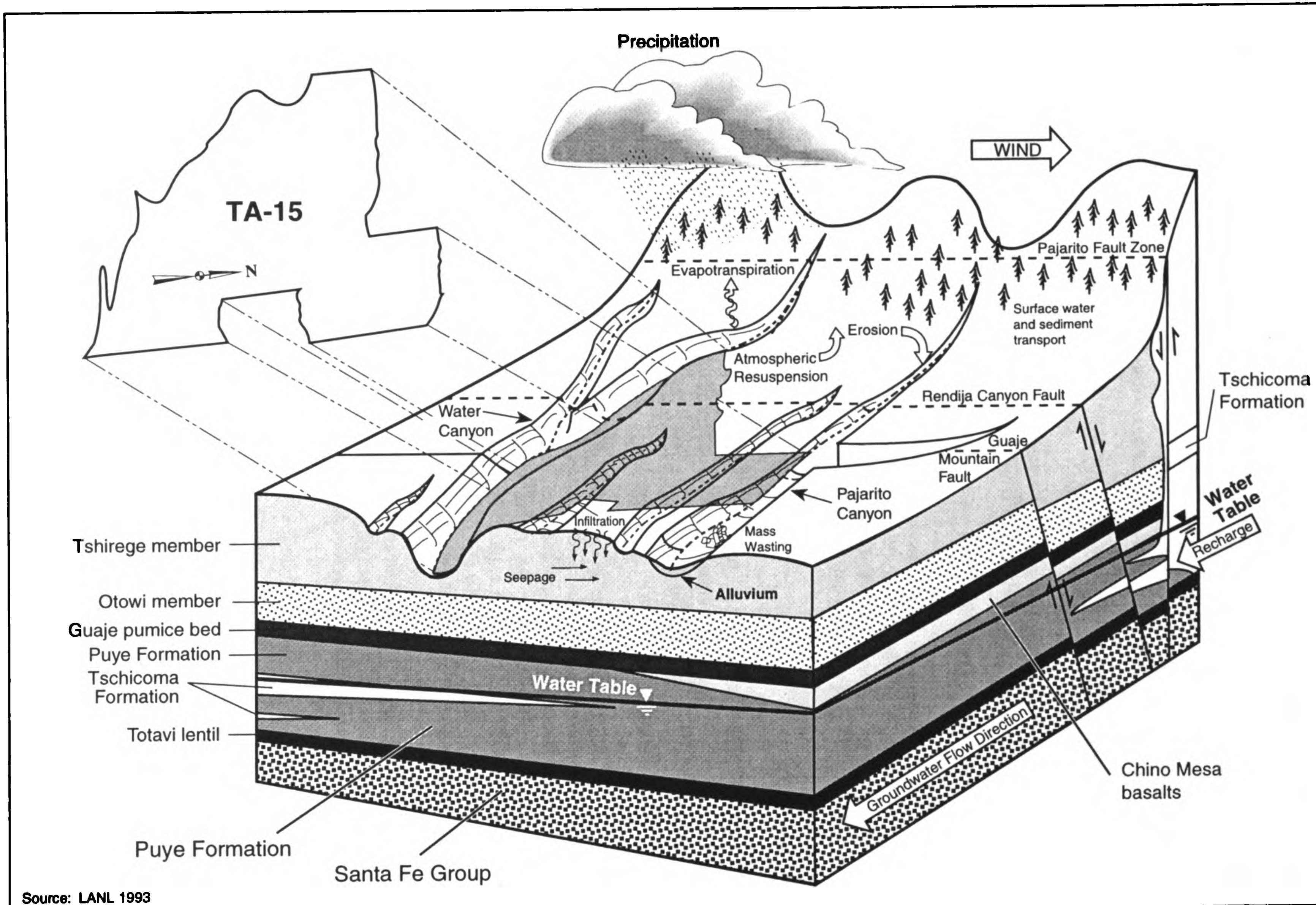


FIGURE 4-13.—*Conceptual Model of TA-15 Showing the General Relationship of Major Geologic and Hydrologic Units on the Pajarito Plateau.*

4.4.3 Water Monitoring

LANL monitors surface waters and ground waters to detect any contaminants from LANL. Measurable concentrations of radionuclides from operations (primarily during the early years) have been transported by surface water offsite to Pueblo and Los Alamos Canyons. Surface water transport almost certainly is the predominant mechanism for redistributing many of the contaminants at the DARHT site. Important contaminant transport mechanisms associated with surface water include:

- Erosion and sedimentation (sediment and contaminant accumulation) of contaminated surface and near-surface materials
- Infiltration of surface water that may be contaminated, or movement of water through a contaminated deposit that in turn carries contamination deeper into the soil/rock profile
- Movement of contaminants in surface water as solutes, suspended sediments, and bedload phases. (LANL 1993a).

Los Alamos, Sandia, and Mortandad Canyons currently receive treated industrial or sanitary effluent. Pueblo Canyon does not receive LANL effluents. Surface waters in these canyons are not a source of municipal, industrial, or agricultural water supply. Only during periods of heavy precipitation or snowmelt would waters from Pueblo, Los Alamos, or Sandia Canyons extend beyond LANL boundaries and reach the Rio Grande.

In Mortandad Canyon, no surface runoff to LANL's boundary has occurred since studies were initiated in 1960. Pueblo Canyon received both untreated and treated industrial effluents from 1944 to 1964. It currently receives treated sanitary effluents from Los Alamos County treatment plants in its upper and middle reaches.

Existing wastewater generation from LANL is approximately 183 million gal/yr (693 million L/yr) (DOE 1993a). Permitted effluent discharges at LANL emerge from 2 sanitary wastewater treatment facilities and 124 industrial outfalls. Some of these outfalls include power plant discharges (1 outfall), boiler blowdown (2 outfalls), treated cooling wastewater (40 outfalls), noncontract cooling wastewater (44 outfalls), radioactive wastewater (1 outfall), high explosive production facilities wastewater (18 outfalls), photographic laboratory rinse wastewater (14 outfalls), asphalt plant wastewater (1 outfall), printed circuit board process wastewater (1 outfall), and sanitary wastewater (2 outfalls) (LANL 1994a).

Surface water sampling station locations near TA-15 are presented in figure 4-14. The radiochemical, trace metals, and chemical quality analyses of samples taken at Pajarito Canyon, Water Canyon, and Ancho Canyon at the Rio Grande are listed in tables 4-6 and 4-7 (LANL 1994a).

The perched alluvial ground water in offsite reaches of Pueblo and Los Alamos Canyons also shows the ongoing influence of both industrial and sanitary effluents.

Ground water sampling station locations and results of analyses are presented in figures 4-15 and 4-16 and tables 4-8 and 4-9. Ground water samples from wells are collected after sufficient water has been pumped or bailed to ensure that the sample is representative of the aquifer (LANL 1994a).

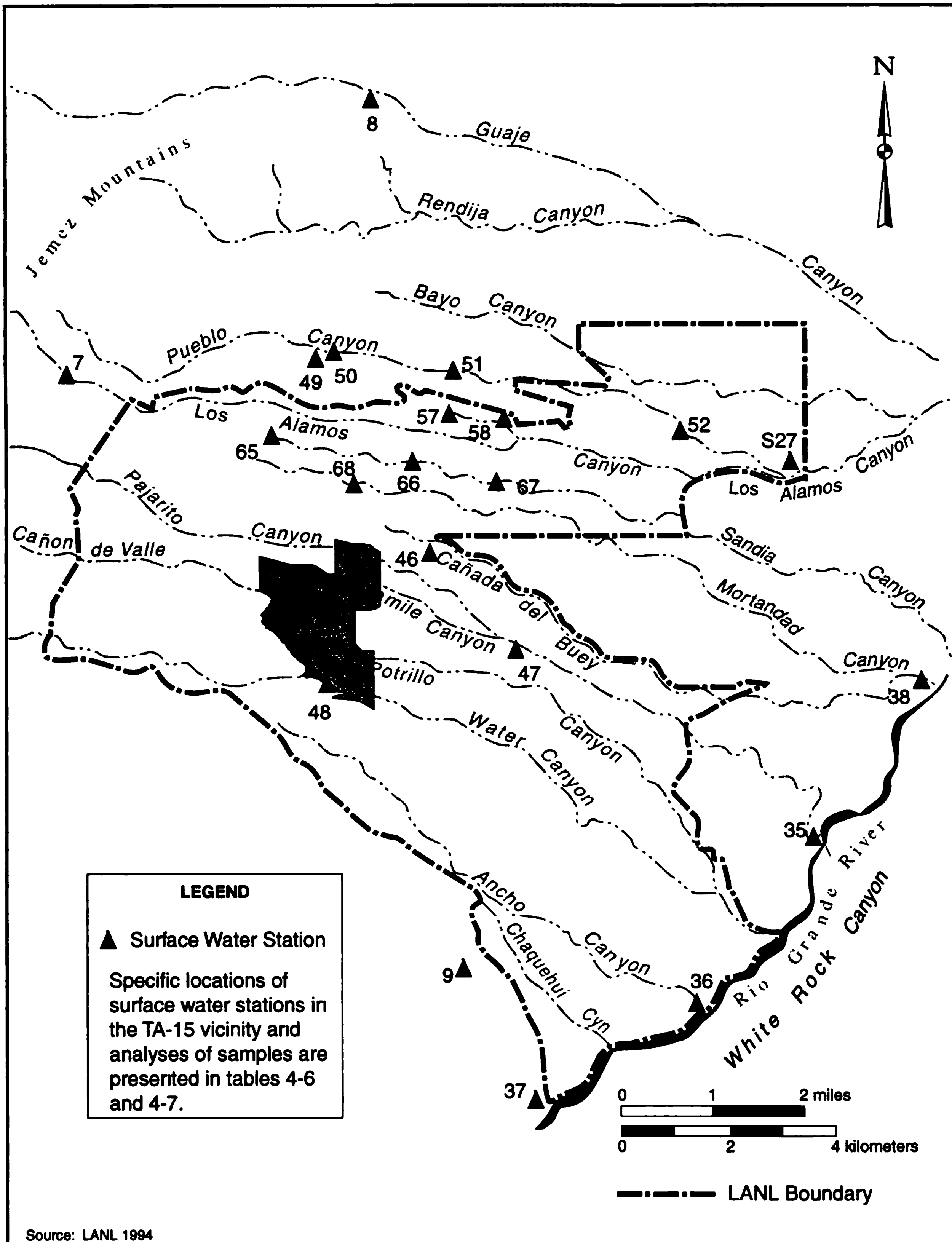


FIGURE 4-14.—*Surface Water Sampling Locations for LANL Onsite and Offsite Perimeter Locations.*

TABLE 4-6.—*Radiochemical Analyses of Surface Waters at LANL*

Location (Map Designation – see figure 4-10.)	Tritium (nCi/L)[a]	Sr-90 (pCi/L)	Cs-137 (pCi/L)	Total Uranium (μg/L)	Pu-238 (pCi/L)	Pu-239,240 (pCi/L)	Am-241 (pCi/L)	Gross Alpha (pCi/L)	Gross Beta (pCi/L)	Gross Gamma (pCi/L)	Gross Gamma (counts/min/L)
Water Quality Criteria	20,000 pCi/L[b]	8 pCi/L[b]	120 pCi/L[c]	—[d]	1.6 pCi/L[c]	1.2 pCi/L[c]	1.2 pCi/L[c]	—[e]	—[e]	—[d]	
Pajarito Canyon (47)[f]	0.4 (0.3)[h]	NA[i]	1.8 (1.2)	< 0.2[j] (0.0)	-0.013 (0.013)[k]	0.018 (0.011)	NA	0 (1)	5 (1)	0 (90)	
Water Canyon at Beta (48)a[g]	0.3 (0.3)	NA	53.60 (67.70)	0.3 (0.0)	-0.004 (0.004)	0.004 (0.004)[g]	NA	NA	NA	NA	10 (80)
Ancho at Rio Grande (36)[f]	0.4 (0.3)	0.0 (1.5)	3.3 (1.3)	0.4 (0.2)	-0.004 (0.004)	0.022 (0.012)	0.032 (0.030)	1 (1)	5 (1)	-30 (90)	

[a] Tritium as tritiated water in moisture distilled from sample.
[b] Maximum Contaminant Level (MCL) National Primary Drinking Water Regulations [40 CFR 141].
[c] U.S. Department of Energy derived concentration guides (DCG) for Drinking water (DOE Order 5400.5).
[d] No specified limit.
[e] Screening limits for Gross Alpha are 5 pCi/L and for Gross Beta are 50 pCi/L.
[f] Results from 1992 sampling.
[g] Results from 1991 sampling (most recent data available) (LANL 1993).
[h] Radioactivity counting uncertainties (± standard deviation) are shown in parentheses.
[i] NA means analysis not performed, lost in analysis, or not completed.
[j] Less than (<) means measurement was below the specified detection limit of the analytical method.
[k] Measurements of radiochemical samples require that analytical or instrumental backgrounds be subtracted to obtain net values. Thus, net values are sometimes obtained that are lower than the minimum detection limit of the analytical technique. Consequently, individual measurements can result in values of positive or negative. Although a negative value does not represent a physical reality, a valid long-term average of many measurements can be obtained only if the very small and negative number values are included in the population calculations.

Source: LANL 1994 and LANL 1993.

TABLE 4-7.—*Surface Water Quality Monitoring at LANL*

Parameter	Units of Measure	Water Quality Criteria	Pajarito Canyon[a] (47)[b]	Water Canyon at Beta[c] (48)	Ancho at Rio Grande[a] (36)
Aluminum	mg/L	NA[d]	0.09	2.5	0.05
Beryllium	mg/L	NA	0.0026	<0.0003[e]	<0.0005
Bicarbonate	mg/L	NA	95	61	55
Calcium	mg/L	NA	25	15	14
Carbonate	mg/L	NA	<5	<2	16
Chlorine	mg/L	250[f]	17	9	3
Copper	mg/L	1[f]	<0.005	<0.002	0.007
Fluorine	mg/L	NA	0.3	<0.2	0.4
Magnesium	mg/L	NA	6.3	5	3.2
Mercury	mg/L	0.002[g]	<0.0001	<0.0002	<0.0001
Nitrate	mg/L	10[g]	0.12	2.7	0.91
pH	pH units[h]	6.5 – 8.5[f]	7.2	6.8	8.9
Phosphorus	mg/L	NA	0.0	0.2	<0.0
Potassium	mg/L	NA	4	4	2
Sodium	mg/L	NA	21	19	12
Sulfate	mg/L	250[f]	4	7	4
Total Dissolved Solids	mg/L	500[f]	196	168	90
Total Hardness	mg/L	NA	88	58	48

[a] Results from 1992 sampling.
[b] Sampling locations shown in figure 4-14
[c] Results from 1991 sampling (most recent data available).
[d] NA means analysis not performed, lost in analysis, or not completed.
[e] Less than symbol (<) means measurement was below the specified detection limit of the analytical method.
[f] Maximum contaminant level (MCL) for secondary constituents, applicable to drinking water system, given here for comparison only [40 CFR141].
[g] MCL for primary constituents, applicable to drinking water systems, National Primary Drinking Water Regulations, given here for comparison only [40 CFR141].
[h] Standard Units.

Source: LANL 1994 and LANL 1993.

In 1991, in an effort to better understand the nature of recharge (replenishment of ground water) to the main aquifer in the Los Alamos area, LANL initiated a study to help define the sources and times of recharge. These studies include a range of geochemical and geochronological techniques to help identify ages and potential sources of water in the main aquifer.

"Age of water" means the time elapsed since the water, as precipitation, entered the ground and became isolated from the atmosphere. The precipitation at the time of entry into the ground is assumed to have

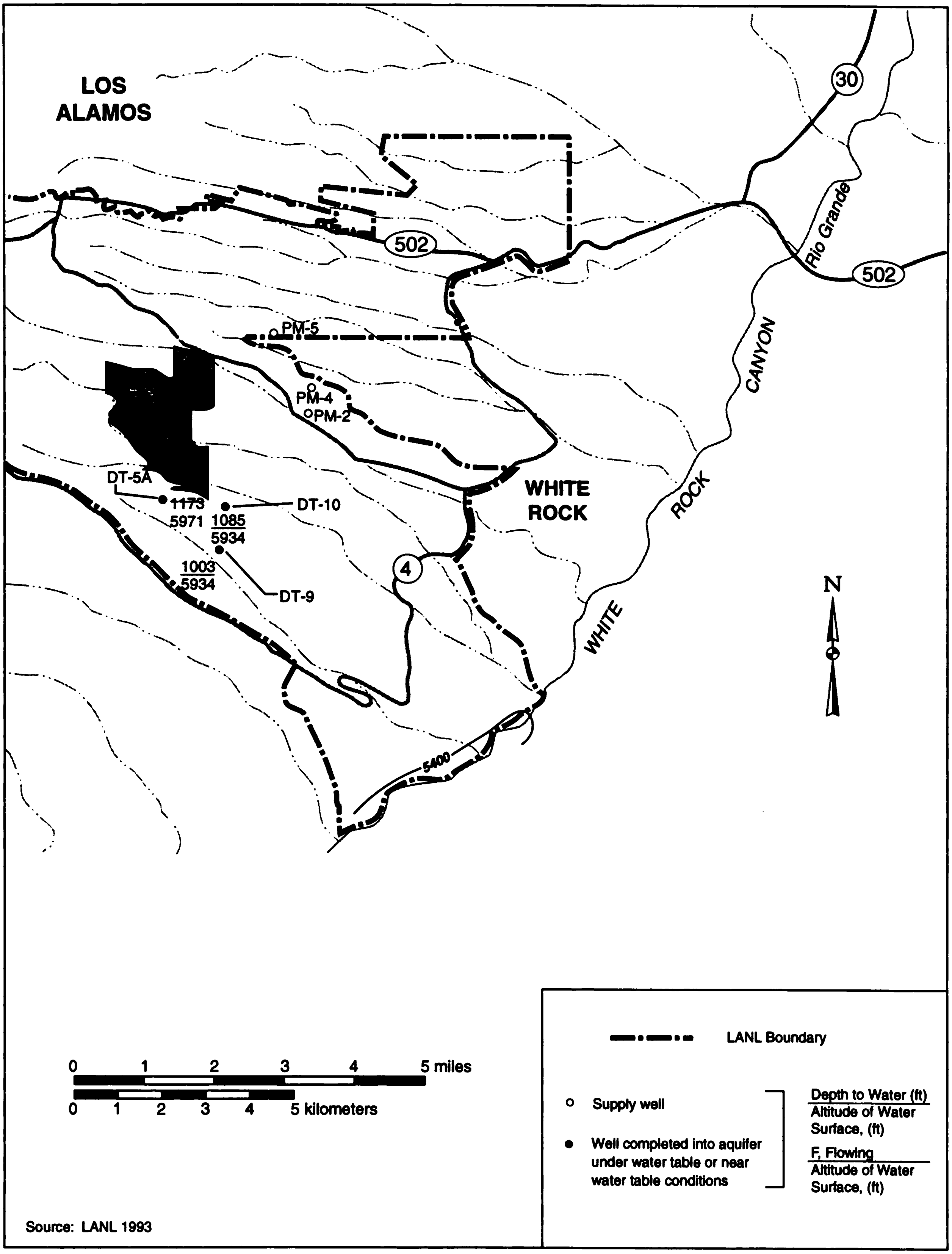


FIGURE 4-15.—*Ground Water Sampling Locations in the Vicinity of TA-15.*

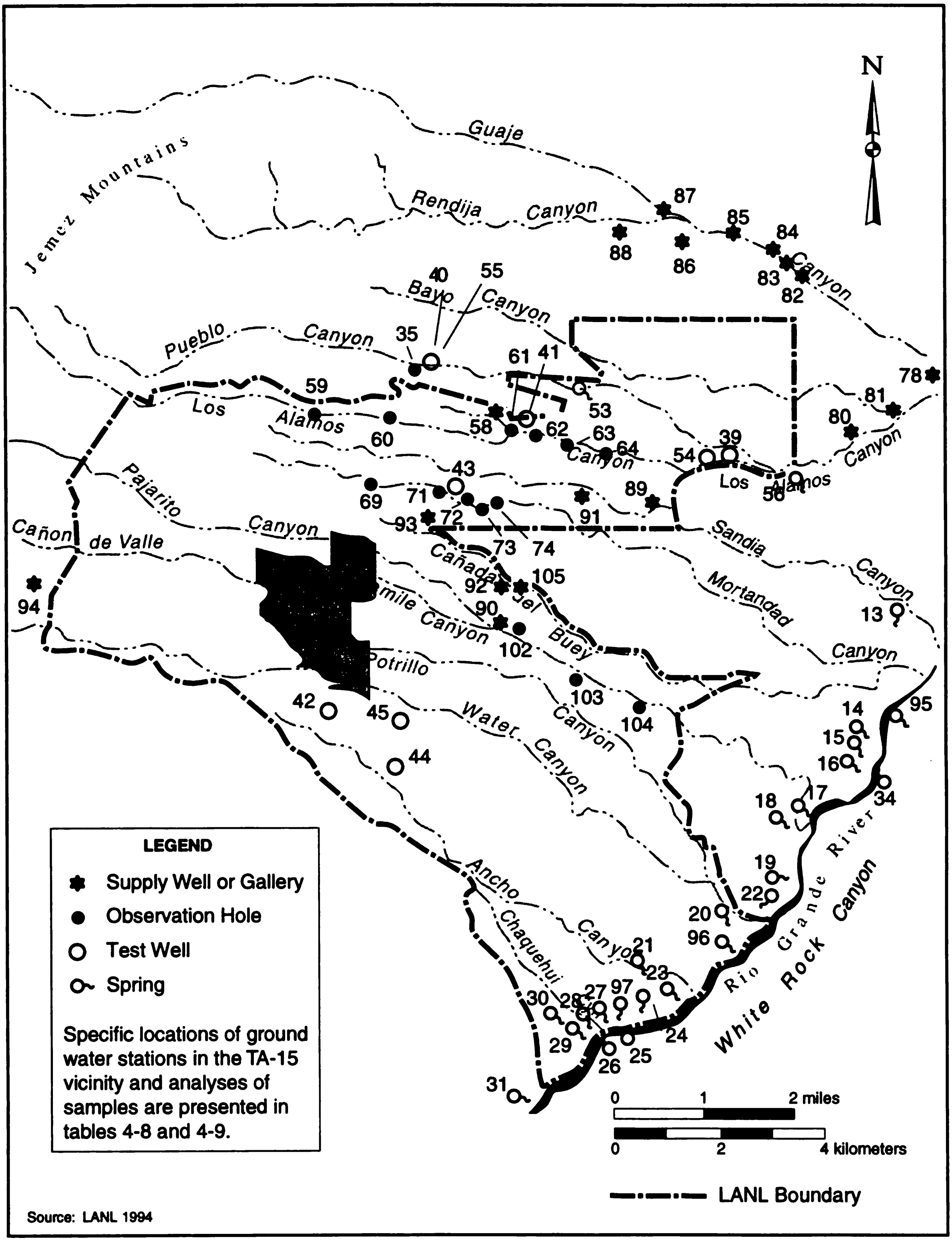


FIGURE 4-16.—*Ground Water Sampling Locations for LANL Onsite and Offsite Perimeter Locations.*

TABLE 4-8.—*Radiochemical Analyses of Ground Water Samples for 1992 at the Main Aquifer On the LANL Site*

Location	Tritium (nCi/L)	Sr-90 (pCi/L)	Cs-137 (pCi/L)	U (µg/L)	Pu-238 (pCi/L)	Pu-239,240 (pCi/L)	Am-241 (pCi/L)	Gross Alpha (pCi/L)	Gross Beta (pCi/L)	Gross Gamma (pCi/L)
Water Quality Criteria	20,000 pCi/L[a]	8 pCi/L[a]	120 pCi/L[b]	—[c]	1.6 pCi/L[b]	1.2 pCi/L[b]	1.2 pCi/L[b]	15 pCi/L[d]	—[d]	—[c]
Main Aquifer Onsite Test Wells										
Test Well DT-5A	0.3 (0.3)[e]	NA[f]	1.6 (1.1)	0.2 (0.1)	-0.005[g] (0.030)	-0.005 (0.020)	NA	1 (0)	2 (0)	40 (100)
Test Well DT-9	0.2 (0.3)	NA	1.3 (1.2)	< 1.0[h] (0.0)	-0.004 (0.030)	0.017 (0.020)	0.008 (0.030)	1 (1)	9 (1)	160 (100)
Test Well DT-10	0.1 (0.3)	NA	1.5 (1.1)	< 1.0 (0.0)	0.005 (0.030)	0.005 (0.020)	0.013 (0.030)	1 (1)	3 (0)	170 (100)
Water Supply Wells										
Well PM-2	0.2 (0.3)	NA	0.6 (1.0)	<0.6 (0.0)	0.008 (0.010)	0.008 (0.010)	0.020 (0.010)	0 (1)	2 (0)	50 (90)
Well PM-4	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Well PM-5	0.2 (0.3)	NA	0.3 (1.0)	<0.6 (0.0)	0.010 (0.012)	0.060 (0.019)	0.028 (0.015)	0 (1)	3 (1)	10 (90)

[a] Maximum Contaminant Level (MCL) National Primary Drinking Water Regulations [40 CFR 141].
[b] U.S. Department of Energy derived concentration guides (DCG) for drinking water (DOE Order 5400.5).
[c] No specified limit.
[d] Screening limits for Gross Alpha are 5 pCi/L and for Gross Beta are 50 pCi/L.
[e] Radioactivity counting uncertainties (±1 Standard Deviation) are shown in parentheses.
[f] NA means analysis not performed, lost in analysis, or not completed.
[g] Measurements of radiochemical samples require that analytical or instrumental beckgrounds be subtracted to obtain net values. Thus, net values are sometimes obtained that are lower than the minimum detection limit of the analytical technique. Consequently, individual measurements can result in values of positive or negative. Although a negative value does not represent a physical reality, a valid long-term average of many measurements can be obtained only if the very small and negative numbers values are included in the population calculations.
[h] Less than symbol (<) means measurement was below the specified detection limit of the analytical method.

Source: LANL 1994.

TABLE 4-9—*Water Quality Criteria and Ground Water Monitoring Results at LANL*[a]

Parameter	Units of Measure	Water Quality Criteria	Test Well DT-5A[b]	Test Well DT-9[b]	Test Well DT-10[b]	Supply Well PM-2[b]	Supply Well PM-5[b]
Aluminum	mg/L	NA[c]	<0.02[d]	0.26	0.16	<0.03	<0.03
Beryllium	mg/L	NA	<0.0020	0.0020	0.0016	<0.0020	0.0020
Bicarbonate	mg/L	NA	51	51	66	47	74
Calcium	mg/L	NA	9	20	10	10	13
Carbonate	mg/L	NA	<5	<5	<5	<5	<5
Chlorine	mg/L	250[e]	2	3	3	2	3
Copper	mg/L	1[e]	<0.003	0.800	<0.100	<0.003	<0.003
Fluorine	mg/L	NA	0.4	0.6	0.5	0.2	0.3
Magnesium	mg/L	NA	2.3	5.4	3.0	2.9	4.7
Mercury	mg/L	0.002[f]	<0.0001	<0.0002	<0.0002	<0.0001	<0.0001
Nitrate	mg/L	10[f]	0.33	0.28	0.19	0.34	0.30
pH	pH units[g]	6.5 – 8.5[e]	7.6	7.9	8.2	7.9	7.5
Phosphorus	mg/L	NA	NA	NA	NA	0.0	0.1
Potassium	mg/L	NA	2	2	1	2	2
Sodium	mg/L	NA	11	22	9	11	14
Sulfate	mg/L	250[e]	3	3	3	3	3
Total Dissolved Solids	mg/L	500[e]	128	114	92	144	170
Total Hardness	mg/L	NA	31	72	37	36	51

[a] Results from 1992 sampling.
[b] These well locations are shown on figure 4-15.
[c] NA means analysis not performed, lost in analysis, or not completed.
[d] Less than symbol (<) means measurement was below the specified detection limit of the analytical method.
[e] Maximum contaminant level (MCL) for secondary constituents, applicable to drinking water system, given here for comparison only [40 CFR141].
[f] MCL for primary constituents, applicable to drinking water systems, National Primary Drinking Water Regulations, given here for comparison only [40 CFR141].
[g] Standard Units.

Source: LANL 1994.

contained atmospheric equilibrium amounts of both tritium and carbon-14. Therefore, the amount of tritium and carbon-14 in the aquifer would be an indicator of the water's age. Radioactive carbon-14 is mainly from natural sources, while tritium comes from both natural sources and fallout from atmospheric nuclear weapons testing. For comparative purposes, the studies included a series of isotope (tritium) and age-dating (carbon-14) measurements on ground water samples.

LANL has also collected samples from the test wells and the water supply production wells that penetrate the main aquifer and tested them with a variety of radioactive and stable isotope measurements. At present, a number of measurements of carbon-14 and low-level tritium are available that permit some preliminary estimates of the age of the water in the main aquifer at various locations (Gallaher 1995).

Before atmospheric nuclear testing, the tritium levels in atmospheric water were about 20 pCi/L, or about 6 tritium units (TU). By the mid 1960s, tritium in atmospheric water in northern New Mexico reached a peak level of about 6,400 pCi/L (2,000 TU) (annual average for 1963 to 1964). Since then, both radioactive decay and dilution by mixing through the global hydrologic cycle have reduced the concentrations of tritium in atmospheric water. At present, general atmospheric levels in northern New Mexico are about 30 pCi/L (10 TU). As a basis for comparison, the present EPA and New Mexico state drinking water standard is 20,000 pCi/L (6,200 TU). Routine compliance with the drinking water regulations is done by liquid scintillation counting with a detection limit of about 300 to 7,000 pCi/L (100 to 2,200 TU) (Gallaher 1995). See table 4-10 for the results of the most recent analyses from samples taken at wells near TA-15 (Gallaher 1995).

Run off from the PHERMEX firing site is potentially contaminated with depleted uranium and other materials released during explosive testing. Four separate watersheds, each with an established stream channel drainage network, are present within TA-15. These watersheds are Threemile Canyon, Potrillo Canyon, Water Canyon, and Cañon de Valle. A fifth watershed, Pajarito Canyon, receives runoff from a small, undeveloped area within TA-15. This watershed is not expected to receive any contaminants from activities at TA-15. All surface water transport of contaminants at TA-15 ultimately will flow into one of the other four canyons mentioned previously (LANL 1993a).

The presence of either perched or alluvial aquifers in Threemile, Potrillo, Cañon de Valle, or Water Canyons has not been confirmed; however, the geology and hydrology of these canyons are clearly consistent with the existence of perched and alluvial aquifers (LANL 1993a). These four perched or alluvial aquifers are within the influence of TA-15 operations.

There are no wells in TA-15; therefore, all inferences on the main aquifer beneath this technical site have been drawn from information derived from supply wells and deep test wells near TA-15 (table 4-11 and figure 4-15) (LANL 1993a). Data in the table are measures of the amount of water and its ability to move through the rocks.

4.5 BIOTIC RESOURCES

The LANL area contains a diversity of plant communities (figure 4-17) due in part to the dramatic 5,000 ft (1,500 m) elevational gradient from the Rio Grande on the east, to the Jemez Mountains 12 mi (20 km) on the west, and to the many canyons with abrupt surface slope changes that dissect the area (figure 4-7 shows the location of many of these features). Biological surveys of LANL have been carried

TABLE 4-10—*Summary of Carbon-14 and Tritium-Based Age Estimates for Wells Near TA-15*

Well Locations	Carbon-14 (% modern)	Carbon-14 Age Estimates		Tritium (pCi/L)[c]	Tritium Age Estimates	
		Minimum[a]	Maximum[b]		Piston Flow[d]	Well Mixed[e]
Los Alamos Supply Wells (Main Aquifer)						
PM-1	18.5	5,620	14,000	1.65	>45	>3,000
PM-2	62.7	50	3,860	1.59	>45	>3,000
PM-3	23.9	4,950	11,800	0.45	>70	>9,000
PM-3 @ 987 ft	28.2	6,770	10,500	0.42	>70	>9,000
PM-3 @ 1,226 ft	24.5	7,700	11,600	0.26	>70	>10,000
PM-3 @ 1,650 ft	22.9	7,910	12,200	0.03	>100	>10,000
PM-3 @ 2,000 ft	23.9	6,390	11,800	0.10	>100	>10,000
PM-5	53.7	1,040	5,140	0.29	>70	>10,000
Los Alamos Test Wells (Main Aquifer)						
DT-5A	57.6	1,810	4,560	0.23	>80	>10,000
DT-9	69.1	163	3,060	0.45	>70	>9,000
DT-10	82.0	<0[f]	1,640	1.33	~55	>4,500

[a] Assumes dilution by "dead" carbon from dissolution of carbonates, estimated by ratios of carbon isotopes
[b] Assumes radioactive decay only, no dilution by dissolution of carbonates.
[c] 3.24 pCi/L = 1 Tritium Unit (TU); one tritium atom in 10^{18} hydrogen atoms.
[d] Piston Flow model assumes no mixing or dilution with other water.
[e] Well Mixed model assumes complete mixing in reservoir, inflow = outflow, no other inputs.
[f] Applying dilution factor (footnote[a]) results in meaningless minimum age.
[g] "Contaminated" indicates sample contains recent contamination from the surface because concentration of tritium or carbon-14 greater than that could be attributed to any atmospheric precipitation.

Source: Gallaher 1995.

out at various times – most recently in 1992 – to identify the plant and animal species of the area. These studies were summarized by Dunham (1995) and Risberg (1995). Plant and animal species found in these surveys are listed in appendix E. This section describes the terrestrial resources, wetlands, and aquatic resources, and addresses threatened and endangered species at LANL and the DARHT site.

4.5.1 Terrestrial Resources

Ecological diversity in terrestrial landscapes is typified by plant communities (assemblages of similar plant forms, each of which is dominated by one or two major species). Six major vegetative community types

TABLE 4-11.—*Hydrological Characteristics of Supply and Test Wells Near TA-15*

Well	Saturated Thickness (ft)	Specific Capacity (gpm/ft)	Transmissivity (gpd/ft)	Field Coefficient of Permeability (gpd/ft^2)
PM-2	1,426	23.1	40,000	28
PM-4	1,828	36.8	44,000	24
DT-5A	643	5.7	11,000	17
DT-9	498	22	61,000	122
DT-10	324	16	36,100	111

Well locations shown on figure 4-14.

Source: LANL 1993.

are found in Los Alamos County. Three of them – juniper-grassland, piñon-juniper, and ponderosa pine – are predominant, each occupying about one-third of LANL (figure 4-17). The other three are mixed-conifer, spruce-fir, and subalpine grassland (Risberg 1995).

The juniper-grassland community is found along the Rio Grande on the eastern border of the Pajarito plateau and extends upward on the south-facing sides of the canyons at 5,600 to 6,200 ft (1,700 to 1,900 m). Principal species in this community include one-seeded juniper (*Juniperus monosperma*), skunk bush sumac (*Rhus trilobata*), and sagebrush (*Artemisia spp*).

The piñon-juniper community, generally found in the 6,200 to 6,900 ft (1,900 to 2,100 m) elevation range, includes large portions of the mesa tops and north-facing slopes at the lower elevations. This woodland consists of stands of piñon pine (*Pinus edulis*) and one-seeded juniper, both dominant, and includes grasses such as blue grama (*Bouteloua gracilis*) and galleta (*Hilaria jamesii*) (Travis 1992).

The ponderosa pine community is found in the western portion of the plateau and on mesa tops in the 6,900 to 7,500 ft (2,100 to 2,300 m) elevation range. This community is characterized by ponderosa pine (*Pinus ponderosa*) as the primary overstory vegetation. It also contains Douglas fir (*Pseudotsuga menziesii*), Gambel oak (*Quercus gambelii*), mountain muhly (*Muhlenbergia montana*), and little bluestem grass (*Andropogon scoparius*) (Travis 1992).

The mixed conifer, at 7,500 to 9,500 ft (2,300 to 2,900 m), interfaces with the ponderosa pine in the deeper canyons and north slopes and extends to the west from the higher mesas on the slopes of the Jemez Mountains. The major species found here include quaking aspen (*Populus tremuloides*), Engelmann spruce (*Picea engelmannii*), Douglas fir, limber pine (*Pinus flexilis*), and white fir (*Abies concolor*). This community also has an understory of bearberry (*Arctostaphylos uvaursi*), creeping barberry (*Berberis repens*), and various grasses and forbs (Travis 1992).

The subalpine grassland is mixed with the spruce fir community at elevations of 9,500 to 10,500 ft (2,900 to 3,200 m). The pronounced east-west canyon and mesa orientation, with accompanying differences in soils, moisture, and solar radiation, produces an interlocking finger effect, resulting in transitional overlaps of plant and animal communities within small areas (DOE 1979). Species within this community include blue spruce (*Picea pungens*), Engelmann spruce, and mountain muhly.

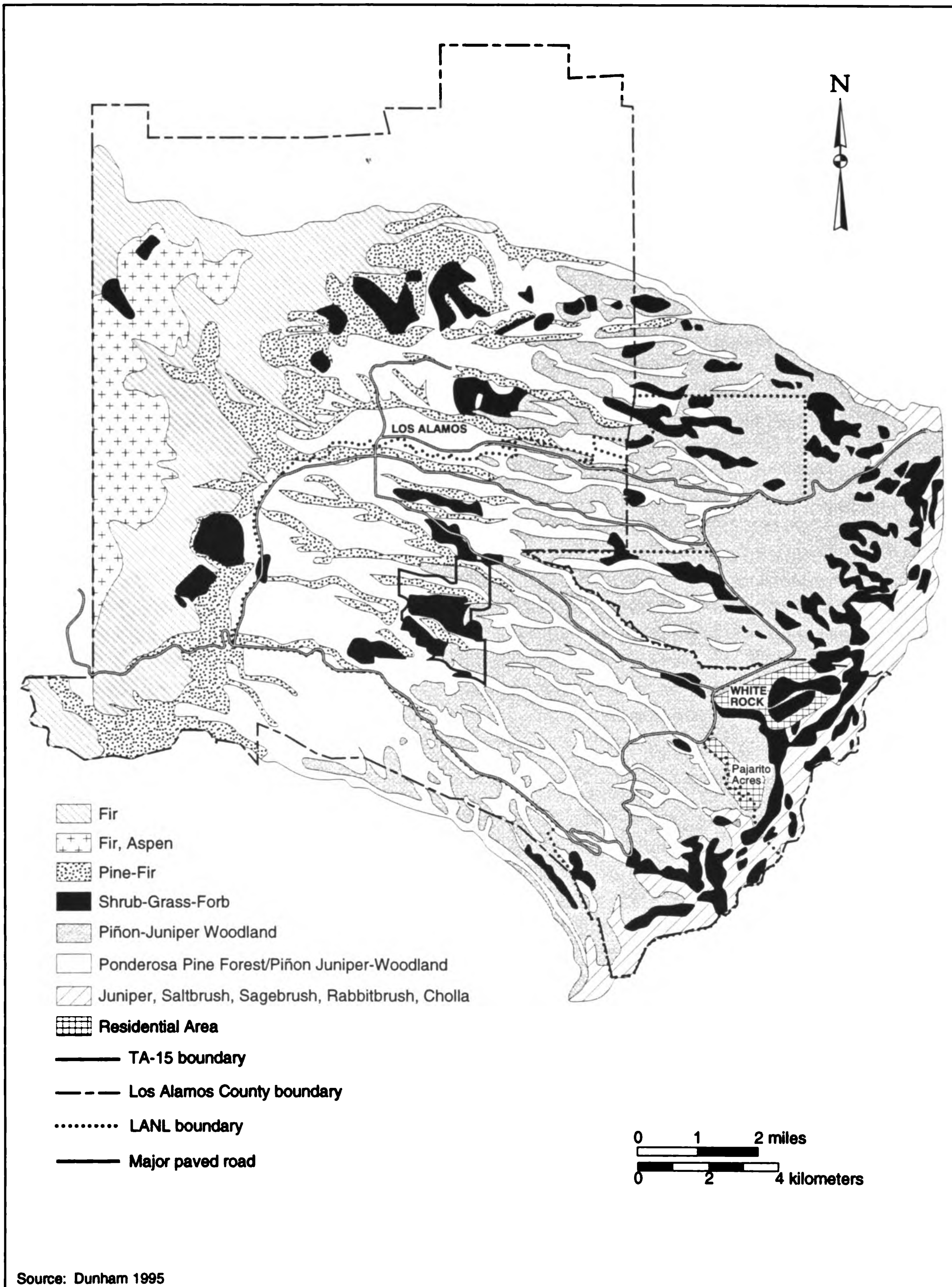


FIGURE 4-17.—*Plant Communities on the Pajarito Plateau.*

The top of Threemile Mesa is characterized by piñon-juniper and ponderosa pine communities. The dominant overstory species are ponderosa pine, one-seed juniper, and piñon pine. Oak species (*Quercus spp.*) dominate the shrub layer. The dominant understory species are blue grama, mountain muhly, galleta, and big bluestem (*Andropogon gerardii*) grasses. A mixed-conifer forest of Douglas fir and mountain muhly covers the north-facing slopes. The south-facing slopes support a ponderosa pine forest and piñon-juniper woodland with ponderosa pine and wavyleaf oak (*Quercus undulata*). Douglas fir and open ponderosa pine forests make up the canyon bottom.

Undeveloped areas within LANL provide habitat for a diversity of terrestrial wildlife. Species lists have been compiled from observational data and published data, but the occurrence of some species has not been verified (Risberg 1995). Invertebrates at LANL include a number of ant species collected in 1986 as well as many other invertebrates (Risberg 1995). Among vertebrates, the collared lizard (*Crotaphytus collaris*), eastern fence lizard (*Sceloporus undulatus*), and whiptail lizard (*Cnemidophorus spp.*) are some of the reptiles found at LANL. Typically, these are found at elevations between 6,265 and 7,000 ft (1,910 and 2,134 m). Bird species which nest in the area include the great-horned owl (*Bubo virginianus*) and red-tailed hawk (*Buteo jamaicensis*) among the raptors, and Say's phoebe (*Sayornis saya*), lesser goldfinch (*Carpodacus psaltria*), and American robin (*Turdus migratorius*) among other types. Overwintering species include the scrub jay (*Aphelocoma coerulescens*), common raven (*Corvus corax*), and house finch (*Carpodacus mexicanus*) (Travis 1992).

Some of the larger mammals at LANL are the American black bear (*Ursus americanus*), coyote (*Canis latrans*), and raccoon (*Procyon lotor*) while the smaller species include the Mexican woodrat (*Neotoma mexicana*), deer mouse (*Peromyscus maniculatus*), Abert's squirrel (*Sciurus aberti*), and cottontail rabbit (*Sylvilagus nuttalli*) (Risberg 1995). The most important and prevalent big game species at LANL are the Rocky Mountain mule deer (*Odocoileus hemionus*) and Rocky Mountain elk (*Cervus canadensis*). LANL lands have traditionally been a transitional area for wintering elk and deer. More recently, these two species have been using LANL property on a year-round basis.

Throughout LANL's history, developments within various technical areas have caused significant alterations in the terrain and the general landscape of the Pajarito Plateau. These alterations have resulted in significant changes in land use by most groups of wildlife species, particularly birds and larger mammals that have large seasonal and/or daily ranges. Certain projects required the segregation of large areas, such as mesa tops, and in some cases, project areas were secured by virtually impenetrable fences around their perimeters. These have undoubtedly caused some species of wildlife, such as elk and deer, to alter their land use patterns by cutting off seasonal and/or daily travel corridors to wintering areas, breeding habitat, foraging habitat, and bedding areas, as well as other necessary habitats.

In 1980, elk were primarily using the southwestern portion of LANL (White 1981). In addition, critical calving areas and important high-use areas were identified, all of which were primarily in the west and southwest part of LANL. Since 1980, the number of elk using LANL lands has increased significantly. Studies of elk conducted from 1991 to 1993 (Risberg 1995) reveal increased use of habitats north and northeast of previously documented high-use areas (White 1981). There have also been recent concerns about increases in motor vehicle accidents involving elk and deer in the LANL area (Kirk 1995). In general, however, little is known of habitat use patterns, population trends, and characteristics of elk on the Pajarito Plateau.

4.5.2 Wetlands

Wetlands have characteristics of both aquatic and terrestrial systems and include riparian (streambank) and floodplain ecosystems. Riparian areas are characterized by an abundance of deciduous and moisture-loving species. Riparian zones are generally associated with floodplains, and in the Southwest these zones have a higher diversity of plants providing cover, food, and breeding areas for a wider diversity of animals than the surrounding arid areas.

A 1992 LANL field study at TA-15 determined that no wetlands exist in the immediate area where the DARHT site is located (Dunham 1995). However, natural wetland areas, both floodplain and riparian, occur in some canyons of TA-15, and more extensive wetlands have developed as a result of effluent outfalls from LANL facilities (LANL 1993a). Floodplains are located at the bottom of Potrillo, Water, Threemile, and Pajarito Canyons, and Cañon de Valle (Dunham 1995). Narrow riparian areas line the intermittent stream channels in the canyon bottoms, and the perennial channel in Pajarito Canyon. These riparian zones consist of arroyos with water flowing intermittently during the spring runoff and summer monsoon season (usually July into August). The U.S. Fish and Wildlife Service (USFWS) has mapped the floodplain areas of LANL (figure 4-18).

The canyon riparian zones manifest a mixed-conifer tree canopy dominated by ponderosa pine. The understory layer is a mixed-deciduous woodland, dominated by boxelder (*Acer negundo*). The shrub layer consists of various oak (*Quercus*) species along with mountain mahogany (*Cercocarpus montanus*) and Apache plume (*Fallugia paradoxa*). The herbaceous layer is dominated by redtop (*Agrostis spp.*), accompanying other grasses, notably bluegrass (*Poa spp.*), bromegrass (*Bromus spp.*), and blue grama. This layer also contains a number of forbs, particularly meadowrue bedstraw (*Thalictrum fendleri*) (Dunham 1995).

4.5.3 Aquatic Resources

Aquatic habitats at LANL are limited to the Rio Grande and several springs and intermittent streams in the canyons. These habitats currently receive National Pollutant Discharge Elimination Systems (NPDES)-permitted wastewater discharges. The springs and streams at LANL do not support fish; however, many other aquatic species thrive in these waters (DOE 1993a; Cross 1994; Bennett 1994).

4.5.4 Threatened and Endangered Species

Surveys conducted at TA-15 in 1992 (Risberg 1995) did not locate any currently listed threatened or endangered species (table 4-12), although suitable habitat may exist for many of these. Twelve species which may occur on the DARHT site are listed as threatened or endangered by either the USFWS or the New Mexico Departments of Game and Fish, and Energy, Minerals and Natural Resources. Eight more are considered candidates for inclusion on the Federal endangered or threatened list or are considered rare by the state of New Mexico (table 4-12).

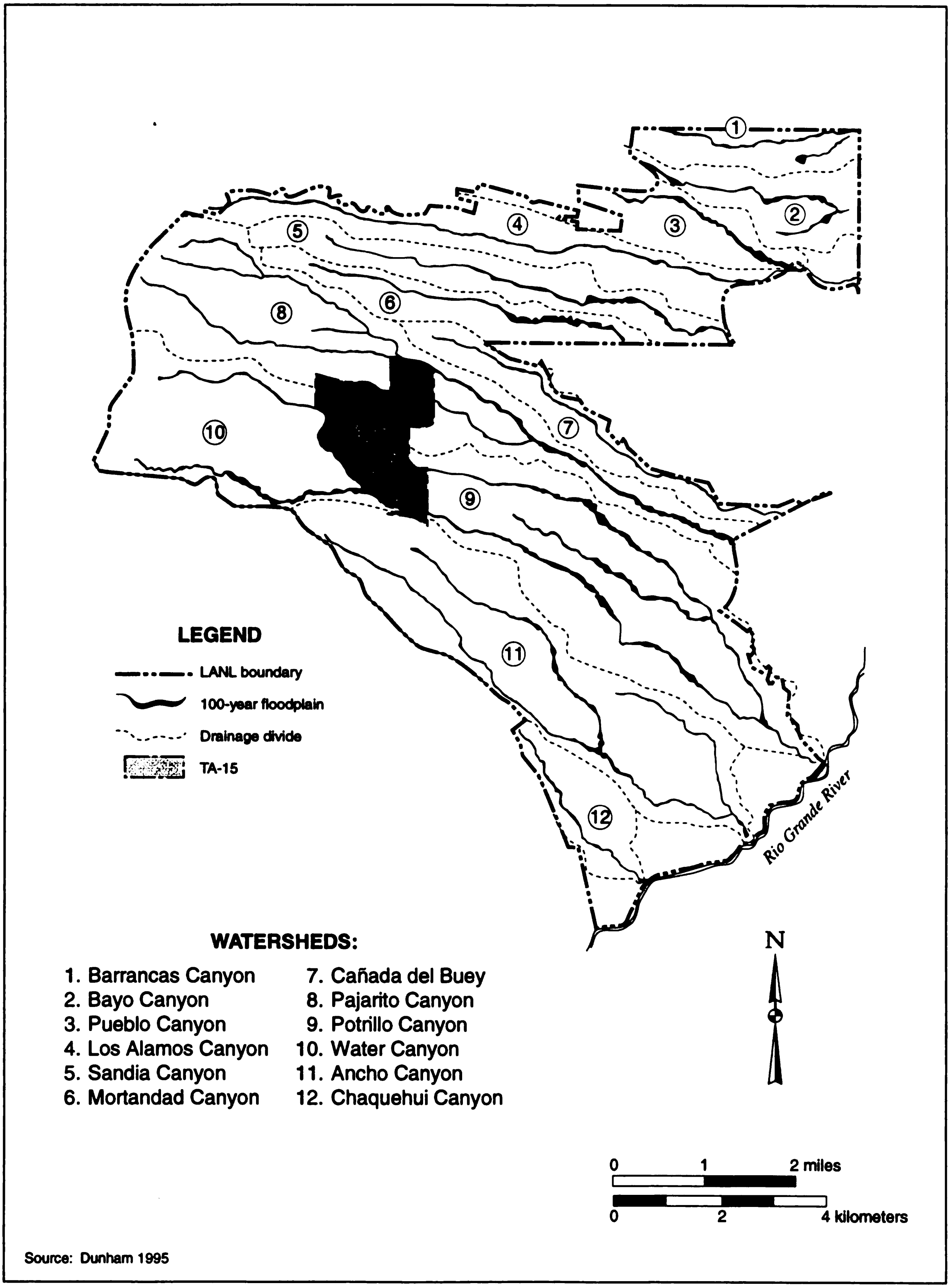


FIGURE 4-18.—*Floodplain map of LANL.*

TABLE 4-12.—*Threatened and Endangered Species Potentially Present at Area III, TA-15*

Scientific Name	Common Name	Status	Habitat	Potential for Occurrence
PLANTS				
Fritillaria atropurpurea	Checker lily[c]	SE	Mixed conifer	Moderate
Lilium philadelphicum	Wood lily[c]	SE	Ponderosa to mixed conifer, cliffs 6,000 to 10,000 ft (1,829 to 3,048 m)	Moderate
Mammillaria wrightii	Wright's fishook cactus[c]	SE	Desert grassland to piñon-juniper 3,000 to 7,000 ft (914 to 2,134 m)	Low
Opuntia viridiflora	Santa Fe cholla[c]	SE	Piñon-juniper 7,200 to 8,000 ft (2,195 to 2,438 m)	Low
Pediocactus papyracanthus	Grama grass cactus[a,c]	FC	Grasslands, piñon-juniper woodlands 5,000–7,300 ft (1,524–2,225 m)	Moderate
ANIMALS				
Plethodon neomexicanus	Jemez Mountain salamander[a]	FC, SE	Densely wooded, shady canyons	None
Accipiter gentilis	Northern goshawk[a,b,c]	FC	Ponderosa; dense, mature, or old-growth coniferous forest	Low
Buteo regalis	Ferruginous hawk[a]	FC	Grasslands	Low
Buteogallus anthracinus	Common black hawk[c]	SE	Riparian with cottonwood	None
Cynanthus latirostris	Broad-billed hummingbird[b,c]	SE	Riparian woodlands	None
Falco peregrinus	Peregrine falcon[a,b,c]	FE, SE	Ponderosa-piñon, streams and lakes	Low
Haliaeetus leucocephalus	Bald eagle[a,b,c]	FE, SE	Riparian near streams and lakes	Low
Ictinia mississippiensis	Mississippi kite[c]	SE	Riparian and shelterbelts	None
Lanius ludovicianus	Loggerhead shrike[a]	FC	Grasslands, open woodland	Low

TABLE 4-12.—*Threatened and Endangered Species Potentially Present at Area III, TA-15 – Continued*

Scientific Name	Common Name	Status	Habitat	Potential for Occurrence
ANIMALS (continued)				
Plegadis chihi	White-faced ibis[a]	FC	Streams, marshes, ponds	None
Strix occidentalis lucida	Mexican spotted owl[a,b,c]	FT, SE	Mixed conifer; mountains and canyons, uneven-aged, multi-storied forest with closed canopy	Low
Euderma maculatum	Spotted bat[a,b,c]	FC, SE	Ponderosa, piñon-juniper, cliffs and rock crevices	Low
Myotis lucifugus occultus	Occult little brown bat[a]	FC	Mountains, caves, and hollow trees	Low
Ochotona princeps nigrescens	Goat peak pika[a]	FC	Lava boulders	None
Zapus hudsonius luteus	New Mexican jumping mouse[a]	FC	Near streams and vegetation	Low

[a] From U.S. Department of Interior Fish and Wildlife Service letter, January 23, 1995 (USFWS 1995).
[b] From Biological and Floodplain/Wetland Assessment for the DARHT, 1995 (Risberg 1995).
[c] From Biological and Floodplain/Wetland Assessment for OU 1086, TA-15, 1995 (Dunham 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 thoughout all or a significant portion of its range." (Endangered Species Act of 1973).

POTENTIAL FOR OCCURRENCE:
None: 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.

4.6 CULTURAL AND PALEONTOLOGICAL RESOURCES

This section provides a summary evaluation of the prehistoric and historic cultural resources within a 2,500 ft (760 m) radius of shrapnel of the DARHT site. The published data on cultural and paleontological resources were presented relative to the DARHT site, rather than the site as defined in the introduction. Figure 4-19 shows the DARHT site and the remaining areas to be surveyed. There are other archeological sites within the PHERMEX hazard radius of 4,000 ft (1,250 m) of that facility, but none have standing walls other than those at Nake'muu. These archeological sites are shown in figure 4-20.

Prehistoric cultural resources refer to any material remains of items used or modified by people prior to the establishment of a European presence in the upper Rio Grande valley in the early 17th century (Spanish Colonial and Territorial Periods as shown on table 4-13). Historic cultural resources include all material remains and any other physical alterations of the landscape since the arrival of Europeans in the region. An overview of the prehistory and history of the LANL area is summarized in table 4-13 (Larson 1995).

Types of prehistoric sites identified in the vicinity of LANL include large multi-room pueblos, pithouse villages, field houses, talus houses, cave kivas, shrines, towers, rockshelters, animal traps, hunting blinds, water control features, agricultural fields and terraces, quarries, rock art, trails, campsites, windbreaks, rock rings, and limited activity sites. Approximately 75 percent of LANL has been inventoried for cultural resources. Coverage for some inventories has been less than 100 percent; however, about 60 percent of LANL has received 100 percent coverage. Over 975 prehistoric sites have been recorded; about 95 percent of these sites are considered eligible or potentially eligible for the National Register for Historic Places (NRHP) (DOE 1993a).

4.6.1 Prehistoric Archeological Resources

Two field surveys were conducted and a third is planned to determine the presence of archeological and historical cultural resources in the area of potential affects for the DARHT site. Each is described below. The first survey was constructed between June 1987 and November 1988 in the DARHT construction area and involved examination of 24.7 acres (10 ha). Three archeological sites were recorded in the construction area. Laboratory of Anthropology (LA) 71408, LA 71409 and LA 71410 (tables 4-14 and 4-15). The New Mexico State Historic Preservation Officer (NM SHPO) concurred that these sites were eligible for the National Register of Historic Places (NRHP) based solely on their research potential (Criterion D) in correspondence with the DOE dated February 21, 1989) (SHPO 1989). An additional archeological site was also discussed in this report, LA 12655, also known as "Nake'muu," and will be discussed below.

The second survey was conducted in the summer of 1992 as part of a larger survey conducted for the LANL Environmental Restoration (ER) Program site characterizations of TA -15, -16 and -49. The larger ER survey included areas within the 2,500 ft (760 m) hazard radius around the DARHT firing point. A total of 35 archeological sites have been located as a result of these two surveys. Thirty-two of these are eligible for nomination to the NRHP under criterion D (research potential) and one archeological site (Nake'muu) is also eligible under criterion C (excellent state of preservation) (tables 4-13 and 4-14). The remaining resources were recommended as not eligible for nomination to the NRHP because their research potential has been exhausted through data retrieval. Evaluations of potential effect for individual cultural

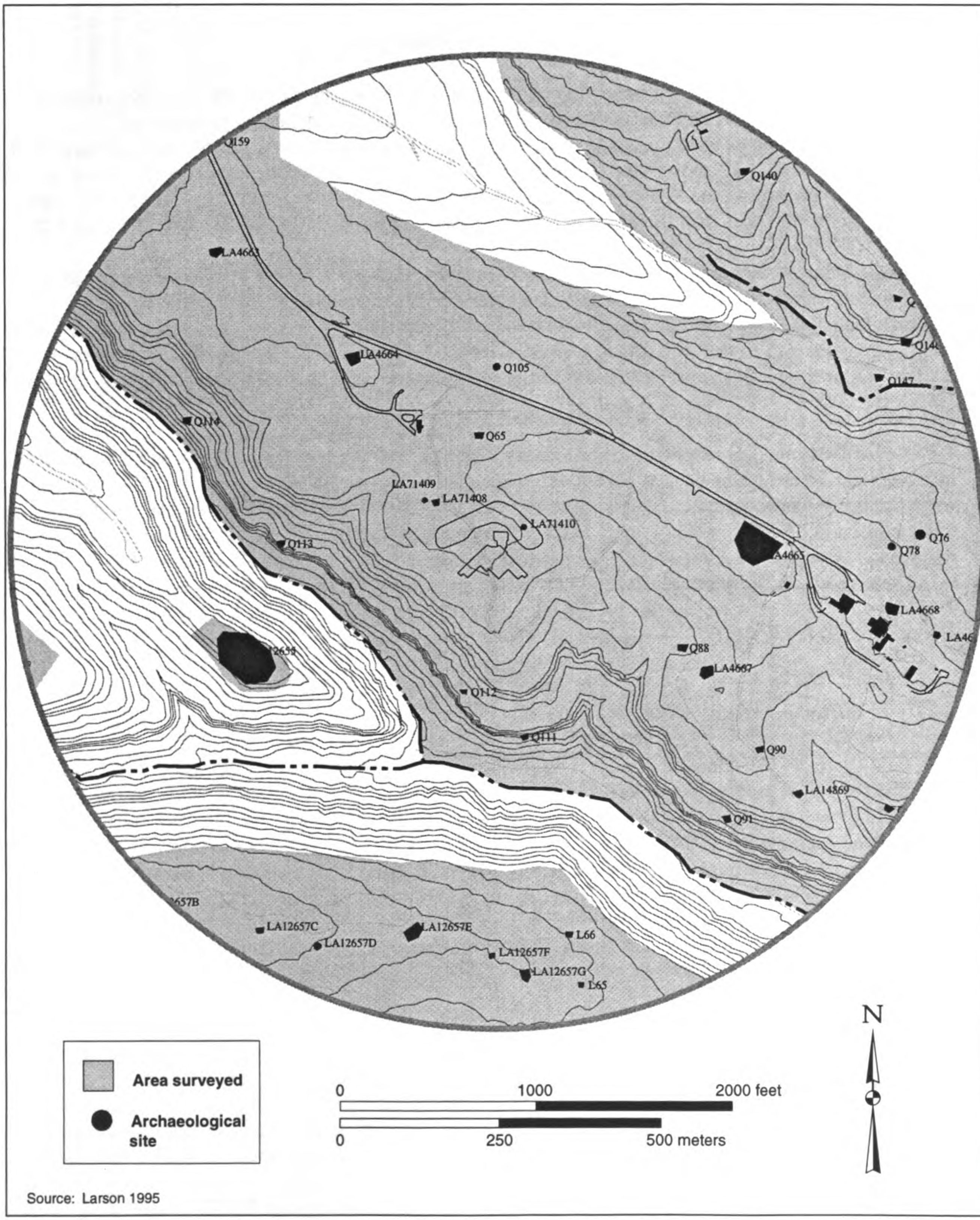


FIGURE 4-19.—*Archeological Sites Located within a 2500-ft (760-m) Radius of the DARHT Site.*

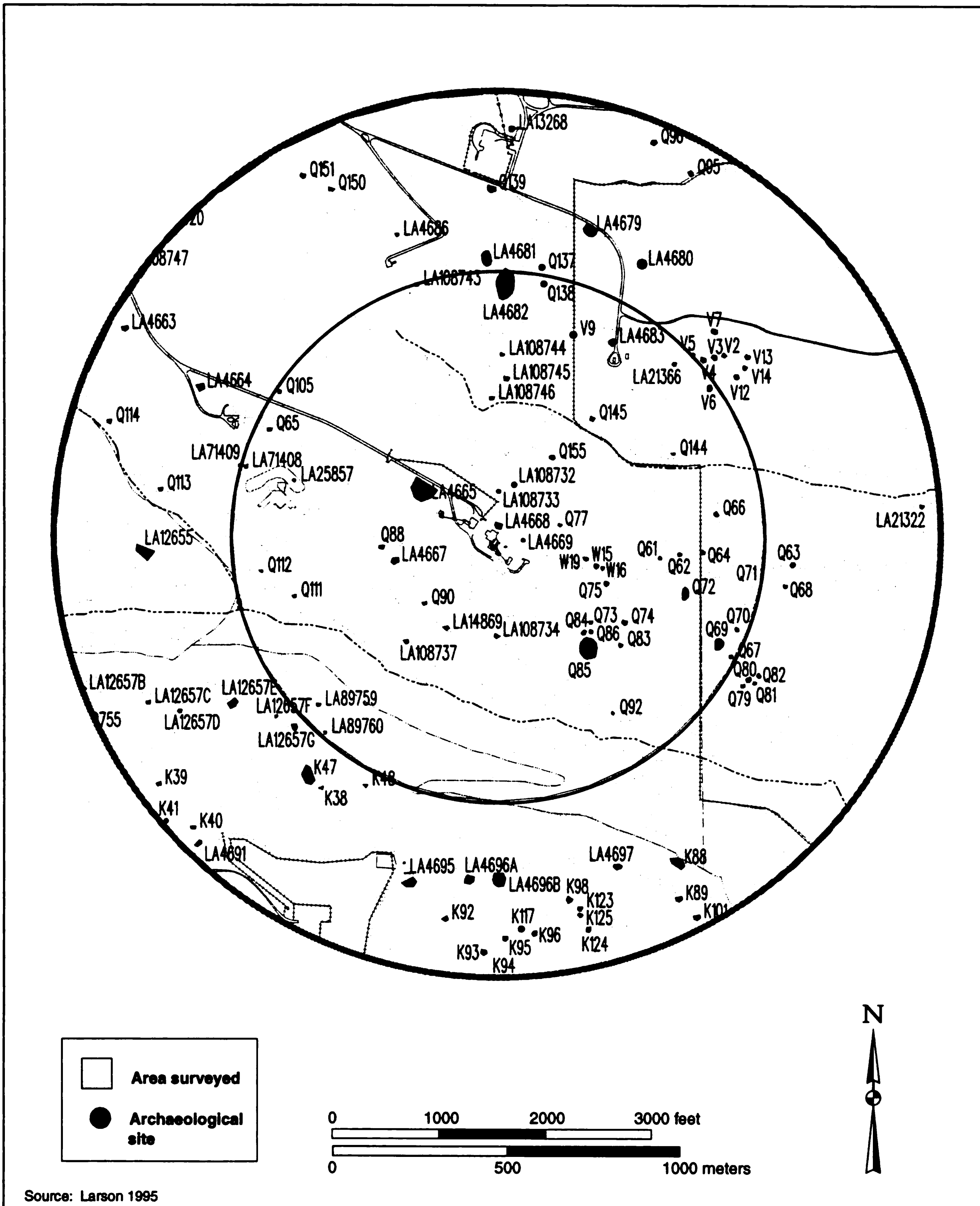


FIGURE 4-20.—*Archeological Sites Located Within a 4,000-ft (1,250-m) Radius of the PHERMEX Facility.*

TABLE 4-13.—*Summary of Cultural Periods for the Central Pajarito Plateau*

	Cultural Period	Years	Characteristics
Prehistoric	Paleo-Indian Period	10,000 B.C. to 4,000 B.C.	Small groups of big game hunters who may have followed game herds along the Rio Grande, with trips onto the Pajarito Plateau to procure obsidian and other resources. This period is represented at LANL by occasional surface finds of diagnostic projectile points made from both local obsidian and exotic unidentified chert.
	Archaic Period	4,000 B.C. to A.D. 600	Small groups who may have used the Pajarito Plateau for hunting and for seasonal uses of certain wild plants. This period is represented at LANL as scatters of lithic tools, chipping debris, and diagnostic projectile points. Little research has been conducted for this period; it is possible that buriod habitation sites are also present at LANL.
	Early Developmental Period	A.D. 600 to 900	Settled hunter-gatherers living in semi-subterranean pithouses and making simple pottery. Some possible pithouse locations and associated artifacts have been identified at LANL, but identification is tenuous.
	Late Developmental Period	A.D. 900 to 1100	Small groups of maize horticulturalists who also relied to a great extent on gathering wild plants. Sites are typically small adobe, sometimes crude masonry, pueblo structures. Very few sites from this period are at LANL; most of those recorded are located close to the Rio Grande in the vicinity of Chaquehui Mesa and Lower Water Canyon.
	Coalition Period	A.D. 1100 to 1325	Maize horticulturalists. Early sites are adobe and masonry rectangular structures, and later sites are large masonry enclosed plaza roomblocks of over 100 rooms. Most of the ruins, recorded at LANL can be attributed to this time period; 700 ruins have been recorded. Some researchers attribute the increase in site density to migration while others see the increase in site numbers as a result of local population growth.
	Classic Period	A.D. 1325 to 1600	Intensive maize horticulturists. Settlements on the Pajarito Plateau aggregated into three population clusters with outlying one- to two-room fieldhouses. The central site cluster consists of four temporally overlapping sites: Navawi, Otowi, Tsankawi, and Tsirege. Otowi and Tsirege are at LANL. These ruins are ancestral to the Tewa speakers now living at San Ildefonso Pueblo.
Historic	Spanish Colonial and Territorial Periods	A.D. 1600 to 1900	Grazing and seasonal use of the Plateau during this time by non-Indian groups is highly probable but has not been thoroughly documented.
	Homesteading Period	A.D. 1890 to 1943	This was an outgrowth of the earlier undocumented use of the plateau for cattle grazing, timbering, and farming activities. Hispanic and Anglo homestead era sites are characterized by wooden cabin and corral structures, rock or cement cisterns, and scattering of debris associated with household and farming/grazing activities. In 1918 the Los Alamos Ranch School, a school for boys, was founded in present day Los Alamos.
	Post 1943	A.D. 1943 to Present	In the 1940s during the early stages of the Manhattan Project, many of the Los Alamos Ranch School buildings were appropriated for use by the U.S. Government. The central portion of the Pajarito Plateau is now owned by either the Federal government, Los Alamos County, San Ildefonso Pueblo, or by private citizens.

TABLE 4-14.—*Archeology Sites within a 2,500-ft (750-m) Radius of the DARHT Firing Site*

Site Number[a]	Site Type	Tech Area	General Location	National Register Eligibility
Q 65	Artifact scatter	15	Mesita del Potrillo	Eligible – Criterion D
Q 76	One- to three-room structure	15	Mesita del Potrillo	Eligible – Criterion D
Q 78	Single roomblock pueblo	15	Mesita del Potrillo	Eligible – Criterion D
Q 87	Rock shelter	15	Water Canyon	Eligible – Criterion D
Q 88	Water control structure	15	Mesita del Potrillo	Not eligible
Q 90	Artifact scatter	15	Mesita del Potrillo	Eligible – Criterion D
Q 91	Cavate	15	Water Canyon	Not eligible
Q 105	One- to three-room structure	15	Mesita del Potrillo	Eligible – Criterion D
Q 111	Cavate	15	Water Canyon	Eligible – Criterion D
Q 112	Rock art	15	Water Canyon	Eligible – Criterion D
Q 113	Rock shelter	15	Water Canyon	Eligible – Criterion D
Q 114	Cavate	15	Water Canyon	Eligible – Criterion D
Q 140	Single roomblock pueblo	15	Mesita del Potrillo	Eligible – Criterion D
Q 142	Single roomblock pueblo	15	Mesita del Potrillo	Eligible – Criterion D
Q 146	Recent structure (Laboratory era)	15	Potrillo Canyon	Eligible – Criterion D
Q 147	Historic structure	15	Potrillo Canyon	Eligible – Criterion D
Q 159	One- to three-room structure	15	Mesita del Potrillo	Eligible – Criterion D
LA 4663	Single roomblock pueblo	15	Threemile Mesa	Eligible – Criterion D
LA 4664	Single roomblock pueblo	15	Threemile Mesa	Eligible – Criterion D
LA 4665	Enclosed plaza pueblo	15	Threemile Mesa	Eligible – Criterion D
LA 4667	One- to three-room structure	15	Mesita del Potrillo	Eligible – Criterion D
LA 4668	One- to three-room structure	15	Threemile Mesa	Not eligible (excavated)
LA 4669	One- to three-room structure	15	Threemile Mesa	Eligible – Criterion D
LA 12657C	One- to three-room structure	49	Frijoles Mesa	Eligible – Criterion D
LA 12657D	One- to three-room structure	49	Frijoles Mesa	Eligible – Criterion D
LA 12657E	Single roomblock pueblo	49	Frijoles Mesa	Eligible – Criterion D
LA 12657F	One- to three-room structure	49	Frijoles Mesa	Eligible – Criterion D
LA 12657G	One- to three-room structure	49	Frijoles Mesa	Eligible – Criterion D
LA 14869	Rock ring	15	Threemile Mesa	Eligible – Criterion D & potentially elig. Crit. A
LA 89759	One- to three-room structure	49	Frijoles Mesa	Eligible – Criterion D
LA 89760	One- to three-room structure	49	Frijoles Mesa	Eligible – Criterion D
LA 71408	Single roomblock pueblo	15	Mesita del Potrillo	Eligible – Criterion D, SHPO concurrence
LA 71409	Single roomblock pueblo	15	Mesita del Potrillo	Eligible – Criterion D, SHPO concurrence
LA 71410	One- to three-room structure	15	Mesita del Potrillo	Eligible – Criterion D, SHPO concurrence
LA 12655	Nake'muu – enclosed plaza pueblo	15	Mesita del Potrillo	Eligible – Criteria C & D, SHPO concurrence

[a] LA - New Mexico Laboratory of Anthropology number; Q - LANL Field Number.

Source: Larson 1995.

TABLE 4-15.—*Archeology Sites within a 2,500-ft (750-m) and 4,000-ft (1,250-m) Radius of the PHERMEX Firing Site*

Site Number[a]	Site Type	Tech Area	General Location	National Register Eligibility
2,500-ft Radius				
Q 77	One- to three-room structure	15	Mesita del Potrillo	Eligible – Criterion D
LA 4665	Enclosed plaza pueblo	15	Threemile Mesa	Eligible – Criterion D
LA 4668	One- to three-room structure	15	Threemile Mesa	Not eligible (excavated)
LA 4669	One- to three-room structure	15	Threemile Mesa	Eligible – Criterion D
LA 108732	One- to three-room structure	15	Mesita del Potrillo	Eligible – Criterion D
LA 108733	Single roomblock pueblo	15	Mesita del Potrillo	Eligible – Criterion D
Q 61	Single roomblock pueblo	15	Mesita del Potrillo	Eligible – Criterion D
Q 73	Single roomblock pueblo	15	Mesita del Potrillo	Eligible – Criterion D
Q 74	Single roomblock pueblo	15	Mesita del Potrillo	Eligible – Criterion D
Q 75	Single roomblock pueblo	15	Mesita del Potrillo	Eligible – Criterion D
Q 83	Artifact scatter	15	Mesita del Potrillo	Eligible – Criterion D
Q 84	Single roomblock pueblo	15	Mesita del Potrillo	Eligible – Criterion D
Q 85	Artifact scatter	15	Mesita del Potrillo	Eligible – Criterion D
Q 86	Single roomblock pueblo	15	Mesita del Potrillo	Eligible – Criterion D
Q 145	Rock shelter	36	Potrillo Canyon	Eligible – Criterion D
Q 155	One- to three-room structure	15	Mesita del Potrillo	Eligible – Criterion D
W 15	Single roomblock pueblo	15	Mesita del Potrillo	Eligible – Criterion D
W 16	One- to three-room structure	15	Mesita del Potrillo	Eligible – Criterion D
W 19	Single roomblock pueblo	15	Mesita del Potrillo	Eligible – Criterion D
LA 4667	One- to three-room structure	15	Mesita del Potrillo	Eligible – Criterion D
LA 14869	Rock ring	15	Threemile Mesa	Eligible – Criterion D & potentially elig. Crit. A
LA 108734	Rock shelter	15	Water Canyon	Eligible – Criterion D
LA 108735	Water control feature	15	Potrillo Canyon	Not eligible
LA 108736	Artifact scatter	15	Potrillo Canyon	Eligible – Criterion D
LA 108737	Cavate	15	Mesita del Potrillo	Not eligible
LA 108745	Historic structure	15	Mesita del Potrillo	Eligible – Criterion D
LA 108746	Historic rockpile and artifact scatter	15	Mesita del Potrillo	Eligible – Criterion D
Q 62	Artifact scatter	15	Mesita del Potrillo	Eligible – Criterion D
Q 64	One- to three-room structure	36	Mesita del Potrillo	Eligible – Criterion D
Q 66	One- to three-room structure	36	Mesita del Potrillo	Eligible – Criterion D
Q 67	One- to three-room structure	36	Mesita del Potrillo	Eligible – Criterion D
Q 69	Single roomblock pueblo	36	Mesita del Potrillo	Eligible – Criterion D
Q 70	Single roomblock pueblo	36	Mesita del Potrillo	Eligible – Criterion D
Q 72	Single roomblock pueblo	15	Mesita del Potrillo	Eligible – Criterion D
Q 92	Cavate	15	Water Canyon	Eligible – Criterion D
Q 138	Water control feature	15	Mesita del Potrillo	Not Eligible
Q 144	Rock Art	36	Potrillo Canyon	Eligible – Criterion D
V 6	One- to three-room structure	36	Mesita del Potrillo	Eligible – Criterion D
V 9	Single roomblock pueblo	36	Mesita del Potrillo	Eligible – Criterion D
LA 4682	Enclosed plaza pueblo	15	Mesita del Potrillo	Eligible – Criterion D
LA 4683	One- to three-room structure	36	Mesita del Potrillo	Eligible – Criterion D
LA 21366	Single roomblock pueblo	36	Mesita del Potrillo	Eligible – Criterion D

TABLE 4-15.—*Archeology Sites within a 2,500-ft (750-m) and 4,000-ft (1,250-m) Radius of the PHERMEX Firing Site – Continued*

Site Number[a]	Site Type	Tech Area	General Location	National Register Eligibility
LA 71408	Single roomblock pueblo	15	Water Mesa	Eligible – Criterion
LA 71410	One- to three-room structure	15	Water Mesa	D,SHPO Concurrence
LA 89759	One- to three-room structure	49	Frijoles Mesa	Eligible – Criterion
LA 89760	One- to three-room structure	49	Frijoles Mesa	D,SHPO Concurrence
LA 108731	Artifact scatter	15	Mesita del Potrillo	Eligible – Criterion D
LA 108738	One- to three-room structure	15	Mesita del Potrillo	Eligible – Criterion D
LA 108739	Cavate	15	Water Canyon	Eligible – Criterion D
LA 108740	Rock Art	15	Water Canyon	Eligible – Criterion D
LA 108743	Single roomblock pueblo	15	Mesita del Potrillo	Eligible – Criterion D
LA 108744	Single roomblock pueblo	15	Mesita del Potrillo	Eligible – Criterion D
4,000-ft Radius				
Q 63	Artifact scatter	36	Mesita del Potrillo	Eligible – Criterion D
Q 68	Single roomblock pueblo	36	Mesita del Potrillo	Eligible – Criterion D
Q 71	Single roomblock pueblo	36	Mesita del Potrillo	Eligible – Criterion D
Q 79	Single roomblock pueblo	36	Mesita del Potrillo	Eligible – Criterion D
Q 80	Water control feature	36	Mesita del Potrillo	Eligible – Criterion D
Q 81	One- to three-room structure	36	Mesita del Potrillo	Eligible – Criterion D
Q 82	Single roomblock pueblo	36	Mesita del Potrillo	Eligible – Criterion D
Q 137	Single roomblock pueblo	15	Mesita del Potrillo	Eligible – Criterion D
Q 139	Single roomblock pueblo	15	Mesita del Potrillo	Eligible – Criterion D
V 2	Water control feature	36	Mesita del Potrillo	Not Eligible
V 3	Water control feature	36	Mesita del Potrillo	Not Eligible
V 4	Water control feature	36	Mesita del Potrillo	Not Eligible
V 5	Water control feature	36	Mesita del Potrillo	Not Eligible
V 7	One- to three-room structure	36	Mesita del Potrillo	Eligible – Criterion D
V 12	Single roomblock pueblo	36	Mesita del Potrillo	Eligible – Criterion D
V 13	Water control feature	36	Mesita del Potrillo	Not Eligible
V 14	Water control feature	36	Mesita del Potrillo	Not Eligible
LA 4664	Single roomblock pueblo	15	Threemile Mesa	Eligible – Criterion D
LA 4679	Single roomblock pueblo	36	Mesita del Potrillo	Eligible – Criterion D
LA 4680	One- to three-room structure	36	Mesita del Potrillo	Not eligible (excavated)
LA 4681	Single roomblock pueblo	15	Mesita del Potrillo	Eligible – Criterion D
LA 4666	One- to three-room structure	15	Mesita del Potrillo	Not eligible (excavated)
LA 4696A	Single roomblock pueblo	49	Frijoles Mesa	Eligible – Criterion D
LA 4697A	Single roomblock pueblo	49	Frijoles Mesa	Eligible – Criterion D

TABLE 4-15.—*Archeology Sites within a 2,500-ft (750-m) and 4,000-ft (1,250-m) Radius of the PHERMEX Firing Site – Continued*

Site Number[a]	Site Type	Tech Area	General Location	National Register Eligibility
LA 4697B	Single roomblock pueblo	49	Frijoles Mesa	Eligible – Criterion D
LA 12655A	Enclosed plaza pueblo	37	TA-16 Mesa	Eligible – Criterion C,SHPO Concurrence
LA 12657E	Single roomblock pueblo	49	Frijoles Mesa	Eligible – Criterion D
LA 12657F	One- to three-room structure	49	Frijoles Mesa	Eligible – Criterion D
LA 12657G	One- to three-room structure	49	Frijoles Mesa	Eligible – Criterion D
LA 71409	Single roomblock pueblo	15	Water Mesa	Eligible – Criterion D,SHPO Concurrence
LA 89761	Artifact scatter	49	Frijoles Mesa	Potentially eligible – Crit. D
LA 89762	Cavate	49	Branch of Water Canyon	Potentially eligible – Crit. D
LA 89763	Rock shelter	49	Water Canyon	Potentially eligible – Crit. D
LA 108741	Rock shelter	15	Water Canyon	Eligible – Criterion D
Q 95	One- to three-room structure	15	Potrillo Canyon	Eligible – Criterion D
Q 96	Cavate	15	Potrillo Canyon	Eligible – Criterion D
Q 150	One- to three-room structure	15	Mesita del Potrillo	Eligible – Criterion D
Q 151	One- to three-room structure	15	Mesita del Potrillo	Eligible – Criterion D
LA 4683	Single roomblock pueblo	15	Threemile Mesa	Eligible – Criterion D
LA 4667	One- to three-room structure	49	Frijoles Mesa	Eligible – Criterion D
LA 4691	One- to three-room structure	49	Frijoles Mesa	Eligible – Criterion D
LA 4695	One- to three-room structure	49	Frijoles Mesa	Eligible – Criterion D
LA 4698	Single roomblock pueblo	49	Frijoles Mesa	Eligible – Criterion D
LA 4698	One- to three-room structure	49	Frijoles Mesa	Eligible – Criterion D
LA 4699	Single roomblock pueblo	49	Frijoles Mesa	Eligible – Criterion D
LA 4699	One- to three-room structure	49	Frijoles Mesa	Eligible – Criterion D
LA 12657	Single roomblock pueblo	49	Frijoles Mesa	Eligible – Criterion D
LA 12657	One- to three-room structure	49	Frijoles Mesa	Eligible – Criterion D
LA 12657	One- to three-room structure	49	Frijoles Mesa	Eligible – Criterion D
LA 13286	Cairn	15	Threemile Mesa	Not eligible (excavated)
LA 21322	Artifact scatter	36	Potrillo Canyon	Potentially eligible – Crit. D
LA 89736	Artifact scatter	49	Frijoles Mesa	Potentially eligible – Crit. D
LA 89738	Artifact scatter	49	Frijoles Mesa	Potentially eligible – Crit. D
LA 89739	Water control feature	49	Frijoles Mesa	Not Eligible
LA 89740	Artifact scatter	49	Frijoles Mesa	Potentially eligible – Crit. D
LA 89741	Artifact scatter	49	Frijoles Canyon	Potentially eligible – Crit. D
LA 89742	One- to three-room structure	49	Frijoles Mesa	Eligible – Criterion D
LA 89744	Rubble Mound	49	Frijoles Mesa	Potentially eligible – Crit. D
LA 89745	Rubble Mound	49	Frijoles Mesa	Potentially eligible – Crit. D
LA 89746	Rubble Mound	49	Frijoles Mesa	Potentially eligible – Crit. D
LA 89756	One- to three-room structure	49	Frijoles Mesa	Eligible – Criterion D
LA 89757	Artifact scatter	49	Frijoles Mesa	Potentially eligible – Crit. D
LA 108742	Cavate	15	Water Canyon	Eligible – Criterion D

[a] LA - New Mexico Laboratory of Anthropology number; Q - LANL Field Number

Source: Larson 1995.

resources and recommendations/concurrences for "determinations of no effect" and/or "determinations of no adverse effect" will be presented in chapter 5.

A third survey is underway to identify cultural resources in the remaining unsurveyed areas within the 2,500 ft (760 m) radius. Additional archeological sites recorded in this survey are anticipated to be similar to those previously recorded as eligible for the National Register under criteria D. The evaluation of cultural resources identified in this survey will be coordinated with the NM SHPO for concurrence of eligibility determinations and potential effects. Results from this survey will be documented in an additional cultural resource survey report and included in the final EIS.

The Nake'muu site, LA 12655, is an enclosed plaza pueblo located 1,100 ft (335 m) to the southwest from the DARHT facility. Unique architectural features are still visible, making it eligible for NRHP nomination under both criteria D and C. The NM SHPO concurred in this determination in correspondence to the DOE dated February 21, 1989 (SHPO 1989). This site is an irregular shaped pueblo of possibly 50 rooms. The site has been described as the best-preserved ruin in this region.

This site is unusual in that it is located at a high elevation, 7,175 ft (2,187 m), and is built on bedrock somewhat distant from agricultural resources as compared to other similar sites in the LANL area. Nake'muu is positioned on a high point of rocks above the junction of Cañon de Valle and Water Canyon, which at first appears to be for defensive purposes, yet the mesita above the ruin to the west allows easy access to it, and there is no sign of any defensive work west of the site (Larson 1988).

Assigning occupational dates to the Nake'muu site is difficult. Based on masonry style, which is notable for the large size of tuff masonry blocks and excellent workmanship, the ruin resembles other classic period sites on the Pajarito Plateau. The roomblock arrangement around a central plaza is also more typical of Classic Period ruins than of Early Coalition ruins. There is very little pottery on the surface of the site. It is possible that trash was thrown over the steep canyon walls, leaving very little in the way of datable material immediately near the site (Larson 1988). The third survey will investigate the area in Water Canyon and Cañon de Valle below Nake'muu and will resurvey the mesa where Nake'muu is located in an effort to find additional cultural material that can be used to establish the dates of occupation for the pueblo.

LA 71408 and LA 71409 are located outside the construction zone proper but early plans for the facility placed the access road adjacent to the sites. The access road was re-sited in 1989 to avoid contact with the site boundaries and the two sites were fenced to protect them from any accidental disturbance during construction work. The NM SHPO, in correspondence to the DOE dated February 21, 1989, stated satisfaction "... that adequate consideration has been given to measures to avoid adverse effects to the recorded sites." (SHPO 1989)

LA 71410 is located in the construction zone under the earth berm to the north of the firing point. Realignment of the berm in order to avoid disturbing this archeological site would have exposed Nake'muu to more potential debris from blasting (see chapter 5 for a full discussion). At the request of the Pueblo San Ildefonso (Torres 1994) and with the concurrence of the NM SHPO (SHPO 1994), LA 71410 was thoroughly recorded and then capped with clean earth on April 26, 1994, and buried several days later under the earth berm.

4.6.2. Historical Resources

There are two Manhattan Project/Early Cold War buildings in the 2,500 ft (760 m) radius which are potentially eligible for inclusion on the NRHP under criterion A: Control Chamber B (TA-15-9) and Firing Pit H/Camera Chamber (TA-15-92). The PHERMEX Facility itself, although not 50 years old, is also potentially eligible for NRHP inclusion because of its association with the Cold War. A thematic NRHP nomination of LANL structures associated with the Manhattan Project and the Cold War Era is ongoing.

4.6.3. Native American Cultural Resources

Cultural resources are of special importance to Native Americans. Those resources, located on LANL, may consist of prehistoric sites with ceremonial features such as kivas, village shrines, petroglyphs, burials, or may consist of traditional cultural properties with no observable man-made features. Figure 4-21 shows the locations of Native American Pueblos in the immediate vicinity of LANL.

Consultations with local Native Americans to identify any such locations have been conducted in the past and are currently ongoing.

In the spring of 1993, consultations with San Ildefonso Pueblo were renewed. On December 6, 1993, a tribal representative visited LA 71410, LA 714108 and LA 71409 to discuss mitigation alternatives for LA 71410. A copy of the 1988 cultural resource survey report was given to this representative to present to the tribal council. On January 27, 1994, the DOE sent a copy of the cultural resource survey report and all relevant SHPO consultation to the governor of San Ildefonso Pueblo and specifically asked for recommendations for mitigation of LA 71410. Council representatives visited LA 71408, LA 71409 and LA 71410 on February 7, 1994. Another copy of the original 1988 cultural resource survey report was sent on February 11, 1994, to the governor of San Ildefonso Pueblo, the Native American group with the most direct claim to descent from the prehistoric inhabitants of what is now TA-15. No response was received. Representatives from San Ildefonso Pueblo, Jemez Pueblo, and Cochiti Pueblo were given a briefing on the DARHT project on December 2, 1994, and visited Nake'muu as well as LA 71408 and LA 71409 (LA 71410 had already been buried beneath the earth berm). Native American input on possible effects to unidentified traditional cultural properties was requested during this visit.

If cultural resources of ceremonial importance or traditional cultural properties are identified during the continuing consultation process, these will be discussed in the final EIS.

4.6.4 Paleontological Resources

No paleontological sites are reported on Threemile Mesa, and the near-surface stratigraphy is not conducive to preserving plant and animal remains. These near-surface materials are volcanic ash and pumice that may have been hot when deposited. Occasionally, some charcoal is found at the base of an ashfall. The deposits date mostly from about one million years ago and have a total thickness of about 750 ft (229 m).

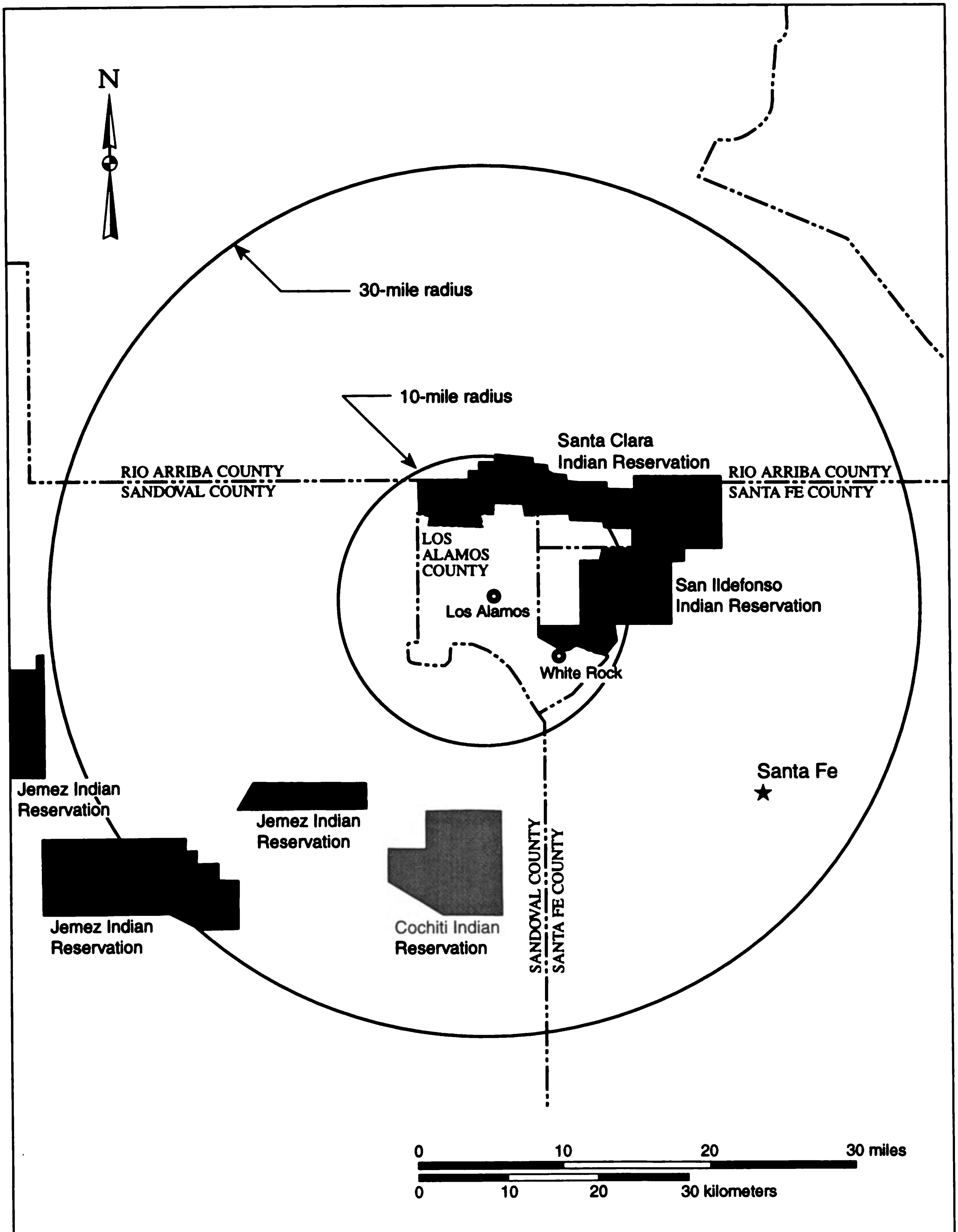


FIGURE 4-21.—*Locations of Indian Reservations of Four Pueblo Tribes in Accord with LANL and DOE.*

4.7 SOCIOECONOMIC ENVIRONMENT

Any major changes in activities undertaken at LANL have the most immediate socioeconomic effects on LANL employees and their respective communities. These communities are located throughout Los Alamos, Santa Fe, and Rio Arriba counties in north-central New Mexico (see figure 4-1). The LANL Office of Community Relations estimates that 91.6 percent of the LANL employees reside in this tri-county region (LANL 1994c). Furthermore, the U.S. census estimated that 95.6 percent of the Los Alamos County workforce resided in this tri-county region in 1990 (Bureau of the Census 1994). Based on both considerations, any major changes in activities at the LANL site would potentially have their most immediate socioeconomic effects on residents in this tri-county region. A description of this affected environment is provided in the following sections based on a summary of its demographic, economic, and social characteristics.

4.7.1 Demographic Characteristics

The predominant population in the region-of-interest is white caucasian with 50.1 percent having Hispanic ethnic background (see table 4-16). Native Americans residing in Los Alamos, Rio Arriba, and Santa Fe counties account for 5 percent of the general population. Extending this region to include Sandoval county increases the percentage of Native Americans to just under 10 percent of the greater general population. The Pueblos of San Ildefonso, Cochiti, Jemez, and Santa Clara are important centers of these Native American populations.

Some 62.5 percent of the total population in the tri-county region are between the ages of 18 and 65. Approximately 80.7 percent of this population has completed high school, and 30.5 percent have attained a baccalaureate degree or higher. A significant difference exists in educational attainment levels within the region, as evidenced by Los Alamos and Rio Arriba counties.

The median and per capita income levels of the population in the region were $30,408 and $14,538 in 1990. While both of these income levels are close to their respective state averages of $27,623 and $14,254, there are very significant differences in income levels among the various counties. At the time of the 1990 Census, it was estimated that 15 percent of the tri-county residents fell below official poverty thresholds. Poverty thresholds vary by size of family and number of related children under 18 years (Bureau of the Census 1990). For example in 1989, $14,990 was the official poverty threshold for a family of five persons.

4.7.2 Economic Base

This section summarizes the economic base of the tri-county region. An overview of the economic base is shown in figure 4-22 in terms of income and expenditure flows between LANL, households, businesses, and governments.

LANL is the largest employer in the tri-county region. Its *direct* economic impact on the tri-county region is significant even after deducting procurement and wage/salary payments made outside the tri-county region – denoted as leakage(s). For FY 1993, the LANL payroll for the tri-county region was $450 million for 7,256 full-time personnel (LANL 1994c). During the same year, LANL spent

TABLE 4-16.—*Demographic Profile of the Population in the Tri-County Region-of-Interest*

Parameters	Los Alamos	Santa Fe	Rio Arriba	Regional Total
Total Population (1990)	18,115	98,928	34,365	151,408
Households (1990)	7,213	37,840	11,461	56,514
Persons per Household (1990)	2.50	2.54	2.97	2.67
Race (1990) – Percent of Total Population				
White	94	80	70	79
Black	1	1	1	1
Native American	1	3	15	5
Asian	2	1	1	1
Other	2	15	13	14
Ethnicity (1990)				
Hispanic	2,008	48,939	24,955	75,902
Percent of total population	11.1	49.5	72.6	50.13
Ages (1990)				
Percent under 18	26.0	26.0	32.4	27.6
Percent 65 and over	9.2	10.1	9.7	9.90
Education (1990) – Persons 25 years and older				
Percent High School Graduate or Higher	94.7	82.6	65.9	80.7
Percent Bachelor's Degree or Higher	53.4	32.3	10.3	30.5
Income (1989)				
Median Household Income ($)	54,801	29,403	18,373	30,408
Per Capita Income ($)	22,900	15,327	7,859	14,538
Percent of Persons Below Poverty Line	2.4	13.0	27.5	15.0

Source: Bureau of the Census 1994.

approximately $220 million in procurement in the tri-county region (LANL 1994c). 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 and wage earnings by economic sector within the tri-county region is provided in table 4-17.

The average annual employment in the tri-county region during CY 1993 covered 71,776 workers who earned a total of $1.82 billion in wages (New Mexico State Department of Labor 1994). At the sectoral

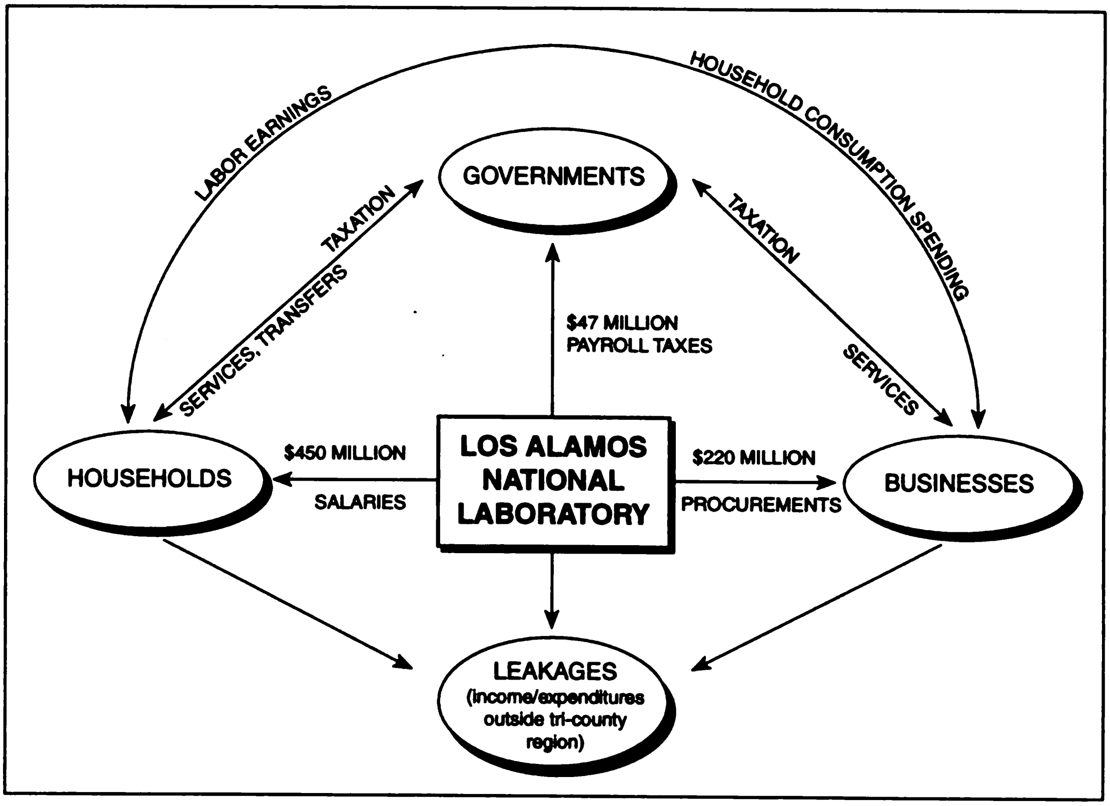


FIGURE 4-22.—***Income and Expenditure Flows from LANL to Businesses, Households, and Governments for FY 1993.***

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 percent of the employment and 79 percent of the wages in the regional economy. Meanwhile, the unemployment rate for the tri-county region as a whole was 5.5 percent.

The sectoral patterns of employment and wages are significantly different from county to county. Employment and wages during 1993 were highest in Santa Fe, followed by Los Alamos and Rio Arriba counties. Meanwhile, 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.

The flow of income and expenditures from LANL also generates direct State and local tax revenue. In FY 1993, LANL paid $41 million in payroll taxes and $6 million in additional tax payments within the tri-county region. Consequently, significant changes in the level of LANL activities could potentially affect government tax revenues, payments, and services in the tri-county region.

The operating costs associated with PHERMEX for FY 1994 were about $3.5 million. The allocation for FY 1995 is $4.2 million. These annual costs are considered reasonably typical. This funding provides support for operating personnel, physics support, clearance staff, firing crew, fire department, LANL's facility space tax, contractor support, facility scheduling, and a safety and environmental compliance program. Contractor support includes janitorial services, routine maintenance, minor upgrades, and firing point cleanup. DOE has invested about $1 million per year in maintenance, minor upgrades, and

TABLE 4-17.—*1993 Employment and Wage Profile in the Tri-County Region-of-Interest*

Economic Sectors	Santa Fe		Los Alamos		Rio Arriba		Total	
	Employment	Total Wages (in millions)	Employment	Total Wages (in millions)	Employmen t	Total Wages (in millions)	Employment	Total Wages (in millions)
Agriculture	364	$ 6.08	28	$ 0.42	59	$ 0.55	451	$ 7.05
Construction and Mining	3,120	65.57	170	2.90	382	6.87	3,672	75.34
Manufacturing	2,016	48.24	63	1.27	315	5.01	2,394	54.52
Transportation and Utilities	1,056	26.18	66	1.29	268	8.37	1,390	35.84
Trade	12,725	190.80	1,236	19.40	1,480	18.50	15,441	228.70
F.I.R.E.	2,311	69.21	341	8.38	216	3.96	2,868	81.55
Services	13,520	281.33	4,424	133.38	2,331	35.76	20,275	450.47
Government								
Federal	1,510	51.54	190	7.38	455	11.96	2,155	70.88
State	9,104	225.84	157	1.88	493	9.87	9,754	237.59
LANL	NA	NA	7,256	450.00	NA	NA	7,256	450.00
Local	3,613	75.27	1,081	29.55	1,426	25.89	6,120	130.71
Totals	49,339	$1,040.06	15,012	$ 655.85	7,425	$ 126.74	71,776	$1,822.71
Percent Unemployment	4.9		2.1		11.8		5.5	

Sources: The covered employment and wage figures presented here are based on counts of employees covered under the New Mexico Unemployment Compensation Law, consistent with the ES-202 series reported to the U.S. Bureau of Labor and Statistics (New Mexico Department of Labor 1994). The reported unemployment figures are published by the U.S. Department of Census (Bureau of the Census 1994). Note that the employment and wage data are based on survey data by place of residence while the unemployment data is based on survey information reported by place of work.

replacement parts for PHERMEX. This would be expected to increase each year as long as the facility is operated. The current amount is less than 0.2 percent of LANL's total annual expenditures.

4.7.3 Community Infrastructure and Social Services

This section describes community infrastructure and social services within the tri-county region. Table 4-18 lists the status of occupied and vacant housing units in the tri-county region and the number of new private housing units authorized by building permits for the period 1990-1992 (Bureau of the Census 1994).

TABLE 4-18.— *Status of Housing Infrastructure by County in the Region-of-Interest*

Criteria	Los Alamos	Santa Fe	Rio Arriba	Total
Total housing units (1990)	7,565	41,464	14,357	63,386
Occupied Units	7,213	37,840	11,461	56,514
Owner occupied (1990)	5,367	25,621	9,218	40,206
Percent owner occupied (1990)	74.4	67.7	80.4	71
Median value (1990)	$126,100	$103,300	$58,800	NA
Renter occupied (1990)	1,846	12,219	2,243	16,308
Median gross rent (1990)	$467	$489	$285	NA
Vacant units (1990)	352	3,624	2,896	6,872
vacancy rate	4.7	8.7	20.2	10.8
New housing building permits (1990-1992)	119	1188	28	1,335
Percent of 1990 housing stock	1.6	2.9	0.2	NA

Source: Bureau of the Census 1994.

In 1990, the tri-county region contained a total of 63,386 housing units, of which 40,206 were owner-occupied and 16,308 were renter-occupied. The median value of owner-occupied units was $126,100 in Los Alamos county, which is higher than both other counties in the region. The median gross rent was lowest in Rio Arriba county and about the same in both Los Alamos and Santa Fe counties. Coincidentally, the vacancy rate was lowest in Los Alamos county and highest in Rio Arriba county. Santa Fe county appeared to be the fastest growing county in the region, as measured by the number of new housing permits issued during the period 1990 to 1992 relative to the existing housing stock in 1990.

Community infrastructure is further defined by education and health-care infrastructure in the tri-county region. Each county government provides its own public education and health-care services. Table 4-19 lists the status of these two elements by county.

In 1990, student enrollment totaled 40,414 in selected school districts throughout Los Alamos, Santa Fe, and Rio Arriba counties (Bureau of the Census 1994). These students attended 102 schools within the

TABLE 4-19.—*Education and Health Care Infrastructure by County in the Region-of-Interest*

Criteria	Los Alamos	Santa Fe	Rio Arriba	Total
Total School Enrollment[a] (1990)				
College (1990)	5,020	25,743	9,651	40,414
Elementary or high school	1,288	6,727	1,808	9,823
(1990)	3,236	17,363	7,316	27,915
Percent public (1990)	96.2	90.6	91.7	
Number of Schools[a] (1994)	12	67	23	102
Public (1994)	7	25	14	46
Private (1994)	5	42	9	56
Community Hospitals (1990)	1	1	1	3
Number of beds (1990)	53	226	54	333
Number of physicians (1990)	42	228	26	296

[a] The figures presented are for county school districts. Only in the case of Los Alamos County are they comparable to the county-wide figures.

Source: The figures on pupil enrollment and health care services are from the U.S. Census County Data Book, 1994 (Bureau of the Census 1994). The figures on number and composition of schools in the county districts are from the New Mexico State Department of Education (1994).

tri-county region (New Mexico State Department of Education 1994). Similarly, health care services and facilities are heavily concentrated in Santa Fe county relative to the other two counties in the region.

4.7.4 Environmental Justice

Under Executive Order 12898, *Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations*, Federal agencies are responsible for identifying and addressing the possibility of disproportionately high and adverse health and environmental impacts of programs and activities on minority and low-income populations. Hereafter, minority populations refer to all people of color, exclusive of white non-Hispanics. Low-income populations refer to household incomes below $15,000 per year. Figures 4-23 through 4-26 illustrate the percentages of minority populations and low-income households within a 10-, 30-, and 50-mi (16-, 48-, and 80-km) radius of the site. This area spans portions of Los Alamos, Rio Arriba, Santa Fe, and Sandoval counties.

Figure 4-23 also illustrates that a relatively small proportion of Hispanics or Native Americans live within a 10-mi (16-km) radius. A much larger concentration of minority populations resides between 10, 30, and 50 mi (16, 48, and 80 km) from the site (figures 4-23 and 4-24). Table 4-20 describes the geographic distribution of these minority populations in relation to distance from the site. Of a total population of 18,115 persons living within a 10-mi (16-km) radius of the proposed site, minorities account for 14 percent of the population. In contrast, minorities account for 65 percent of the general population living 10 to 30 mi (16 to 48 km) from the site. The overall percentage of minorities within 30 and 50 mi (48 and 80 km) from the site exceeds the white non-Hispanic segment of the population.

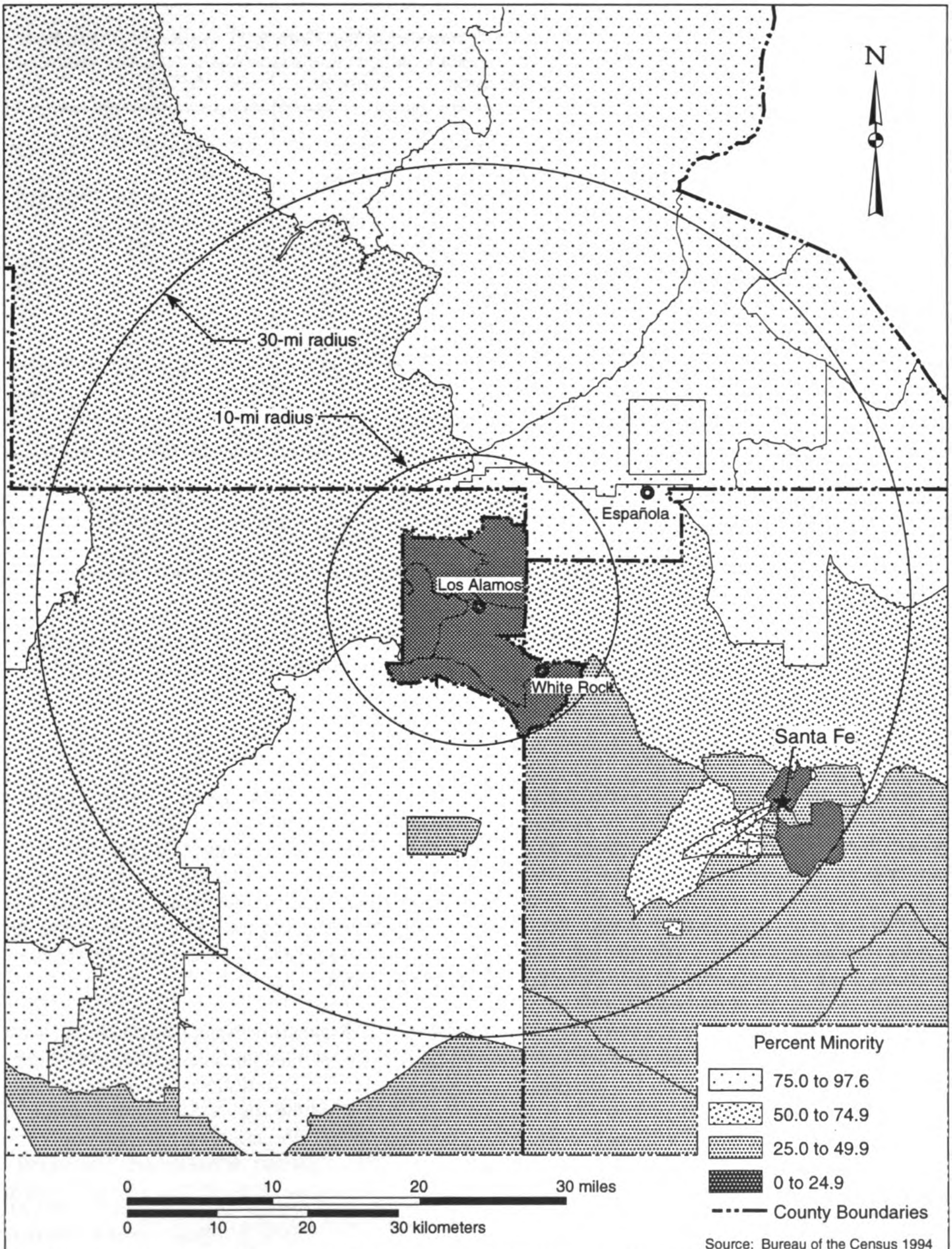


FIGURE 4-23.—*Distribution of Minority Population Within a 30-mi (48.3-km) Radius of the DARHT Site.*

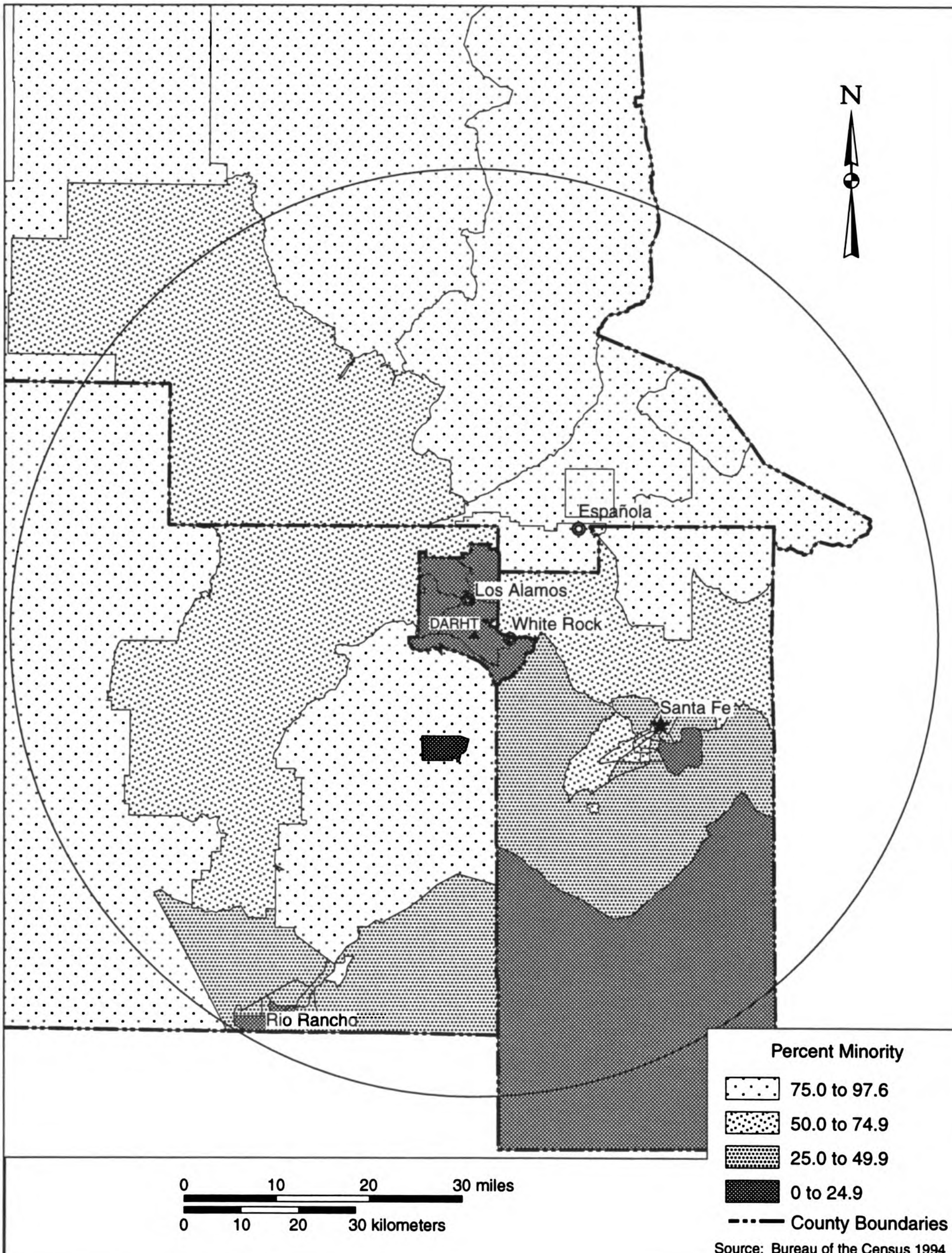


FIGURE 4-24.—*Distribution of Minority Population within a 50-mi (80-km) Radius of the DARHT Site.*

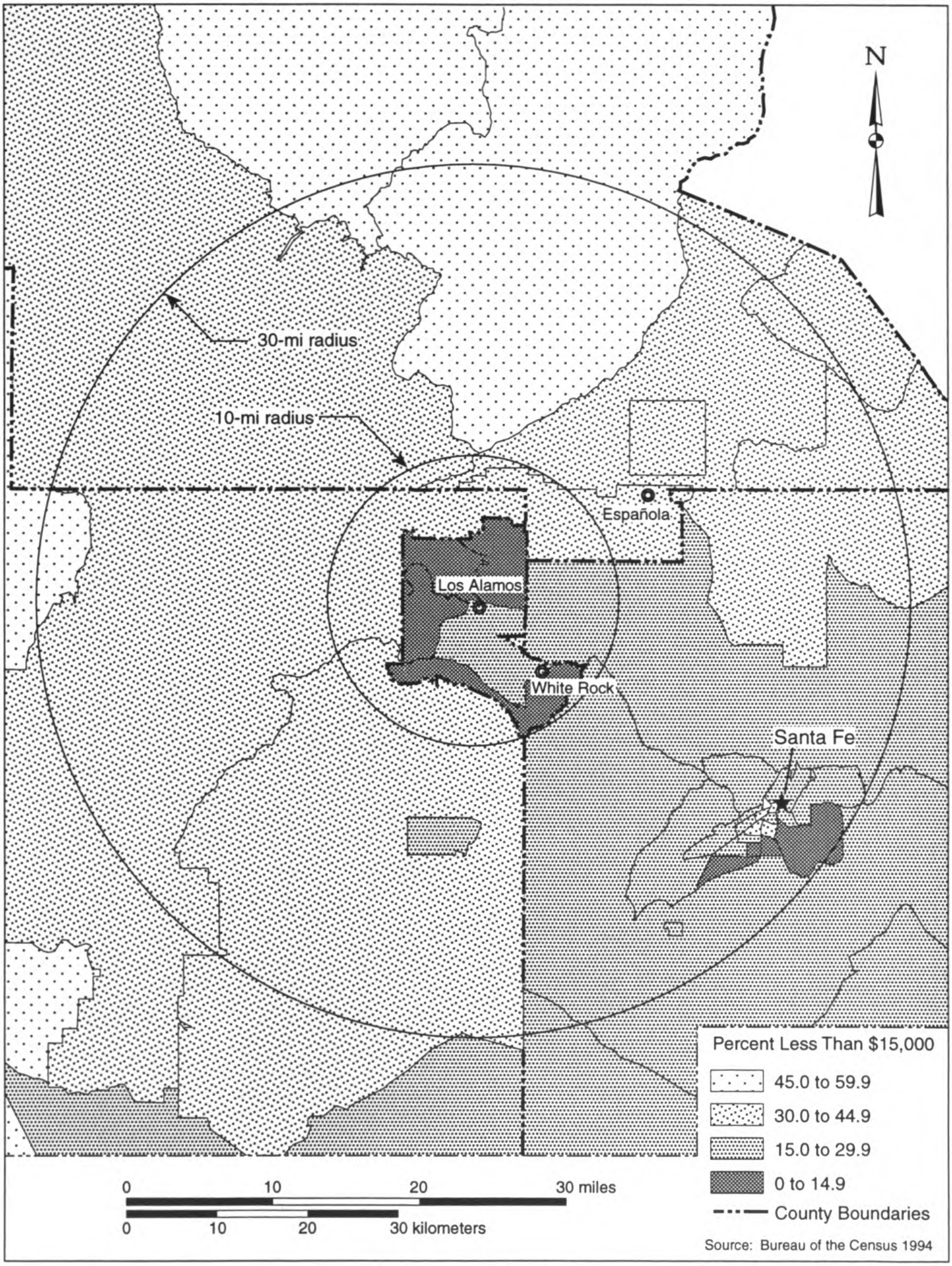


FIGURE 4-25.—*Distribution of Low-Income Population within a 30-mi (48-km) Radius of the DARHT Site.*

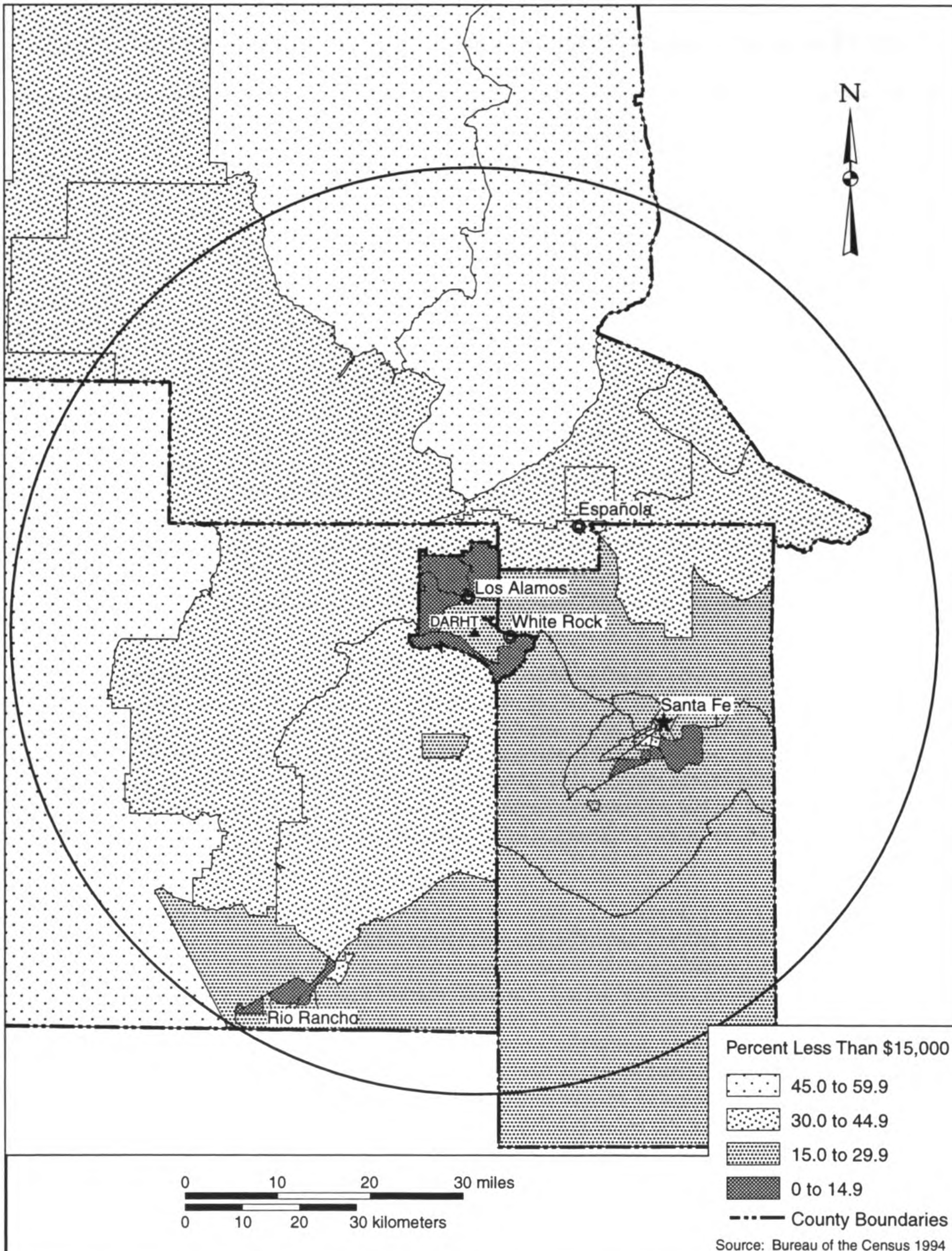


FIGURE 4-26.—*Distribution of Low-income Population within a 50-mi (80-km) Radius of the DARHT Site.*

TABLE 4-20.—*Distribution of Population by Ethnicity Within a 50-mi (80-km) Radius of the DARHT Site*

Population Group	Population within a 10-mi (16-km) Radius of the Site	Population within a 10- to 30-mi (16- to 48-km) Radius of the Site	Population within a 30-mi (48-km) Radius of the Site	Population within a 50-mi (80-km) Radius of the Site
Total	18,115	133,028	151,143	214,727
Total Nonminority	15,556	47,059	62,615	99,257
Total Minority	2,559	85,969	88,528	115,470
Hispanic Origin	1,933	72,470	74,403	92,954
Native American	154	12,368	12,522	19,421
Other Minority	472	1,131	1,603	3,095
Percent Minority	14	65	59	0.54
Percent Nonminority	86	35	41	46

Source: Bureau of the Census 1994.

Table 4-21 and figures 4-25 and 4-26 provide similar descriptions of the concentration of low-income households within 10, 30, and 50 mi (16, 48, and 80 km) of the site. Of a total of 55,411 households in the 10-mi (16-km) radius, 13,536 (24 percent) had incomes below $15,000. However, the number of these relatively low-income households increases sharply beyond the 10-mi (16 km) radius. Only 581 (2 percent) households had incomes below $15,000 within 10 mi (16 km) from the site while 12,995 (23 percent) households had equally low incomes between 10 and 30 mi (16 and 48 km) from the site. Within a 50-mi (80-km) radius of the site, 18,519 (24 percent) households had annual incomes of $15,000 or less in 1990.

4.8 RADIOLOGICAL AND CHEMICAL ENVIRONMENT

This section describes the radiological and chemical environments at LANL and Area III.

4.8.1 Regional Environment

The regional study area for the radiological and chemical environment includes LANL and a number of sampling stations up to approximately 20 mi (30 km) from LANL. LANL routinely monitors for radioactive and nonradioactive pollutants on LANL sites and in the surrounding region.

TABLE 4-21.—*Distribution of Population by Income Within a 50-mi (80-km) Radius of the DARHT Site*

Income Class	No. of Households within a 10-mi (16-km) Radius of the Site	No. of Households within a 10- to 30-mi (16- to 48-km) Radius of the Site	No. of Households within a 30-mi (48-km) Radius of the Site	No. of Households within a 50-mi (80-km) Radius of the Site
Total Households	7,211	48,200	55,411	77,448
< $15,000	581	12,955	13,536	18,519
$15,000 to $24,999	597	9,582	10,179	14,531
$25,000 to $34,999	704	7,694	8,398	12,983
$35,000 to $49,999	1,281	7,943	9,224	13,600
$50,000 to $74,999	2,092	6,389	8,481	11,283
$75,000 to $99,999	1,219	1,792	3,011	3,572
$100,000 or more	737	1,845	2,582	2,960

Source: Bureau of the Census 1994.

4.8.1.1 Radiological

Many of the activities that take place at LANL involve handling radioactive materials and operating radiation-producing equipment. Radiological doses are calculated to estimate the potential health impacts of any releases of radioactivity to the public. Standards exist which limit the maximum effective dose equivalent (EDE) to the public. The DOE's public dose limit (PDL) is 100 mrem/yr EDE received from all pathways, and EPA restricts the EDE received by air to 10 mrem/yr. These values are in addition to those from normal background, consumer products, and medical sources, which total about 300 to 350 mrem per year. Both standards apply to locations of maximum probable exposure to an individual in an offsite, uncontrolled area.

EPA-approved methods were used to calculate radiation doses to the public from LANL emissions and demonstrate compliance with National Emissions Standards for Hazardous Air Pollutants (NESHAP) requirements [40 CFR 61]. The EPA approved methods do not allow LANL to take into account shielding or occupancy standards. In 1992, that EDE was 7.9 mrem, which is in compliance with EPA standards of 10 mrem/yr from the air pathway (DOE 1993b). The maximum probability of a latent cancer fatality from such a dose would be 4×10^{-6}. The estimated maximum EDE resulting from LANL operations in 1993 was 5.6 mrem (DOE 1994). Thus, 1992 is considered a representative year for recent LANL operations. The 1993 EDE shows a reduction which may be indicative of DOE's change in mission which halted production of weapons.

DOE directs use of site-specific input data, where available, and realistic dose calculation estimates for annual site environmental reporting. In 1992, the estimated maximum EDE resulting from LANL operations was 6.1 mrem, taking into account shielding by buildings (30 percent reduction) and occupancy (100 percent for residences, 25 percent for businesses). The maximum probability of a latent cancer fatality from such a dose would be 3×10^{-6}. This dose is 6 percent of DOE's 100 mrem/yr PDL for all pathways (LANL 1994a). Approximately 95 percent of the dose (DOE 1993b) was from external radiation from short-lived, airborne emissions from a linear particle accelerator at Los Alamos Meson Facility (LAMPF).

In 1992, the annual collective dose to the population from operations at LANL was 1.4 person-rem. No latent cancer fatalities (7×10^{-4} LCFs) would be expected among the members of the population. Table 4-22 presents a comparison of the 1992 annual EDEs with DOE dose limits and background values. The estimated maximum EDE from LANL operations is less than two percent of the 346 mrem received from background radiation and radioactivity in Los Alamos during 1992 (figure 4-27).

LANL measures environmental external penetrating radiation (including x-rays, gamma rays, and charged-particle contributions from cosmic, terrestrial, and LANL sources) with thermoluminescent dosimeters (TLDs) at 166 locations within three independent networks including 4 regional and 23 perimeter offsite locations (Jacobson 1995 and LANL 1994a). The locations of these networks are onsite at LANL and offsite (perimeter and regional), at the LANL boundary north of the LAMPF, and at low-level radioactive waste management areas as shown in figure 4-28 (LANL 1994a). The natural terrestrial components are primarily from the decay of potassium-40 and the radionuclides in the decay chains of thorium and uranium. In 1992, the annual average TLD measurement taken from offsite regional stations was 102 mrem. This offsite average was generally the same as the average TLD measurement taken from perimeter stations and onsite stations which averaged 119 mrem and 128 mrem respectively (LANL 1994a). The average dose at the Frijoles Mesa station, which is the closest station to PHERMEX, was 119 mrem.

Samples of foods (produce, fish, and honey) are collected and analyzed for radioactivity in an effort to monitor potential contamination in the food chain resulting from LANL operations (figure 4-29). The two main objectives of the foodstuffs monitoring program are to:

- Compare levels of radionuclides in foodstuffs collected from offsite regional (background) areas to levels in foods collected from LANL and perimeter areas
- Calculate any additional radiation dose to LANL and area residents (Los Alamos and White Rock) based on the data collected.

The data also are compared to radiation protection standards recommended by the International Commission on Radiological Protection and the National Council on Radiation Protection and Measurements (LANL 1994a).

In 1992, radiation levels in surface- and bottom-feeding fish were collected upstream of LANL at Abiqui, Heron and/or El Vado reservoirs, and downstream of LANL at Cochiti reservoir. The mean total uranium level in the surface-feeding fish was 1.2 ± 1.5 (2σ) ng/dry g for the upstream reservoirs and 5.4 ± 18.6 (2σ) ng/dry g for the downstream reservoir. In the bottom-feeding fish, the mean total uranium level was 5.2 ± 8.0 (2σ) ng/dry g for the upstream reservoirs and 8.8 ± 6.4 (2σ) ng/dry g for the downstream reservoir.

Elk *(Cervus elaphus)* spend the winter in areas at LANL that may contain radioactivity above natural and/or worldwide fallout levels. A LANL study found no significant differences in radionuclide contents in any tissue samples collected from elk on LANL lands compared with elk collected from offsite locations (Fresquez et al. 1994)

TABLE 4-22.—*Comparison of 1992 Annual Effective Dose Equivalents Near LANL Operations with Dose Limits and Background*

Criteria	Maximum Individual Dose[a]	Average Dose to Nearby Residents		Collective Dose[b]
		Los Alamos	White Rock	
Dose Attributable to LANL	6.1 mrem	0.12 mrem	0.11 mrem	1.4 person-rem
Location	Residence north of TA-53	—	—	Area within 50 mi (80 km) of LANL
Natural Background	340 mrem	340 mrem	327 mrem	72,000 person-rem
DOE Public Dose Limit	100 mrem	—	—	—
Percentage of Public Dose Limit	6.1	0.12	0.11	—
Percentage of Background	2	0.04	0.03	0.002

[a] The maximum individual dose to any individual at or outside LANL at sites where the highest dose rate occurs (the location of the maximum exposed individual [MEI]). Calculations take into account occupancy (the fraction of time a person is actually at that location) and shielding by buildings, as specified by the DOE 5400.5 for calculating public dose limits (PDL).
[b] Collective dose to population within 50 mi (80 km) of LANL.

Source: LANL 1994.

4.8.1.2 Chemical

The regional chemical environment depends on background chemical data for soils and the LANL activities that may produce hazardous/toxic wastes. Some activities at LANL use chemicals that may present a significant risk to humans and the environment.

Recent background chemical data for soils collected at Los Alamos are shown in table 4-23. These data were collected from soils, which may have application for fill or reworked unconsolidated material found at the townsites and other disturbed areas of LANL. Table 4-23 contains chemical data for all soils and fracture fill material and chemical data from the A horizons, the uppermost soils found on the Pajarito Plateau at LANL.

4.8.2 Local Environment

This section describes the local radiological and chemical environment.

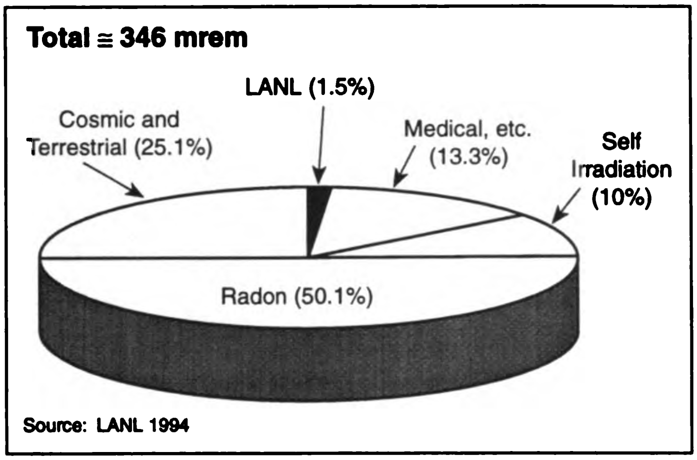


FIGURE 4-27.—*Components of the 1992 Effective Dose Equivalent (EDE) at LANL's Maximum Exposed Individual (MEI) Location.*

4.8.2.1 Radiological

In 1992, PHERMEX operations contributed less than 1 percent of the total dose from LANL operations to the maximally exposed member of the public from LANL operations. The annual collective dose to the population from operations at PHERMEX was approximately 0.1 person-rem. No latent cancer fatalities (5×10^{-5} LCFs) would be expected among the members of the population.

PHERMEX is an insignificant contributor to environmental levels of tritium. Honey samples are periodically collected and analyzed for radioactivity in an effort to monitor potential contamination in the food chain resulting from TA-15 operations. Tritium levels in honey collected from TA-15 from 1979 to 1993 ranged from 0.5 to 26.0 (± 6.0) pCi/mL.

The soil around PHERMEX is contaminated with materials which were part of the experiments exposed to high explosives. DOE has conducted studies, including aerial surveys using helicopters and soil-sampling surveys, that indicate that elevated levels of depleted uranium are found on the firing point (Fresquez 1995). A detailed discussion of these studies can be found in section 4.3.3.

4.8.2.2 Chemical

Materials released during open-air tests at the PHERMEX Facility have resulted in low but observable quantities of lead, beryllium, and mercury on or near the firing site. Soil sample surveys conducted in 1993 indicate that no lead , beryllium or mercury are observed beyond 460 ft (140 m) of the firing point (Fresquez 1994 CTK2). This survey is described in detail in appendix D.

TABLE 4-23.—*Background Concentrations of Selected Elements in Soils at LANL*

Element	All Soils and Fracture Fill Materials (ppm)[a] Mean	Horizon A[b] Concentration (ppm)[a]
Be	1.23 2.37[c]	0.71
Cu	6.6	6.5
Pb	16.7 28.36[c]	15.8
U	0.94	0.9

[a] Using SW846 – An EPA toxicity characteristic leaching procedure test method.
[b] Horizon A is the uppermost soil horizon characterized during background investigation.
[c] Hydrofluoric acid used in sample dissolution.

Source: Longmire 1994.

4.9 HISTORY OF ACCIDENTS AT PHERMEX

Two environmental occurrences or spills have been reported since 1991, the first year occurrence reporting database information was available. In 1992, there was a transitory discharge to the PHERMEX outfall of 0.49 ppm cyanide, in excess

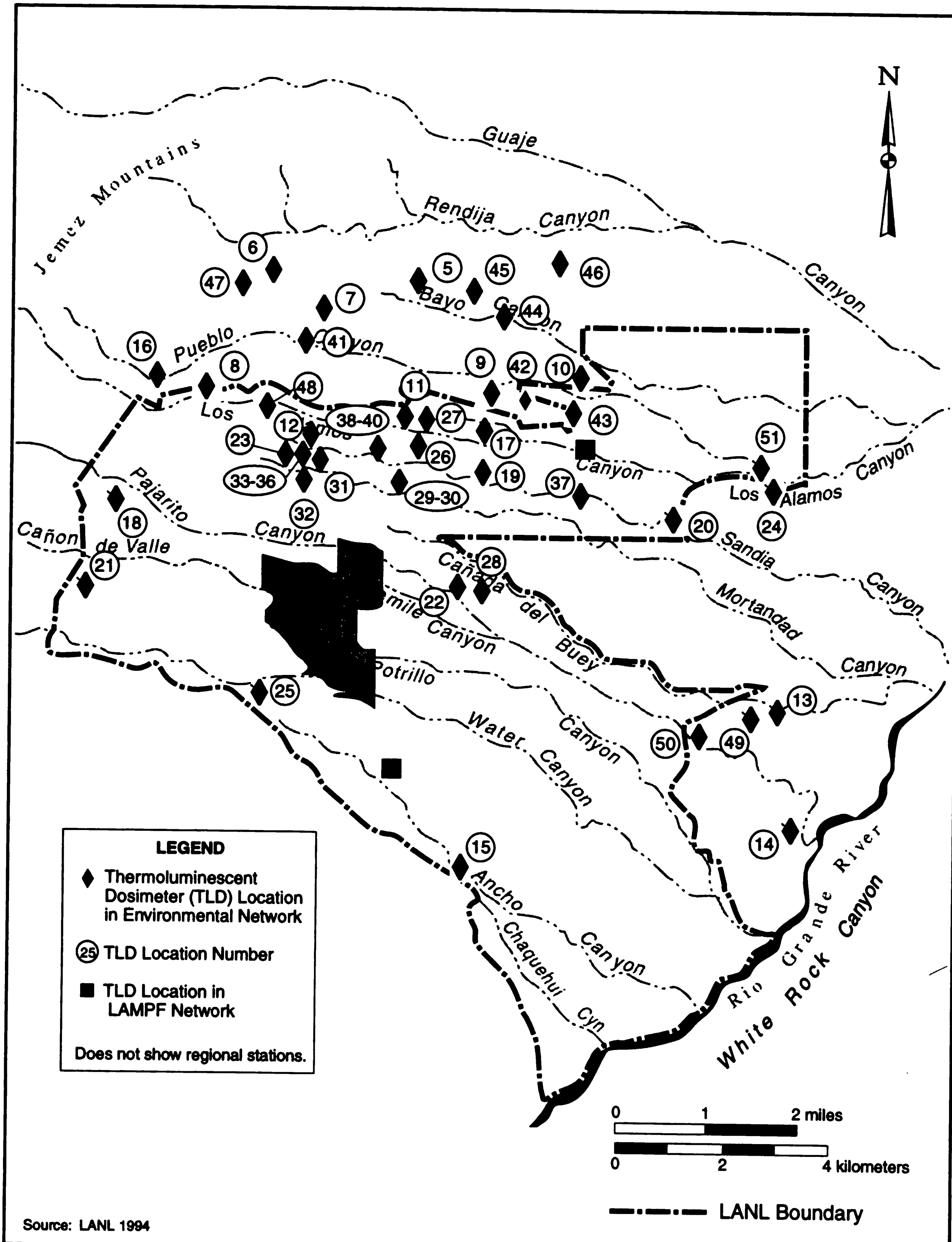


FIGURE 4-28.—*Offsite Perimeter and Onsite LANL TLD locations.*

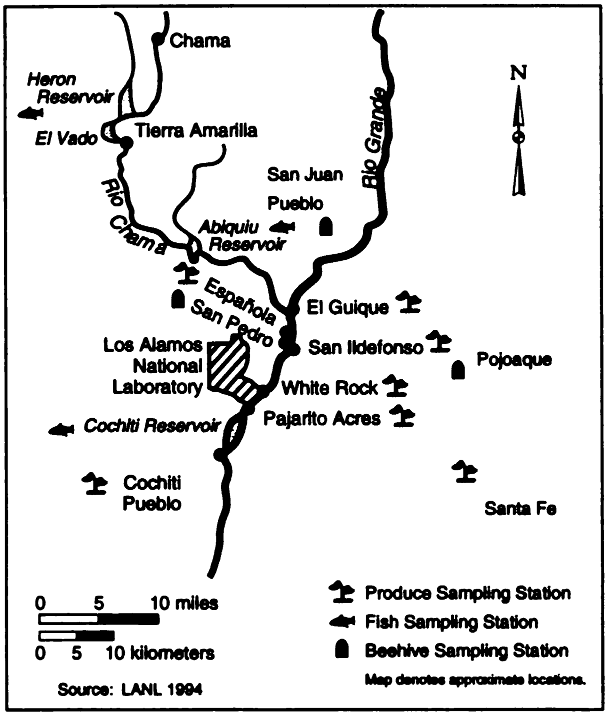


FIGURE 4-29.—***Locations of Offsite Sampling of Produce, Fish, and Beehives.***

of the NPDES permit level of 0.2 ppm cyanide. This occurrence was traced to a single discharge of film processing chemicals, discharged when film bath chemicals were exchanged. In 1995, seven Los Alamos firemen were exposed to smoke and potential detonation by-products when a firing-site debris pile near PHERMEX caught on fire as a result of a firing site detonation. All firemen were checked for exposure to depleted uranium and potential hazardous substances in the pile; all results were negative.

During the most recent ten-year period (1985 to 1994), the accident statistics for PHERMEX indicate that there were a total of 19 lost work days. None of these injuries were considered serious, being a contusion, a concussion, and numerous back strains caused by common workplace accidents. There have been no reported accidents associated with the detonation of explosives.

The PHERMEX accidents, environmental occurrences, and spills reported above have been minor and had negligible consequences to workers, the environment, and the public. A summary of accidents which may occur at the PHERMEX facility is shown in table 4-24.

LANL has developed and maintains an emergency management system that, through emergency planning, emergency preparedness, and effective response capabilities, is capable of responding to and mitigating the potential consequences of emergencies. The Emergency Management Plan incorporates in one document a description of the entire process designed to plan for, respond to, and mitigate the potential consequences of an emergency (LANL 1994a). PHERMEX has an emergency response plan and procedures to initiate a site-wide response, if necessary, through the site-wide program. The PHERMEX plan requires pre-staging of the LANL fire department for uncontained detonations.

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TABLE 4-24.—*Hazards at Hydrodynamic Test Facilities*

Hazard	Location	Comments
Ionizing Radiation Exposure		
Personnel inside exclusion areas during beam pulsing	Accelerator bay, optical room, and firing pad	Beam pulse with up to 2,000 rad x-rays at one meter on axis
Electrical		
Personnel in contact with the power supplies or capacitor banks	Accelerator room and power supply rooms	Power supplies with voltages up to 4MV, high energy-densities in capacitor banks
Personnel in contact with laser power supplies	Accelerator bay and laser rooms	Power supplies with voltages up to 35kV
High Explosive Blast		
Personnel in the hazard radius exclusion area during testing	Firing site exclusion area	Area radius is 2,460 ft (750 m), personnel OK in R-184 and R-310
Accidental detonation of explosive	Firing pad	
Nonionizing Radiation		
Operating personnel intersect laser beam	Laser room	
Mechanical		
Crane maintenance and operation	Accelerator bay, power supply rooms, equipment and assembly rooms	Potential for misuse
Occupational		
Slippery surfaces due to fluids	Accelerator bay, power supply rooms, equipment room	Leaks or spills from tanks, valves, or connections
Gases		
Helium	Firing pad, diagnostics area	Used to drive high-speed cameras
Sulfur hexafluoride	Accelerator hall, power supply room	Leaks from spark gaps
Chemicals/Solvents		
Acetone, ethanol	Accelerator bay and assembly room	Inhalation hazards
Fire		
Insulating oil	Accelerator bay and power supply rooms	EXXON 1830 type insulating oil has a flash point above 149°C (330°F)
Wicking of insulating oil	Power supply rooms	Oil soaked rags
Acetone, ethanol	Accelerator bay and assembly room	Volatile cleaning solvents
Electrical control cables, high voltage cables, and components	Accelerator bay, power supply rooms, equipment room	Faulty items may cause sparks to ignite oil, etc.
Fire from parked vehicles	Parking and delivery area	Gasoline in fuel tanks
Natural gas	Equipment room	Hot water boiler
Trash and rag accumulation	Accelerator bay, power supply rooms, equipment room	Ignition source for oil
Forest or brush fire	External to building	May arise from explosives or natural causes
Natural Phenomena		
High Winds	TA-15	Damage to utilities
Lightning	TA-15	Damage to utilities
Earthquake	TA-15	Damage to any of LANL infrastructure, design level is 0.22 G for DARHT, current expectation is 0.5 to 0.6 G for max. earthquake.

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Chapter 5
Environmental Consequences

CHAPTER 5
ENVIRONMENTAL CONSEQUENCES

This chapter describes the potential environmental impacts associated with the various alternatives:

- No Action Alternative (status quo)
- Preferred Alternative (complete and operate the Dual Axis Radiographic Hydrodynamic Test (DARHT) facility)
- Upgrade Pulsed High Energy Radiation Machine Emitting X-Rays Facility (PHERMEX) Alternative (upgrade PHERMEX to DARHT capabilities)
- Enhanced Containment Alternative (DARHT facility plus vessels or building)
- Plutonium Exclusion Alternative (no experiments with plutonium at the DARHT Facility)
- Single-Axis Alternative (operate only one axis of the DARHT Facility).

This chapter describes the potential environmental impacts, or changes, which would be expected to occur over the next 30 years if any of the alternatives analyzed in this EIS were implemented. Environmental impacts are described in terms of the various aspects of the affected environment which would be expected to change over time. The environmental impacts expected from the No Action Alternative are those associated with maintaining the status quo. The impacts from the No Action Alternative are discussed first to provide a basis of comparison for the impacts expected from the other alternatives. The environmental impacts that would be expected if any other alternative were to be implemented are described as a comparison to the impacts of the No Action baseline – whether the impacts would be the same or different. The discussion in this chapter is augmented by the classified supplement for this EIS.

Aspects of the environment which would not be expected to be affected (changed) as a result of implementing any of the six alternatives analyzed are not discussed in this EIS. In most cases, impacts among the six alternatives are similar, and are cross-referenced but not repeated in detail. The analyses in this EIS indicate that there would be very little difference in the environmental impacts among the alternatives analyzed. The major discriminator among alternatives would be potential impacts from depleted uranium contamination to soils, which would be substantially less under the Enhanced Containment Alternative, and commitments of construction materials, which would be substantially greater under the Upgrade PHERMEX alternative. A summary table of impacts is provided at the end of chapter 3 (table 3-3). The table provides direct comparisons of expected consequences for each environmental factor across the alternatives.

Sums and products of numbers in the chapter may not appear consistent because of rounding. Unless otherwise stated, the word dose refers to the effective dose equivalent.

5.1 NO ACTION ALTERNATIVE

This section presents the expected environmental consequences associated with the No Action Alternative.

5.1.1 Land Resources

5.1.1.1 Land Use

Continued dedication of about 11 ac (4 ha) in Technical Area (TA) 15 of the 28,000-ac (11,300-ha) LANL site for use of the PHERMEX Facility and 8 ac (3 ha) previously disturbed for DARHT construction would be consistent with current and past land uses at LANL and would have no reasonably foreseeable impact on established local land-use patterns.

5.1.1.2 Visual Resources

The PHERMEX Facility is an unobtrusive facility located in an isolated piñon/ponderosa pine forest area and is not accessible or readily visible from offsite; therefore, its continued use would have no impact on visual resources.

5.1.1.3 Regional Recreation

Although a variety of recreational opportunities are offered in the vicinity of LANL, only those individuals in areas relatively near TA-15 might be negatively impacted on occasion by noise associated with uncontained test firings at the PHERMEX site. Otherwise, no impacts on regional recreation would be expected.

5.1.2 Air Quality and Noise

Impacts on nonradiological air quality and the potential for noise impacts associated with the No Action Alternative of continued operation of PHERMEX are discussed in this section.

5.1.2.1 Air Quality

Air quality impacts in this section are presented for the maximally impacted point of unrestricted public access. These impacts were determined using methods described in appendix C, Air Quality. The long-term (annual) and short-term (24 h or less) average pollutant concentrations are calculated at 1.1 mi (1.8 km) south of the facility and 0.9 mi (1.5 km) southwest of the facility, respectively. Air quality impacts associated with transportation of materials are described in section 5.7.

5.1.2.1.1 Construction

No construction activities are planned for the No Action Alternative; however, minor temporary impacts on air quality might occur as a result of fugitive dust from backfilling associated with a recently emplaced concrete pad for the Ector and diesel-fueled equipment used in the placement of the device and cleanup of debris.

5.1.2.1.2 Operations

Pollutant emissions are primarily from hydrodynamic testing; in particular, the detonation of high-explosive materials and gaseous suspension of associated test materials. High explosives would emit NO_2 and particulate matter (all of the aerosolized material is assumed to be respirable, i.e., classed as PM_{10}). The explosives used in testing do not contain sulfur compounds; however, minor amounts of SO_2 would be released from diesel-powered forklifts or other equipment used in setting up the tests. Estimates of maximum air quality impacts from hydrodynamic testing activities are provided in table 5-1. Impacts on air quality from operation of a gas-fired boiler are provided in table 5-2. The standards for NO_2 and SO_2 are adjusted for elevation, based on the New Mexico Air Pollution Control Bureau Dispersion Modeling Guidelines. This adjustment provides an extra measure of conservatism.

The average inventory of metals in each assembly is 110 lb (50 kg) depleted uranium, 8 lb (4 kg) lead, and 1 lb (0.5 kg) beryllium. The assumption is that ten percent of the metals would be aerosolized. Concentrations of these metals in air are regulated by the New Mexico Ambient Air Quality Standards, and their estimated impacts are shown in table 5-1. The estimate of concentrations is based on two experiments per month. The estimated impact for lead is shown separately for comparison to the National Ambient Air Quality Standard. The ambient air concentrations for uranium, lead, and beryllium are for the maximally exposed individual located 0.9 mi (1.5 km) southwest of the site. Impacts on ambient air from testing operations are considered minor. See table 4-3 for a listing of the nonradiological ambient air quality standards.

Increases in the annual concentrations of NO_2 and PM_{10} over ambient would be small; concentrations of these pollutants would remain well within the applicable standards. Maximum offsite 24-h PM_{10} concentration would be on the order of the average ambient air concentration of PM_{10}, but the combination of the two (PHERMEX-related concentration plus ambient air concentration) would be less than five percent of the most stringent air quality standard.

Although the accelerators are pulsed about 25,000 times per year, the duration of the pulse is about 200 nsec. Hence, the total operating time would be about 5 thousandths of a second per year suggesting that formation of ozone would be negligible.

Waste wood from the platforms used to support the experiments is taken to TA-36 for disposal in an open burn permitted by the New Mexico Environment Department (NMED). This wood is potentially contaminated with high explosives and/or depleted uranium. Dose dispersion calculations performed in support of the permit application estimated the effective dose equivalent at the nearest resident of 1.1×10^{-8} rem to 2.9×10^{-8} rem (DOE 1993). The NMED Air Quality Bureau concluded that there would be no health effects from this source (NMED 1993).

TABLE 5-1.—*Impacts on Air Quality from Hydrodynamic Testing in the No Action Alternative*

Pollutant	Averaging Time	Maximally Impacted Point of Unrestricted Public Access ($\mu g/m^3$)	Percent of Regulatory Limit
NO_2	Annual	9.9×10^{-4}	1.4×10^{-3}
	24-h	0.92	6.3×10^{-1}
PM_{10}	Annual	6.6×10^{-3}	1.3×10^{-2}
	24-h	3.2	2.1
Beryllium	30 days	5.0×10^{-4}	4.9×10^{-2}
Heavy Metals[a]	30 days	5.3×10^{-2}	5.3×10^{-3}
Lead	Calendar Quarter	2.6×10^{-3}	1.5×10^{-3}

[a] Sum of the air concentration of uranium and lead.

TABLE 5-2.—*Impacts on Air Quality from Emissions from the Natural Gas Boiler in the No Action Alternative*

Pollutant	Averaging Time	Maximally Impacted Point of Unrestricted Public Access ($\mu g/m^3$)	Percent of Regulatory Limit
NO_2	Annual	0.036	5.0×10^{-2}
	24-h	1.1	7.6×10^{-1}
PM_{10}	Annual	0.0043	8.6×10^{-3}
	24-h	0.13	8.7×10^{-2}
SO_2	Annual	2.2×10^{-4}	5.4×10^{-4}
	24-h	0.0064	3.2×10^{-3}
	3-h	0.033	3.3×10^{-3}

Other radiological impacts on air quality are described in section 5.1.8, Human Health.

5.1.2.2 Noise

Noise predictions were based on measurements made March 11, 1995, during a series of test explosions designed to investigate noise and shock wave behavior. Uncontained hydrodynamic testing, using high explosives similar to those used on the past at PHERMEX [150 lb (70 kg) maximum] would not exceed daytime standards for noise at nearby locations, such as Los Alamos or White Rock (appendix C, Air

Quality and Noise). To be within Los Alamos County residential noise guidelines, propagated level between 65 and 75 dBA is prohibited to exceed for 10 minutes in a given hour between 7:00 am and 9:00 pm. Operating procedures and safety concerns limit the number of detonations to no more than three in one hour period, hence it is not possible to exceed this limit. Noise exceeding 75 dBA is not permitted. However, because blast noise is sensitive to meteorological conditions, peak daytime standards of 75 dBA may be exceeded for large tests under unfavorable weather conditions, particularly at the ranger residence at Bandelier National Monument. For other than small tests close to the facility, nighttime standards (53 dBA) probably would be exceeded.

The general good health and abundance of wildlife in the Bandelier National Monument and on the LANL site indicate no impact on populations of wildlife from operations at the site. However, during the previously mentioned tests, browsing mule deer exhibited a startle and flight response on the first test, indicating that wildlife have not become indifferent to firing noise. On the other hand, birds did not appear to be disturbed by the noise.

Worker protection from noise would be provided in the form of ear muffs or ear plugs depending on the expected noise levels associated with PHERMEX activities.

Because of the limited amount of vehicular traffic associated with the operation of PHERMEX, traffic would not be a significant source of additional noise. Vehicular noise is exempted from Los Alamos County noise regulations.

5.1.3 Geology and Soils

Impacts of the No Action Alternative on geology and soils are described in the following subsections.

5.1.3.1 Geology

Continued operation of the PHERMEX facility would incur no new geologic hazards. PHERMEX has more than 30 years of operations history without site stability problems (see section 4.3.4 Site Stability).

5.1.3.2 Seismic

Seismically induced rockfalls could occur at the mesa rims, but the annual probability for earthquakes is low, and the PHERMEX facility has sufficient setback from the mesa rim to be unaffected by earthquakes during its design life (see section 4.3.4, Site Stability). Vibratory ground motion resulting from the detonation of high explosives is small, in general, being less than the ground motion pulse caused by the air wave from the same detonation.

Although seismic events damaging buildings would have an impact on mission goals, no scenarios were identified wherein a seismic event could trigger an action at the PHERMEX Facility that would result in any offsite environmental impacts.

5.1.3.3 Soils

Operating PHERMEX for an additional 30 years at a moderately higher level of testing, as compared to that of the last 32 years, would result in soil contamination levels approximately double those observed today at PHERMEX. Under the No Action Alternative, maximum average depleted uranium soil contamination in the vicinity of the firing point is not anticipated to be greater than about 9,000 ppm diluted uranium after 30 more years of operation (see appendix D). The present PHERMEX firing site has a soils contamination circle around the firing point of about 460-ft (140-m) radius. Inside this circle, soils are at or above the background concentration for uranium; outside this circle, soils exhibit background concentrations. Because the variety and magnitude of explosive charges to be used in future tests will resemble those previously tested at PHERMEX, the area around the firing point where soils would exhibit uranium concentrations above background is anticipated to remain approximately the same, i.e., a circle with a 460-ft (140-m) radius. The area of land contaminated above background would be about 15 acres (6 ha). Soils sampling has shown that beryllium and lead contamination falls to background levels much closer to the firing point than uranium contamination. Thus, the soil contamination circle defined for uranium would apply to the other metals of interest. Concentrations of metal contaminants in sediments within drainage channels may approximately double also; however, diluted uranium concentrations have been observed to significantly decrease with increasing distance from the firing point. Contaminants within the soil contamination circle would be available for migration in surface runoff to the canyons and deep drainage through the mesa.

5.1.4 Water Resources

Water resources examined for impact in the No Action Alternative are:

- Surface water and sediment in Potrillo and Water Canyons which discharge into the Rio Grande
- The main aquifer underlying Threemile Mesa.

The water quality of surface water entering the discharge sink in Potrillo Canyon is assumed to be an estimate of the quality of water that may ultimately recharge the main aquifer from this area. Stream losses to the bed of Water Canyon are analyzed for their potential to migrate through the vadose zone to the main aquifer. Infiltration is examined for its ability to carry metals in solution into the mesa top at the firing point and communicate contaminants through the unsaturated zone to the main aquifer. Supporting information on deep drainage, the geochemistry of metals in LANL waters and sediments, surface water modeling, and vadose zone and ground water modeling as applied in this EIS can be found in appendix E.

A combination of data review and geochemical analysis was used to determine the solubility and sorption characteristics of several metals in the LANL water and soil/sediment environment (see appendix D2). Because they represent the largest fraction of expended materials in the tests to be conducted, depleted uranium, beryllium, lead, copper, and aluminum were all studied. The study revealed that realistic assignment of solubility for beryllium and lead yielded values at about the drinking water standard for both metals. Values of solubility for both copper and aluminum were both found to be substantially below their secondary drinking water standards. Thus, while the analysis examines the migration of beryllium and lead to gain insight into their migration and behavior in the environment, there is no need to simulate beryllium, lead, copper, or aluminum. The solubility of uranium in LANL waters appeared to be substantially above its proposed maximum concentration level (MCL) value, and therefore its migration was modeled to estimate impact on the water resource.

5.1.4.1 Surface Water

The hydrology-sediment-contaminant transport modeling procedure described in appendix E3 was applied to assess the potential impacts of the No Action Alternative. In this alternative, the transport by surface runoff during the past 32 years for releases of depleted uranium, beryllium, and lead and for releases during the next 30 years from the PHERMEX site was analyzed. Table 5-3 shows the simulated peak concentration of contaminants in the infiltrated water at the discharge sink in Potrillo Canyon and at Water Canyon channels below the source (see appendix E3).

Because of their low solubility, the concentrations of beryllium and lead reach a plateau in their release to Potrillo and Water Canyons but still remain well below drinking water standards. MCLs for beryllium and lead are 4 and 50 µg/L, respectively. Depleted uranium has a relatively high solubility in LANL surface and ground waters. While releases of depleted uranium to the discharge sink of Potrillo Canyon are an order of magnitude below the proposed MCL (20 µg/L), simulations reveal that concentrations of depleted uranium in surface waters released to Water Canyon immediately below PHERMEX could be slightly above the proposed MCL. The Rio Grande is the nearest off-LANL access point for surface water carrying contamination from the firing point. As shown in table 5-3, the quality of surface water entering the Rio Grande is forecast to be more than an order of magnitude below the drinking water standard for uranium and several orders of magnitude below the drinking water MCLs for beryllium and lead.

5.1.4.2 Ground Water

Two analyses of contaminant migration in ground water were conducted. Stream losses into the bed of Water Canyon were analyzed to estimate the migration of contaminants through the vadose zone to the main aquifer. Similarly, infiltration carrying metal in solution into the mesa top at the PHERMEX firing point was analyzed to estimate contaminant migration to the main aquifer.

The peak concentrations of metals in infiltration to Threemile Mesa and in surface water losses from the uppermost reach of Water Canyon opposite the PHERMEX facility are shown in table 5-4. For those cases where the MCLs (shown in bold) are exceeded, analyses are necessary. Only two cases must be modeled: 1) depleted uranium in the uppermost reach of Water Canyon and 2) depleted uranium on the mesa top at the firing point. Releases of beryllium and lead were analyzed in this case only to better understand the influence of dispersion and sorption on the migration of these and less mobile metals.

Analysis of depleted uranium migration through the vadose zone arising from releases to the stream bed of Water Canyon showed a peak concentration of about 0.02 µg/L after nearly 20,000 years in soil water being delivered to the main aquifer. Simulation of depleted uranium migration through the mesa to the main aquifer showed a peak concentration of about 150 µg/L after approximately 40,000 years. Water Canyon stream losses yield soil water entering the main aquifer at concentrations well below the proposed MCL for uranium (20 µg/L); however, releases from the firing point on the mesa top yield soil water concentrations approximately eight times the MCL. Upon entering the main aquifer, the small-scale and low-volume releases from the mesa top would be dispersed in the aquifer and further mixed either with

TABLE 5-3.—*Contaminant Concentrations and Time-to-Peak for the No Action Alternative*

Contaminant	Discharge Sink (Potrillo Canyon) (μg/L)	Reach 12 (Water Canyon) (μg/L)	Reach 13 (Water Canyon) (μg/L)	Reach 14 (Water Canyon) (μg/L)	Reach 15 (Water Canyon) (μg/L)	Rio Grande (In solution) (μg/L)	RioGrande (on sediment) (μg/g)
Peak Concentration							
Depleted Uranium	1.97	2.81×10^{1}	5.92	1.68	6.61×10^{-1}	6.79×10^{-1}	6.79×10^{-2}
Beryllium	1.09×10^{-3}	1.58×10^{-3}	7.03×10^{-4}	3.01×10^{-4}	1.43×10^{-4}	1.43×10^{-4}	1.43×10^{-5}
Lead	4.22×10^{-3}	3.87×10^{-3}	2.18×10^{-3}	4.98×10^{-4}	1.81×10^{-4}	1.85×10^{-4}	3.62×10^{-4}
Time, years							
Depleted Uranium	363	39	89	98	98	98	98
Beryllium	4337	744	4352	2573	4128	4128	4128
Lead	4995	1854	2573	2573	4660	4660	4537

Note: Drinking Water Standards.

Depleted Uranium, 20 μg/L [56 FR 33050]
Beryllium, 4 μg/L [40 CFR 141.62]
Lead, 50 μg/L [40 CFR 141.11]

Table 5-4.—*Peak Input Concentrations (μg/L) Under No Action Alternative to Water Canyon Reaches and Threemile Mesa Predicted by Surface Runoff-Sediment-Contaminant Transport Model*

Location	Contaminant		
	Depleted Uranium	Beryllium	Lead
Maximum Concentration Level	**20 [56 FR 33050]**	**4 [40 CFR 141.62]**	**50 [40 CFR 141.11]**
Threemile Mesa	**300,000**	4	50
Water Canyon Reach 12	**28**	0.0016	0.0039
Water Canyon Reach 13	5.9	0.00070	0.0022
Water Canyon Reach 14	1.7	0.00030	0.00050
Water Canyon Reach 15	0.66	0.00014	0.00018

ground water (if it were recovered in the municipal water supply well), or with the waters of the Rio Grande. The average yield of the Pajarito Field wells of 1,215 gpm (0.07665 m^3/s) is assumed to be representative of a water supply well which could be developed in the vicinity of Threemile Mesa (see appendix E4). The total flow rate of contaminated water from the mesa top firing point would be 0.51 gpm (3.23×10^{-5} m^3/s). This gives a concentration reduction factor greater than 2,000, more than sufficient to reduce the concentration of depleted uranium in municipal water supplies to levels well below the proposed MCL. Based on the average annual flow rate of the Rio Grande, the reduction factor would be even greater for ground water release to the Rio Grande.

Both beryllium and lead releases to the stream bed of Water Canyon and the mesa were analyzed for migration to the main aquifer. The quality of surface water infiltrating the stream bed and mesa is initially below MCLs for both these metals (i.e., 4 and 50 μg/L respectively); therefore, releases to the main aquifer will be well below the MCLs after undergoing dispersion and sorption in the vadose zone. After 100,000 years in the canyon, beryllium release is less than 0.001 μg/L, and the lead release is less than 1.0×10^{-5} μg/L. From the mesa, the beryllium release is less than 4 μg/L and the lead release is less than 30 μg/L.

Releases to the ground water pathway from operation under the No Action Alternative would not adversely impact ground water quality.

5.1.5 Biotic Resources

Biotic resources examined for impact in the No Action Alternative include terrestrial resources, wetlands, aquatic resources, and threatened and endangered species.

5.1.5.1 Terrestrial Resources

Both construction and operation impacts were evaluated for terrestrial resources.

5.1.5.1.1 Construction Impacts

Under the No Action Alternative, no further construction-related impacts to terrestrial biological resources would be expected at the PHERMEX or DARHT sites. Impacts for small and large mammals and birds would continue from construction that has already altered approximately 8 ac (3 ha) of piñon-juniper/ ponderosa pine habitat (Risberg 1995). Further losses of habitat and harassment to biota from noise and human activities would not occur. Populations of plants and animals from surrounding areas may reinvade the site and colonize those parts of the site that provide habitat. Habitat destruction has most likely already caused small mammals formerly occurring there to disperse into similar surrounding habitat, or, less likely, to have died. It is not known if the increased density of small mammals resulting from this emigration would have any impacts on populations already inhabiting the surrounding area. It is most likely they would be absorbed into existing populations.

5.1.5.1.2 Operation Impacts

Test fragments originating from continued use of PHERMEX are highly unlikely to further impact terrestrial biota; however, tests often start grass fires. These fires are quickly controlled by the firefighters who are stationed outside the exclusion fence at the time of the tests. However, some disturbance, and possibly mortality, with respect to some individual plants and animals might occur. Confirmed nesting sites and hunting areas for the red-tailed hawk and the Cooper's hawk have been documented in the PHERMEX site vicinity; other raptors, such as the American kestrel, the flammulated owl, and the great-horned owl use the area. Although not listed as threatened or endangered, these species are protected from collection and maiming under the Migratory Bird Treaty Act (Risberg 1995). No additional impacts to these species are expected under this alternative.

The concentration of depleted uranium and metals in the soil and plants is expected to remain negligible. Consequently, no additional impacts to biotic resources due to biological uptake of these substances is expected to occur under this alternative.

5.1.5.2 Wetlands

Although floodplains lie at the bottom of Potrillo Canyon and Cañon de Valle, no wetlands lie within TA-15; thus, no impacts to wetlands would occur (Risberg 1995).

5.1.5.3 Aquatic Resources

No additional impacts to the aquatic resources located within the canyons surrounding TA-15 is expected.

5.1.5.4 Threatened and Endangered Species

It is unlikely that ongoing activities at PHERMEX would change the attractiveness of the area for potential use by threatened or endangered species. The concentration of depleted uranium and metals in foodstuffs of threatened and endangered species is expected to remain negligible. Ingestion of these substances is not expected to have any consequences to these populations.

5.1.6 Cultural and Paleontological Resources

Impacts on cultural and paleontological resources from the No Action Alternative are described in the following subsections.

5.1.6.1 Archeological Resources

Continuation of normal operations of the PHERMEX Facility would not change any direct or indirect impacts on known archeological sites eligible for the National Register. Debris from 30 years of testing at PHERMEX is observable in the immediate vicinity of archeological sites, especially those sites within the 490 ft (150 m) blast radius. This debris, however, has not changed the research potential of any of the identified archeological sites. As stated, an additional archeological survey is underway in those areas unsurveyed. A minimal number of new archeological sites is expected to be found as a result of this survey, but any new sites would be expected to be similar in nature to those already recorded. Impacts to any new sites are therefore expected to be the same as for the sites previously identified.

Seismic tests conducted on March 11, 1995 (Vibronics 1995) indicated that potential impacts due to the air waves is a greater concern than vibratory ground motion. An explosion of 150 lb of TNT at PHERMEX would give an overpressure of 0.02 psi (12 kg/m^2) at Nake'muu. This overpressure, 0.02 psi (12 kg/m^2), is approximately one-tenth the amount for window breakage and would not affect the standing walls at Nake'muu (DOE 1992, table D.4-4).

5.1.6.2 Historical Resources

No direct or indirect impacts on historic structures are anticipated.

5.1.6.3 Native American Resources

Consultation with the San Ildefonso Pueblo is ongoing, and no impacts on Native American cultural resources have been identified at this time. If any impacts are identified, they will be reported in the final EIS.

5.1.6.4 Paleontological Resources

Because of the nature of the soil and geological substrate, the occurrence of paleontological resources is not anticipated; no potential effects are postulated.

5.1.7 Socioeconomics and Community Services

Environmental impacts on socioeconomics and community services for the No Action Alternative are presented in the following subsections.

5.1.7.1 Demographic Characteristics

The No Action Alternative would not stimulate any change in the existing demographic characteristics of communities within the region-of-interest, as described in section 4.7.1.

5.1.7.2 Economic Activities

The No Action Alternative is not expected to have a significant impact on the level of economic activity in the region-of-interest. Under this Alternative, the PHERMEX facility would continue operations while DARHT-related capital funding would be phased out during FY 1995 and FY 1997, as indicated in table 5-5. The funding of PHERMEX operations would continue to support a variety of personnel, including operations support staff, physics support staff, security clearance staff, and a firing crew. The operations funding also covers the costs of facility scheduling, facility space tax, and safety and environmental compliance.

The underlying cost data in table 5-5 were provided by LANL (Burns 1995). The costs do not include any expenses associated with site cleanup, nor do they include any decontamination or decommissioning costs associated with either the proposed DARHT or PHERMEX facilities. The construction and operations costs were adjusted for future price escalation based on the escalation price change index for DOE defense-related construction projects (Pearman 1994; Anderson 1995). A discussion of the analytical model, assumptions, and procedures underlying the economic impact analysis of the various DARHT alternatives relative to the No Action Alternative is provided in appendix G, Socioeconomic Environment.

TABLE 5-5.— *Capital-Funded Construction and Operating Costs Under No Action Alternative (in millions of 1994 dollars)*

Year/Cost	1995	1996	1997	1998	1999	2000	2001	2002
Capital	6.61	5.88	1.04	0	0	0	0	0
Operations and Maintenance	4.17	4.30	4.43	4.58	4.73	4.88	5.03	5.19

5.1.7.3 Community Infrastructure and Services

The existing community infrastructure in the region-of-interest under the No Action Alternative would be the same as described in section 4.7.3. No significant change in the existing community infrastructure under the No Action Alternative is expected.

5.1.7.4 Environmental Justice

No significant adverse environmental impacts are identified with the continued operation of the PHERMEX Facility. Specifically, these environmental impacts include offsite (fugitive) air and noise emissions caused by the detonation of high explosives (section 5.1.2) and surface or underground water contamination (section 5.1.4). Also, no significant human health impacts appear to exist from either the release of radioactive or hazardous material or from exposing receptors onsite (workers) or offsite (section 5.1.8). Continued PHERMEX Facility operations would have no known disproportionate adverse health or environmental impact on minority or low-income populations in the region-of-interest [populations residing within 50 mi (80 km) of the site].

5.1.8 Human Health

This section presents the impacts to the health of the public and workers from routine operations that would be conducted at the PHERMEX Facility under the No Action Alternative. Impacts may potentially result from routine release and atmospheric transport of radioactive and hazardous material from the facility firing site as a result of planned detonations. Detailed results and methods and assumptions used in calculating potential impacts are described in appendix H, Human Health.

Radiological impacts may result from exposure to depleted uranium and tritium released to the atmosphere from detonations at the PHERMEX site. Depleted uranium would be the principal contributor to radiation dose; tritium would contribute about 1×10^{-7} the dose of depleted uranium for chronic releases. The major exposure pathway would be inhalation of material released to the atmosphere, which would contribute more than 99 percent of the dose. Potential human health impacts may be *over-estimated* by a factor of 100 because of the simplified, elevated point-source atmospheric dispersion model used, rather than an explosive atmospheric dispersion model (see appendix H, Human Health).

5.1.8.1 Public

Potential impacts to the maximally exposed individual (MEI) were evaluated at three locations in the vicinity of the PHERMEX site: Los Alamos, White Rock, and Bandelier. These locations are representative of the neighboring residential clusters of LANL. Potential impacts to the surrounding population were also calculated. Potential radiological and nonradiological impacts are presented in the sections below.

5.1.8.1.1 Radiological Impacts

The maximum annual radiation dose to any nearby resident from routine operations would not exceed 2×10^{-5} rem EDE. Using a risk conversion factor of 5×10^{-4} latent cancer fatalities (LCFs) per person-rem for members of the public, the estimated maximum probability of a latent fatal cancer from this dose would be about 1×10^{-8}. The estimated maximum cumulative dose to an individual over the anticipated 30-year life of the project would be about 7×10^{-4} rem. The estimated maximum probability of a latent cancer fatality from this dose would be about 4×10^{-7}.

The annual collective dose to the population residing within 50 mi (80 km) of the PHERMEX site would be about 0.9 person-rem EDE. Latent cancer fatalities would not be expected among the population from this dose (5×10^{-4} LCFs).

5.1.8.1.2 Nonradiological Impacts

Members of the public might also be exposed to heavy metals and other materials released during the detonation, including uranium, lead, beryllium, and lithium hydride. The maximum probability of a beryllium-induced cancer would be about 4×10^{-11}. Toxicological effects from releases of uranium, beryllium, lead or lithium hydride would not be expected (maximum Hazard Index of 1×10^{-7}). The cumulative probability of a beryllium-induced cancer over the anticipated 30-year life of the project would be about 1×10^{-9}. The maximum Hazard Index expected in the first year immediately after 30 years of operations, accounting for any toxicological effects from buildup of hazardous material in soil, would not exceed 1×10^{-7}. Toxicological effects would not be expected.

Cancer from exposure to beryllium released during a year of normal operations (total incidence of 4×10^{-7} cancers) would not be expected in the population in a 50-mile (80-km) radius.

5.1.8.2 Noninvolved Workers

A noninvolved worker is defined as a LANL employee who works in TA-15, but is not directly involved with the facility operations. This worker would be assumed to work continuously 2,500 ft (750 m) distant from the firing site. This distance would be based on a hazard radius that would typically be put in place for hydrodynamic testing. LANL implements this administrative exclusion area based on explosive safety principles (DOE 1994).

The annual dose to a nearby noninvolved worker would be 2×10^{-5} rem EDE. Using a risk conversion factor of 4×10^{-4} LCFs per person-rem for workers, the maximum probability of an LCF from such a dose would be about 9×10^{-9}. Over the 30-year anticipated operating life of the facility, the same noninvolved worker's cumulative dose would be about 6×10^{-4} rem. The maximum cumulative probability of contracting a fatal cancer from this dose would be about 3×10^{-7}.

A noninvolved worker could also be exposed to heavy metals and other materials released during the detonation, including uranium, lead, beryllium, and lithium hydride. The maximum probability of a beryllium-induced cancer would be about 3×10^{-11}. Toxicological effects from releases of uranium, beryllium, lead or lithium hydride would not be expected (maximum Hazard Index of 2×10^{-7}). The probability of a beryllium-induced cancer over the anticipated 30-year life of the project would be about 9×10^{-10}. The maximum Hazard Index expected after 30 years of operations, accounting for any toxicological effects from buildup of hazardous material in soil, would not exceed 1×10^{-7}. Toxicological effects would not be expected.

5.1.8.3 Workers

Average dose to workers at the facility was estimated to be no more than 0.01 rem EDE annually. The maximum probability of such a worker contracting a latent fatal cancer would be 4×10^{-6}. Over the 30 year operating life of the facility an involved worker's maximum probability of contracting a latent fatal cancer would be about 1×10^{-4}. The annual collective worker dose was estimated to be about 0.3 person-rem/year. No LCFs would be expected among the worker population from this dose (1×10^{-4} LCFs). The cumulative worker dose over the anticipated 30-year life of the project would be about 9 person-rem. No LCFs would be expected among the worker population from this dose (4×10^{-3} LCFs). These estimates were based on past PHERMEX operating experience. No operating information was available on exposure to chemicals or metals. The risks of exposure to these materials would be expected to be similarly low to those for radiation exposure.

Worker exposures to radiation and radioactive materials under normal operations would be controlled under established procedures that require doses to be kept as low as reasonably achievable. Any potential hazards would be evaluated as part of the radiation worker and occupational safety programs at LANL, and no impacts outside the scope of normal work activities would be anticipated.

5.1.9 Facility Accidents

This section presents the impacts from postulated facility accidents to members of the public, noninvolved nearby workers, and workers at the facility. The bounding accident evaluated under the No Action Alternative was the inadvertent detonation of a test assembly on the PHERMEX firing site. Accident initiation events are not addressed; instead, the accidents were evaluated on a "what if" basis even though the likelihood of occurrence is very small. More detailed results, identification of postulated facility accidents, and methods of analysis are described in greater detail in appendix I, Facility Accidents. Much of the technical basis for the health impact of the accident analysis is included in appendix H, Human Health. Transportation-related accidents are described in section 5.7.

Radiological impacts may result from exposure to depleted uranium and tritium released from the PHERMEX site. Depleted uranium would be the principal contributor to radiation dose; tritium would contribute about 1×10^{-8} the dose of depleted uranium for acute releases. The major exposure pathway would be inhalation of material released to the atmosphere, which would contribute more than 99 percent of the dose. Potential human health impacts may be *over-estimated* by a factor of 100 because of the simplified, elevated point-source atmospheric dispersion model used rather than an explosive atmospheric dispersion model (see appendix H Human Health).

In the past, DOE has conducted dynamic experiments at LANL with plutonium. Such experiments also may be conducted in the future. Experiments with plutonium would always be conducted in double-walled containment vessels, and these experiments could not reasonably be expected to result in any release of plutonium to the environment. However, for purposes of this EIS, health consequences of hypothetical accidental releases of plutonium have been estimated and are provided in appendix I.

5.1.9.1 Public

Potential impacts to individual members of the public were evaluated for three nearby points of public access – State Road 4, Pajarito Road, and the Bandelier National Monument. The maximally exposed individual was located at the State Road 4 location, approximately 0.9 miles (1.5 km) southwest of the site. An individual at this location under the assumed accident and exposure conditions would receive a radiation dose of about 6×10^{-4} rem EDE. The maximum probability of an LCF from such a dose would be about 3×10^{-7}. The maximum probability of a beryllium-induced cancer would be about 4×10^{-10}. Toxicological effects would not be expected, as no more than 0.01 mg of any of the released constituents (uranium, beryllium, lead, lithium hydride) would be inhaled, and air concentrations would be less than 0.1 percent of the applicable immediately dangerous to life and health (IDLH) values. Additional results are presented in appendix I, Facility Accidents.

Population impacts of acute accidental releases were evaluated for the direction that would result in the highest impact. Population in the maximally exposed, 22.5 degree sector (east through southeast) out to 50 mi (80 km) is about 50,000 (appendix H, Human Health, table H.3.1-2). Dose to the population in the maximally exposed direction (east-southeast) would be about 13 person-rem. Latent fatal cancers among the population would not be expected from this dose (7×10^{-3} LCFs). Cancer would not be expected among the population from exposure to beryllium (total incidence of 9×10^{-7} cancers).

5.1.9.2 Noninvolved Workers

For the bounding accident analysis, a noninvolved worker was assumed to be outside the facility hazard radius, at a distance of 2,500 ft (750 m), and exposed to the plume of material released from the detonation during the entire period of passage. This distance was based on a hazard radius that would typically be put in place for hydrodynamic tests. LANL implements this administrative exclusion area based on explosive safety principles (DOE 1994). This worker would receive a radiation dose of about 7×10^{-4} rem EDE. The maximum probability of LCF from this dose would be about 3×10^{-7}. The maximum probability of a beryllium-induced cancer would be about 5×10^{-10}. Toxicological effects would not be expected as no more than 3.5×10^{-7} oz (0.01 mg) of any of the released constituents (uranium, beryllium, lead, lithium hydride) would be inhaled, and air concentrations would be about 0.2 percent of the applicable IDLH values. Additional results are presented in appendix I, Facility Accidents.

5.1.9.3 Workers

Workers may be subject to explosive, radiological, chemical, and industrial hazards while working at the PHERMEX Facility. These hazards are typically expected within normal industrial or laboratory workplaces and are controlled by worker protection programs in place at LANL. High explosives and radioactive material are not allowed in PHERMEX; therefore, only ordinary industrial and laboratory hazards are present inside the PHERMEX Facility. The firing site is where accidents outside the scope of normal industrial or laboratory accidents (that is, those involving high explosives and direct exposure to high levels of ionizing radiation) might occur.

Accidents on the PHERMEX firing site could range from those with trivial consequences to those that could be fatal to involved workers. Of greatest consequence would be the inadvertent detonation of high explosives on the firing site when workers are present, which, if it were to occur, might result in up to 15 worker fatalities. This accident is considered unlikely because of comprehensive training requirements, strict procedural control, physical interlocks and control of the fireset (detonating equipment), and limited personnel access. In the late 1950s, an explosives accident resulted in the deaths of four LANL workers (not associated with PHERMEX operations). That accident caused an extensive overhaul and upgrade of the explosive safety program. Since that accident, LANL has not experienced a high-explosive-related fatality, and such accidents are no longer considered reasonably foreseeable.

A possible second accident on the firing site with serious consequences outside the scope of ordinary industrial or laboratory hazards would be the direct exposure of a worker to the ionizing radiation pulse produced by the PHERMEX accelerator. Although this accident would be extremely unlikely, a worker could receive a very high acute radiation dose, delivered over a fraction of a microsecond, to a localized portion of the body. The potential for occurrence is reduced by physical lockout of accelerator controls when personnel are present on the firing site, high training requirements, strict procedural control, access control, and the fact that the accelerator beam pulse is very short-lived, lasting less than a microsecond. Direct exposure of workers to the accelerator beam has never occurred at LANL firing sites.

5.1.10 Waste Management

During the 2-year period from March 1992 through February 1994, the PHERMEX Facility disposed approximately 6,700 ft^3 (190 m^3) of low-level radioactive waste (LLW), representing up to four percent of the total LLW volume disposed at LANL during that period. Using depleted uranium usage as an indicator of overall program activity and LLW generation rates, estimates can be made of future waste generation levels. Since approximately 880 lb (400 kg) of depleted uranium were used at PHERMEX during this two-year period, approximately 1,800 ft^3 (50 m^3) LLW would be generated per 220 lb (100 kg) of depleted uranium used per year.

Yearly usage of depleted uranium under the No Action Alternative would be about 1,500 lb (700 kg). Applying the LLW generation rate of 1,800 ft^3 (50 m^3)/220 lb (100 kg), the estimated total LLW generated and disposed under the No Action Alternative would be about 12,500 ft^3 (350 m^3). The bulk of this waste would be the gravel and soil that is removed with the detonation debris. Total volume of waste generated would depend on the frequency of the firing-site detonations and periodic cleanup. Assuming the total LANL LLW disposal volume in future years will be 1.8×10^5 ft^3 (5,000 m^3)/yr (Bartlit et al. 1993), the No Action Alternative would contribute no more than seven percent of the total LANL LLW volume. (The LANL Sitewide EIS will address the water management matter at LANL.) Approximately 310 lb (140 kg) of solid hazardous waste and 2,500 lb (1100 kg) liquid hazardous waste would be disposed. This is based on estimated historical hazardous waste generation rates at the PHERMEX Facility of 220 lb (100 kg) of the solid hazardous waste and 1,800 lb (800 kg) of liquid hazardous waste disposed for every 1,100 lb (500 kg) of depleted uranium used in normal PHERMEX operations.

Mixed waste would consist of depleted uranium contaminated with lead. The amount of mixed waste to be stored would be small and not expected to exceed one 55 gal (0.2 m^3) drum or 220 lb (100 kg) per year. The volume of nonhazardous solid sanitary waste would be approximately one dumpster load per week.

Wastes generated under the No Action Alternative would be subject to treatment, storage, and/or disposal in other LANL Technical Areas. Transportation of these wastes would be conducted following U.S. Department of Transportation (DOT) guidelines and using Department of Energy- (DOE-) or DOT-approved containers carried on government vehicles using public roads between LANL facilities, as needed.

5.1.11 Monitoring and Mitigation

5.1.11.1 Monitoring

Environmental monitoring currently performed at LANL would continue under the No Action Alternative. Existing stations for monitoring external penetrating radiation and radioactive and hazardous substances in air, water, soil, and sediment would be used to monitor the environmental impacts of the facility. Air monitoring stations added in 1993 would serve as an enhanced air monitoring network for the PHERMEX Facility.

5.1.11.2 Mitigation

Consequences of activities under the No Action Alternative were not considered to be of sufficient magnitude to warrant mitigation measures that would differ significantly from the measures currently applied as part of normal operations at PHERMEX.

5.1.12 Decontamination and Decommissioning (D&D)

After continued operations for an indefinite period of time, the PHERMEX facility would become a candidate for decommissioning. While a D&D plan and NEPA review would be conducted at that time, the activities and impacts associated with D&D can be summarized as:

- Conversion of about 15,200 ft^2 (1,400 m^2) of office and laboratory space, or its demolition and disposal of the rubble as sanitary waste
- Salvage of useable items of equipment, instruments, machined parts, etc. to other LANL uses
- Characterization of wastes and treatment, storage and disposal of nonhazardous solid waste, hazardous radioactive and/or mixed wastes from the facilities and support equipment, containment vessels, and testing instrumentation.

Nonhazardous solid waste would be expected to be disposed at the Los Alamos County landfill. Appreciable waste volumes could result if buildings are demolished. Radioactive wastes are expected to be disposed in Los Alamos low-level waste facilities; however, the volumes would be expected to be negligible compared to LANL annual low-level waste volumes.

Hazardous and mixed-waste disposal requirements are expected to not exceed two to five times the annual PHERMEX generation rates, the higher value reflecting negotiated cleanup levels meeting RCRA "clean closure" criteria. These wastes would be treated and disposed in accordance with LANL RCRA permit requirements. It is not determined at this time whether on-site or off-site disposal would be chosen. The quantities would not be expected to appreciably impact existing treatment or disposal capacities.

5.2 PREFERRED ALTERNATIVE

This section presents the expected environmental consequences associated with the Preferred Alternative.

5.2.1 Land Resources

5.2.1.1 Land Use

Dedication (facility is already partially constructed) of about 8 ac (3 ha) in TA-15 of the 28,000-ac (11,300-ha) LANL site for completion of construction and operation of the DARHT Facility would be consistent with current and past land uses at LANL and would have no reasonably foreseeable impact on established local land-use patterns. The disposition of the 11 ac (4 ha) associated with PHERMEX is unknown at this time.

5.2.1.2 Visual Resources

The DARHT Facility, partially constructed, would be an unobtrusive facility located in an isolated piñon/ponderosa pine forest area and would not be accessible or readily visible from offsite: therefore, its use should have no impact on visual resources.

5.2.1.3 Regional Recreation

Although a variety of recreational opportunities are available in the vicinity of LANL, only those individuals in areas relatively near TA-15 might be negatively impacted (startled) on occasion by noise associated with uncontained test firings at the DARHT site. Otherwise, no impacts on regional recreation would be expected.

5.2.2 Air Quality and Noise

Impacts on nonradiological air quality and the potential for noise impacts associated with the Preferred Alternative are discussed in this section.

5.2.2.1 Air Quality

Air quality impacts for the Preferred Alternative in this section are presented for the maximally impacted point of unrestricted public access. These impacts were determined using methods described in appendix C, Air Quality and Noise. Depending on emission characteristics, time period for averaging pollutant concentrations, and other parameters, maximum air quality impacts to a member of the public could occur at one of the following locations:

- 0.9 mi (1.5 km) to the SW of the DARHT site alongside State Rd 4
- 1.7 mi (3 km) to the NE of the DARHT site alongside Pajarito Rd
- 3.1 mi (5 km) to the SSE of the DARHT site at Bandelier
- 2.7 mi (4 km) to the NNW of the DARHT site at Los Alamos
- 3.7 mi (6 km) to the ESE of the DARHT site at White Rock.

5.2.2.1.1 Construction

Air quality impacts for the Preferred Alternative were evaluated for emissions during both construction and operation phases of DARHT. Construction activities would emit NO_2, SO_2, and respirable particulates (PM_{10}). As a by-product of construction activities, PM_{10} would be emitted in the form of fugitive dust from earth moving. Table 5-6 presents air quality impacts from fugitive dust, and the resulting air quality impacts from operation of construction equipment are reported in table 5-7. Section 3.3.6 provides additional discussion of prior impacts associated with DARHT construction.

During the construction phase, the maximum offsite increases in ambient NO_2, SO_2, and PM_{10} from construction equipment would be very small, producing impacts well within the air quality standards. The offsite impact of fugitive dust emissions would also be small; the maximum increase in the 24-h average PM_{10} concentration would be about 10 percent of the federal standard. The use of standard dust suppression measures would further lower projected impacts.

5.2.2.1.2 Operations

For the most part, impacts on air quality from routine operations in the Preferred Alternative would be substantially the same as in the No Action Alternative described in section 5.1.2.1.

Although the accelerators are pulsed about 25,000 times per year, the duration of the pulse is about 60 nsec. Hence, the total operating time would be less than about two thousandths of a second per year, suggesting that formation of ozone would be negligible.

5.2.2.2 Noise

Noise in the Preferred Alternative would not be significantly different from that described for the No Action Alternative in section 5.1.2.2.

TABLE 5-6.—*Impacts on Air Quality from Fugitive Dust from Completing Construction in the Preferred Alternative*

Pollutant	Averaging Time	Maximally Impacted Point of Unrestricted Public Access ($\mu g/m^3$)	Percent of Regulatory Limit
PM_{10}	Annual 24-h	0.78 17	1.6 12

TABLE 5-7.—*Impacts on Air Quality from Construction Equipment Emission for the Preferred Alternative*

Pollutant	Averaging Time	Maximally Impacted Point of Unrestricted Public Access ($\mu g/m^3$)	Percent of Regulatory Limit
NO_2	Annual 24-h	4.1×10^{-2} 4.8	5.6×10^{-2} 3.3
PM_{10}	Annual 24-h	3.8×10^{-3} 6.0×10^{-2}	0.0076 0.040
SO_2	Annual 24-h 3-h	0.0025 0.34 22	6.2×10^{-3} 1.7×10^{-1} 2.2

5.2.3 Geology and Soils

Impacts of the Preferred Alternative on geology and soils are described in the following subsections.

5.2.3.1 Geology

Geotechnical investigations (Sergent 1988) found no potential problems for the DARHT Facility. PHERMEX has over 30 years of operation history without site stability problems (see section 4.3.4, Site Stability). It is the best analogue for future DARHT operation.

5.2.3.2 Seismic

Seismically induced rockfalls could occur at the mesa rim, but the annual probability for earthquakes is low, and the DARHT Facility has sufficient setback from the mesa rim to be unaffected by earthquakes during its design life (see section 4.3.4, Site Stability). Vibratory ground motion resulting from the detonation of high explosives is small, in general, being less than the ground motion pulse caused by the air wave from the same detonation.

Although seismic events that damage buildings would have an impact on mission goals, no scenarios were identified wherein a seismic event could trigger an action at the DARHT Facility that would result in any offsite environmental impacts.

5.2.3.3 Soils

Operating DARHT for the next 30 years at a moderately higher level of testing, as compared to that of the last 32 years of operating the PHERMEX Facility, is anticipated to result in soil contamination levels somewhat above, but not greatly above, those observed today at PHERMEX. Under the Preferred Alternative, maximum average depleted uranium soil contamination in the vicinity of the firing point is not anticipated to be greater than about 5,000 ppm after 30 years of operation (see appendix D). The present PHERMEX firing site has a soils contamination circle around the firing point of about 460 ft (140 m) radius. Inside this circle, soils are at or above the background concentration for uranium; outside this circle, soils exhibit background concentrations. Because the variety and magnitude of explosive charges to be used in future tests at DARHT will resemble those previously tested at PHERMEX, the area around the firing point where soils would exhibit uranium concentrations above background is anticipated to remain approximately the same, i.e., a circle with a 460-ft (140-m) radius. The area of land contaminated above background would be about 15 acres (6 ha). Soils sampling has shown that beryllium and lead contamination falls to background levels much closer to the firing point than uranium. Thus, the soil contamination circle defined for uranium would apply to the other metals of interest. Concentrations of metal contaminants in sediments within drainage channels is expected to be similar to that seen today in drainage channels at PHERMEX. Contaminants within the soil contamination circle would be available for migration in surface runoff to the canyons and deep drainage through the mesa.

5.2.4 Water Resources

Water resources examined for impact in the Preferred Alternative are:

- Surface water and sediment in Water Canyon which discharges into the Rio Grande
- The main aquifer underlying Threemile Mesa.

Stream losses to the bed of Water Canyon are analyzed for their potential to migrate through the vadose zone to the main aquifer. Infiltration is examined for its ability to carry metals in solution into the mesa top at the firing point and to communicate through the unsaturated zone to the main aquifer. Supporting information on deep drainage, the geochemistry of metals in LANL waters and sediments, surface water modeling, and vadose zone and ground water modeling as applied in this EIS can be found in appendix E.

A combination of data review and geochemical analysis was used to determine the solubility and sorption characteristics of several metals in the LANL water and soil/sediment environment (see appendix E). Because they represent the largest fraction of expended materials in the tests to be conducted, depleted uranium, beryllium, lead, copper, and aluminum were all studied. The study revealed that realistic assignment of solubility for beryllium and lead yielded values at about the drinking water standard for both metals. Values of solubility for both copper and aluminum were both found to be substantially below their secondary drinking water standards. Thus, while the analysis examines the migration of beryllium and lead to gain insight into their migration and behavior in the environment, there is no need to simulate beryllium, lead, copper, or aluminum. The solubility of uranium in LANL waters was found to be substantially above its proposed MCL value, and therefore its migration was modeled to estimate impact on the water resource.

5.2.4.1 Surface Water

The hydrology-sediment-contaminant transport modeling procedure described in appendix E3 was applied to assess the potential impacts of the Preferred Alternative. In this alternative, the transport by surface runoff during the next 30 years for releases of depleted uranium, beryllium and lead from the DARHT site was analyzed. Table 5-8 shows the simulated peak concentration of contaminants in the infiltrated water in Water Canyon below the source (see appendix E3).

Because of their low solubility, the concentrations of beryllium and lead reach a plateau in their release to Water Canyon but still remain well below drinking water standards. MCLs for beryllium and lead are 4 and 50 µg/L, respectively. Depleted uranium has a relatively high solubility in LANL surface and ground waters. Simulations reveal that concentrations of depleted uranium in surface waters released to Water Canyon immediately below DARHT could be slightly above the proposed MCL (20 µg/L). The Rio Grande is the nearest off-LANL access point for surface water carrying contamination from the firing point. As shown in table 5-8, the quality of surface water entering the Rio Grande is forecast to be more than an order of magnitude below the drinking water standard for uranium and several orders of magnitude below the drinking water MCLs for beryllium and lead.

5.2.4.2 Ground Water

Two analyses of contaminant migration were conducted. Stream losses into the bed of Water Canyon were analyzed to estimate the migration of contaminants through the vadose zone to the main aquifer. Similarly, infiltration carrying metal in solution into the mesa top at the DARHT firing point was analyzed to estimate contaminant migration to the main aquifer.

The peak concentrations of metals in infiltration to Threemile Mesa and in surface water losses from the uppermost reach of Water Canyon opposite the DARHT Facility are shown in table 5-9. For those cases where the MCLs are exceeded, (shown in bold), analyses are necessary. Only two cases were modeled; 1) depleted uranium in the uppermost reach of Water Canyon and 2) depleted uranium on the mesa top at the firing point. Releases of beryllium and lead to the soil column were not analyzed in this case because the solution concentrations entering the soil column are below the MCLs. Similar releases to the uppermost reach of Water Canyon were analyzed in the No Action Alternative and were shown to be negligible (see section 5.1.4.2). Because of sorption and dispersion within the vadose zone, and solubility limits in Los Alamos waters and sediments, the metals beryllium, lead, copper and aluminum would not represent a hazard through the ground water pathway.

TABLE 5-8.—*Contaminant Concentrations and Time-to-Peak for the Preferred Alternative*

Contaminant	Discharge Sink (Potrillo Canyon) (μg/L)	Reach 12 (Water Canyon) (μg/L)	Reach 13 (Water Canyon) (μg/L)	Reach 14 (Water Canyon) (μg/L)	Reach 15 (Water Canyon) (μg/L)	Rio Grande (in solution) (μg/L)	Rio Grande (on sediment) (μg/L)
Peak Concentration							
Depleted Uranium	0.0	3.0×10^{1}	6.3	1.80	7.06×10^{-1}	7.26×10^{-1}	7.25×10^{-2}
Beryllium	0.0	3.15×10^{-3}	1.41×10^{-3}	6.03×10^{-4}	2.38×10^{-4}	2.38×10^{-4}	2.38×10^{-5}
Lead	0.0	7.73×10^{-3}	4.37×10^{-3}	9.95×10^{-4}	2.92×10^{-4}	2.92×10^{-4}	5.84×10^{-4}
Time, years							
Depleted Uranium	0	30	89	98	98	98	98
Beryllium	0	744	4352	2573	4128	4128	4128
Lead	0	1854	2573	2573	4537	4537	4537

Note: Drinking Water Standards.

Depleted Uranium, 20 μg/L, [56 FR 33050]
Beryllium, 4 μg/L [40 CFR 141.62]
Lead, 50 μg/L [40 CFR 141.11]

TABLE 5-9.—*Peak Input Concentrations (μg/L) Under Preferred Alternative to Water Canyon Reaches and Threemile Mesa Predicted by Surface Runoff-Sediment-Contaminant Transport Model*

Location	Contaminant		
	Depleted Uranium	Beryllium	Lead
Maximum Concentration Level	**20 [56 FR 33050]**	**4 [40 CFR 141.62]**	**50 [40 CFR 141.11]**
Threemile Mesa	**300,000**	4	50
Water Canyon Reach 12	**30**	0.0032	0.0077
Water Canyon Reach 13	6.3	0.0014	0.0044
Water Canyon Reach 14	1.8	0.00060	0.0010
Water Canyon Reach 15	0.71	0.00024	0.00029

Analysis of depleted uranium migration through the vadose zone arising from releases to the stream bed of Water Canyon showed a peak concentration of about 0.02 μg/L after nearly 20,000 years in soil water being delivered to the main aquifer. Simulation of depleted uranium migration through the mesa to the main aquifer showed a peak concentration of about 80 μg/L after approximately 40,000 years. Water Canyon stream losses yield soil water entering the main aquifer at concentrations well below the proposed MCL for uranium (20 μg/L); however, releases from the firing point on the mesa top yield soil water concentrations approximately four times the MCL. Upon entering the main aquifer, the small-scale and low-volume releases from the mesa top would be dispersed in the aquifer and further mixed either with ground water (if it were recovered in the municipal water supply well), or with the waters of the Rio Grande. The average yield of the Pajarito Field wells of 2.7 ft^3/s (0.07665 m^3/s) is assumed to be representative of a water supply well which could be developed in the vicinity of Threemile Mesa (see appendix E4). The total flow rate of contaminated water from the mesa top firing point would be 1.1×10^{-3} ft^3/s (3.23×10^{-5} m^3/s). This gives a concentration reduction factor greater than 2,000, more than sufficient to reduce the concentration of depleted uranium in municipal water supplies to levels well below the proposed MCL. Based on the average annual flow rate of the Rio Grande, the reduction factor would be even greater for ground water release to the Rio Grande.

Releases to the ground water pathway from operation under the Preferred Alternative do not adversely impact ground water quality.

5.2.5 Biotic Resources

Biotic resources examined for impacts in the Preferred Alternative include terrestrial resources, wetlands, aquatic resources, and threatened and endangered species.

5.2.5.1 Terrestrial Resources

Both construction and operations impacts were evaluated for terrestrial resources.

5.2.5.1.1 Construction Impacts

Under the Preferred Alternative, further construction at the DARHT site would have little, if any, further impact on vegetation. Ground clearing and initial construction has already disturbed approximately 8 ac (3 ha) of mixed piñon-juniper/ponderosa pine habitat used by various species, and only about 0.25 ac (0.1 ha) would be further disturbed. Erosion control and revegetation of disturbed areas implemented during construction would be completed. These actions would minimize soil erosion. Section 3.3.6 provides additional details of the DARHT site.

Further construction at the DARHT site would have little, if any, further impact on the populations of small mammals that formerly inhabited the site. It is also likely that some small mammals, especially mice, would reinvade the disturbed area associated with the buildings.

Large mammals (deer, elk, coyote, bear, raccoon) use the DARHT site as habitat, mostly in a transient fashion, and it is unlikely that further construction would add to the present disruption of their use of this site (Risberg 1995).

Further construction at the DARHT site would not change the area of pinon-juniper/ponderosa pine habitat used by birds for roosting, feeding, and reproduction.

Some piñon-juniper/ponderosa pine habitat has already been disturbed by previous construction, and any reptiles and amphibians inhabiting the DARHT site have either been killed or displaced. Further impacts from completing the construction of DARHT would not be expected.

5.2.5.1.2 Operation Impacts

Further impacts to the DARHT site vegetation would be limited to effects from fires occurring during testing operations. These fires are quickly controlled by the firefighters who are stationed outside the exclusion fence at the time of the tests.

Impacts upon wildlife would be caused by repetitive, short-term disturbances from site activities. However, these impacts would be insignificant to overall population levels. Evidence from PHERMEX demonstrates that pollutant contamination of soil and plants outside the blast area is not above background levels.

5.2.5.2 Wetlands

Although floodplains lie at the bottom of Potrillo Canyon and Cañon de Valle, no wetlands lie within TA-15; thus, no impacts to wetlands would occur (Risberg 1995).

5.2.5.3 Aquatic Resources

No additional impacts to the aquatic resources located within the canyons surrounding TA-15 is expected.

5.2.5.4 Threatened and Endangered Species

It is unlikely that completion of DARHT construction would change the attractiveness of the area for potential use by threatened or endangered species.

5.2.6 Cultural and Paleontological Resources

Impacts on cultural and paleontological resources from the Preferred Alternative are described in the following subsections.

5.2.6.1 Archeological Resources

Archeological resources were evaluated from both construction and operations perspectives.

5.2.6.1.1 Construction

Completion of the DARHT Facility construction under the Preferred Alternative would not be expected to have any direct or indirect impacts on known archeological sites eligible for the National Register. Existing TA-15 security measures that restrict general access would continue to provide protection for possible intentional or incidental impacts from human activities.

5.2.6.1.2 Operations

Potential impacts related to detonation of high explosives at the designated firing point could result from 1) vibratory ground motion, 2) air waves, and 3) dispersal of metal fragments and other airborne debris.

Vibratory ground motion could induce structural instability to standing walls but would not affect other attributes of archeological sites which contribute to their research potential. Since none of the known archeological sites in the area of potential effects have standing walls, with the exception of Nake'muu, ground wave motion has the potential to affect only Nake'muu. This potential is minimal because the location of Water Canyon between the firing point and Nake'muu serves as a barrier which absorbs most of the motion. As stated, seismic tests conducted on March 11, 1995 (Vibronics 1995) indicated that potential impacts due to the air waves is a greater concern than vibratory ground motion. The cumulative potential effects are under evaluation and will be reported in a subsequent cultural resource survey report and included in the final EIS. The effects, if any, would be coordinated with the New Mexico State Historic Preservation Officer (NM SHPO).

Air waves would have no effect on those archeological sites whose eligibility for the National Register is based solely on their research potential. Air waves would have minimal effect on the structural stability of standing walls at Nake'muu. An air wave of 0.08 lb/in^2 (0.6 kPa) from a test blast at the firing point was measured at Nake'muu on March 11, 1995, from an explosion of 150 lb (70 kg) of TNT. This pressure is approximately one half of the air pressure required for window breakage (DOE 1992, table D.4-4). Although no structural damage resulted from this particular test, the cumulative impacts from similar air waves are unknown. In general, quantitatively assessing the effects air waves and ground motion could have on prehistoric structures is difficult because the baseline structural integrity of these sites is unknown. This site would be monitored for any adverse effects, and mitigation measures would be taken if necessary.

Flying debris would have no impact on those archeological sites whose eligibility for the National Register is based solely on their research potential. Flying debris, depending on the size and velocity, could impact those cultural resources which are eligible for the National Register for additional reasons (Criteria A, B or C). No known prehistoric cultural resources in the area of potential effects have been identified as eligible under Criteria A or B (association with important events or people). If any are identified as a result of ongoing surveys and consultations, they will be identified in the final EIS and coordinated with the NM SHPO.

Because Nake'muu is eligible for the National Register under Criterion C based on its well-preserved standing walls, flying debris of sufficient size and velocity could result in an adverse effect. This potential was mitigated in the design stage of the project by aligning one wing of the DARHT building itself between the blast area and Nake'muu so that most blasting debris on a trajectory towards Nake'muu would be deflected away from Nake'muu. Using the height of the DARHT building alone as a barrier wall, some particles would be projected over that wall in the direction of Nake'muu. However, the only particles which would have the velocity to reach Nake'muu would be less than one inch in diameter. By the time they reach Nake'muu, they would no longer be propelled by the force of the blast itself, but would be falling to the ground by gravity alone. Based on the number of shots anticipated for the life of the DARHT Facility, the probability that any particles would reach Nake'muu was determined to be small and would fall without sufficient force and size to affect the site. Constructing an additional barrier on top of the building would decrease even further the number of particles with the potential to reach Nake'muu. In a February 21, 1989, correspondence between the NM SHPO and the DOE, the SHPO concurred that "it is unlikely that the proposed activity will have any effect on the values for which LA 12655 [Nake'muu] is considered significant. However, I do agree that test activities should be monitored by a LANL Archaeologist, as discussed in your letter, to ensure that this assessment of effort is correct. If site damage to important site values is observed during the monitoring visits, further consultation will be necessary to determine appropriate measures to reduce adverse effects of test activities" (SHPO 1989).

The calculations above were made for explosions up to 150 lb (70 kg) of TNT originating specifically at the dual-axis firing point. Explosions exceeding this weight, anticipated to be about 500 lb (230 kg) TNT equivalent require relocation of the firing point away from the dual-axis spot. In this situation, the shielding effect of the DARHT building would be reduced. The potential for blast debris from the larger explosions reaching Nake'muu would be mitigated by temporary construction of a sand bag revetment to create a blast shield. The blast overpressure measured during the March 11, 1995, tests scaled for 500 lb (230 kg) indicate a pressure of 0.12 lb/in^2 (0.8 kPa) at Nake'muu which is still below the value of 0.2 lb/in^2 (1.4 kPa) required for window breakage (DOE 1992, table D.4-4). This overpressure, 0.12 lb/in^2 (0.8 kPa), is very conservative since the mitigating effects of the canyon are not included.

Other data suggest that the canyon can reduce overpressure by as much as one half (Vibronics, Inc., 1995).

If determined to be desirable, additional characterization of the potential impact of DARHT operation on Nake'muu may be conducted. For example, options include design and implementation of a long-term monitoring procedure at Nake'muu and/or completion of a structural assessment of architectural elements. If necessary, several mitigation options are available such as stabilization of standing masonry walls.

5.2.6.2 Historical Resources

No direct or indirect impacts on historic structures are anticipated.

5.2.6.3 Native American Resources

Consultation with the San Ildefonso Pueblo is ongoing, and no impacts on Native American cultural resources have been identified at this time. If any impacts are identified, they will be reported in the final EIS.

5.2.6.4 Paleontological Resources

Because of the nature of the soil and geological substrate, it is unlikely that paleontological resources exist at the DARHT site; no potential effects are postulated.

5.2.7 Socioeconomic and Community Services

Environmental impacts on socioeconomics and community services for the Preferred Alternative are presented in the following subsections.

5.2.7.1 Demographic Characteristics

The Preferred Alternative would not have any significant impact on the existing demographic characteristics of communities in the region-of-interest, as described in section 4.7.1.

5.2.7.2 Economic Activities

The Preferred Alternative encompasses completing construction and operation of the dual-axis facility. The DOE is expected to complete construction and begin operation of the first axis of the proposed DARHT Facility by FY 1999. At that time, the operating costs of DARHT would replace PHERMEX operating costs, although construction expenditures would continue until the completion of the second DARHT axis in FY 2000. For the purpose of estimating the economic impacts (employment, labor income, and output) of the Preferred Alternative, the analysis recognizes the incremental construction and operating expenditures associated with the Preferred Alternative, relative to ones associated with the No

Action Alternative. The estimated capital construction expenditures, shown in table 5-10, do not include any site cleanup nor decommissioning and decontamination of the dual-axis facility at the end of its lifetime. The direct and indirect economic impacts of the proposed alternative are described below.

Over the period FY 1996-FY 2002, the Preferred Alternative is estimated to generate 169 full-time equivalent jobs in the regional economy, 73 directly related to project construction and operating expenditures, and 96 indirectly generated by subsequent indirect spending and income generation within the regional economy. Over the same time period, the Preferred Alternative is estimated to generate an annual average of $3.61 million of regional labor income, $1.55 million directly related to the project, and $2.05 million indirectly generated through subsequent indirect spending in the regional economy. Finally, the Preferred Alternative is estimated to generate an annual average of $6.23 million of goods and services in the regional economy, $3.21 million directly generated by the project, and $3.02 million indirectly generated by subsequent indirect spending within the regional economy.

The underlying cost data were provided by LANL (Burns 1995). The costs do not include any expenses associated with site cleanup nor decontamination and decommissioning either the DARHT or PHERMEX facilities. These relevant data were adjusted using an escalation price change index for DOE defense-related construction projects (Pearman 1994; Anderson 1995).

5.2.7.3 Community Infrastructure and Services

The Preferred Alternative would not have any significant impact on the existing community infrastructure in the region-of-interest, as described in section 4.7.3.

5.2.7.4 Environmental Justice

Referring to other sections of the EIS, no significant adverse environmental impacts are identified with the construction or operation of the DARHT Facility under the Preferred Alternative. The impacts considered include air and noise emissions caused during facility construction and subsequent operations (section 5.2.2), and the potential for surface or ground water contamination (section 5.2.4). Any foreseeable impacts on air, noise, or water quality during the course of normal operations would not pose significant health impacts on human populations (section 5.2.8) and would fall within regulatory compliance requirements. Accordingly, DARHT facility construction and planned operation under the Preferred Alternative would have no known disproportionate adverse health or environmental impact on minority or low-income populations in the region-of interest [populations residing within 50 mi (80 km) of the site].

TABLE 5-10.—*Capital-Funded Construction and Operating Costs Under Proposed Action (in millions of 1994 dollars)*

Year/Cost	1995	1996	1997	1998	1999	2000	2001	2002
Capital	6.61	18.93	18.38	22.81	20.29	0.70	0	0
Operations and Maintenance	4.17	4.30	4.43	4.58	6.96	7.18	7.40	7.63

5.2.8 Human Health

Potential human health impacts under the Preferred Alternative would be essentially the same as for the No Action Alternative, described in section 5.1.8.

5.2.9 Facility Accidents

Potential impacts of facility accidents under the Preferred Alternative would be the same as for the No Action Alternative, described in section 5.1.9.

5.2.10 Waste Management

Potential impacts of the Preferred Alternative on waste management would be the same as for the No Action Alternative, described in section 5.1.10.

5.2.11 Monitoring and Mitigation

5.2.11.1 Monitoring

Potential impacts that would need to be monitored under the Preferred Alternative would be the same as for the No Action Alternative, described in section 5.1.11.

5.2.11.2 Mitigation

Under normal operating conditions, only one potential impact would appear to warrant mitigation. Protection of the Nake'muu archeological site might be necessary under certain detonation test configurations. Detonations would be shielded, if necessary, to avoid fragment impact to the site. No other archaeological sites in the hazard radius have standing walls that would require mitigation activities. Other mitigation measures taken would not differ significantly from measures currently taken as part of normal operations at the PHERMEX facility. Mitigation activities for cultural resources are presented in section 4.6.

5.2.12 Decontamination and Decommissioning

Potential impacts of decontamination and decommissioning under the Preferred Alternative would be similar to that described for the No Action Alternative in section 5.1.12. The following differences from D&D activities and impacts in the No Action Alternative would be expected:

- Increased salvage and conversion to other uses because of the presence of two accelerator facilities and their buildings

- Increased soil, gravel, and debris resulting from the repositioning of the firing site from the PHERMEX location.

5.3 UPGRADE PHERMEX ALTERNATIVE

This section presents the expected environmental consequences associated with the Upgrade PHERMEX Alternative.

5.3.1 Land Resources

Potential impacts on land resources in the Upgrade PHERMEX Alternative would be essentially the same as described in section 5.1.1 for the No Action Alternative.

5.3.2 Air Quality and Noise

5.3.2.1 Air Quality

Air quality impacts for the Upgrade PHERMEX Alternative would be essentially the same as those described in section 5.2.2 for the Preferred Alternative.

5.3.2.2 Noise

Because the period of construction would be somewhat longer and some construction would probably take place converting the existing DARHT Facility to other uses, construction noise would be generated for a period longer than in the Preferred Alternative. However, construction noise would not be expected to be noticeable away from the construction site. Disturbance of wildlife during operations would be about the same as with the No Action Alternative (appendix C2, Noise).

5.3.3 Geology and Soils

Potential impacts of the Upgrade PHERMEX Alternative on geology and soils would be essentially the same as those described in section 5.1.3 for the No Action Alternative.

5.3.4 Water Resources

Potential impacts of the Upgrade PHERMEX Alternative on surface and ground water would be essentially the same as those described in section 5.1.4 for the No Action Alternative.

5.3.5 Biotic Resources

Impacts on biotic resources in the Upgrade PHERMEX Alternative would be essentially the same as described for the No Action Alternative in section 5.1.5.

5.3.6 Cultural and Paleontological Resources

Potential impacts on cultural and paleontological resources in the Upgrade PHERMEX Alternative would be essentially the same as described in section 5.1.6 for the No Action Alternative.

5.3.7 Socioeconomic and Community Services

Environmental impacts on socioeconomics and community services for the Upgrade PHERMEX Alternative are presented in this section. Potential impacts on demographic characteristics, community infrastructure and services, and environmental justice would be essentially the same as the No Action Alternative and are described in sections 5.1.7.1, 5.1.7.2, and 5.1.7.3, respectively. Potential impacts on economic activities are presented in the following section.

5.3.7.1 Economic Activities

The Upgrade PHERMEX Alternative involves upgrading the present PHERMEX Facility to accommodate new technology developed for DARHT. Under this alternative, the DOE is expected to complete construction and begin operation of the upgraded PHERMEX Facility in FY 2002. During the upgrade of the PHERMEX Facility, construction costs would be incurred along with PHERMEX operating costs (see table 5-11). To estimate the regional economic impacts of the Upgrade PHERMEX Alternative, the analysis recognizes additional construction and operating expenditures under the Upgrade PHERMEX Alternative, relative to those associated with the No Action Alternative. The estimated capital construction expenditures do not include any site cleanup nor D&D of the dual-axis facility at the end of its lifetime.

Over the period FY 1996 to FY 2002, the Upgrade PHERMEX Alternative is estimated to generate 139 full-time equivalent jobs in the regional economy, 63 directly related to project construction and operating expenditures, and 76 indirectly generated by consecutive rounds of spending and regional

TABLE 5-11.— *Capital-Funded Construction and Operating Costs Under Upgrade PHERMEX Alternative (in millions of 1994 dollars)*

Year/Cost	1995	1996	1997	1998	1999	2000	2001	2002
Capital	6.61	26.89	29.23	11.61	8.57	10.84	3.37	0
Operations and Maintenance	4.17	4.30	4.43	4.58	4.73	4.88	5.03	8.11

income generation. The Upgrade PHERMEX Alternative is also estimated to generate an annual average of $3.26 million of regional labor income, $1.38 million directly related to the project, and $1.88 million indirectly generated through consecutive rounds of spending in the regional economy. Finally, the Upgrade PHERMEX Alternative is estimated to generate an annual average of $5.46 million of goods and services in the regional economy, $2.58 million directly generated by the project, and $2.78 million indirectly generated by consecutive rounds of spending in the regional economy.

The underlying cost data were provided by LANL (Burns 1995). The costs do not include any expenses associated with site cleanup nor D&D of either the proposed DARHT or PHERMEX facilities. These relevant data were adjusted using an escalation price change index for DOE defense-related construction projects (Pearman 1994; Anderson 1995).

5.3.8 Human Health

Potential impacts of the Upgrade PHERMEX Alternative on human health would be essentially the same as for the No Action Alternative, described in section 5.1.8.

5.3.9 Facility Accidents

Potential impacts of facility accidents under the Upgrade PHERMEX Alternative would be essentially the same as for the No Action Alternative, described in section 5.1.9.

5.3.10 Waste Management

Potential impacts of the Upgrade Alternative on waste management would be essentially the same as for the No Action Alternative, described in section 5.1.10.

5.3.11 Monitoring and Mitigation

Monitoring and mitigation measures taken under the Upgrade Alternative would be essentially the same as the No Action Alternative, described in section 5.6.11.

5.3.12 Decontamination and Decommissioning

Impacts of decontamination and decommissioning under the Upgrade Alternative would be essentially the same as in the No Action Alternative described in section 5.1.12; however, the buildings partially constructed for DARHT would also be subject to D&D evaluation.

5.4 ENHANCED CONTAINMENT ALTERNATIVE

This section presents the expected environmental consequences associated with the enhanced containment alternative.

5.4.1 Land Resources

5.4.1.1 Land Use

Both the building and vessel containment options under this alternative require a building addition for the recycling facility. To accommodate either of these options, it is anticipated that 1 ac (0.4 ha) of land would have to be cleared for construction, in addition to the 8 ac (3 ha) of land previously disturbed by DARHT. This dedication of land would be consistent with current and past land uses at LANL and would have no reasonably foreseeable impact on established local land-use patterns.

5.4.1.2 Visual Resources

The proposed DARHT Facility with either building containment or vessel containment would be an unobtrusive facility located in an isolated piñon/ponderosa pine forest area and would not be accessible or readily visible from offsite; therefore, it should have no impact on visual resources.

5.4.1.3 Regional Recreation

Although a variety of recreational opportunities are available in the vicinity of LANL, only those in areas relatively near TA-15 might be negatively impacted by noise associated with test firings at the proposed DARHT site. Test firings within the building containment would be expected to have no impacts on recreational resources. Under the vessel containment option, it is possible that some tests would be conducted without using a containment vessel. These tests would have the same small potential for impacts on nearby recreation as other alternatives using uncontained test firing.

5.4.2 Air Quality and Noise

5.4.2.1 Air Quality

Air quality impacts for the Enhanced Containment Alternative are presented in this section for maximally impacted point of unrestricted public access. These impacts were determined using methods described in appendix C Air Quality and Noise.

5.4.2.1.1 Construction

Pollutant emissions for the building option (4b) of the Enhanced Containment Alternative have not been quantified. However, it is unlikely that construction of the building would significantly add to the emissions already cited for the Preferred Alternative. Pollutant emissions during the construction phase of the vessel option (4a) of the Enhanced Containment Alternative would be essentially the same as those for the Preferred Alternative. As a result, impacts presented for the Preferred Alternative would also be representative of the vessel option of the Enhanced Containment Alternative.

5.4.2.1.2 Operations

In the building option (4b) of the Enhanced Containment Alternative, the building is designed to prevent release of fine particles or fragments. Ambient air quality impacts from emissions during testing are given in table 5-12. The calculated values for nitrogen dioxide, sulfur dioxide and PM_{10} are the same for all of the alternatives except the No Action Alternative. This is due to fugitive dust and emissions from construction equipment for those alternatives that include construction. Emissions of beryllium, heavy metal, and lead are consistently higher than the other alternatives since the calculations for the Enhanced Containment Alternative are performed as a ground level release. The other air dispersion calculations for the other alternatives are performed as an elevated release, 325 ft (99 m). All of the ambient air impacts from testing operations are considered minimal.

In the vessel option (4a) of the Enhanced Containment Alternative, the vessel would be used on most, but not all, tests. In those tests for which containment would be used, the impacts would be essentially the same as those for the building option (4b). In tests for which containment would not be used, the impacts would be bounded by those described for the Preferred Alternative.

5.4.2.2 Noise

Either in the building option (4b) or the vessel option (4a) of the Enhanced Containment Alternative, impacts associated with noise and blast pressure waves would be significantly reduced compared to the No Action Alternative. A reduction of at least 80 percent is estimated to occur. Because in the vessel option (4a) not all tests would be performed within the vessel, an occasional opportunity would arise for noise and blast wave impacts of the same magnitude as with the No Action Alternative.

Noise associated with construction and construction worker traffic would occur until completion of the DARHT Facility with the building option, or the vessel option (which includes a recycling facility). However, construction noise would not be expected to be noticeable away from the construction site. Disturbance of wildlife during operations would be about the same as with the No Action Alternative (appendix C, Air Quality and Noise).

5.4.3 Geology and Soils

Impacts of the Enhanced Containment Alternative on geology and soils are described in the following subsections.

TABLE 5-12.—*Impacts on Air Quality from Hydrodynamic Testing in the Enhanced Containment Alternative*

Pollutant	Averaging Time	Maximally impacted Point of Unrestricted Public Access ($\mu g/m^3$)	Percent of Regulatory Limit
NO_2	Annual 24-h	8.1×10^{-4} 0.92	1.1×10^{-3} 6.3×10^{-1}
PM_{10}	Annual 24-h	0.0037 0.23	0.0074 0.16
Beryllium	30 days	3.3×10^{-3}	3.3
Heavy Metals[a]	30 days	0.25	2.5×10^{-2}
Lead	Calendar Quarter	4.0×10^{-3}	2.7×10^{-3}

[a] Sum of the air concentration of uranium and lead.

5.4.3.1 Geology

Geologic impacts under the Enhanced Containment Alternative would be similar to those under the Preferred Alternative.

5.4.3.2 Seismic

Seismic impacts under the Enhanced Containment Alternative would be similar to those under the Preferred Alternative.

Although seismic events that damage buildings would have an impact on mission goals, no scenarios were identified wherein a seismic event could trigger an action at the proposed DARHT Facility that would result in any offsite environmental impact.

5.4.3.3 Soils

Soil contamination under the Enhanced Containment Alternative would be much less than under any other alternative. An estimated maximum of six percent of the Preferred Alternative inventory could be released in the vicinity of the firing point if highly unlikely events were to occur. However, much less release is anticipated, and it is likely that soils contamination in the vicinity of the firing point would be indistinguishable from background levels.

5.4.4 Water Resources

Water resources examined for impact in the Enhanced Containment Alternative are:

- Surface water and sediment in Water Canyon which discharges into the Rio Grande
- The main aquifer underlying Threemile Mesa.

Stream losses to the bed of Water Canyon are analyzed for their potential to release contaminants through the vadose zone to the main aquifer. Infiltration is examined for its ability to carry metals in solution into the mesa top at the firing point and to communicate contaminants through the unsaturated zone to the main aquifer. Supporting information on deep drainage, the geochemistry of metals in LANL waters and sediments, surface water modeling, and vadose zone and ground water modeling as applied in this EIS can be found in appendix E.

A combination of data review and geochemical analysis was used to determine the solubility and sorption characteristics of several metals in the LANL water and soil/sediment environment (see appendix E). Because they represent the largest fraction of expended materials in the tests to be conducted, depleted uranium, beryllium, lead, copper, and aluminum were all studied. The study revealed that realistic assignment of solubility for beryllium and lead yielded values at about the drinking water standard for both metals. Values of solubility for both copper and aluminum were both found to be substantially below their secondary drinking water standards. Thus, while the analysis examines the migration of beryllium and lead to gain insight into their migration and behavior in the environment, there is no need to simulate beryllium, lead, copper, or aluminum. The solubility of uranium in LANL waters was found to be substantially above its proposed MCL value, and therefore its migration was modeled to estimate its potential impact on the water resource.

5.4.4.1 Surface Water

The hydrology-sediment-contaminant transport modeling procedure described in appendix E3 was applied to assess the potential impacts of the Enhanced Containment Alternative. In this alternative, the transport by surface runoff during the next 30 years for releases of depleted uranium, beryllium and lead from the DARHT site was analyzed. Table 5-13 shows the simulated peak concentration of contaminants in the infiltrated water in Water Canyon below the source (see appendix E3).

Because of their low solubility, the concentrations of beryllium and lead reach a plateau in their release to Water Canyon but still remain well below drinking water standards. MCLs for beryllium and lead are 4 and 50 μg/L, respectively. Depleted uranium has a relatively high solubility in LANL surface and ground waters. Consequently, depleted uranium is quickly infiltrated into the mesa top soils by storms that are sufficiently large to solubilize and move the depleted uranium, but too small to cause runoff to the canyons. Thus, depleted uranium contamination in surface water released to Water Canyon would be negligible in this alternative. The Rio Grande is the nearest offsite access point for surface water carrying contamination from the firing point. As shown in table 5-13, the quality of surface water entering the Rio Grande would be several orders of magnitude below the drinking water MCLs for beryllium and lead.

TABLE 5-13.—*Contaminant Concentrations and Time-to-Peak for the Enhanced Containment Alternative*

Contaminant	Discharge Sink (Potrilio Canyon)	Reach 12* (Water Canyon)	Reach 13 (Water Canyon)	Reach 14 (Water Canyon)	Reach 15 (Water Canyon)	Rio Grande (in solution)	RioGrande (on sediment)
Peak Concentration	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/g)
Depeleted Uranium	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Beryllium	0.0	3.15×10^{-3}	1.41×10^{-3}	6.03×10^{-4}	2.38×10^{-4}	2.38×10^{-4}	2.38×10^{-5}
Lead	0.0	6.16×10^{-3}	2.58×10^{-3}	4.58×10^{-4}	1.54×10^{-4}	1.55×10^{-4}	3.07×10^{-4}
Time, years							
Depeleted Uranium	0	0	0	0	0	0	0
Beryllium	0	744	4352	2573	4128	4128	4128
Lead	0	525	747	889	889	889	889

Note: Drinking Water Standards

*See Figure E3-1 for location of the Water Canyon reaches.

Depleted Uranium, 20 µg/L [56 FR 33050]
Beryllium, 4 µg/L [40 CFR 141.62]
Lead, 50 µg/L [40 CFR 141.11]

5.4.4.2 Ground Water

A single analysis of depleted uranium migration was conducted for the Enhanced Containment Alternative. Stream losses into the bed of Water Canyon were not analyzed in this case because all metals of interest in surface water were below MCLs. Infiltration carrying depleted uranium into the mesa top at the DARHT firing point was analyzed to estimate contaminant migration into the main aquifer.

The peak concentrations of metals in infiltration to Threemile Mesa and in surface water losses from the uppermost reach of Water Canyon opposite the DARHT Facility are shown in table 5-14. For those cases where the MCLs are exceeded (shown in bold), analyses are necessary. Only one case must be modeled – depleted uranium on the mesa top at the firing point. Other metals were not analyzed because sorption and dispersion within the vadose zone would only further reduce soil water concentrations that enter the soil column at concentrations at or below the MCLs for drinking water.

Analysis of depleted uranium migration through the mesa to the main aquifer showed a peak concentration of 4.8 μg/L after approximately 43,000 years. Thus, release from the mesa top yield soil water entering the main aquifer at concentrations well below the proposed MCL for uranium (20 μg/L), and releases to the ground water pathway from operation under the Enhanced Containment Alternative would not adversely impact ground water quality.

5.4.5 Biotic Resources

5.4.5.1 Terrestrial Resources

5.4.5.1.1 Construction Impacts

Two options are being considered for this alternative:

- Option 4a – use of a containment vessel
- Option 4b – construction of a containment building around the DARHT test site.

If either containment option is adopted, it would necessitate the construction of a recycling facility in TA-15. For the containment and recycling buildings, an additional disturbance of pinon-juniper/ponderosa pine habitat of about 1.25 ac (0.5 ha) would be incurred with a resulting disturbance of biota. See section 5.1.5.1 for a description of these types of impacts.

5.4.5.1.2 Operation Impacts

This section is the same as for 5.2.5.1 except that disruption of wildlife from noise associated with detonations would probably be considerably lessened. Information received to date does not indicate that any liquid effluent from the recycling facility (option 4a or option 4b) would reach the environment.

TABLE 5-14.—*Peak Input Concentrations (μg/L) Under Containment Alternative to Water Canyon Reaches and Threemile Mesa Predicted by Surface Runoff-Sediment-Contaminant Transport Model*

Location	Contaminant		
	Depleted Uranium	**Beryllium**	**Lead**
Maximum Concentration Levels	**20 [56 FR 33050]**	**4 [40 CFR 141.62]**	**50 [40 CFR 141.11]**
Threemile Mesa at DARHT firing point	**21,300**	4	50
Water Canyon Reach 12 (below DARHT)	0	0.0032	0.0077
Water Canyon Reach 13	0	0.0014	0.0044
Water Canyon Reach 14	0	0.00060	0.0010
Water Canyon Reach 15	0	0.00024	0.00029

5.4.5.2 Wetlands

Although floodplains lie at the bottom of Potrillo Canyon and Cañon de Valle, no wetlands lie within TA-15; thus, no impacts to wetlands would occur (Risberg 1995).

5.4.5.3 Aquatic Resources

No additional impacts to the aquatic resources located within the canyons surrounding TA-15 is expected.

5.4.5.4 Threatened and Endangered Species

Potential impacts on threatened and endangered species in the Enhanced Containment Alternative would be essentially the same as those described in section 5.2.5.4 for the Preferred Alternative.

5.4.6 Cultural and Paleontological Resources

Impacts on cultural and paleontological resources from the Enhanced Containment Alternative are described in the following subsections.

5.4.6.1 Archeological Resources

5.4.6.1.1 Construction

Completion of construction of the proposed DARHT Facility with either the building or vessel options would not be expected to have any direct or indirect impacts on known archeological sites eligible for the National Register. Existing TA-15 security measures that restrict general access would continue to provide protection for possible intentional or incidental impacts from human activities.

5.4.6.1.2 Operations

Firing shots, as part of the operation of the proposed DARHT Facility in the Enhanced Containment Alternative, might have some effects on Nake'muu, located on a small mesa across Cañon de Valle from the DARHT construction site. Potential impacts would, however, be restricted to vibratory ground motion as a result of detonation of high explosives because overpressure resulting from the air wave would be greatly reduced and debris would be contained. The impacts from vibratory ground motion are considered negligible.

5.4.6.2 Historical Resources

No direct or indirect impacts on historic structures are anticipated.

5.4.6.3 Native American Resources

Consultation with the San Ildefonso Pueblo is ongoing, and no impacts on Native American resources have been identified at this time. If any impacts are identified, they will be reported in the final EIS.

5.4.6.4 Paleontological Resources

Because of the nature of the soil and geological substrate, the occurrence of paleontological resources is not anticipated; no potential effects are postulated.

5.4.7 Socioeconomic and Community Services

Environmental impacts on socioeconomics and community services for the Containment Alternative are presented in the following subsections.

5.4.7.1 Demographic Characteristics

The Enhanced Containment Alternative would not have any significant impact on the existing demographic characteristics of communities in the region-of-interest, as described in section 4.7.1.

5.4.7.2 Economic Activities

The Enhanced Containment Alternative would involve construction and operation of the dual-axis facility but with some modification to contain airborne emissions of fragments or other debris – either option 4a, a containment vessel, or option 4b, a containment building. Under the containment vessel option, the DOE would complete construction and begin operation of the dual-axis facility in FY 1999. At that time, DARHT operating costs would replace PHERMEX operating costs. Under the containment building option, the DOE would complete construction and begin operation of the dual-axis facility in FY 2002, at which time DARHT operating costs would replace PHERMEX operating costs (table 5-15).

For the purpose of estimating the regional economic impacts of the two containment alternatives, the analysis illustrates their respective levels of construction and operating expenditures relative to those associated with the No Action Alternative. These estimated costs do not include any site cleanup, nor D&D of the dual-axis facility at the end of its lifetime.

Over the period FY 1996 to FY 2002, the containment vessel alternative is estimated to generate 326 full-time equivalent jobs in the regional economy, 139 directly related to project construction and operating expenditures, and 187 indirectly generated by consecutive rounds of spending and income generation within the regional economy. This alternative is also estimated to generate an annual average of $6.87 million of regional labor income, $2.91 million directly related to the project, and $3.96 million indirectly generated through consecutive rounds of spending in the regional economy. The alternative is estimated to add an annual average of $12.42 million of goods and services to the regional economy, $6.60 million directly generated by the project, and $5.82 million indirectly generated by consecutive rounds of spending within the regional economy.

Alternatively, the 150-lb (70-kg) containment building option is estimated to generate 200 full-time equivalent jobs in the regional economy, and the 500-lb (230-kg) containment building option is estimated to generate 217 full-time equivalent jobs. Of these totals, for the smaller and larger buildings respectively, 85 and 91 jobs would be directly accounted for by project construction and operating expenditures. The other 115 or 126 jobs for the two building sizes would be indirectly accounted for by consecutive rounds of regional spending and income generation.

Correspondingly, the containment building options are estimated to add annual averages of $4.28 million and $4.63 million in regional labor income, with $1.83 million and $1.96 million directly related to the project, and $2.45 million and $2.67 million indirectly generated by consecutive rounds of spending in the regional economy. Relative to these impacts, the containment building options are estimated to generate annual averages of $7.21 million [150-lb (70-kg)] and $7.77 million [500-lb (230 kg)] of goods and services in the regional economy, $3.59 million [150-lb (70-kg)] or $3.83 million [500-lb (230-kg)] directly generated by the project, and $3.61 million [150-lb (70-kg)] or $3.94 million [500-lb (230-kg)] indirectly generated through consecutive rounds of spending in the regional economy.

The underlying cost data were provided by LANL (Burns 1995). The costs do not include any expenses associated with site cleanup nor D&D of either the proposed DARHT or PHERMEX facilities. Those relevant data were adjusted using an escalation price change index for DOE defense-related construction projects (Pearman 1994; Anderson 1995).

TABLE 5-15.—*Capital-Funded Construction and Operating Costs Under Containment Alternatives (in millions of 1994 dollars)*

Cost	Option	1995	1996	1997	1998	1999	2000	2001	2002
Capital	Vessels	6.61	19.13	33.38	37.81	21.18	0.70	0	0
	Building (150 lb)	6.61	21.61	35.70	23.01	9.96	15.12	0.66	0
	Building (500 lb)	6.61	22.54	39.41	27.04	10.62	15.21	0.67	0
Operations and Maintenance	Vessels	4.17	4.30	4.43	4.58	11.50	11.86	12.22	12.60
	Building (150 lb)	4.17	4.30	4.43	4.58	4.73	4.88	5.03	12.60
	Building (500 lb)	4.17	4.30	4.43	4.58	4.73	4.88	5.03	12.60

5.4.7.3 Community Infrastructure and Services

The Enhanced Containment Alternative would not have any significant impact on the existing community infrastructure in the region-of-interest, as described in section 4.7.3.

5.4.7.4 Environmental Justice

Referring to other sections of the EIS, the construction and operation of the DARHT Facility under Enhanced Containment Alternative options (4a and 4b) would pose no significant environmental impacts. The foreseeable impacts include fugitive air and noise emissions during facility construction and operations (section 5.3.2), and potential surface or underground water contamination (section 5.3.4). No significant human health impacts appear to exist from either radioactive or hazardous material released or from exposing receptors onsite (workers) or offsite (section 5.1.8). Accordingly, DARHT Facility construction and planned operations under the Enhanced Containment Alternative options would not pose a disproportionate adverse health or environmental impact on minority or low-income populations in the region-of-interest [populations residing within 50 mi (80 km) of the site].

5.4.8 Human Health

This section presents the impacts to the health of workers and the public from routine operations that would be conducted at the DARHT Facility under the Enhanced Containment Alternative. Impacts may potentially result from release and atmospheric transport of radioactive and hazardous material from the facility firing site as a result of planned detonations. Methods and assumptions used in calculating potential impacts are described in appendix H, Human Health.

Radiological impacts may result from exposure to depleted uranium and tritium released to the atmosphere from detonations at the DARHT site. Depleted uranium would be the principal contributor to radiation dose; tritium would contribute about 1×10^{-7} the dose of depleted uranium for chronic releases. The major exposure pathway would be inhalation of material released to the atmosphere, which would contribute more than 99 percent of the dose. Potential human health impacts may be *over-estimated* by a factor of 100 because of the simplified, elevated point-source atmospheric dispersion model used rather than an explosive atmospheric dispersion model (see appendix H.2, Human Health).

5.4.8.1 Public

Potential impacts to the MEI were evaluated at three locations in the vicinity of the DARHT site – Los Alamos, White Rock, and Bandelier. These locations are representative of the neighboring residential clusters of LANL. Potential impacts to the surrounding population were also calculated. Potential radiological and nonradiological impacts are presented in the sections below.

5.4.8.1.1 Radiological Impacts

The maximum annual dose to any nearby resident would not exceed 2×10^{-5} rem EDE. Using a risk conversion factor of 5×10^{-4} LCFs per person-rem for members of the public, the estimated maximum probability of a latent fatal cancer would be about 10×10^{-9}. The highest estimated cumulative dose to an individual over the anticipated 30-year life of the project would be about 5×10^{-4} rem. The estimated maximum probability of a latent fatal cancer would be about 2×10^{-7}.

The annual collective dose to the population residing within 50 mi (80 km) of the DARHT site would be about 0.44 person-rem for the vessel containment option and about 0.27 person-rem for the building containment option. Latent cancer fatalities would not be expected among the population from either of these doses (2×10^{-4} and 1×10^{-4} LCFs, respectively).

5.4.8.1.2 Nonradiological Impacts

Members of the public might also be exposed to heavy metals and other materials released during the detonation, including uranium, lead, beryllium, and lithium hydride. The maximum probability of a beryllium-induced cancer would be about 1×10^{-11}. Toxicological effects from releases of uranium, beryllium, lead or lithium hydride would not be expected (maximum Hazard Index of 5×10^{-8}). The probability of a beryllium-induced cancer over the anticipated 30-year life of the project would be about 3×10^{-10}. The maximum Hazard Index expected in the first year immediately after 30 years of operations, accounting for any toxicological effects from buildup of hazardous material in soil, would not exceed 4×10^{-8}. Toxicological effects would not be expected.

Cancers from exposure to beryllium released during a year of normal operations under either the vessel or building containment scenarios would not be expected in the population in the surrounding 50 mi (80 km) (total incidence of 1×10^{-7} and 5×10^{-8} cancers, respectively).

5.4.8.2 Noninvolved Workers

A noninvolved worker is defined as a LANL employee who works in TA-15, but would not be directly involved with the proposed facility operations. Nearby workers uninvolved with the proposed DARHT detonation process would not likely be affected by detonations occurring within containment. It was assumed that access control would still be in place for the Enhanced Containment Alternative. Uncontained detonations could still occur under this alternative (vessel containment scenario), as well as potential breaches of the containment vessels or releases from the containment building. To evaluate potential impacts from these occurrences, an uninvolved worker is assumed to work continuously 2,500 ft (750 m) distant from the firing site. This distance is based on a hazard radius that would typically be put in place for hydrodynamic test. LANL implements this administrative exclusion area based on explosive safety principles (DOE 1994).

The annual dose to a noninvolved worker is estimated to be about 2×10^{-5} rem EDE under vessel containment, and 1×10^{-5} rem under building containment. The maximum probability of LCF from these doses would be about 6×10^{-9} and 5×10^{-9}, respectively. Over the 30-year anticipated operating life of the facility, a noninvolved worker's cumulative dose would be about 5×10^{-4} rem and 4×10^{-4} rem, respectively. The maximum probability of LCF from these doses would be about 2×10^{-7} for both.

A noninvolved worker could also be exposed to heavy metals and other materials released during the detonation, including uranium, lead, beryllium, and lithium hydride. The maximum probability of a beryllium-induced cancer would be about 2×10^{-10} under the vessel containment scenario and 1×10^{-10} under the building containment scenario. The probability of a beryllium-induced cancer from exposure over the anticipated 30-year life of the project would be about 6×10^{-9} and 3×10^{-9}, respectively. Toxicological effects from exposure to releases of uranium, beryllium, lead or lithium hydride would not be expected (maximum Hazard Indexes of 9×10^{-7} and 6×10^{-7}, respectively).

5.4.8.3 Workers

Impacts to workers under the Enhanced Containment Alternative could be somewhat higher than those observed under previous PHERMEX operating experience or projected for the uncontained alternatives because cleanup of contained space (vessels or buildings) could involve exposure to greater quantities and concentrations of materials. The average annual worker dose would probably not exceed 0.020 rem. The maximum probability of LCF from this dose would be 8×10^{-6}. The annual collective worker dose, assuming a maximum of 100 workers, would probably not exceed 2 person-rem. Latent cancer fatalities would not be expected from this dose (8×10^{-4} LCFs). The cumulative worker dose over the assumed 30-year lifetime of the facility would probably not exceed 60 person-rem. Latent cancer fatalities would not be expected from this dose (2.4×10^{-2} LCFs).

Involved worker exposures to radiation and radioactive materials under normal operations would be controlled under established procedures that require doses to be kept as low as reasonably achievable. Any potential hazards would be evaluated as part of the radiation worker and occupational safety programs at LANL, and no impacts outside the scope of normal work activities would be anticipated.

5.4.9 Facility Accidents

This section presents the impacts from postulated facility accidents to individual members of the public, noninvolved workers nearby, and workers at the facility. The bounding accident evaluated under the Enhanced Containment Alternative differed for the vessel containment option and the containment building option. Under the vessel containment option, the bounding accident is the catastrophic failure of a containment vessel. Under the building containment option the bounding accident is the cracking and loss of integrity of the containment walls or major failure of the HEPA-filtered overpressure release system. Both of these bounding accidents would result in greater potential consequences to members of the public and noninvolved workers than inadvertent uncontained detonation of a test assembly because releases of materials would be at ground level rather than at a higher elevation. The inadvertent detonation would be the bounding accident for workers at the facility. Accident initiation events were not addressed; accidents were simply evaluated on a "what if" basis even though the likelihood of occurrence is very small.

Radiological impacts may result from exposure to depleted uranium and tritium released to the atmosphere from detonations at the DARHT site. Depleted uranium would be the principal contributor to radiation dose; tritium would contribute about 1×10^{-8} the dose of depleted uranium for acute releases. The major exposure pathway would be inhalation of material released to the atmosphere, which would contribute more than 99 percent of the dose. Potential human health impacts may be *over-estimated* by a factor of 100 because of the simplified, elevated point-source atmospheric dispersion model used, rather than an explosive atmospheric dispersion model (appendix H.2, Human Health).

More detailed results, identification of postulated facility accidents, and methods of analysis were described in greater detail in appendix I, Facility Accidents. Much of the technical basis for the health impact of the accident analysis is included in appendix H, Human Health. Transportation-related accidents are described in section 5.7.

In the past, DOE has conducted dynamic experiments at LANL with plutonium. Such experiments also may be conducted in the future. Experiments with plutonium would always be conducted in double-walled containment vessels, and these experiments would not be expected to result in any release of plutonium to the environment. However, for the purposes of this EIS, health consequences of hypothetical accidental releases of plutonium have been estimated and are provided in appendix I.

5.4.9.1 Public

As in the No Action Alternative, potential impacts to members of the public were evaluated for three nearby points of public access – State Road 4, Pajarito Road, and the Bandelier National Monument. The MEI would be located at the State Road 4 location, approximately 0.9 miles (1.5 km) southwest of the site. An individual at this location under the assumed accident and exposure conditions would receive a radiation dose of about 0.01 rem EDE under the vessel containment failure scenario, and about 0.001 rem under the building containment breech scenario . The maximum probability of a LCF from these doses would be about 6×10^{-6} and 6×10^{-7}, respectively. The maximum probability of beryllium-induced cancers would be about 8×10^{-9} and 8×10^{-10}, respectively. Toxicological effects would not be expected, as no more than 0.2 and 0.02 mg, respectively, of any of the released constituents (uranium, beryllium, lead, lithium hydride) would be inhaled. Highest concentrations in air would be of uranium, which would be less than 1 percent and 0.1 percent, respectively, of the applicable IDLH values. All other materials would have lower concentrations and lower fractions of the IDLH values. Additional results are presented in appendix I, Facility Accidents.

Maximum population dose would occur under the containment vessel breech scenario, in the east-through-southeast direction, with a population dose of about 17 person-rem. Population dose under the building containment breech scenario would be about 1.7 person-rem. Latent cancer fatalities among the population would not be expected from either of these doses (9×10^{-3} and 9×10^{-4} LCFs, respectively). Cancer would not be expected among the population from exposure to beryllium (total incidence of 9×10^{-7} cancers and 9×10^{-8} cancers, respectively).

5.4.9.2 Noninvolved Workers

As in the No Action Alternative, nearby workers not involved with the detonation process would be affected to a lesser extent than involved workers because of their distance from the firing point. Under the vessel containment operational scenario access control and other area restrictions would be maintained for planned uncontained detonations that could take place. Other precautions taken under the No Action Alternative would also be maintained. However, for contained detonations it was assumed that the hazard radius would be lessened, to 1,300 feet (400 m), and that a noninvolved worker would be at this distance and exposed to the material released from the detonation during the entire period of passage.

A noninvolved worker would receive a radiation dose of about 0.05 rem EDE under the containment vessel failure scenario, and a dose of about 0.005 rem under the building containment breech scenario. The maximum probability of an noninvolved worker contracting a fatal latent cancer from these doses would be about 2×10^{-5} and 2×10^{-6}, respectively. The maximum probability of beryllium-induced cancers would be about 3×10^{-8} and 3×10^{-9}, respectively. Toxicological effects would not be expected, as no more than 0.7 and 0.07 mg, respectively, of any of the released constituents (uranium, beryllium, lead, lithium hydride) would be inhaled. Highest concentrations in air would be of uranium, which would be less than 10 percent and 1 percent, respectively, of the applicable IDLH values. All other materials would have lower concentrations and lower fractions of the IDLH values. Additional results are presented in appendix I, Facility Accidents.

5.4.9.3 Workers

Impacts to involved workers would differ little from those described under the No Action Alternative in section 5.1.9. During completion of DARHT construction and the associated material reprocessing facility, normal construction-type hazards would be encountered. During operations, the accident of greatest consequence would be the inadvertent detonation of high explosive on the firing site or in the containment building when workers are present. This accident is considered unlikely, but it could result in the deaths of all workers (a maximum of 15) in the immediate area.

Also, like the No Action Alternative, a possible second accident on the firing site with serious consequences outside the scope of normal industrial or laboratory hazards would be the direct exposure of a worker to the ionizing radiation pulse produced by the DARHT accelerator. Although this accident would be extremely unlikely, a worker could receive a very high acute radiation dose, delivered over a fraction of a micro-second, to a localized portion of the body.

5.4.10 Waste Management

Under this alternative, debris from the majority of detonations at the facility would be contained either by vessels or inside a containment building. Mixed-waste volumes, solid and liquid hazardous waste quantities, and nonhazardous solid waste volumes generated under the Enhanced Containment Alternative for both the vessel containment and building scenarios would be essentially the same as those for the No Action Alternative, described in section 5.1.10. Wastes generated under the Enhanced Containment Alternative, as for other alternatives, would be subject to treatment, storage, and/or disposal in other LANL Technical Areas. Transportation of these wastes would be conducted following DOT guidelines and using DOE- or DOT-approved containers carried on government vehicles using public roads between LANL facilities, as needed.

5.4.10.1 Vessel Containment Scenario LLW

Under the vessel containment scenario some uncontained detonations would be conducted, up to 25 percent of total annual depleted uranium expenditures of 1,540 lb (700 kg) or a maximum of 385 lb (175 kg) per year. The total estimated LLW generated and disposed from uncontained detonations would be less than 3,000 ft^3 (90 m^3), based upon a LLW generation rate of 1,800 ft^3 (50 m^3) LLW per 220 lb (100 kg) of depleted uranium used, as developed for the No Action Alternative (section 5.1.10). The bulk of this waste would be the gravel and soil that is removed with the detonation debris. Total volume of waste generated would depend on the number and frequency of the firing-site detonations and periodic cleanup.

For contained detonations, a reasonably predictable amount of waste would be generated each time. For contained major (hydrodynamic) detonation, the waste volume generated would be about 36 ft^3 (1 m^3) or up to five 55-gal drums. Some of the waste would be finely divided debris containing uranium, other metals, and occasionally lead. Much of this material would be separated out in the associated recovery facility and either recovered or disposed of separately, so that a reduced volume of LLW would remain for disposal. Assuming 50 percent recovery or separation of contained detonation material, and 20 major contained detonations per year, no more than 360 ft^3 (10 m^3) of LLW would be generated per year from contained detonations.

Total LLW generation is expected to be no more than 3,600 ft^3 (100 m^3) of LLW per year under the vessel containment scenario. Assuming the total LANL LLW disposal volume in future years would be 5,000 m^3/yr (Bartlit et al 1993), the Enhanced Containment Alternative, vessel containment scenario would be projected to contribute no more than two percent of the total LANL LLW volume.

Given a bounding failure rate of five percent and 20 shots per year, one vessel may be projected to fail each year. The failed vessels would be decontaminated and decommissioned and reused as scrap metal so that they would not enter the waste management program.

5.4.10.2 Building Containment Scenario LLW

All detonations under the building containment scenario would be conducted inside the containment building. Under this scenario, no uncontained detonations would occur, and therefore none of the large volumes of contaminated gravel and soil would be generated from cleaning the firing site of debris. LLW generation would be limited to that from contained detonations. As described above under the vessel containment scenario, this would typically be no more than about 36 ft^3 (1 m^3) or up to five 55-gal drums per major hydrodynamic detonation. Assuming 50 percent recovery or separation of contained detonation material, and 20 major contained detonations per year, no more than 360 ft^3 (10 m^3) of LLW would be generated per year under the building containment scenario. Assuming the total LANL LLW disposal volume in future years would be 5,000 m^3/yr (Bartlit et al 1993), the Enhanced Containment Alternative, building containment scenario would be projected to contribute no more than 0.2 percent of the total LANL LLW volume.

5.4.11 Monitoring and Mitigation

5.4.11.1 Monitoring

Monitoring under the Enhanced Containment Alternative would be essentially the same as that undertaken for the No Action Alternative, described in section 5.1.11.

5.4.11.2 Mitigation

Under normal operating conditions, only one potential impact would appear to warrant mitigation. Protection of the Nake'muu archeological site may be necessary under certain uncontained detonation test configurations of the vessel containment option. Mitigating measures similar to those of the other alternatives (e.g., blast shielding) may be necessary to avoid fragments reaching the site. No other archeological sites in the hazard radius have standing walls that would require mitigation activities. The containment structures used in this alternative would reduce the environmental consequences of operating DARHT and the need for mitigation for detonations performed in containment. Mitigation activities for cultural resources are presented in section 4.6.

5.4.12 Decontamination and Decommissioning

Decontamination and decommissioning under the Enhanced Containment Alternative would be essentially the same as described for the Preferred Alternative in section 5.2.12. In addition to those D&D activities and impacts, this alternative would result in decommissioning of a containment building and/or an undetermined number of vessels used for a 20- to 30-year design life. However, the amount of soil cleanup would be substantially less (25 to 90 percent) because of containment of wastes within the vessels or building.

5.5 PLUTONIUM EXCLUSION ALTERNATIVE

This section presents the expected environmental consequences associated with the Plutonium Exclusion Alternative.

5.5.1 Land Resources

Potential impacts of the Plutonium Exclusion Alternative on land resources would be essentially the same as for the Preferred Alternative, described in section 5.2.1.

5.5.2 Air Quality and Noise

Potential impacts of the Plutonium Exclusion Alternative on air quality and potential noise impacts would be essentially the same as for the Preferred Alternative, described in section 5.1.2.

5.5.3 Geology and Soils

Potential impacts of the Plutonium Exclusion Alternative on geology and soils would be essentially the same as for the Preferred Alternative, described in section 5.1.3.

5.5.4 Water Resources

Potential impacts of the Plutonium Exclusion Alternative on surface and ground water would be essentially the same as for the Preferred Alternative, described in section 5.1.4.

5.5.5 Biotic Resources

Potential impacts of the Plutonium Exclusion Alternative on biotic resources would be essentially the same as for the Preferred Alternative, described in section 5.1.5.

5.5.6 Cultural and Paleontological Resources

Potential impacts of the Plutonium Exclusion Alternative on cultural and paleontological resources would be essentially the same as for the Preferred Alternative, described in section 5.1.6.

5.5.7 Socioeconomic and Community Services

Potential socioeconomic impacts of the Plutonium Exclusion Alternative and potential impacts on community services would be essentially the same as for the Preferred Alternative, described in section 5.1.7.

5.5.8 Human Health

Potential impacts of the Plutonium Exclusion Alternative on human health would be essentially the same as for the Preferred Alternative, described in section 5.1.8.

5.5.9 Facility Accidents

Potential impacts of facility accidents under the Plutonium Exclusion Alternative would be essentially the same as for the Preferred Alternative, described in section 5.1.9.

5.5.10 Waste Management

Potential impacts of the Plutonium Exclusion Alternative on waste management would be essentially the same as for the Preferred Alternative, described in section 5.1.10.

5.5.11 Monitoring and Mitigation

Potential impacts that would be need to be monitored or mitigated under the Plutonium Exclusion Alternative would be essentially the same as for the Preferred Alternative, described in section 5.1.11.

5.5.12 Decontamination and Decommissioning

Impacts of D&D under the Plutonium Exclusion Alternative would be essentially the same as for the Preferred Alternative described in section 5.2.12.

5.6 SINGLE-AXIS ALTERNATIVE

This section presents the expected environmental consequences associated with the Single-Axis Alternative.

5.6.1 Land Resources

Potential impacts on land resources in the Single-Axis Alternative would be essentially the same as those described in section 5.2.1 for the Preferred Alternative.

5.6.2 Air Quality and Noise

5.6.2.1 Air Quality

Air quality impacts for the Single-Axis Alternative are presented in this section for maximally impacted point of unrestricted public access. These impacts were determined using methods described in appendix C, Air Quality and Noise.

5.6.2.1.1 Construction

Pollutant emissions during the construction phase of the Single-Axis Alternative would be essentially the same as for the Preferred Alternative. As a consequence, construction impacts on air quality would be essentially the same as for the Preferred Alternative as described in section 5.1.2.1.

5.6.2.1.2 Operations

In this alternative, the amount of high explosive used in hydrodynamic testing would probably be somewhat larger than for the Preferred Alternative. Air quality impacts from emissions of NO_2, SO_2, and PM_{10} from the gas-fired boiler that would be located at the facility would be essentially the same as those reported for the Preferred Alternative.

During the operations phase, the maximum offsite increase in ambient NO_2, and SO_2 concentrations would be very small, producing impacts that are well within the most stringent air quality standards. The maximum offsite increase in ambient PM_{10} would be equivalent to that noted for the Preferred Alternative.

5.6.2.2 Noise

Although the period of construction would be somewhat shorter, some remediation of the second accelerator site would be expected, and, on balance, noise impacts probably would not be significantly different from those of the Preferred Alternative as described in section 5.2.2.2.

5.6.3 Geology and Soils

Potential impacts of the Single-Axis Alternative on geology and soils would be essentially the same as those described in section 5.2.3 for the Preferred Alternative.

5.6.4 Water Resources

Potential impacts of the Single-Axis Alternative on surface and ground water would be essentially the same as those described in section 5.2.4 for the Preferred Alternative.

5.6.5 Biotic Resources

Impacts on biotic resources in the Single-Axis Alternative would be essentially the same as described in section 5.2.5 for the Preferred Alternative.

5.6.6 Cultural and Paleontological Resources

Impacts on cultural and paleontological resources from the Single-Axis Alternative would be essentially the same as those for the Preferred Alternative described in section 5.2.6.

5.6.7 Socioeconomic and Community Services

Environmental impacts on socioeconomics and community services for the Single-Axis Alternative are presented in this section. Potential impacts on demographic characteristics, community infrastructure and services, and environmental justice would be essentially the same as the Preferred Alternative and are described in sections 5.2.7.1, 5.2.7.2, and 5.2.7.3, respectively. Potential impacts on economic activities are presented below.

5.6.7.1 Economic Activities

Under the Single-Axis Alternative, the DOE is expected to complete construction of the facility by FY 1999. At that time, DARHT operating costs would replace PHERMEX operating costs (see table 5-16). For purposes of estimating the impacts of the Single-Axis Alternative on the regional economy (employment, labor income, and output), the analysis shows the construction and operating expenditures under the Single-Axis Alternative relative to those under the No Action Alternative. The estimated capital construction expenditures do not include any site cleanup nor D&D of the dual-axis facility at the end of its lifetime.

Over the period FY 1996 to FY 2002, the Single-Axis Alternative is estimated to generate 87 FTE jobs in the regional economy, 38 directly related to project construction and operating expenditures, and the other 49 indirectly generated by consecutive rounds of spending and income generation within the regional economy. The Single-Axis Alternative is also estimated to generate an annual average of $1.84 million of regional labor income, $0.80 million directly related to the project, and $1.04 million indirectly generated through consecutive rounds of spending. Finally, the Single Axis Alternative is estimated to generate an annual average of $3.28 million of goods and services in the regional economy, $1.75 million of these directly generated by the project, and $1.53 million indirectly generated by consecutive rounds of spending in the regional economy.

The underlying cost data were provided by LANL (Burns 1995). The costs do not include any expenses associated with site cleanup, nor D&D of either the DARHT or PHERMEX facilities. These relevant data were adjusted using an escalation price change index for DOE defense-related construction projects (Pearman 1994; Anderson 1995).

5.6.8 Human Health

Potential impacts of the Single-Axis Alternative on human health would be essentially the same as for the No Action Alternative, described in section 5.1.8.

TABLE 5-16.—*Capital-Funded Construction and Operating Costs Under Single-Axis Alternative (in millions of 1994 dollars)*

Year/Cost	1995	1996	1997	1998	1999	2000	2001	2002
Capital	6.61	18.93	17.71	5.83	0	0	0	0
Operations and Maintenance	4.17	4.30	4.43	4.58	6.26	6.46	6.66	6.86

5.6.9 Facility Accidents

Potential impacts of facility accidents under the Single-Axis Alternative would be essentially the same as for the No Action Alternative described in section 5.2.9.

5.6.10 Waste Management

Potential impacts of the Single-Axis Alternative on waste management would be the same as for the No Action Alternative, described in section 5.1.10.

5.6.11 Monitoring and Mitigation

5.6.11.1 Monitoring

Potential impacts that would need to be monitored under the Single-Axis Alternative would be the same as for the No Action Alternative, described in section 5.1.11.

5.6.11.2 Mitigation

Mitigation measures taken under the Single-Axis Alternative would be the same as those under the Preferred Alternative, described in section 5.2.11.2.

5.6.12 Decontamination and Decommissioning

Potential impacts of D&D under the Single-Axis Alternative would be essentially the same as under the Preferred Alternative, described in section 5.1.12, except that there would be only one accelerator hall and support equipment for D&D evaluation.

5.7 TRANSPORTATION OF MATERIALS

This section presents the results of an analysis of incident-free (routine operations) and accident consequences associated with transportation of materials, details of which are given in appendix J, Transportation of Materials. For purposes of this EIS, one transportation analysis applies to the No Action Alternative and the Upgrade Alternative (associated with PHERMEX); another analysis applies to the remaining alternatives (associated with DARHT).

All transportation would be in LANL-controlled areas. The analysis presented in appendix J is based on the assumption that the test device would be secured to a flat bed truck and transported to the receiving facility. The assembled test device would be transported from TA-16-410 to the PHERMEX or the DARHT Facility using roads internal to TA-16 and TA-15 (see figure 3-1). The truck would be loaded at TA-16-410 and transported nonstop approximately 4.7 mi (7.5 km) to the magazine (Building R242). From the magazine, the test device would be transported nonstop approximately 1.2 mi (2 km) to the PHERMEX gate or 0.9 mi (1.5 km) to the DARHT gate. At each of the facilities, the test device would be transported approximately 1,000 ft (300 m) from the facility gate to the firing site. Because the total distances are so similar, less than 0.3 mi (0.5 km) difference, the longer distance to PHERMEX is used for data presented here.

For purposes of this analysis, 20 shipments per year were assumed. Although 150 lb (70 kg) high explosive is the normal maximum at the firing points, three hypothetical test devices were assumed for analysis to cover a range of high explosive content, including the maximum sizes for the firing points, 500 lb (230 kg) (see sections 3.4.2 and 3.5.2). The three hypothetical test devices are: Test Device 1 with 22 lb (10 kg) high explosive, Test Device 2 with 500 lb (230 kg) high explosive, and Test Device 3 with 1,010 lb (460 kg) high explosive.

Contrary to intuition, Test Device 1 would produce the worst case worker doses because the device materials would be less dispersed in an accidental explosion. The worst case results, Test Device 1, are presented in this section unless otherwise stated.

5.7.1 Incident-Free Transportation

Potential impacts of routine transportation are discussed in the following sections.

5.7.1.1 Nonradiological Impacts

Nonradiological impacts of routine transportation would result principally from pollutants emitted from the vehicles. The estimated number of fatalities due to vehicle emissions from routine transportation was found to be essentially zero (2.4×10^{-4} LCFs over the life of the project).

5.7.1.2 Radiological Impacts

Radiological doses to the truck crew, onsite workers, and the public, resulting from transportation activities were calculated using methods described in appendix J, Transportation. Results of the analysis are provided in table 5-17. The calculated dose is based on 20 shipments per year. The dose to truck crews over the life of the project would be about 1 x 10^{-4} person-rem. The calculated dose to the public over the life of the project would be less than 3 x 10^{-9} person-rem. The total dose to the onsite worker population over the life of the project for the No Action Alternative would be about 0.004 person-rem.

TABLE 5-17.—*Summary of Analyses for Routine Transportation*

Population Group[a]	No Action Alternative and Preferred Alternative			
	Per Shipment		Annually	
	Radiological Dose (person-rem)	Health Effects (LCFs)	Radiological Dose (person-rem)	Health Effects (LCFs)
Radiological Impacts[b]				
Truck Crew	6 x 10^{-6}	2 x 10^{-9}	1 x 10^{-4}	4 x 10^{-8}
Onsite Worker	2 x 10^{-4}	7 x 10^{-8}	3 x 10^{-3}	1 x 10^{-6}
Total	2 x 10^{-4}	7 x 10^{-8}	4 x 10^{-3}	1 x 10^{-6}
Nonradiological Impacts				
Onsite Worker		4 x 10^{-7}		8 x 10^{-6}
Total Radiological and Nonradiological Impacts				
Truck Crew	6 x 10^{-6}	2 x 10^{-9}	1 x 10^{-4}	4 x 10^{-8}
Onsite Worker	2 x 10^{-4}	5 x 10^{-7}	3 x 10^{-3}	9 x 10^{-6}

[a] The calculated dose to the public is less than 1 x 10^{-10} person-rem and for this analysis is considered essentially zero.
[b] The maximum individual in-transit dose is 5.8 x 10^{-9} person-rem per shipment. Truck crew doses for the Preferred Alternative are slightly lower.

The potential LCFs were calculated using dose conversion factors given in ICRP 60 (ICRP 1991 ICL13), i.e., 0.0004 LCFs/person-rem to the onsite worker and truck crew and 0.0005 LCFs per person-rem to the general public, respectively. Cancer would not be expected to occur for the life of the project (workers and crew, 2 x 10^{-6} LCFs; onsite worker, 5 x 10^{-5} LCFs; public, less than 4 x 10^{-11} LCFs).

5.7.2 Impacts of Transportation of Materials Under Accident Conditions

Potential impacts of transportation of materials under accident conditions are discussed in the following subsections. If an accident occurs, the resulting debris and contamination, if any, would be removed and taken to appropriate LANL facilities as is done for firing-point debris.

5.7.2.1 Nonradiological Impacts

Transport vehicle speed is limited to 35 mph; therefore, vehicle collisions with other vehicles on the transportation route are not considered severe enough to cause fatalities to the truck occupants or occupants of the other vehicles involved in the accident. For the purposes of the analysis in appendix J, the transport vehicle is assumed to impact a stationary object with sufficient force to detonate the high explosive.

Impacts due to explosions are modeled based on accidental detonation of high explosive in each of the hypothetical test devices. Assuming that a peak overpressure of 30 psi (186 kpa) is fatal, all individuals within an approximate radius of 15 ft (5 m), 43 ft (13 m), and 53 ft (16 m) for test devices 1, 2, and 3, respectively, would be subjected to potentially fatal overpressures. The truck crews are assumed to be located within 30 ft (10 m) of the accident. Additionally, approximately 50 percent of the individuals at distances up to 80 ft (24 m) might be killed because of the blast wave. Injuries and fatalities to bystanders from flying shrapnel have not been estimated. There have been no such transportation accidents during more than 30 years of firing activities at TA-15.

In addition to evaluating the impacts from a detonation of the high explosives, an assessment of the consequences of a release of the hazardous materials associated with the devices was performed. It was assumed that 10 percent of the material released would be respirable (see appendix C). The results, based on the meteorological data for the LANL site, are shown in table 5-18. For comparison, although plume passage times are very short in duration, the IDLH exposure limits are also provided in table 5-18.

5.7.2.2 Radiological Impacts

The analyses of radiological impacts evaluates the impacts to MEI and the public because of a release of radioactive material. The analysis is based on the assumption that the transport vehicle would impact a stationary object, and the high explosive would be detonated. The accident rate used, about 4 accidents per 10 million mi (2 accidents per 10 million km) (Saricks and Kvitek, 1994), is a combination of accident rates for rural and urban federally aided highway systems.

Radiological doses were calculated for two population densities of interest [i.e., laboratory open space, about 5 workers/0.4 mi^2 (1 km^2); and occupied buildings, about 360 workers/0.4 mi^2 (1 km^2)]. It was assumed that 10 percent of the material aerosolized was respirable. The calculated dose, on a per shipment basis, to the two populations is estimated to be 0.2 person-rem and 17 person-rem, respectively. The integrated risk to the public (i.e., consequences times accident frequency integrated over the entire shipping distance) was estimated to be less than 1×10^{-4} person-rem.

TABLE 5-18.—*Nonradiological Transportation Accident Impacts to the Public*

Population Group	Beryllium (mg/m^3)	Lead (mg/m^3)	Lithium Hydride (mg/m^3)
Allowable Limit[a]	10.0	700.0	55.0
Onsite Worker[b]	1.2×10^{-4}	1.9×10^{-4}	1.2×10^{-3}
Offsite Individual[c]	1.1×10^{-4}	1.7×10^{-4}	1.1×10^{-3}

[a] IDLH limits taken from NIOSH 1990.
[b] Assumed to be located 0.5 mi (0.75 km) Northwest
[c] Assumed to be located 1 mi (1.5 km) Southwest

Radiological doses were also calculated for the MEI, located about 300 ft (100 m) from the release, the onsite MEI, located at the nearest occupied facility, and the offsite MEI, located at the site boundary. For this analysis, based on the location of the site boundary and the nearest public roadway, and the meteorological data, the offsite MEI was assumed to be located approximately 0.9 mi (1.5 km) to the northwest. The onsite MEI is assumed to be located 2,500 ft (0.75 km) to the northwest. The results of the radiological analyses for the MEI are presented in table 5-19.

The largest dose among the groups investigated was calculated to be to the onsite worker and amounted to 4.1×10^{-4} rem. The dose to the offsite MEI would be 3.7×10^{-4} rem. The maximum probability of LCF from this dose would be about 2×10^{-7} for both the onsite worker and the offsite individual. The dose to the individual at 300 ft (100 m) was calculated to be essentially zero; the radioactive cloud was lofted well above and over the individual.

5.8 UNAVOIDABLE ADVERSE IMPACTS AND IRREVERSIBLE AND/OR IRRETRIEVABLE COMMITMENT OF RESOURCES

The following subsections address unavoidable adverse environmental impacts and irreversible and/or irretrievable commitment of resources.

5.8.1 Unavoidable Adverse Impacts

Potentially unavoidable adverse impacts associated with the No Action Alternative, Preferred Alternative, Upgrade PHERMEX Alternative, Plutonium Exclusion Alternative, and Single-Axis Alternative were identified as follows:

- Contaminating soils with various materials, including depleted uranium, beryllium, lead, copper, aluminum, and other metals within approximately 500 ft (140 m) of the firing point during testing
- Disturbing wildlife as a result of blast noise from detonation of high explosives

- Initiating small fires as a result of explosives testing.

Unavoidable adverse impacts identified with the Enhanced Containment Alternative would be limited to destruction of a small amount [about 0.25 ac (0.1 ha)] of piñon/ponderosa pine forest habitat for the construction of the cleanup/recycle facility. Any tests which are uncontained may result in the same unavoidable adverse impacts listed above.

TABLE 5-19.—*Radiological Accident Impacts to the Maximally Exposed Individuals*

Receptor	Radiological Dose per Accident (rem)
Maximum Onsite Worker[a]	4.1×10^{-4}
Maximum Offsite Individual[b]	2.4×10^{-4}

[a] Assumed to be located 0.5 mi (0.75) km Northwest
[b] Assumed to be located 1 mi (1.5) km Northwest

5.8.2 Irretrievable and/or Irreversible Commitment of Resources

Irretrievable and/or irreversible commitment of resources associated with the various alternatives are presented in table 5-20.

5.9 CUMULATIVE IMPACTS

The following discussion of cumulative impacts addresses the potential for impacts that are insignificant, when viewed separately, but may become significant when viewed together. Cumulative impacts include impacts on the affected environment of the proposed activities over the life of the project, in addition to past and reasonably foreseeable future activities, whether onsite or offsite and public or private. The only measurable cumulative impacts are those discussed in this section.

As currently projected for the foreseeable future, concentrations of metal contaminants (depleted uranium, beryllium, lead, and other metals) in soil would approximately double for the TA-15 PHERMEX test area under the No Action Alternative or the Upgrade PHERMEX Alternative. For the Preferred Alternative, Plutonium Exclusion Alternative, and the Single-Axis Alternative, an area equivalent to that of the PHERMEX test area would be contaminated at the DARHT test site to approximately the current level of the PHERMEX test area. In the Enhanced Containment Alternative, if the vessel approach were used for uncontained tests, the DARHT test site would be contaminated to approximately 10 percent of the current contamination level of the PHERMEX test area. All of these areas could in time (centuries to millennia) contribute to contamination of ground water; however, the contamination levels were estimated through model simulations over 30 years and were found to be lower than drinking water standards. LANL has contaminated soils in other areas that might contribute to ground water contamination. Although these other potential sources have not been quantified, the contribution of any of the alternatives is not expected to increase the cumulative effects to ground water.

Collective worker dose for the LANL site for 1993 amounted to 239 person-rem, with approximately 0.3 person-rem attributable to testing at the PHERMEX facility. Because the future testing program is expected to be roughly the same under all alternatives, and worker dose is related to operations, worker dose would be expected to be roughly the same 0.1 percent regardless of the alternative analyzed. Testing at PHERMEX or DARHT would be expected to contribute the same, about 0.1 percent, to LANL worker dose and would be inconsequential in terms of cumulative impacts.

TABLE 5-20.—*Irreversible and/or Irretrievable Commitment of Resources*

Factor	No Action[a] Alternative	Preferred Alternative	Enhanced Containment Alternative (Vessels)[b]	Enhanced Containment Alternative (Building)[c]	Plutonium Exclusion Alternative	Single-Axis Alternative	Upgrade PHERMEX[d] Alternative
CONSTRUCTION							
Construction Materials							
Concrete (yd^3)	15,000	15,000	16,000	22,000	15,000	15,000	28,000
Cement (tons)	4,500	4,500	5,100	7,100	4,900	4,900	9,000
Rebar (tons)	600	600	600	900	600	600	1,000
Fuel							
Diesel (gal)	9,500	11,500	12,500	18,500	11,500	11,500	17,000
Gasoline (gal)	9,500	11,500	12,500	18,500	11,500	11,500	17,000
Propane (lb)	9,500	11,500	12,500	18,500	11,500	11,500	17,000
Electricity (kWh)	365,000	365,000	365,000	450,000	365,000	365,000	750,000
Work Force (worker years)							
Craft	50	59	74	140	59	59	120
Noncraft	12	14	18	26	14	14	29
Project Management (people)	max. 15/day	max. 15/day	max. 15/day	max. 15/day	max. 15/day	max. 15/day	max. 15/day
Waste Disposal Costs ($ thousands)	14.5	14.5	14.5	30.0	14.5	14.5	14.5
TOTAL COSTS ($ millions) (construction and equipment)	49	123	154	159	123	85	145
OPERATIONS							
Materials Used (Annual)							
Water (gal)	40,000	70,000	110,000	110,000	100,000	60,000	70,000
Helium (ft^3)	6,000	36,000	36,000	36,000	36,000	36,000	36,000
Sulfur Hexafluoride (ft^3)	3,100	0	0	0	0	0	0

TABLE 5-20.—*Irreversible and/or Irretrievable Commitment of Resources – Continued*

Factor	No Action[a] Alternative	Preferred Alternative	Enhanced Containment Alternative (Vessels)[b]	Enhanced Containment Alternative (Building)[c]	Plutonium Exclusion Alternative	Single-Axis Alternative	Upgrade PHERMEX[d] Alternative
Operations (continued)							
Energy (Annual)							
Natural Gas (ft^3)	8,700	10,400	13,300	14,800	10,400	10,400	13,000
Electricity (kWh)	550,000	2,250,000	2,600,000	2,900,000	2,250,00	1,350,000	2,500,000
Work Force, (worker years)							
Radiation-trained workers	9	15	24	24	20	13	15
Support staff	5	5	5	5	5	5	5
Operating Costs per Year ($ millions)	4.2	6.5	10.4	10.4	6.5	5.4	6.5
Material Releases[e]							
Depleted Uranium (lb)	1,540	1,540	90	90	1,540	1,540	1,540
Beryllium (lb)	20	20	2	2	20	20	20
Lead (lb)	30	30	2	2	30	30	30
Copper (lb)	220	220	13	13	220	220	220
Other Metals (lb)	440	440	25	25	440	440	440
High Explosive (lb)	3,300	3,300	3,100	3,100	3,300	3,300	3,100
Tritium (Ci)	3	3	0.3	0.3	3	3	3
Lithium Hydride (lb)	220	220	13	13	220	220	220

[a] No construction at PHERMEX; however, construction at proposed DARHT site to complete building for nonhydrodynamic testing purposes.
[b] DARHT Facility plus recycling facility.
[c] DARHT Facility plus recycling facility and containment building.
[d] New construction at PHERMEX plus DARHT construction noted in footnote a.
[e] For all alternatives, the annual materials used in this group are the same as the table entries for No Action.

Collective dose for the population within 50 miles (80 km) of the LANL site was 1.4 person-rem for 1992. Under the various hydrodynamic testing alternatives addressed here, the collective dose would be expected to range from 0.13 to 0.32 person-rem/yr. Thus, at a maximum for foreseeable conditions, hydrodynamic testing at TA-15 would continue to contribute roughly 10 to 25 percent of the reported collective population dose from LANL operations. Assuming the last 32 years of hydrodynamic testing to have resulted in about 10 person-rem and that an additional 30 years would double that, the cumulative collective dose from hydrodynamic testing at LANL would be about 20 person-rem out of an approximate 90 person-rem for all site sources (based on constant 1992 level). Cancer would not occur from such a cumulative collective dose since the calculated risk is 0.05 LCFs. The annual collective population dose for the same population from natural background radiation would be about 110,000 person-rem/yr. Hence, over the 30-year period, the collective population dose from natural background radiation would be about 3,200,000 person-rem for which, using the same conversion factor, about 1,600 LCFs would be inferred.

5.10 IMPACTS ON LONG-TERM PRODUCTIVITY

This section addresses the relationship between short-term uses of the environment and the maintenance of its long-term productivity.

Based on the analyses performed in this EIS, impacts on long-term productivity at Area III of TA-15 would be limited to consequences of deposition of depleted uranium and other metals on the soils of the site from continued testing and the potential of such metals for affecting the piñon/ponderosa pine forest habitat. However, no adverse effects on the piñon/ponderosa pine forest habitat over the last 32 years of operations similar to those proposed have been observed. Therefore, no impacts are expected on long-term productivity of the site from implementation of any of the alternatives.

5.11 REFERENCES CITED IN CHAPTER 5

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Chapter 6
Regulatory Requirements

CHAPTER 6
REGULATORY REQUIREMENTS

This section discusses the significant Federal, State, and local permit and approval requirements required for construction and operation of the Preferred Alternative and the other analyzed alternatives. A list of outside agencies and individuals contacted during preparation of the draft EIS is also included in this chapter.

6.1 RADIOACTIVE AIR EMISSIONS

Radioactive emissions from LANL facilities are subject to the Environmental Protection Agency (EPA) National Emission Standards for Hazardous Air Pollutants 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. 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 10 mrem/yr [40 CFR 61.92]. DOE submitted an application to construct the DARHT Facility, as described in the Preferred Alternative, to the Region VI Office of EPA in 1988. In a letter to DOE dated August 2, 1988, that approved the construction, EPA determined the projected dose to the nearest offsite resident from DARHT operations and other activities conducted at LANL would be well within the 10 mrem/yr standard.

Subpart H of 40 CFR Part 61 was promulgated on December 15, 1989 (54 FR 51695) and prescribes emission monitoring and test procedures to determine compliance with the 10 mrem/yr standard at DOE facilities. By letter dated June 25, 1991, DOE informed EPA that LANL was not in full compliance with Subpart H. Although DOE monitors LANL's radionuclide emissions, its monitoring program does not meet the requirements of Subpart H. EPA subsequently issued a Notice of Noncompliance to DOE on November 27, 1991. Shortly thereafter DOE and EPA entered into discussions to execute a Federal Facilities Compliance Agreement to bring LANL into compliance. Although the Agreement has not yet been finalized, DOE has been working in the interim to bring sources which emit radionuclides into compliance. The source which emits 95 percent of the radionuclides at LANL, the Los Alamos Meson Physics Facility, is in full compliance and DOE anticipates full compliance for all sources by the end of 1997. On September 13, 1994, the Concerned Citizens for Nuclear Safety, Inc. brought a civil action against DOE under the Clean Air Act to enforce the 40 CFR Part 61, requirements at LANL. That matter is still in litigation.

6.2 NONRADIOACTIVE AIR EMISSIONS

Nonradioactive emissions from LANL facilities are subject to the regulatory requirements of the New Mexico Environment Department (NMED) established under the New Mexico Air Quality Control Act. The NMED Air Quality Control Regulation requires a permit for constructing stationary sources or modifying existing sources in the event that the source would have potential emission rates greater than 10 lb/hr (4.54 kg/hr) or 25 ton/yr (22.67 metric ton/yr) of any regulated air contaminant subject to a Federal or New Mexico ambient air quality standard [NMED Air Quality Control Regulations §702 Part

Two.A(1)]. The PHERMEX Facility has not been subject to this requirement because its construction and operation preceded the effective date of §702 Part Two. The Preferred Alternative and the alternatives other than the No Action Alternative could be subject to the §702 Part Two permit requirement if they are classified as new stationary sources or modified stationary sources. The NMED regulations give a research facility, such as LANL, the opportunity to group its sources for the purposes of §702 at NMED's discretion [NMED Air Quality Control Regulations §702 Part One.33]. Consequently, the DARHT Facility could potentially be grouped with PHERMEX and not classified as a new stationary source. The DARHT Facility would be a "modification" to the PHERMEX Facility if 1) potential emissions of any regulated air contaminant increase in the event that DARHT became operational and PHERMEX were closed, or 2) new contaminants would be emitted by the DARHT Facility [NMED Air Quality Control Regulations §702 Part One.19].

NMED regulations also require a permit prior to the construction of new or modified sources with potential emissions of toxic air pollutants exceeding specified quantities [NMED Air Quality Control Regulations §702 Part Three.C]. The term *new source* is defined to be any source for which construction commenced after 1988, but not including any new source which is integrally related with and connected to the process of an existing source [NMED Air Quality Control Regulations §702 Part Three.B.(4)]. All alternatives analyzed except the No Action and PHERMEX Upgrade Alternatives are, consequently, potentially subject to the permit requirement. However, the rule exempts from the permitting requirements activities such as those analyzed in this EIS (except for the Enhanced Containment Alternative) which are classified as "non-process fugitive emissions of toxic air pollutants from stationary sources" [NMED Air Quality Control Regulations §702 Part Two.C(3)(j)]. The Enhanced Containment Alternative, if implemented, would not be automatically exempt from the air toxic permit requirements since emissions from containment structures would pass through a vent and, therefore, not be classified as *fugitive emissions* under the definition of this term in §702 Part One.16. Appendix A to §702 Part Three of the NMED Air Quality Control Regulations contains the threshold quantity emission limits that would trigger the need for a toxic air emissions permit. The air pollutants from the alternatives under consideration with the greatest likelihood of triggering the permit requirement are uranium and lithium hydride. Appendix A specifies that a permit would be needed if emissions of natural uranium exceed 0.0133 lb/hr (6 g/hr) and emissions of lithium hydride exceed 0.00167 lb/hr (0.76 g/hr). (The Preferred Alternative and the alternatives use depleted uranium; however, the toxicity of depleted uranium is similar to natural uranium.)

If the Enhanced Containment Alternative were to be implemented, a material reprocessing facility would be built to handle the debris resulting from cleaning the containment structure after each use. Air emissions for this facility are not currently defined. The need for an emissions permit under §702 will be evaluated when information becomes available.

NMED regulations require owners of sources with potential emissions greater than 10 ton/yr (9.1 metric tons/yr) of any regulated contaminant or 1 ton/yr (.91 metric tons/yr) of lead file a Notice of Intent with NMED, whether or not a permit is required, as a condition of construction [NMED Air Quality Control Regulations §703.1 Part Two.A]. Emissions from the Preferred Alternative or the other alternatives would be within these levels; consequently, a Notice of Intent would not be needed.

All of Los Alamos County has attainment status for the National Ambient Air Quality Standards listed at 40 CFR Part 50. Consequently, a written determination indicating that implementing any alternative analyzed in this EIS would conform to the New Mexico State Implementation Plan does not need to be prepared [20 New Mexico Administrative Code 2.98(2)]. Major new sources of pollutants in attainment areas are subject to prevention of significant deterioration (PSD) permit requirements. None of the alternatives analyzed would need a PSD permit because they are not *major stationary sources* (as that term is defined in the NMED Air Quality Control Regulations §707.P.26) of regulated air pollutants.

The Preferred Alternative and the other alternatives would not be included within the source categories subject to new source performance standards [NMED Air Quality Control Regulations §750].

Emissions of hazardous air pollutants from the Preferred Alternative or its alternatives would be less than 10 tons/yr (9.1 metric tons/yr) for a single hazardous air pollutant and 25 tons/yr (22.7 metric tons/yr) for any combination of two or more hazardous air pollutants. Consequently, the Preferred Alternative and the other alternatives would not be major sources of hazardous air pollutants subject to the requirements covering the construction or modification of major sources of hazardous air pollutants at 20 New Mexico Administrative Code 2.83.

Nonradioactive emissions from implementing the Preferred Alternative or another alternative would eventually be covered in an operating permit issued under NMED Air Quality Control Regulations §770 for the entire LANL site. DOE expects to submit an operating permit application to NMED in late 1995.

6.3 LIQUID DISCHARGES TO SURFACE WATER AND THE GROUND

The three sources of liquid discharges from the Preferred Alternative and all but the No Action Alternative are cooling tower blowdown, septic tank sanitary waste effluent, and storm water runoff. Although these sources would discharge to the ground, the discharges may enter Water Canyon, an ephemeral tributary to the Rio Grande. The State of New Mexico Environmental Improvement Division issued DOE a septic tank permit (number SF890589) for the DARHT Facility on October 30, 1989. Other septic tank permits have been issued for the Radiographic Support Laboratory and the PHERMEX Facility. EPA issued to LANL on December 29, 1994, a National Pollutant Discharge Elimination System (NPDES) permit (number NMR10A236) covering storm water discharges from construction activity at the DARHT site. A storm water pollution prevention plan for the construction activity was completed and implemented. The cooling tower blowdown from the Preferred Alternative would have an average flow of 2000 gal/day (7600 l/day). This discharge is incorporated into the LANL sitewide NPDES permit (permit number NM0028355) issued to DOE and LANL by EPA Region VI on June 24, 1994.

6.4 CHEMICAL AND MATERIAL STORAGE

Chemical and material storage at a LANL facility would be conducted according to DOE Orders and Manuals. In particular, DOE Orders 5480.4 (Environmental Protection, Safety, and Health Protection Standards) and 5480.7A (Fire Protection) require compliance by DOE and its contractors with National Fire Protection Association Codes and Standards, the Occupational Safety and Health Standards at 29 CFR Part 1910 established by the Occupational Safety and Health Administration (OSHA), and the DOE Explosives Safety Manual. In addition, DOE rules at 10 CFR Part 835 establish radiation protection standards and program requirements to protect occupational workers at DOE facilities.

6.5 WASTE MANAGEMENT

If implemented, the Preferred Alternative or the other alternatives would produce four categories of regulated waste: solid waste, hazardous waste, low-level radioactive waste, and mixed radioactive and hazardous waste (mixed waste).

Solid waste that is not classified under Subtitle C of the Resource Conservation and Recovery Act (RCRA) as a hazardous waste would be disposed at the LANL Area J landfill in TA-54 or sent offsite to an approved disposal facility. The Area J landfill is operated according to the requirements in Subtitle D of RCRA, the New Mexico Solid Waste Act, and regulations issued under each Act.

Waste that is classified as hazardous waste under Subtitle C of RCRA would be taken to TA-54 for temporary storage. Ultimate treatment and disposal would occur at RCRA interim status or permitted facilities at LANL or offsite. Hazardous waste storage areas in TA-54 are operated according to the requirements of Subtitle C of RCRA, the New Mexico Hazardous Waste Act, and regulations issued under each Act.

Low-level radioactive waste would be disposed at the LANL low-level radioactive waste disposal site in TA-54. This site is operated according to the requirements in chapter III of DOE Order 5820.2A (Radioactive Waste Management).

Mixed waste would be treated and disposed according to the site treatment plan for LANL developed in response to the Federal Facility Compliance Act [42 U.S.C. 6939c(b)]. The availability of proposed site treatment plans for various DOE sites including LANL was announced April 5, 1995 [60 FR 17346].

6.6 NOISE

If implemented, the Preferred Alternative or the other alternatives would create substantial noise during those times when explosions occur as discussed in section 5.2.3.

Federal efforts to regulate noise largely derive from the Noise Control Act of 1972 [42 U.S.C. 4901-4918]. Under the Act, Federal agencies such as DOE are to carry out their programs to further the Act's purpose of promoting an environment for all Americans that is free from noise that jeopardizes health or welfare [42 U.S.C. 4903(a)]. DOE seeks to meet this obligation by placing high explosives test areas, such as PHERMEX or the DARHT Facility, away from populated areas, localizing the noise impacts to the extent practicable, and conducting operations involving explosives during hours when most people within hearing distance are not sleeping. 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 conducted at the Preferred Alternative and its alternatives [42 U.S.C. 4309].

OSHA has established regulations to regulate the noise exposure of occupational workers [29 CFR 1910.95]. DOE Order 5480.4 specifies that DOE contractor operations, such as those to be conducted under the Preferred Alternative or an alternative, are to meet all OSHA standards in 29 CFR Part 1910.

The Noise Control Act requires Federal agencies to meet state and local requirements relating to the abatement of noise [42 U.S.C. 4903(b)]. No state requirements would prohibit or regulate the noise associated with operation of the Preferred Alternative or the other alternatives. The Los Alamos County Code does have noise restrictions. It is a violation of the code to cause noise levels exceeding 65 dBA in residential areas of the county between 7 a.m. and 9 p.m. and 53 dBA between 9 p.m. and 7 a.m. (Los Alamos County Code, Ch. 8.28.030). Between 7 a.m. and 9 p.m., the permissible noise level can be increased to 75 dBA in residential areas provided the noise is limited to 10 minutes in any 1 hour. Persons who cannot meet the preceding requirements can request a permit from the county for noise-generating activities of a temporary nature [Los Alamos County Code, Ch. 8.28.060(d)].

6.7 FLOODPLAINS AND WETLANDS

DOE's 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, issued by President Carter in 1977, requires Federal agencies to avoid direct or indirect support of floodplain development when there is a practicable alternative. Executive Order 11990, also issued by President Carter in 1977, 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. DOE has determined no floodplains or wetlands are present on land which would be affected by the Preferred Alternative or the other alternatives.

6.8 THREATENED AND ENDANGERED SPECIES AND MIGRATORY BIRDS

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 their habitat [16 U.S.C. 1536]. Unless otherwise permitted by regulation, the Migratory Bird Treaty Act makes it unlawful to pursue, hunt, take, capture, kill (or to attempt any of the preceding) any migratory bird or nest or eggs of such bird [16 U.S.C. 703]. The Bald and Golden Eagle Protection Act [16 U.S.C. 668] protects bald and golden eagles. The Fish and Wildlife Coordination Act [16 U.S.C. 661] provides other requirements for protecting wildlife. DOE has reviewed the preceding authorities and has determined that construction and operation of the Preferred Alternative or another alternative would be consistent with the authorities through implementation of appropriate mitigating measures.

DOE is in the process of consulting with the U.S. Fish and Wildlife Service, the New Mexico Department of Game and Fish, and the New Mexico Department of Energy, Minerals, and Natural Resources regarding whether or not any of the alternatives analyzed in this EIS would jeopardize the habitat of any threatened or endangered species, and appropriate mitigating measures.

6.9 NATIVE AMERICAN, ARCHAEOLOGICAL, AND HISTORIC PRESERVATION

DOE's American Indian Tribal Government Policy is in DOE Order 1230.2, issued April 8, 1992. DOE commits in the Order to consult with Tribal governments to assure that tribal rights and concerns are considered prior to DOE taking actions that may affect tribes. DOE also has committed to avoiding unnecessary interference with traditional tribal religious practices.

The August 11, 1978, American Indian Religious Freedom Act [42 U.S.C. 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 U.S.C. 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 receipt of certification that notice has been received by the Tribal governments. No human remains have been discovered at either the PHERMEX or DARHT site. During the comment period on this draft EIS, DOE will consult with local American Indian Tribes regarding the requirements under these laws.

The Archaeological Resources Preservation Act 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 U.S.C. 470bb, 470ee]. The Federal land manager for LANL is DOE.

The National Historic Preservation Act authorizes the Secretary of the Interior to maintain a National Register of Historic Places [16 U.S.C. 470a(a)(1)]. Federal agencies cannot approve projects that would affect properties listed on the Register without considering the effect on the listed properties [16 U.S.C. 470f]. For proposed actions at LANL, DOE consults with the New Mexico State Historic Preservation Office and the Advisory Council on Historic Preservation, as necessary. DOE consulted with these offices, and with the San Ildefonso Pueblo, prior to initiating construction at the DARHT site, and employed the mitigation measures agreed to at that time to protect archaeological sites.

DOE has reviewed the preceding authorities and has determined that construction and operation of the Preferred Alternative or another alternative would be consistent with the authorities through implementation of appropriate mitigating measures.

6.10 SITING AND PLANNING

All of the alternatives under consideration, including the No Action Alternative, involve land in TA-15 at LANL. The *LANL Site Development Plan* provides that existing and planned land uses for TA-15 are for high explosives research, development, and testing (LANL 1994). All alternatives analyzed in the EIS are consistent with the planned land uses for TA-15.

6.11 OTHER AGENCIES AND INDIVIDUALS CONSULTED

In addition to the agencies discussed above, during the preparation of this draft EIS the following outside governmental agencies and individuals were consulted:

John L. Temple, Assistant Director, Bureau of Business and Economic Research, University of New Mexico, 1920 Lomas NE, Albuquerque, NM 87131-6021 (505-277-2216).

Karma A. Shore, Economist, Bureau of Business and Economic Research Data Bank, University of New Mexico, 1920 Lomas NE, Albuquerque, NM 87131-6021 (505-277-8300).

Gerry Bradley, Labor Economist Supervisor, New Mexico Department of Labor, Economic Research and Analysis, P.O. Box 1928, Albuquerque, NM 87103 (505-841-8645).

Jim Greenwood, Los Alamos Economic Development Corporation, 901 18th St., Los Alamos, NM 87544 (505-662-0001).

6.12 REFERENCES CITED IN CHAPTER 6

LANL (Los Alamos National Laboratory), 1994, *Environmental Surveillance at Los Alamos During 1992*, LA-12764-ENV, Los Alamos, New Mexico.

Glossary

DARHT DEIS

GLOSSARY

Access Control Office	LANL office that monitors activities and controls access within the PHERMEX controlled area.
aerosolize	The process of converting a solid or a liquid into a gaseous suspension of fine particles (an aerosol).
air quality	A measure of the quantity of pollutants in the air.
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 and/or gravel deposits found in a stream channel or in low parts of a stream valley that is subject to flooding.
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.
aquifer	Geologic material that contains sufficient saturated permeable material to conduct ground water and to yield worthwhile quantities of ground water to wells and springs.
aqueous	In liquid form (i.e., dissolved in water).
atmosphere	The layer of air surrounding the earth.
background radiation	Normal radiation present in the lower atmosphere from cosmic rays and earth sources. Background radiation varies with location, depending on altitude and natural radioactivity present in the surrounding geology.
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.
bounded	Producing greater consequences than other accidents; or would "bound" the remainder of the accidents.
breccias	A coarse-grained rock composed of angular broken rock fragments held together by a mineral cement.
°C	Degree Celsius. $°C = 5/9 \times (°F - 32)$.

cancer	Any malignant new growth of abnormal cells or tissue.
capable (fault)	A term defined by the Nuclear Regulatory Commission to indicate that a fault is a hazard to be considered in safety analyses.
carcinogen	An agent capable of producing or inducing cancer.
carcinogenic	Capable of producing or inducing cancer.
cavate	A hand-dug cavity in the tuff cliff face.
collective dose	The sum of the individual doses to all members of a specific population.
community	A group of people or a site within a spatial scope exposed to risks that potentially threaten health, ecology, or land values, or exposed to industry that stimulates unwanted noise, smell, industrial traffic, particulate matter, or other nonaesthetic impacts. (environmental justice definition)
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 in diameter set in fine-grained sand or silt. It is commonly cemented naturally by hardened clay.
control and accountability	Continuing control and accountability, particularly of special nuclear materials such as plutonium and highly enriched uranium.
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 effects	Additive environmental, health, and socioeconomic effects that result from a number of similar activities in an area.
cumulative impacts	The sum of environmental, health, and socioeconomic impacts that result from a number of activities in an area.
curie (Ci)	A unit of radioactivity equal to 37,000,000,000 (37×10^{10}) decays per second.
dBA	Decibel on the A weighted scale.

decay, radioactive	The spontaneous transformation of one nuclide into a different nuclide or into a different energy state of the same nuclide. The process results in the emission of nuclear radiation (alpha, beta, or gamma radiation).
decommissioning	The removal from service of facilities such as processing plants, waste tanks, and burial grounds, and the reduction or stabilization of radioactive contamination, if present.
depleted uranium	A mixture of uranium (U) isotopes where U-235 represents less than 0.7 percent of the uranium by mass.
design life	The design life of components or systems generally refers to the estimated period of time that the component or system is expected to perform within specifications before the effects of aging result in performance deterioration or a requirement to replace the component or system.
disablement	A means to disable a nuclear weapon so that it cannot be detonated.
dose rate	The radiation dose delivered per unit time (e.g., rem per year).
dynamic experiment	An experiment to provide information regarding changes in materials under conditions caused by the detonation of high explosives.
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.
ecotone	A transition zone that exists between two ecologic communities.
Ector	An existing x-ray diagnostic machine scheduled to be moved to PHERMEX in mid-1995.
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).
effluent	Liquid or airborne material released to the environment. In common usage, however, the term "effluent" implies liquid release.
effluent standards	Defined limits of effluent in terms of volume, content of contaminants, temperature, etc.

EIS	Environmental impact statement; a document required by the National Environmental Policy Act (NEPA) of 1969, as amended, for proposed major Federal actions involving potentially significant environmental impacts.
electron accelerator	A device which uses intense electrical and magnetic energy to increase the velocity of electrons, thereby increasing their energy.
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 quantities and kinds of air contaminants that can be emitted into the atmosphere.
endangered species	Plants and animals that are threatened with extinction, serious depletion, or destruction of critical habitat. Requirements for declaring a species endangered are contained in the Endangered Species Act.
energy	The capacity to produce heat or do work.
enhanced radiography	A radiography technique for producing extremely high resolution, time-phased, photographic images of an opaque object (see also radiography).
environment	The sum of all external conditions and influences affecting the life, development, and ultimately the survival of an organism.
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 channel which carries 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.
equation-of-state	A mathematical expression which defines the physical state of a homogeneous substance by relating volume to pressure and absolute temperature for a given mass of the material.
erosion	The process in which the actions of wind or water carry away soil and clay.
evapotranspiration	Loss of water from the earth's surface to the atmosphere by evaporation from the soil, lakes, streams, and by transpiration from plants.

exclusion zone	The area surrounding the firing point that is cleared of all personnel for a test shot. The radius of this area is determined by the size of the shot.
exposure to radiation	The incidence of radiation on living or inanimate material by accident or intent. Background exposure is the exposure to natural background ionizing radiation. Occupational exposure is the exposure to ionizing radiation that occurs during a person's working hours. Population exposure is the exposure to a number of persons who inhabit an area.
°F	Degree Fahrenheit. F = °C x 9/5 + 32.
fallout	The descent to earth and deposition on the ground of particulate matter (that might be radioactive) from the atmosphere.
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.
fissionable	Capable of being split or divided (fissioned) by the absorption of thermal neutrons. The most common fissile materials are uranium-233, uranium-235, and plutonium-239.
fission	The splitting of a heavy nucleus into two approximately equal 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.
forb	A general term for a weed or broadleaf 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.
fugitive emission	Those emissions which could not reasonably pass through a stack, chimney, vent, or other fundamentally equivalent opening.
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.
ground water	All subsurface water, especially that part that is in the zone of saturation.
group	The geological term for the rock layer next in rank above formation.
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 millionths of a second to billions of years.
Hazard Index (HI)	An indicator of the potential toxicological hazard from exposure to a particular substance. The HI is equal to an individual's estimated exposure divided by the U.S. EPA's substance-specific reference dose.
hazard zone	A circular area in which personnel are not allowed outside the control rooms during tests involving high explosives. The area is centered on the firing point and its radius is determined from the amount of explosives to be used.
He-Ne Laser	A device which uses a gaseous mixture of helium (He) and Neon (Ne) to produce an intense beam of light.
HEPA filter	High efficiency particulate air filter designed to remove 99.9 percent of particles as small as 0.3 micrometer in diameter from a flowing air stream.
historic resources	The sites, districts, structures, and objects considered limited and nonrenewable because of their association with historic events, persons, or social or historic movements.
Horizon A soil	The top-most layer of soil distinguishable by color, texture, or structure.
hydrodynamic test	A dynamic integrated systems test of a mock-up nuclear package during which the high explosives are detonated and the resulting motions and reactions of materials and components are measured. The explosively generated high pressures and temperatures cause some of the materials to behave hydraulically (like a fluid).
hydrodynamic testing facility	A facility in which to conduct dynamic and hydrodynamic testing for nuclear and conventional weapons research and assessment. Fast diagnostic systems that are available include radiographic, electrical, optical, laser, and microwave. The testing can provide both two- and three-dimensional information for performance evaluation.
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 Meralli 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.

interfingers	The combination of markedly different rocks through vertical succession of thin interlocking or overlapping of wedge-shaped layers.
interflow breccias	A breccia that occurs in or between volcanic flows.
ion	An atom or molecule that has gained or lost one or more electrons to become electrically charged.
ionization	The process that creates ions. Nuclear radiation, x-rays, high temperatures, and electric discharges can cause ionization.
ionizing radiation	Radiation capable of displacing electrons from atoms or molecules to produce ions.
irradiation	The process of exposing a material to radiation.
ISC2	A computerized dispersion program used to calculate ground-level concentrations of air pollutants.
isotope	An atom of a chemical element with a specific atomic number and atomic weight. Isotopes of the same element have the same number of protons but different numbers of neutrons. Isotopes are identified by the name of the element and the total number of protons and neutrons in the nucleus. For example, uranium-238 is a uranium atom with 238 protons and neutrons.
laser	An active electron device that converts input power into a very narrow, intense beam of light.
latent cancer fatalities (LCFs)	Deaths resulting from cancer that has become active after a latent period following exposure (i.e., a period of inactivity). LFCs can be calculated for the public by using the risk conversion factor of 5×10^{-4} deaths per person-rem and for the worker by using the risk conversion factor of 4×10^{-4} deaths per person-rem.
lineament	A geological term for straight or gently curved, lengthy topographic features expressed as depressions or lines of depressions.
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.
lithic	The description of rocks on the basis of such characteristics as color, mineralogic composition, and grain size.
low-income communities	A community where 25 percent or more of the population is identified as living in poverty.

low-level waste	Radioactive waste not classified as high-level waste; it would consist mainly of solid material contaminated with low-levels of depleted uranium.
lystric fault	The fault that is steep at the ground surface and becomes less and less steep as its depth increases. It eventually becomes horizontal or nearly horizontal.
maximum contaminant levels (MCLs)	The maximum permissible level of a contaminant in water that is delivered to a user of a public water system.
maximally exposed individual (MEI)	A hypothetical person located to receive the maximum possible dose by a given exposure scenario.
member	A geological term for a layer of rock that includes some specially developed part of a formation.
migration	The natural travel of a material through the air, soil, or groundwater.
mitigate	To take practicable means to avoid or minimize environmental harm from a selected alternative.
National Register of Historic Places	A list maintained by the National Park Service of architectural, historic, archaeological, and cultural sites of local, state, or national importance.
natural radiation or natural radioactivity	Radiation from naturally occurring materials, in distinction to materials made to become radioactive by bombardment in a reactor or accelerator. Additionally, natural radiation includes x-rays and other radiation that does not originate on Earth.
noninvolved worker	For this EIS, a worker who is not involved in the operation of a facility when a radioactive release occurs, and who is assumed to be 2,500 ft (750 m) or 1,300 ft (400 m) from the point of release, depending on the exposure scenario and alternative.
NEPA	National Environmental Policy Act of 1969; it requires the preparation of an EIS for Federal projects that could present significant impacts to the environment.
nonproliferation	The restriction of ability to easily access fissile material in concentrations sufficient to assemble a nuclear weapon.
NO_x	Oxides of nitrogen, primarily nitrogen oxide (NO) and nitrogen dioxide (NO_2). These are produced in the combustion of fossil fuels, and can constitute an air pollution problem.

nuclear radiation	See radiation.
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.
nuclear stockpile	The total aggregation of the nation's nuclear weapons that are in the custody of the Department of Defense. This quantity is defined in the nuclear weapons stockpile memorandum.
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 weapon primaries	Those components of a nuclear weapon involved in the reaction up to the point where nuclear criticality is achieved.
nuclide	A species of atom, characterized by its nuclear constitution (number of protons and number of neutrons).
organic compounds	Chemical compounds containing carbon.
outfall	Place where liquid effluents enter the environment and are monitored.
oxide	A compound in which an element chemically combines with oxygen.
ozone	A compound of oxygen in which three oxygen atoms are chemically attached to each other.
particulates	Solid particles and liquid droplets small enough to become airborne.
passive safety system	A system that provides safety features requiring no human intervention or adverse condition to actuate.
perennial stream	A stream that contains water at all times except during extreme drought.
perched aquifer	A body of ground water separated from an underlying body of ground water by an unsaturated zone.
people of color communities	A population classified by the U.S. Bureau of the Census as Black, Hispanic, Asian and Pacific Islander, American Indian, Eskimo, Aleut, and other nonwhite persons, the composition of which is at least equal to or greater than the state minority average of a defined area or jurisdiction.
permeability	Ability of liquid to flow through rock, groundwater, soil, or other substance.

person-rem	The radiation dose to a given population; the sum of the individual doses received by a population segment.
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	Geographic regions based on geologic setting.
plutonium (Pu)	A transuranic, heavy (average atomic mass ranging from about 237–244 atomic mass units), silvery metallic element with 15 isotopes that is produced by the neutron irradiation of natural uranium.
PM_{10}	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.
progeny	Stable or radioactive elements formed by the radioactive decay of another nuclide, which is the "parent".
pulse width	The duration of a brief burst of energy, such as x rays or direct current electricity.
Puye Formation	A stratigraphic unit composed of basalts, interflow breccias, conglomerates, sandstones, and siltstones that underlies Los Alamos National Laboratory.
radiation	The emitted particles and photons from the nuclei of radioactive atoms.
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)
radioactivity	The spontaneous decay of unstable atomic nuclei, accompanied by the emission of radiation.
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.
radionuclide	A nuclide that emits radiation (see nuclide).
reach	A continuous and unbroken expanse or surface of water (used in hydrologic contexts).

recharge	The processes involved in the absorption and addition of water to an aquifer.
rem	The unit of effective dose equivalent.
render-safe	A means to render a nuclear weapon safe from unwanted detonation.
Richter Scale	A numerical scale of earthquake magnitude that represents the size of an earthquake at its source.
risk	In accident analysis, the probability weighted consequence of an accident, defined as the accident frequency per year multiplied by the dose. The term "risk" is also used commonly to describe the probability of an event occurring.
runoff	The portion of rainfall, melted snow, or irrigation water that flows across the ground surface and eventually returns to streams.
Santa Fe Group	The name applied to a sequence of geologic formations that have been deposited mostly in the Rio Grande rift. These deposits are primarily sediments with some limestones, volcanic tuffs and basalts.
science-based stockpile stewardship	The DOE program to develop a new approach, based on scientific understanding and expert judgement, to ensure continued confidence in the safety, performance, and reliability of the nuclear weapons stockpile.
seismicity	The tendency for earthquakes to occur.
shield	Material used to reduce the intensity of radiation that would irradiate personnel or equipment.
short-lived	A designation for radionuclides with relatively short half-lives (i.e., they decay to stable materials relatively quickly).
solid state laser	A device which uses a semiconductor or a special glass to produce an intense beam of light in which it acts like a He-Ne Laser. This term is often used to distinguish a device from gas lasers.
spallation products	Products that result from a nuclear reaction in which the energy of the incident particle is so high that more than two or three particles are ejected from the target nucleus, and both its mass number and atomic number are changed.
stabilization	The action of making a nuclear material more stable by converting its physical or chemical form or placing it in a more stable environment.

stabilization	The action of making a nuclear material more stable by converting its physical or chemical form or placing it in a more stable environment.
static testing	Using radiographic equipment to make an x-ray image of a test assembly before other testing is done.
stockpile management	Maintenance, evaluation, repair, or replacement of weapons in the existing stockpile.
stockpile stewardship	A program of activities to maintain the technical competence and capability for the nation to continue to have confidence in the safety, reliability, and performance of our nuclear weapons.
strata	Layers of rock usually in a sequence.
stratum	A single layer of rock, usually one of a sequence.
stratigraphy	Geographic position and chronological order of sequence of strata.
surface water	All bodies of water on the Earth's surface (e.g., streams, lakes, reservoirs), as distinguished from ground water.
threatened species	Any species which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range.
transuranic elements	Elements that have atomic numbers greater than 92; all are radioactive, and are products of artificial nuclear changes.
tritium	A radioactive isotope of hydrogen; its nucleus contains one proton and two neutrons.
Tshirege member	Layer of volcanic rock that is a member of the Bandelier tuff. It is composed of multiple flow units of tuff.
tuff	A type of rock formed of compacted volcanic fragments.
uranium (U)	A heavy (average atomic mass of about 238 atomic mass units), silvery-white metal with 14 radioactive isotopes.
welding	Consolidation of sediments by pressure resulting from weight of material or from earth movement.
x-ray	A penetrating electromagnetic radiation, usually generated by accelerating electrons to high velocity and suddenly stopping them by collision with a solid body.

List of Preparers and Contributors

LIST OF PREPARERS AND CONTRIBUTORS

This list identifies individuals who were principal preparers and contributors to this environmental impact statement (EIS). M. Diana Webb of the Los Alamos Area Office of the Department of Energy (DOE), directed the preparation of the EIS. Glen T. Hanson of Battelle's Albuquerque Office provided overall project management, technical and document preparation support. Dr. E. B. Moore provided management of the technical support from participating staff from DOE's Pacific Northwest Laboratory (managed and operated by Battelle).

Name:	**ROSANNE L. AABERG**
Affiliation:	Battelle – Pacific Northwest Laboratory
Education:	• B.S., Chemical Engineering, University of Washington, 1976
Technical Experience:	Nineteen years of experience in the fields of environmental health physics, nuclear fuel cycle analysis, and RCRA compliance.
EIS Responsibility:	Prepared the monitoring and mitigation sections of chapter 5.

Name:	**SAMUEL T. ALEXANDER**
Affiliation:	Los Alamos National Laboratory
Education:	• M.S., Applied Mathematics, University of Wisconsin, 1968 • B.S., Applied Mathematics, University of California at Berkeley, 1965
Technical Experience:	Twenty-three years of experience in facility and project management for explosives firing sites, facility support, and radiographic analyses.
EIS Responsibility:	Co-preparer of chapter 3 and provided baseline data for appendix B, coordinated DX-Division information for the EIS.

Name:	**KURT ANAST**
Affiliation:	Los Alamos National Laboratory
Education:	• B.S., Metallurgical Engineering, Colorado School of Mines, 1979
Technical Experience:	Sixteen years of experience in process design, construction and operation in the chemical, metallurgical, and waste treatment areas.
EIS Responsibility:	Contributed to development of Enhanced Containment Alternative.

Name:	**DR. ALLAN B. ANDERSON**
Affiliation:	Los Alamos National Laboratory
Education:	• Ph.D., Solid State Physics, Colorado State University, 1976 • B.S., Physics, Western Illinois University, 1970
Technical Experience:	Eighteen years of experience in high explosives research and development.
EIS Responsibility:	Contributed to appendix B.

Name: **DAVID M. ANDERSON**

Affiliation: Battelle – Pacific Northwest Laboratory

Education:
- M.S., Forest Economics, Oregon State University, 1991
- B.S., Forest Resources, Oregon State University, 1989

Technical Experience: Five years of experience with regional socioeconomic modeling using various regional impact assessment codes.

EIS Responsibility: Contributed to the socioeconomics section.

Name: **MICHAEL J. BURNS**

Affiliation: Los Alamos National Laboratory

Education:
- M.S., Mechanical Engineering, University of California at Berkeley, 1984
- B.S., Mechanical Engineering, New Mexico State University, 1983

Technical Experience: Ten years of experience in design, fabrication, and testing of linear induction accelerator systems for electron-beam and radiographic research.

EIS Responsibility: Co-preparer of chapter 3, provider of baseline data for appendix B, contributed to description of technical alternatives.

Name: **DAVID C. CHASTAIN**

Affiliation: Los Alamos National Laboratory

Education:
- M.A.E., Architectural Engineering, Oklahoma State University, 1977
- B.S., Architectural Studies, Oklahoma State University, 1975

Technical Experience: Eighteen years of experience in facility design and construction with the last ten years in project management.

EIS Responsibility: Co-preparer of chapter 3 and provider of baseline data for appendix B and construction data on the DARHT Facility.

Name: **COLBERT E. CUSHING**

Affiliation: Battelle – Pacific Northwest 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: Thirty-four years of experience in freshwater ecological research in streams and radioecology, and over 20 years of experience in EIS preparation.

EIS Responsibility: Prepared biotic resources consequence section of chapter 5.

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:	Seven years of experience with geographical, biological, and quantitative methods research.
EIS Responsibility:	Prepared the biotic resources section in chapter 4, and assisted with the overall review. Prepared appendix F.

Name:	**MICHAEL J. FAYER**
Affiliation:	Battelle – Pacific Northwest Laboratory
Education:	• Ph.D., Soil Physics, University of Massachusetts, 1984 • M.S., Plant and Soil Science, University of Maine, 1980 • B.S., Plant and Soil Science, University of Maine, 1976
Technical Experience:	Eleven years of experience in water, energy, mass transport in porous media, and recharge measurement and modeling.
EIS Responsibility:	Contributed to geohydrological analyses for chapter 5 and determined the deep drainage rate beneath the DARHT site.

Name:	**NANCY FOOTE**
Affiliation:	Battelle – Pacific Northwest Laboratory
Education:	• B.A., Sociology and English, University of Missouri, 1952
Technical Experience:	Nineteen years of experience in technical writing and editing.
EIS Responsibility:	Assisted in technical editing of chapter 5.

Name:	**CHRISTIAN J. FOSMIRE**
Affiliation:	Battelle – Pacific Northwest Laboratory
Education:	• M.S., Meteorology, Pennsylvania State University, 1993 • B.S., Meteorology, Pennsylvania State University, 1990
Technical Experience:	One year of experience in computer programming and data collection and analysis in the area of atmospheric diffusion modeling and risk assessment.
EIS Responsibility:	Prepared air quality sections of chapter 5 and appendix C1.

Name:	**BRUCE GALLAHER**
Affiliation:	Los Alamos National Laboratory
Education:	• M.S., Hydrology, University of Arizona, 1979 • B.S., Mathematics, Eastern New Mexico University, 1972
Technical Experience:	Seventeen years of experience in the field of contaminant hydrology.
EIS Responsibility:	Provided input to water resources sections in chapter 4.

Name:	**GARIANN GELSTON**
Affiliation:	Battelle – Pacific Northwest Laboratory
Education:	• B.S., Applied Mathematics, Mesa State College, 1991
Technical Experience:	One year of experience in environmental assessment modeling.
EIS Responsibility:	Modeled nonradiological chronic/cumulative exposure analyses for human health sections of chapter 5.

Name:	**BARBARA A. GEORGITSIS**
Affiliation:	Battelle – Albuquerque
Education:	• B.S., Civil Engineering, University of New Mexico, 1994
Technical Experience:	One year of experience in data management, quality assurance, and NEPA compliance.
EIS Responsibility:	Assembled and prepared sections of chapter 4.

Name:	**CLIFFORD S. GLANTZ**
Affiliation:	Battelle – Pacific Northwest 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:	Twenty-seven years of experience in research in the fields of environmental risk assessment and risk management, air pollution meteorology, and multipathway pollutant transport modeling.
EIS Responsibility:	Contributed to the air quality sections of chapter 5 and appendix C1.

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:	Twenty-four years of experience in environmental and resource management, regulatory compliance, environmental assessment and impact analyses for NEPA documentation, facility siting, site characterization, cultural resource assessment and management, and environmental program management.
EIS Responsibility:	Project Manager - Battelle – Albuquerque. Technical and management reviewer.
Name:	**PAUL L. HENDRICKSON**
Affiliation:	Battelle – Pacific Northwest 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:	Twenty-two years of experience in energy and environmental studies with special emphasis on regulatory issues.
EIS Responsibility:	Prepared sections on land use impacts in chapter 5 and chapter 6 regulatory requirements.
Name:	**RUTH A. HENDRICKSON**
Affiliation:	Battelle – Columbus
Education:	• Ph.D., English, The Ohio State University, 1988 • M.A., English, Marshall University, 1982 • B.A., English, Marshall University, 1980
Technical Experience:	Thirteen years of experience in technical writing, editing, and publications management, and ten years of university-level teaching experience in the fields of writing and communications.
EIS Responsibility:	Technical editor/writer.
Name:	**JAMES A. HILEMAN**
Affiliation:	Battelle – Albuquerque
Education:	• Ph.D., Seismology, California Institute of Technology, 1977 • M.S., Seismology, California Institute of Technology, 1971 • Geophysical Engineer, Colorado School of Mines, 1960
Technical Experience:	Thirty years of experience in exploration, research, management and review, particularly in siting critical facilities and assessing geologic hazards.
EIS Responsibility:	Lead preparer of chapter 3 and sections on geological environment (chapter 4) and geological consequences (chapter 5).

Name:	**TRACY A. IKENBERRY**
Affiliation:	Battelle – Pacific Northwest Laboratory
Education:	• M.S., Radiology & Radiation Biology, Colorado State University, 1982 • B.A., Biology, McPherson College, 1979
Technical Experience:	Thirteen years of experience in radiological assessment, operational and environmental health physics. Diplomate, American Board of Health Physics, 1988.
EIS Responsibility:	Task Manager for chapter 5 environmental consequences. Technical reviewers and contributor to chapter 5 and associated appendices.
Name:	**JOYCE B. JOHNSON**
Affiliation:	Battelle – Columbus
Education:	• M.A., English, Ball State University, 1971 • B.A., English, Hanover College, 1967
Technical Experience:	Twenty-four years of experience in preparing and managing publications, writing, editing, and training, and ten years of experience managing groups of publications specialists.
EIS Responsibility:	Technical editor/writer.
Name:	**EDWARD L. JOLLY**
Affiliation:	Butler Service Group (Subcontractor to Los Alamos National Laboratory)
Education:	• M.S., Nuclear Engineering, University of New Mexico, 1968 • B.S., Physics, New Mexico Institute of Mining and Technology, 1961
Technical Experience:	Thirty-four years of experience in pulsed power, explosives testing, and accelerator technology.
EIS Responsibility:	Co-preparer of chapter 3 and provided baseline data for appendix B, provided input to containment alternative; technical reviewer.
Name:	**CHARLES T. KINCAID**
Affiliation:	Battelle – Pacific Northwest Laboratory
Education:	• Ph.D., Engineering, Utah State University, 1979 • B.S., Civil Engineering, Humboldt State College, 1970
Technical Experience:	Sixteen years of experience in the area of water flow and contaminant transport in the subsurface environment.
EIS Responsibility:	Lead preparer for water resources and soils sections of chapter 5 and appendixes D and E.

Name:	**BEVERLY M. LARSON**
Affiliation:	Los Alamos National Laboratory
Education:	• M.A., Anthropology, Wichita State, 1980 • B.A., Anthropology, Wichita State, 1976
Technical Experience:	Twenty years of experience in archaeological research and cultural resource management in the southwest and plains states.
EIS Responsibility:	Assisted in the preparation of the cultural and archaeological sections of chapter 4.

Name:	**JAY C. LAVENDER**
Affiliation:	Battelle – Pacific Northwest Laboratory
Education:	• B.A., Industrial Technology, Washington State University, 1984
Technical Experience:	Ten years of experience in risk, safety, reliability, and statistical analysis techniques and in the preparation of safety analysis documents for a wide variety of nonnuclear and nuclear operations, facilities, and transportation systems.
EIS Responsibility:	Prepared transportation section for chapter 5 and appendix I.

Name:	**DONALD A. McCLURE**
Affiliation:	The Delphi Group, Inc. (Subcontractor to Los Alamos National Laboratory)
Education:	• Ph.D., Nuclear Physics, University of Missouri at Rolla, 1970 • M.S., Physics/Mathematics, University of Missouri at Rolla, 1966 • B.A., Physics/Mathematics, Nebraska Wesleyan University, 1964
Technical Experience:	Twenty-five years of professional teaching and research experience in the areas of reactor safety, personnel dosimetry, environmental monitoring, licensing, emergency response, facility safety, order compliance, operational readiness, and environmental impact analysis.
EIS Responsibility:	Co-preparer of chapter 3, provider of baseline data for appendix B, coordinator and developer of technical, management, and administrative information for chapter 3.

Name:	**EMMETT B. MOORE**
Affiliation:	Battelle – Pacific Northwest Laboratory
Education:	• Ph.D., Physical Chemistry, University of Minnesota, 1956 • B.S., Chemistry, Washington State University, 1951
Technical Experience:	Twenty years of experience in environmental regulation, and participation in and management of the preparation of environmental permits and documentation.
EIS Responsibility:	Project Manager of technical support provided by Battelle – Pacific Northwest Laboratory.

Name:	**MARK T. MURPHY**
Affiliation:	Battelle – Pacific Northwest Laboratory
Education:	• Ph.D., Geology, Johns Hopkins University, 1989 • M.S., Geology, University of New Mexico, 1985 • B.S., Earth Science, University of California at Santa Cruz, 1977
Technical Experience:	Fourteen years of professional experience in environmental geology and geological engineering.
EIS Responsibility:	Contributed to seismic impact section of chapter 5 and appendix D.
Name:	**ELIZABETH A. NAÑEZ**
Affiliation:	Battelle – Albuquerque
Education:	• M.S., Environmental Engineering, University of New Mexico, in progress • B.S., Industrial Engineering, Texas Tech University, 1990
Technical Experience:	Five years of experience in engineering, including three years' concentration in environmental engineering.
EIS Responsibility:	Prepared sections of chapter 3 and assisted in data collection.
Name:	**IRAL C. NELSON**
Affiliation:	Battelle – Pacific Northwest Laboratory
Education:	• M.A., Physics, University of Oregon, 1955 • B.S., Mathematics, University of Oregon, 1951
Technical Experience:	Forty years of experience in various aspects of health physics (radiation protection) and 24 years of experience in conducting NEPA reviews and preparing NEPA documentation. Diplomate, American Board of Health Physics, 1962.
EIS Responsibility:	Deputy Project Manager of technical support provided by Battelle – Pacific Northwest Laboratory; technical reviewer and contributor to chapter 5.
Name:	**WILLIAM E. NICHOLS**
Affiliation:	Battelle – Pacific Northwest Laboratory
Education:	• M.S., Civil Engineering, Oregon State University, 1990 • B.S., Agricultural Engineering, Oregon State University, 1987
Technical Experience:	Five years of experience in hydrologic and hydrothermal vadose zone modeling for performance assessment of waste isolation and disposal issues.
EIS Responsibility:	Prepared ground water transport modeling for water resources section of chapter 5.

Name:	**PAUL NICKENS**
Affiliation:	Battelle – Pacific Northwest Laboratory
Education:	• Ph.D., Anthropology, University of Colorado, 1974 • M.A., Anthropology, University of Colorado, 1972 • B.A., Anthropology, University of Colorado, 1969
Technical Experience:	Twenty-one years of experience in southwestern archaeology and cultural site protection and preservation.
EIS Responsibility:	Prepared the cultural resources sections of chapter 5.
Name:	**YASUO ONISHI**
Affiliation:	Battelle – Pacific Northwest 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:	Twenty years of experience in fluid mechanics and hydrology with expertise in transport and chemical interactions of sediment and contaminants.
EIS Responsibility:	Obtained solubility and adsorption properties of potential contaminants for water resources section of chapter 5.
Name:	**TED M. POSTON**
Affiliation:	Battelle – Pacific Northwest Laboratory
Education:	• M.S., Fisheries, Central Washington University, 1978 • B.A., Fisheries, Central Washington University, 1973
Technical Experience:	Twenty years of experience in research, environmental assessment, and noise analysis.
EIS Responsibility:	Prepared noise analysis sections of chapter 5 and appendix C2.
Name:	**RANDY F. REDDICK**
Affiliation:	Battelle – Albuquerque
Education:	• M.S., Environmental Health Engineering, University of Kansas, 1983 • B.S., Civil Engineering, University of Kansas, 1982
Technical Experience:	Twelve years of experience with NEPA compliance, NEPA document preparation, and safety studies.
EIS Responsibility:	Deputy Project Manager - Battelle – Albuquerque. Prepared portions of chapters 3 and 4.

Name:	**MARSHALL C. RICHMOND**
Affiliation:	Battelle – Pacific Northwest Laboratory
Education:	• Ph.D., Civil and Environmental Engineering, University of Iowa, 1987 • M.S., Civil and Environmental Engineering, Washington State University, 1983 • B.S., Civil and Environmental Engineering, Washington State University, 1982
Technical Experience:	Eight years of experience in the development and application of hydrodynamic and contaminant transport models for surface water flow systems.
EIS Responsibility:	Modeled water transport for chapter 5 and appendix E.

Name:	**ALAN C. ROHAY**
Affiliation:	Battelle – Pacific Northwest Laboratory
Education:	• Ph.D., Geophysics, University of Washington, 1982 • B.S., Geology, Massachusetts Institute of Technology, 1974
Technical Experience:	Fifteen years of experience in seismic and volcanic hazards, structure of the earth, earthquake, explosion, and noise signal analysis.
EIS Responsibility:	Supported the sections on seismic hazard and facility noise consequences in chapter 5.

Name:	**DAVID E. ROSSON, JR.**
Affiliation:	U.S. Department of Energy
Education:	• B.S., Metallurgical Engineering, University of Tennessee, 1963
Technical Experience:	Thirty-five years of government service with increasing responsibilities in program and project management, including five years' experience in the safety and environmental area.
EIS Responsibility:	Director, DOE/Albuquerque Operations, EIS Project Office.

Name:	**NANCY N. SAUER**
Affiliation:	Los Alamos National Laboratory
Education:	• Ph.D., Inorganic Chemistry, Iowa State University, 1986 • B.S., Chemistry, University of Idaho, 1981
Technical Experience:	Twelve years of experience in metal ion coordination chemistry and four years' experience in development of waste treatment technologies.
EIS Responsibility:	Contributed to development of Enhanced Containment Alternative in chapter 3.

Name:	**SANDRA F. SNYDER**
Affiliation:	Battelle – Pacific Northwest Laboratory
Education:	• M.S.P.H., Radiological Hygiene, University of North Carolina, 1991 • B.S., Environmental Resource Management, Pennsylvania State University, 1986
Technical Experience:	Seven years of experience in modeling of environmental releases of radioactive materials.
EIS Responsibility:	Prepared human health section of chapter 5. Prepared appendixes G and H.

Name:	**LISSA STAVEN**
Affiliation:	Battelle – Pacific Northwest Laboratory
Education:	• M.S., Health Physics, Colorado State University, 1990 • B.S., Environmental Conservation, University of New Hampshire, 1984
Technical Experience:	Five years of experience in environmental health physics and low-level waste disposal management practices.
EIS Responsibility:	Contributed to decontamination and decommissioning sections and prepared waste management sections of chapter 5.

Name:	**CARLOS A. ULIBARRI**
Affiliation:	Battelle – Pacific Northwest Laboratory
Education:	• Ph.D., Economics, University of New Mexico, 1992 • B.A., Economics and Spanish Literature, University of New Mexico, 1984
Technical Experience:	Five years of experience in natural resource and environmental economics.
EIS Responsibility:	Prepared sections on socioeconomics and environmental justice in chapters 4 and 5. Prepared appendix G.

Name:	**JANIS L. VOMACKA**
Affiliation:	Battelle – Albuquerque
Education:	• Graduate, American Business College, 1964
Technical Experience:	Twenty-eight years of experience in publication preparation and management, including technical editing, graphics design and production, desktop publishing, and printing.
EIS Responsibility:	Technical editor, graphics designer, and production coordinator.

Name:	**DAVE WARD**
Affiliation:	Battelle –Albuquerque
Education:	• B.S., Engineering Physics, University of Maine, 1957
Technical Experience:	Thirty-eight years of nuclear engineering and safety analysis experience.
EIS Responsibility:	Assisted in data collection for chapter 3.

Name:	**M. DIANA WEBB**
Affiliation:	Department of Energy, Los Alamos Area Office
Education:	• M.L.A., Landscape Architecture, University of Illinois, 1975 • B.F.A., Fine Arts, University of Illinois, 1966
Technical Experience:	Twenty-eight years of experience in the areas of environmental planning and NEPA compliance.
EIS Responsibility:	DOE NEPA Document Manager.

Name:	**MARK WIGMOSTA**
Affiliation:	Battelle – Pacific Northwest Laboratory
Education:	• Ph.D., Environmental Engineering, University of Washington, 1991 • M.S., Geological Sciences, University of Washington, 1983 • B.S., Geological Sciences, University of Washington, 1981
Technical Experience:	Twelve years of experience in the area of surface water hydrology, erosion processes, and sediment transport.
EIS Responsibility:	Contributed to water resources section of chapter 5 in areas of surface runoff and sediment and contaminant transport in chapter 5 and appendix E.

Appendixes

Appendix A

Notice of Intent

APPENDIX A
NOTICE OF INTENT

This appendix presents the entire text of the Notice of Intent that appeared in the *Federal Register* on November 22, 1994.

DEPARTMENT OF ENERGY

Environmental Impact Statement; Dual Axis Radiographic Hydrodynamic Test Facility, Los Alamos National Laboratory

AGENCY: Department of Energy.

ACTION: Notice of intent to prepare an environmental impact statement.

SUMMARY: The United States Department of Energy (DOE) provides notice of its intent to prepare an environmental impact statement (EIS) on the DARHT facility at its Los Alamos National Laboratory (LANL), Los Alamos, New Mexico. The EIS will be prepared pursuant to the National Environmental Policy Act of 1969 (NEPA) (42 U.S.C. 4321 et seq.), the Council on Environmental Quality NEPA Regulations (40 CFR Parts 1500-1508), and the DOE NEPA Regulations (10 CFR Part 1021). The EIS will analyze the impacts of completing construction and operating the DARHT facility at LANL, and reasonable alternatives.

With this Notice, DOE initiates a public comment period to solicit suggestions on the scope of analyses for this EIS. DOE also extends an invitation to attend public scoping meetings in Los Alamos and Santa Fe, New Mexico, and to provide suggestions for public participation opportunities for this NEPA review.

DATES: Written comments on the scope of the EIS are invited from the public. To ensure consideration, comments should be postmarked by Tuesday, January 10, 1995. Comments sent after that date will be considered to the fullest extent practicable. Public scoping meetings will be held as follows:

Wednesday, December 7, 1994, Los Alamos, 1:00 pm-4:30 pm, and 6:30 pm-9:00 pm, Hilltop House, 400 Trinity Drive, Los Alamos, New Mexico.

Thursday, December 8, 1994, Santa Fe, 1:00 pm-4:30 pm, and 6:30 pm-9:00 pm, Sweeney Center, 201 West Marcy Street, Santa Fe, New Mexico.

The meetings will use a workshop format to facilitate dialogue among DOE, LANL, and the public and will provide an opportunity for individuals to provide written or oral statements.

ADDRESSES: Written comments on the scope of the DARHT EIS, or other matters regarding this environmental review, should be addressed to: Ms. Diana Webb, NEPA Compliance Officer, Los Alamos Area Office, Department of Energy, 528 35th Street, Los Alamos, NM 87544, Attn: DARHT EIS. Ms. Webb may be contacted by phone at (505) 665-6353, facsimile (505) 665-4872.

FOR FURTHER INFORMATION CONTACT: For general information on the DOE NEPA process, please contact: Carol M. Borgstrom, Director, Office of NEPA Oversight, EH-25, Department of Energy, 1000 Independence Ave., SW, Washington, DC 20585. Ms. Borgstrom may be contacted by leaving a message at (800) 472-2756 or by calling (202) 586-4600.

SUPPLEMENTARY INFORMATION:

Purpose and Need for Action

One of the most urgent and difficult technical tasks facing the DOE is to assess the effects of aging on the weapons that remain in the nation's nuclear stockpile, and to ensure the continuing safety of those weapons. Because the President has decided not to build any new nuclear weapons for the foreseeable future, but instead to continue to rely upon a smaller stockpile of existing but aging weapons as a nuclear deterrent, DOE must ensure that the weapons remaining in the stockpile are safe, secure and reliable. Under the Atomic Energy Act, this mission rests with DOE and essentially requires DOE to certify that the weapons will not accidentally detonate during storage and handling, that the weapons would thwart any attempts for unauthorized use, and that they would function as designed in the event of authorized use.

To fulfill this mission, DOE needs to collect diagnostic information regarding the condition of the weapons which remain in the enduring stockpile. Some of these weapons are approaching the end of their design life, and DOE is not certain how they may be affected by the aging process. One important type of information that is currently lacking concerns the three-dimensional condition of the various internal components of aging weapons. These are often shielded by thick and dense materials. Multiple view hydrodynamic testing (experiments to look at the flow of adjacent materials as they are driven by high explosives) and dynamic testing (experiments to study other effects of high explosives), combined with computer modeling, provide the only means of obtaining this data in the absence of nuclear testing. The President has endorsed hydrodynamic testing as the preferred means of conducting experiments in support of stockpile stewardship and maintenance. Hydrodynamic testing has become more important since the United States moratorium on nuclear testing was extended. A future Comprehensive Test

Ban Treaty, moreover, would foreclose the acquisition of additional performance and safety data through nuclear testing.

Proposed Action

DARHT would be a specialized high energy X-ray machine that would take three-dimensional, sequential and high-resolution X-ray pictures of the dynamic behavior of dense materials that are being shocked and compressed by high explosives. DARHT would be used to evaluate the nonnuclear behavior of nuclear weapons components and would provide that nation with a significantly improved diagnostic capability to evaluate and assess the safety and reliability of the existing nuclear weapons stockpile. DARHT would consist of an existing support lab, a new firing site, and the necessary infrastructure, all located at Technical Area 15 at LANL. DARHT would be used to detonate high explosives, and to use very high-speed, tightly-focused radiographic (X-ray) photography to determine the motions (dynamic experiments) or flow (hydrodynamic tests) of the explosive-driven materials. Two X-ray machines at right angles to each other (dual-axis lines of sight) would be powered by two 16 million electron volt (MeV) electron accelerators, each housed in a building about 225 feet long. By using two machines, DARHT would be able to provide three-dimensional, sequential information on occurrences within millionths of a second during a test. The accelerators' small beam size would allow DARHT to provide a very high-quality resolution of the radiographic image. This resolution is necessary to resolve the fine details of the material flowing in these experiments.

DARHT experiments would variously involve radioactive materials (primarily depleted uranium), beryllium and other hazardous materials, and other metals. Additionally, experiments involving plutonium contained in steel vessels may be conducted. DARHT would not test materials that could result in nuclear yield, or a nuclear detonation. Experiments at DARHT would be expected to result in metal fragments and other airborne debris being deposited up to 750 meters from the open-air explosives testing (standard operating procedures would require the evacuation of this area before any experiments were conducted).

In addition to testing the nonnuclear behavior of nuclear weapons components, DARHT would be used to evaluate conventional weapons systems, explosives-driven materials for non-weapons uses, and high-velocity impact phenomena. The facility would also be used to support non-proliferation and counter-proliferation efforts, such as experiments intended to disable a terrorist-designed or proliferant-designed nuclear weapon. Although DARHT could be used to collect information relevant to the design of new weapons, no new weapons are anticipated to be designed in the foreseeable future.

Design of DARHT began in the early 1980's. Memoranda to File, describing the environmental impacts of constructing and operating DARHT, were completed in 1983 and 1987. DARHT construction began in 1988 with the Radiographic Support Laboratory, which was completed in 1990. The Radiographic Support Laboratory is currently being used to support the development of the accelerator equipment that is planned to be used in DARHT. In May 1994, DOE began construction of the Hydrodynamic Firing Site. Approximately 20 percent of the Hydrodynamic Firing Site construction work (e.g., site preparation, foundation pouring) has been completed. Current schedules call for the Hydrodynamic Firing Site construction to be completed, and the first X-ray machine to be operating, in 1997 at a cost of approximately $86 million, and the second X-ray machine, if approved, would begin operation in 2000. The total estimated project cost of DARHT in its final two-axis configuration is $124 million; to date, approximately $44 million has been spent or obligated on the project.

In response to public concern, the DOE has decided to prepare this EIS at this time to allow for a full dialogue between DOE and the State, tribes, other agencies and the general public regarding the environmental impacts of completing and operating DARHT, and the impacts of other alternatives. The EIS will also assist in ensuring that appropriate mitigation measures are developed if DARHT is completed and put into operation. Construction and related work on the facility will continue during the preparation of the EIS.

Proposed Alternatives

DOE has tentatively identified the following alternatives for analysis in the EIS and seeks public comment on their adequacy, inclusiveness and reasonableness:

(1) Proposed Action

Under this alternative, DOE would complete construction and operate the DARHT facility as currently planned. This alternative would provide a state-of-the-art diagnostic capability for ensuring the safety, security and reliability of the aging nuclear weapons stockpile. If DARHT becomes operational, operation of the Pulsed High Energy Radiation Machine Emitting X-Rays (PHERMEX) facility, an existing facility at LANL also located at Technical Area 15, near the DARHT site, will be phased out.

(2) No Action (status quo) Alternative

Under this alternative, DARHT would not be completed and DOE would continue to operate the Pulsed High Energy Radiation Machine Emitting X-Rays and the Flash X-Ray facility at the Department's Lawrence Livermore National Laboratory Site 300 located near Livermore, California. The Pulsed High Energy Radiation Machine Emitting X-Rays, a single-axis radiographic facility, was built in the mid-1960's and has been used continuously since that time. It uses a pulsed power accelerator to power the X-ray machine, and does not have the small beam size (tight focus) planned for DARHT, thereby precluding the high-resolution images that DARHT would provide. Flash X-Ray, also a single-axis radiographic facility, was built in 1982 and has been used continuously since that time. It uses a linear induction accelerator to power the X-ray machine and also does not have the small beam size planned for DARHT.

(3) Containment Alternative

Under this alternative, DOE would modify the construction and/or operation of DARHT to contain some or all airborne emissions of fragments or other debris. Under one approach, the X-ray pictures would be taken through the walls of a containment vessel. Another approach would be to construct a building to enclose and contain the explosive experiments; X-ray pictures would be taken within the containment building. These two approaches may be considered separately or together, for some tests or for all tests.

(4) Institutional Control Alternative

Under this alternative, DOE would complete and operate DARHT, but would limit use of the facility to exclude any applications involving experiments with plutonium.

(5) Single-Axis Alternative

Under this alternative DOE would complete construction of the Hydrodynamic Firing Site but would operate only a single axis of DARHT with one accelerator. This alternative would provide an improved technical capability over present accelerators with a single view (i.e., the Pulsed High Energy Radiation Machine Emitting X-Rays and Flash X-Ray).

(6) Upgrade Alternative

Under this alternative DOE would upgrade the present Pulsed High Energy Radiation Machine Emitting X-Rays capability with the new technology developed for DARHT.

DOE does not intend, in this EIS, to analyze alternatives or issues beyond the construction and operation of DARHT that relate to the nation's nuclear weapons policies, the DOE mission of stockpile stewardship and management, the need for hydrodynamic testing or dynamic testing that are part of the stockpile stewardship and management program, the mission of LANL, or continued operation of other facilities at LANL. To the extent that these matters are under the purview of DOE, they will be considered in the Programmatic EIS on Stockpile Stewardship and Management or the LANL Sitewide EIS, as discussed below in the section on related NEPA reviews.

Proposed Issues

The EIS will identify and analyze the direct, indirect and cumulative effects resulting from the completion and operation of DARHT. DOE has tentatively identified the following environmental and socioeconomic issues for consideration in the EIS and seeks public comment on the adequacy and inclusiveness of these issues:

- Natural ecosystems, including air quality, surface and groundwater quality, and plants and animals.
- Cultural resources, including archeological sites, historic resources, other facilities and infrastructure at LANL, and actual and potential uses of the site including Native American cultural, traditional and religious uses; DOE has previously identified Native American archeological sites in the vicinity of DARHT and has conducted mitigating activities.
- Economic impacts, including those from constructing, equipping and operating DARHT.
- Socioeconomic impacts, including any disproportionately high and adverse impacts on minority and low income populations.
- Health and safety impacts to on-site workers, other LANL personnel, local communities and tribes, and the general population of northern New Mexico.
- Other construction and operational impacts, such as transportation of people and materials.
- Waste management considerations, including the eventual decontamination and decommissioning of the facility after the end of its useful life (approximately 30 years).
- Health and safety, environmental, and other impacts related to the transport, storage and use of hazardous and radioactive materials and generation of X-ray radiation.
- Other relevant issues identified by DOE or the State, tribes, other agencies, or the public through this scoping process.

Related NEPA Reviews

The Department is currently preparing to undertake two related NEPA reviews. The planned LANL Sitewide EIS (59 FR 40889, August 10, 1994) will consider the cumulative impacts of operations and planned activities foreseen within the next 5 to 10 years. The planned Stockpile Stewardship and Management Programmatic EIS (59 FR 54175, October 28, 1994) will evaluate activities required to maintain a high level of confidence in the safety, reliability, and performance of nuclear weapons in the absence of nuclear testing, and to be prepared to test weapons if so directed by the President.

Classified Material

The Department will review classified material while preparing this EIS. Within the limits of classification, DOE will provide to the public as much information as possible. If DOE needs to generate classified material to explain the purpose and need, use, materials, or impacts from this project, that material will be segregated into a classified appendix.

Public Involvement Opportunities

DOE will develop a stakeholder involvement plan to guide the public review aspects of this EIS. To assist with developing the stakeholder involvement plan, DOE requests suggestions by the public on how this EIS process should be conducted, including suggestions regarding the type, format and conduct of public involvement opportunities.

Through this Notice, DOE formally invites the State, tribes, other government agencies and the public to comment on the scope of the EIS. DOE will offer informational briefings to tribal governments, local (county and municipal) governments, and the State of New Mexico.

A second formal opportunity for comment will be provided after DOE issues the draft EIS, expected in mid-1995. Public hearings will be held in conjunction with that comment period. DOE will inform the State, tribes, local governments, other agencies and the general public of its final decisions at the time the Record of Decision is issued, expected in October 1995.

In addition to formal opportunities for comment, any person may submit comments at any time during the NEPA review process; however, to ensure that comments are considered at specific points in the NEPA review, and to best assist DOE, the public is encouraged to comment during the formally established comment periods.

Copies of DARHT design and other background documents, written comments, records of public meetings, and other materials related to the development and analyses of the EIS have been and are being placed in the Los Alamos National Laboratory Community Reading Room, 1450 Central Avenue, Suite 101, Los Alamos, New Mexico 87544. For information on the availability of specific documents and hours of operation, please contact the reading room at (505) 665-2127 or (800) 543-2342.

Signed in Washington, D.C., this 18 day of November 1994, for the United States Department of Energy.

Tara O'Toole,

Assistant Secretary, Environment, Safety and Health.

[FR Doc. 94-28889 Filed 11-18-94; 11:46 am]

BILLING CODE 6450-01-p

Appendix B
PHERMEX Baseline

APPENDIX B
PHERMEX BASELINE

This section describes the current condition of the PHERMEX firing site and summarizes the materials used to conduct current operations and the materials that have been released to the immediate environment of the firing point. This baseline represents PHERMEX conditions before any decision is made on the hydrodynamic testing alternatives. This baseline information was compiled to develop reasonable testing activities which are analyzed under each alternative in this EIS in order to determine valid impacts and to establish a comparative analysis of alternatives with respect to current conditions. Historically, numbers of tests and quantities of various materials have varied by year, in accordance with program needs. Material usage over the past five years has been used in this EIS to establish the baseline for material usage. This baseline does not reflect projected future changes in the activities at PHERMEX under various alternatives. The current levels of migration of materials by air and water pathways are discussed, as well as the disposition of materials removed from the site during periodic cleanup activities. Waste streams resulting from the current operation are also discussed.

B.1 AIR QUALITY AND NOISE

This section describes the nonradioactive ambient air criteria pollutants emitted from PHERMEX operations as well as the noise impacts from PHERMEX experiments.

B.1.1 Air Quality

The ambient air criteria pollutants potentially released due to PHERMEX operations include nitrogen dioxide, PM_{10} (aerosolized material assumed to be respirable), beryllium, heavy metals (depleted uranium and lead), and lead (the concentration of pollutants is similar to those presented in section 5.1.2; see related discussion in section 4.2.4). Cleaning chemicals are not used on a scale large enough to produce measurable releases. Materials used are rags dampened with acetone, chlorinated hydrocarbons, toluene, xylene or 1,1,1-trichloroethane.

Since the PHERMEX operations are classified as intermittent fugitive emission sources, no stations are established to directly monitor potential emissions from PHERMEX (see related discussion in section 4.2.5 and figure 4-6). A sitewide sampling network is available at LANL to provide air monitoring data for the site. The radiological dose from TA-15 operations has been estimated at one percent or less of the total LANL dose to the public.

Waste wood from the platforms used to support the experiments is taken to TA-36 for disposal in an open burn. An existing open burn permit from the NMED indicates approximately four to five burns per year are required to reduce the fire and safety hazards due to the accumulation of wood. Some of the wood waste may be contaminated with small quantities of high explosives and/or depleted uranium.

In support of the open burn permit application, the DOE Los Alamos Area Office submitted dose dispersion estimates. The nearest residential community, White Rock 9,767 ft (2,977 m) away, was estimated to receive 1.1 x 10^{-8} rem using the HOTSHOT 6.5 modeling program and 2.9 x 10^{-8} rem using the DISPERSION modeling program (DOE 1993). The NMED Air Quality Bureau reviewed the dose estimates and concluded that the results indicate reasonable assurance of no health effects in White Rock from this source (NMED 1993).

B.1.2 Noise

Noise from a 150-lb test explosion, the largest in normal operation at PHERMEX, was measured March 11, 1995, at several locations in and around LANL (Burns 1995; Vigil 1995; Vibronics 1995). Peak overpressure in the air, reported in dB, is the important measurement for assessing the potential effects of an air wave but is not the same as a dBA noise measurement. (See section 4.2.6). These peak overpressure measurements showed 138 dB at a distance of 2,150 ft (655 m) from the 150-lb (70-kg) shot, and 137 dB at the Nake'muu ruin site, a distance of 3,880 ft (1,180 m). If the largest explosive charge for PHERMEX, 1,000 lb (450 kg) were fired, the expected pulse would be about 6 dB higher than for the 150-lb (70-kg) explosion.

Two types of instrumentation were used for the noise measurements recorded during the tests conducted at PHERMEX on March 11, 1995. A sound level meter set up for a broad frequency range (about 20 to 12,000 Hz), slow time response, and frequency sensitivity corresponding to human hearing (A scale, ANTI-S1.4-1971) was used. The results are reported in decibels weighted for hearing response, dBA. The peak overpressure was measured in the air with a microphone sensitive to low frequencies (2 to 200 Hz) and having fast time response. These results are reported in decibels (dB) and are important for assessing potential effects of an air wave but are not the same as "noise" measurements.

Both types of instruments were used at only one location, on State Highway 4, which is the closest possible public approach to the firing point [1.3 mi (2 km) to the south]. The slow time response and frequency sensitivity corresponding to human hearing measured 71 dBA while the fast time response instrument measured 120 dB; the peak pulse energy was at about 20 Hz. These two values are comparable because the A-scale weighing at 20 Hz is about -50 dB (ANTI-S1.4-1971). Using the sound level meter, 60 dBA was measured near the entrance to Bandelier National Monument [closest permanent residences, 2.6 mi (4.3 km)], and about 70 dBA in White Rock [a nearby residential community, 4 mi (6.4 km)]. At these levels and distances, variations in local atmospheric conditions may account for the louder noise at the more distant site, but measurements under a range of known atmospheric conditions have not been made. These measured levels can be used to estimate a sound level of 61 to 68 dBA in southern Los Alamos, the closest residential area to PHERMEX at a distance of 3 mi (5 km).

B.2 SOILS

In 1993, LANL collected and analyzed over 20 surface soil samples and 2 sediment samples at the PHERMEX firing site (Fresquez 1994). These soil sampling surveys indicate that no lead, beryllium or mercury are observed beyond 460 ft (140 m) of the firing point. The samples were analyzed for RCRA-regulated metals (silver, arsenic, barium, cadmium, chromium, lead, mercury, beryllium, selenium) using the Toxicity Characteristics Leaching Procedure (TCLP); total beryllium, gallium, lead, thorium, and uranium; semivolatile organic compounds (SVOCs); and high explosive residues. The sampling plan and the results for uranium, beryllium, and lead are described in appendix D. Metals were detected by the

TCLP in the soil and sediment samples, but at levels below the proposed U.S. Environmental Protection Agency (EPA) action level of 5 ppm. Among the other metals analyzed, beryllium levels were above the EPA action level (see appendix D). The PHERMEX area soils contained traces of 21 SVOCs, but no detectable high explosive residues.

B.3 HUMAN HEALTH

The average dose received for 92 workers who were assigned dosimetry badges in 1993 and who worked regularly or occasionally at PHERMEX was 0.003 rem/person. LANL has established an administrative dose limit of 2 rem/year, which is below the DOE limit of 5 rem/year.

The PHERMEX facility operated an internal dosimetry program for three years beginning in 1992. No dose equivalent greater than 0.003 rem was detected, and over 50 percent of the participants registered doses at or below natural background levels. It was concluded that no radiological hazard exists for PHERMEX and the program was discontinued except for suspected exposures. Chemical toxicity has also been evaluated, and calculated fractions of nephrotoxic limits have not approached any levels of concern (Kottmann 1994).

B.4 ACCIDENTS

Operations at PHERMEX pose accident hazards expected at industrial sites. In addition, there are unique hazards associated with high explosives, high voltages, high densities for energy stored in capacitor banks, intense x-rays, and test materials. Hazards that have the potential to lead to accidents at a hydrodynamic test facility are summarized in table B-1.

The accident hazards in table B-1 are addressed by physical barriers, interlock systems, and administrative controls. The accidents with the most serious potential consequences (i.e., radiation exposure, high explosive detonation, and electrical discharges) were analyzed for likelihood of occurrence. An annual probability of less than 10^{-4} was estimated for each of these accidents, with no likely common-mode accidents identified. Probabilities for the other hypothetical accidents are based on commercial industry experience. All these accident probabilities are shown in table B-2.

During the most recent 10-year period (1985 to 1994) the accident statistics for PHERMEX indicate that there were a total of 19 lost-work days due to injury. None of these injuries were considered serious; they consisted of a contusion, a concussion, and numerous back strains. The most recent incident that resulted in lost time occurred in 1991 when an employee who suffered a strain injury as a result of a lifting activity lost three workdays. There have been no reported accidents that were initiated by the detonation of explosives.

B.4.1 Radiation Exposure

The safety system associated with radiation protection provides controls and barriers to prevent radiation exposure. This system consists of positive interlocks, alarms, warning lights, television monitors, and

TABLE B-1.—*Hazards at Hydrodynamic Test Facilities*

Hazard	Location	Comments
Ionizing Radiation Exposure		
Personnel inside exclusion areas during beam pulsing	Accelerator bay, optical room, and firing pad	Beam pulse with up to 2,000 rad x-rays at one meter on axis
Nonionizing Radiation		
Operating personnel intersect laser beam	Laser room	
Electrical		
Personnel in contact with the power supplies or capacitor banks	Accelerator room and power supply rooms	Power supplies with voltages up to 4MV, high energy-densities in capacitor banks
Personnel in contact with laser power supplies	Accelerator bay and laser rooms	Power supplies with voltages up to 35kV
High Explosives Blast		
Personnel in the hazard radius exclusion area during testing	Firing site exclusion area	Area radius is 2,460 ft (750 m), personnel OK in R-184 and R-310
Accidental detonation of explosive	Firing pad	
Mechanical		
Crane maintenance and operation	Accelerator bay, power supply rooms, equipment and assembly rooms	Potential for misuse
Occupational		
Slippery surfaces due to fluids	Accelerator bay, power supply rooms, equipment room	Leaks or spills from tanks, valves, or connections
Gases		
Helium	Firing pad, diagnostics area	Used to drive high-speed cameras
Sulfur hexafluoride	Accelerator hall, power supply room	Leaks from spark gaps
Chemicals/Solvents		
Acetone, ethanol	Accelerator bay and assembly room	Inhalation hazards
Fire		
Insulating oil	Accelerator bay and power supply rooms	EXXON 1830 type insulating oil has a flash point above 149°C (330°F)
Wicking of insulating oil	Power supply rooms	Oil soaked rags
Acetone, ethanol	Accelerator bay and assembly room	Volatile cleaning solvents
Electrical control cables, high voltage cables, and components	Accelerator bay, power supply rooms, equipment room	Faulty items may cause sparks to ignite oil, etc.
Fire from parked vehicles	Parking and delivery area	Gasoline in fuel tanks
Natural gas	Equipment room	Hot water boiler
Trash and rag accumulation	Accelerator bay, power supply rooms, equipment room	Ignition source for oil
Forest or brush fire	External to building	May arise from explosives or natural causes
Natural Phenomena		
High Winds	TA-15	Damage to utilities
Lightning	TA-15	Damage to utilities
Earthquake	TA-15	Damage to any of LANL infrastructure, design level is 0.22 G for DARHT, current expectation is 0.5 to 0.6 G for max. earthquake.

TABLE B-2.—*Hypothetical Accidents and Probabilities*

Accident	Levels[a]	Probability
Unplanned exposure to radiation	III–IV	$< 10^{-4}$
Normal exposures to radiation	< IV	$< 10^{-1}$
Laser hazards	III	$< 10^{-4}$
Electrical energy hazards	III–IV	$< 10^{-4}$
Blast hazards	III	$< 10^{-4}$
Accidental detonation	II	$< 10^{-4}$
Normal firing	IV	$< 10^{-4}$
Mechanical hazards	IV	$< 10^{-2}$
Occupational hazards	IV	$< 10^{-2}$
Confined space	IV	$< 10^{-4}$
Pressurized containers and distribution systems	IV	$< 10^{-4}$
Toxic gases and vapors	IV	$< 10^{-4}$
Chemicals/solvents	IV	$< 10^{-2}$
Fire hazards	IV	$< 10^{-4}$
Natural phenomena	IV	$< 10^{-4}$

[a] System failure level categories are as follows:
II–Critical. May cause severe injury, severe occupational illness, major damage to a facility operation, or major environmental damage.
III–Marginal. May cause minor injury, minor occupational illness, or minor environmental damages.
IV–Negligible. Will not result in a significant injury or occupational illness, or have a significant environmental effect.

personnel accountability sweeps of the area prior to testing. These functions can be monitored from the control room. Extensive operator training, personnel radiation dosimetry, and use of thermoluminescent dosimeter (TLD) surveys for facility radiation monitoring are integral parts of facility operations to monitor exposures and prevent accidental overexposure. The following two accident scenarios have been analyzed to provide the radiation exposure probabilities in table B-2:

- The walk-through clearance plan fails to detect personnel in the exclusion areas
- The interlock safety system fails, and the accelerator is pulsed while personnel are in the accelerator hall

B.4.2 Electrical Discharge

Controls and barriers associated with electrical energy hazards are designed into the PHERMEX facility. Physical barriers, such as cabinets around power supplies and capacitor banks and the injector power supplies, along with an interlocked high voltage safety system, prevent entry during pulsing or hydrodynamic testing. Only experienced, trained personnel are allowed to perform the operations at the firing point. Potential accident scenarios include personnel contact with power supplies, charged capacitor banks, or laser power supplies.

B.4.3 Explosives

The most serious hazard to operation personnel is from firing high explosives during a hydrodynamic test. The buildings and structures at the firing site are designed to withstand repetitive explosions, but only R-184 and R-310 may be occupied during a test. Safety interlocks prevent firing the high explosives if personnel exit these buildings during the firing sequence. Hazards involved with handling explosives are well recognized and are based on long experience. The hazard radius around the firing site varies from test to test depending on the size of the shot. Two main accident scenarios have been analyzed to provide the blast hazards probability in table B-2:

- By error, some personnel are within the hazard radius during a test
- Predetonation of the explosives occurs during test setup

Occupational injuries at PHERMEX have primarily dealt with injuries such as strains, lacerations, and contusions that have resulted from the movement of equipment and materials associated with the experiments.

B.5 MITIGATION AND MONITORING

B.5.1 Mitigation

The PHERMEX facility employs mitigation systems and administrative controls in a defense-in-depth approach to facility safety. Physical barriers consisting of passive shielding for radiation control and blast protection form the first level of barrier to prevent injury to personnel. Active barriers are in place, consisting of locked and interlocked gates and roadblocks or passageway closures to prevent entry to radiation areas or explosives areas. Audible and visual warning systems are in place which are activated whenever the imminent exposure to radiation or explosive blast is possible. Red stop or scram buttons are placed near visual alarms to allow any personnel inadvertently left in the area to abort the test or hazardous condition. In-place administrative procedures control the transportation and movement of explosives and hazardous materials and limit the number of personnel who might be exposed to a given hazard. Trucks and cranes may be operated only by personnel who are trained and experienced in the operation being conducted.

Access is controlled to ensure that no personnel are within the hazard area for each shot. Clearance personnel maintain radio contact with each other, and the access control office visually checks the hazard area from the firing point to the clearance radius before each test and then establishes road blocks to prevent inadvertent entry to the area until the test has completed. Small fires after a test are not unusual, and the fire suppression personnel are available at the boundary to the hazard area for each explosive shot. Fire suppression personnel, trained for the hazards to be expected when fighting fires immediately following explosives tests, are allowed access to the firing point immediately after the all-clear is sounded to extinguish any resulting fires.

B.5.2 Monitoring

Monitoring consists of radiological area monitors and visual television monitoring of critical areas. The accelerator hall and firing point are monitored annually for radioactivity. TLDs are placed at potential exposure areas in and around the facility and are read annually to monitor cumulative doses. Except for the expected high dose observed at the firing point and on the axis of the PHERMEX beam, all recorded doses are in the mrem/year range.

Environmental Surveillance at Los Alamos during 1992 describes LANL's surveillance and monitoring program (LANL 1994). LANL routinely monitors radioactive and nonradioactive pollutants in environmental media (air, water, soil) on the LANL site and in the surrounding region.

Three air monitoring networks are operated or accessed by LANL. Nonradiological ambient air monitors are used to measure criteria pollutants, beryllium, acid precipitation, and visibility. A network of continuously operating sampling stations measures ambient airborne radioactivity. Thermoluminescent dosimeter are used to monitor doses of external penetrating radiation. LANL's air monitoring program is discussed in detail in section 4.2.5.

Surface waters and ground water are monitored to detect any contaminants from LANL operations. Water monitoring is discussed in detain in section 4.4.3.

B.6 MATERIALS USED

The materials used at the PHERMEX site include water, industrial chemicals, and materials comprising the test assemblies. Water at the PHERMEX site is not separately metered, but is supplied through an 8 in (20 cm) line from a 250,000 gal (946,000 L) tank located near TA-15. Water is used in a cooling tower, and deionized water is used in a closed cycle for magnet cooling. Sulfur hexafluoride is used as an insulating material. The major uses of industrial chemicals on an annual basis for the No Action Alternative are:

- Helium – 6,000 ft^3 (170 m^3)
- Sulfur hexafluoride – 3,100 ft^3
- Acetone – 3 gal (11 L)
- Ethanol – 6 gal (23 L)

The tests themselves contain materials that are released to the environment during uncontained tests. Table B-3 shows the number of separate tests conducted at both PHERMEX and FXR during CY 1990 to 1994. The tables include all tests at the facility, not only those using the accelerator radiographic diagnostics. A large range of complexity exists among high-explosives tests, and simply counting the number of tests serves only as a broad summary of the testing efforts at each facility. Table B-4 shows the corresponding materials released as a result of these tests, prior to regular firing point cleanups.

TABLE B-3.—*Number and Type of Tests at PHERMEX (P) and FXR (F) for CY 1990 to c1994*

Area of Research	CY90		CY91		CY92		CY93		CY94	
	P	F	P	F	P	F	P	F	P	F
Weapon Development	2	3	2	13	6	5	0	0	0	0
Stockpile Support	9	12	8	48	5	23	6	14	4	8
Predictive Capability	10	—[a]	12	—[a]	8	—[a]	26	—[a]	11	—[a]
Proliferation Assessment and Disablement	0	4	0	4	1	3	1	1	5	11
Conventional Munitions	70	5	0	22	0	22	7	18	3	3
Measurement Technique Development	0	0	0	0	10	0	5	0	15	0
Other Applications	6	5	3	10	1	20	0	0	0	0
TOTALS	97	30	25	97	31	73	45	33	38	22

[a] Due to record-keeping differences, the FXR totals under Stockpile Support include both Stockpile Support and Predictive Capability.

Definition of research areas:

1. **Weapon Development** – This type of testing supported engineering development of new weapon systems.
2. **Stockpile Support** – This type of testing was directed to stockpile surveillance, benchmarking against the underground nuclear test database, stockpile life extension, and nuclear safety. Experiments included large, full-scale mock-ups of weapons systems to observe integrated operation and smaller-scale mock-ups of weapons systems to observe integrated operation and smaller-scale experiments dedicated to observing selected phenomena isolated as much as possible from other effects. Each large-scale test was accompanied by a smaller test used to calibrate experimental timing and recording instruments and this smaller test is also counted in this category.
3. **Predictive Capability** – This type of testing included smaller-scale experiments to validate or develop parts of computer simulations and to gather data for computer models of equations-of-state, turbulence, high-explosive detonation, etc. This type of testing was also meant to explore new or poorly understood phenomena. Large tests were done of weapons geometries to benchmark three-dimensional or other advanced computer simulation tools that integrated several complex models.
4. **Proliferation Assessment and Disablement** – Tests done to evaluate actual or potential foreign, proliferant, or terrorist nuclear devices. This included tests to develop and evaluate disablement technologies.
5. **Conventional Munitions** – Tests done to develop and evaluate non-nuclear, conventional munitions, usually for the Department of Defense.
6. **Measurement Technique Development** – Tests done to develop and evaluate new diagnostics and techniques for radiographic hydrodynamics and other high-explosives experiments.
7. **Other Applications** – Experiments not covered by the other categories.

For this EIS, DOE averaged the amount of material used at PHERMEX over the past five years to estimate the expected amounts of material that will be used in the future. However, operations at PHERMEX during the last five years underrepresent the facility's use of depleted uranium. For this estimate, DOE looked at use over the past 30 years. For example, the average annual release of depleted uranium during the mid-1980s was approximately 450 lb (200 kg) per year. Earlier use expended even greater amounts of material. Based on the known use of depleted uranium during the period from 1963 until 1994, DOE estimates that the expected use of depleted uranium would be higher than the average of the past five years, as shown in table B-4.

TABLE B-4.—*Materials Released to the Environment Before Regular Firing Site Cleanup at PHERMEX and FXR for CY 1990 to 1994*

Year	DU (kg)	Be (kg)	Pb (kg)	Cu (kg)	Other Metals	HE (kg)	Tritium (Ci)	LIH (kg)	Fluoride Salts (kg)
PHERMEX									
CY94	66	4	12	7	77	148	0[b]	9	—[a]
CY93	251	4	20	75	91	269	0[b]	12	—[a]
CY92	244	2	48	0[b]	29	146	0.8	17	—[a]
CY91	245	2	0[b]	0[b]	156	340	0[b]	21	—[a]
CY90	71	—[a]	0[b]	11	75	301	0[b]	—[a]	—[a]
FXR									
CY94	204	4	0	14	4	371	0	5	0
CY93	186	2	0	20	3	413	0	9	0
CY92	154	10	10	22	19	1,744	0	13	0
CY91	214	6	0	41	14	1,466	0	14	0
CY90	315	16	0	19	15	411	0	15	9

[a] None reported.
[b] The material was reported as 0.

Notes: "DU", short for depleted uranium, refers to uranium in which the isotope uranium-235 has been depleted below the content of 0.7 percent found in naturally occurring uranium. DU is less radioactive than naturally occurring uranium. The majority isotope in the material is uranium-238.

When referring to PHERMEX, "other metals" means the sum of all aluminum, boron, brass, iron, inconel, niobium, nickel, silver, tin, tantalum, titanium, tungsten, and vanadium used during each year. For FXR, "other metals" includes those metals listed above, plus barium, chromium, cobalt, and molybdenum.

Standardized symbols are used for the following materials: beryllium (Be), lead (Pb), copper (Cu), high explosives (HE), and lithium hydride (LiH).

For this EIS, DOE estimates that the average annual releases over the past 32 years to the environment as a result of high-explosives testing, prior to regular firing-point cleanups, were:

- Depleted uranium – 1,100 lb (500 kg)
- Beryllium – 15 lb (7 kg)
- Lead – 22 lb (10 kg)
- Copper – 155 lb (70 kg)
- Other metals – 310 lb (140 kg): consists of 50 percent aluminum, 35 percent stainless steel, and 15 percent other metals and alloys including tantalum, brass, nickel, silver, tin, and very small quantities of others.
- Tritium – 2 Ci
- Lithium hydride – 155 lb (70 kg)
- High explosives – 2,400 lb (1,100 kg)

The alternatives analyzed in this EIS predict an increase in hydrodynamic testing and dynamic experiments. This predicted increase incorporates conservative estimates for the purpose of analyzing impacts in this EIS. It reflects the increased use of radiographic hydrodynamic testing and dynamic experiments over the next few years for reasons such as: the cessation of underground nuclear testing and the pursuit of a Comprehensive Test Ban treaty, the need for stewardship of the nuclear weapons stockpile, benchmarking computer simulations of the stockpile that will be compared to the past data obtained from underground nuclear tests, increases in proliferation assessment and disablement; and the need for tests to improve nuclear weapons safety, security, and reliability.

B.7 WASTE MANAGEMENT

During more than 30 years of PHERMEX operations, a total of about 34,200 lb (16,000 kg) of depleted uranium has been used. This amount of depleted uranium represents a total volume of about 30 ft^3 ($1m^3$). At least 70 percent of the depleted uranium remained on or near the firing point after test assembly detonations and has been removed during routine operational cleanup of the firing site. The depleted uranium and other firing-site debris are handled as low-level radioactive waste. Approximately 10 to 12 truck loads each having an average weight of 7 tons (6,400 kg) are sent to TA-54 Area G for disposal each year, totaling about 160,000 lb (70,000 kg). This material consists mainly of firing-site soil, wood, metal, glass, plastic, rubber, and cabling used to set up a test assembly detonation. The average quantity of depleted uranium in this waste would be about 770 lb (350 kg), less than 1 percent of the total waste mass.

Lead has been a constituent of a small number of test assemblies fired at the site; however, when lead is present in a test assembly, the site is cleaned both before and after the test so that the site is cleared of lead before the next test. The firing-site debris (including soil on and around the firing site) is characterized periodically for the presence of RCRA controlled metals. The negative findings of these characterizations have always resulted in the firing-site debris being classified as low-level radioactive waste (not mixed waste). Other lead is used for shielding (rather than as part of a test assembly) which may become contaminated with radioactive material and is kept onsite for reuse. Approximately 10 percent, less than one 55-gal drum or 220 lb (100 kg) per year, of the lead shielding that is potentially radioactively contaminated is considered unusable, becomes waste, and is transferred to the established LANL mixed waste program.

As shown in table 3-1, plastics, glues, foams, binders, and other organic materials are used in constructing test assemblies. However, only small quantities, less than a few pounds total for each assembly, are used and these are mostly destroyed when the assembly is detonated. What little remains would be part of the shot-point debris described above.

A small amount of industrial chemicals and solvents are routinely used to support normal operations at PHERMEX. The major industrial chemicals used on an annual basis are solvents: 3 gal (11 L) of acetone and 6 gal (23 L) of ethanol. Other solvents, which are used on rags for cleaning and are used in very small quantities, are chlorinated fluorocarbons, toluene, 1,1,1-trichloroethane, and xylene. The cleaning rags are collected and disposed as solid potentially hazardous waste following laboratory guidelines. Historically, no more than 220 lb (100 kg) of solid hazardous waste and 1,800 lb (800 kg) of liquid hazardous waste have been disposed for every 1,000 lb (450 kg) of depleted uranium used at PHERMEX firing site.

Nonhazardous solid waste from the building is sent to the county landfill. Approximately one dumpster of nonhazardous solid waste is generated per week.

Wastes generated under current operations and under the proposed alternatives would be subject to treatment, storage, and disposal in other LANL Technical Areas. Transportation of these wastes is conducted using DOE- or DOT-approved containers carried on government vehicles using public roads between LANL facilities, as needed.

The PHERMEX facility has sanitary and storm water management systems. The sanitary system employs a septic tank and leach field. The storm system directs rainwater run-off away from buildings. The sanitary system is registered with Los Alamos County and the storm system has an EPA authorization to discharge. Cooling tower blowdown consisting of a few gallons per year is discharged into the sanitary system.

When containment was used for a test shot, the containment vessel was taken to another LANL facility for cleaning and refurbishing. The blast debris removed was taken to appropriate LANL facilities for processing and disposition.

B.8 DISTRIBUTION OF MATERIAL RELEASED TO THE ENVIRONMENT

For the purposes of this EIS, DOE has estimated the distribution of test assembly material released to the environment to support evaluation of potential impacts for the proposed alternatives. Approximately 50 percent of the depleted uranium in test assemblies at the PHERMEX site is contained in simulated secondaries and blast pipes of pin experiments. During detonation this fraction of the depleted uranium is ejected as relatively large fragments (see figure B-1) that remain in the immediate vicinity of the firing point and are collected during routine cleanup operations. Another approximately 40 percent of the total depleted uranium may be dispersed as relatively small, platelet-shaped fragments having surface areas ranging from 0.08 to 1.1 in^2 (0.5 to 7 cm^2). About half of this material remains in the immediate vicinity of the firing point and is also collected during routine cleanup. Therefore, about 70 percent of the total depleted uranium used on the firing site is collected during cleanup operations. The remaining depleted uranium (about 10 percent of the total) may be released as an aerosol, of which 20 percent (2 percent of the total depleted uranium) is considered respirable (McClure 1995). Respirable particles are those with an activity median aerodynamic diameter (AMAD) of 3.94 x 10^{-4} inches (10 μ) or less. Based on the average amount of depleted uranium used per year over the PHERMEX operating period, the amount of depleted uranium of respirable size available for dispersal beyond the immediate vicinity of the PHERMEX site and offsite would amount to about 22 lb (10 kg) annually.

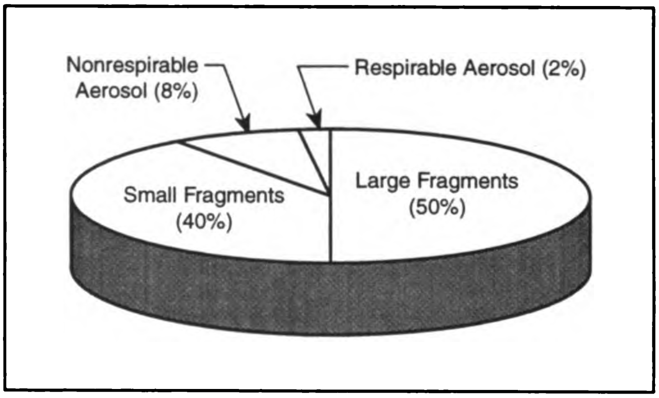

FIGURE B-1.—***Depleted Uranium Debris from a Typical Test.***

The other half of the small depleted uranium fragments (20 percent of the total depleted uranium) dispersed as a result of detonation typically fall within a 4,100-ft (1,250-m) circle. The large non-respirable aerosol fraction (about 8 percent of the total depleted uranium) falls out from the plume of released material and is deposited within a few hundred meters of the firing point. These two fractions constitute the majority of depleted uranium contamination that has been detected in the soil.

The release and aerosolization fractions described above are also used to estimate the dispersion of other constituents in test assemblies detonated on the PHERMEX firing site.

B.9 TRANSPORTATION

Test assemblies that include high explosives are shipped using DOE and LANL trucks, containers, and tie-down techniques from the assembly area at TA-16 to the PHERMEX site. This is a total distance of about 3.5 miles under a speed limit of 35 miles per hour. This shipment is conducted on LANL secure roads and is not conducted on public roads. Transportation requirements consist of one trip for each assembly and up to three trips for shipment of support materials. Support shipments might include high explosives or surrogate materials, but not both simultaneously. Shipments of radioactive surrogate materials exhibit no external radiation exposure characteristics either because of the nature or the characterization of the shipping container.

B.10 REFERENCES CITED IN APPENDIX B

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Appendix C

Air Quality and Noise

APPENDIX C
AIR QUALITY AND NOISE

This appendix presents the methods used for analyzing potential impacts to air quality and potential noise impacts. Appendix C1, Air Quality, addresses routine emission of nonradiological air pollutants from the DARHT and PHERMEX sites from construction activities and normal operations. Pollutants addressed in this appendix include nitrogen dioxide (NO_2), sulfur dioxide (SO_2), and respirable particulate matter (PM_{10}). Appendix C2, Noise, provides methods and information on potential noise impacts from explosive detonation activities, construction, and traffic that would be associated with the DARHT or PHERMEX facilities.

APPENDIX C1: AIR QUALITY

Emission of nonradiological air pollutants into the atmosphere is regulated by Federal and State ambient air quality standards. Nonradioactive air pollutants at LANL are summarized in chapter 4. Estimates of the air quality impacts that would result from the emission of nitrogen dioxide (NO_2), sulfur dioxide (SO_2), and particulate matter with a 10 μ or less aerodynamic diameter (PM_{10}) were presented. Other criteria pollutants are carbon monoxide (CO) and ozone (O_3) but these pollutants are not emitted in any significant quantities by the operation of the facilities. Modeling tools and assumptions used to generate estimate impact on air quality are presented in this appendix. In formulating inputs for air quality modeling, a series of conservative assumptions were made (i.e., assumptions which tended to maximize air quality impacts).

C1.1 MODELS

The Industrial Source Complex (ISC2) computer code was used to estimate the annual air quality impacts, as well as some of the short-term air quality impacts of criteria pollutants. The ISC2 model consists of the ISC2 short-term model (ISCST2) and the ISC2 long-term model (ISCLT2). The two models use steady-state Gaussian plume algorithms to estimate pollutant concentrations from a wide variety of sources associated with industrial complexes (EPA 1992a). The models are appropriate for flat or rolling terrain, modeling domains with a radius of less than 31 mi (50 km), and urban or rural environments. The ISC2 models are approved by the EPA for specific regulatory applications and designed for use on personal computers. Input requirements for the ISC2 model include a variety of information that defines the source configuration and pollutant emission parameters. The user may define point, line, area, or volume sources. The ISCST2 model uses hourly meteorological data to compute straight-line plume transport and diffusion, while the ISCLT2 model uses a joint frequency distribution of wind direction, wind speed, and atmospheric stability data to compute the transport and diffusion. Plume rise, stack tip downwash, and building wake can be computed and deposition taken into account. The ISC2 models compute a variety of short- and long-term averaged products (concentrations and depositions) at user-specified receptor locations. Tables C1-1 and C1-2 present input parameters for the short-term and long-term models, respectively.

TABLE C1-1.—*Input Parameters for Modeling Short-term Releases of NO_2 Emission from Natural Gas Boiler, ISCST2 Model*

Parameter	Value
Pollutant Type	NO_2
Averaging Time	24 h
X-coordinate of Source on Grid	0.0
Y-coordinate of Source on Grid	0.0
Release Height of Source	0.0 m
Emission Rate of Source	4.53×10^{-3} g/s
Exit Temperature of Source	373 K
Exit Velocity of Source	0.0 m/s
Exit Diameter of Source	0.0 m
Origin of Receptor Rings:	
x-coordinate	0.0
y-coordinate	0.0
Radii of Polar Rings (m)	100. 200. 400. 800. 1000. 1200. 1500. 1800. 2000. 2500. 2700. 3000. 4000. 4400. 5000. 5500. 6000. 7000.
Number of Receptors per Ring	16
Height of Receptors	0.0 m
Starting Angle at each Ring	0.0 deg
Angle between Receptors on Ring	22.5 deg
Meteorological Input File	TA61994.MET
Anemometer Height	10 m

To calculate some of the short-term (24-h or less) criteria pollutant impacts, the SCREEN2 model was used. SCREEN2 is a screening model used to estimate short-term air pollutant concentrations, including estimates of maximum ground-level concentrations from a single source (EPA 1992b). The model uses a steady-state Gaussian plume algorithm to calculate the concentration from a single point, area, or simple volume source. The model can be applied to both simple and complex terrain for modeling domains out to 62 mi (100 km). Input requirements for SCREEN2 include information about the source configuration and pollutant emission parameters. Plume rise, building wake downwash, fumigation, and plume impaction on complex terrain can be computed. While specific meteorological values of wind speed and stability can be input to calculate pollutant transport and diffusion, the model can also calculate a worst-case maximum concentration, in which the model examines a range of stability classes and wind speeds to identify the "worst case" meteorological conditions. Output of the SCREEN2 model is 1-h maximum

TABLE C1-2.—***Input Parameters for Modeling Long-term NO_2 Emissions from Natural Gas Boiler, ISCLT2 Model***

Parameter	Value
Pollutant Type	NO_2
Averaging Time	24 h
X-coordinate of Source on Grid	0.0
Y-coordinate of Source on Grid	0.0
Release Height of Source	0.0 m
Emission Rate of Source	4.53×10^{-3} g/s
Exit Temperature of Source	373 K
Exit Velocity of Source	0.0 m/s
Exit Diameter of Source	0.0 m
Origin of Receptor Rings:	
x-coordinate	0.0
y-coordinate	0.0
Radii of Polar Rings (m)	100. 200. 400. 800. 1000. 1200. 1500. 1800. 2000. 2500. 2700. 3000. 4000. 4400. 5000. 5500. 6000. 7000.
Number of Receptors per Ring	16
Height of Receptors	0.0 m
Starting Angle at each Ring	0.0 deg
Angle between Receptors on Ring	22.5 deg
Meteorological Input File	LANLTA6.JFD
Anemometer Height	10 m
Average Wind Speed for Six Wind Speed Categories (m/s)	1.23 2.40 4.08 6.46 9.30 13.28
Average Temperature for Six Stability Classes	282 K
Averaging Mixing Height for:	
Stability A	2600.0 m
Stability B	2170.0 m
Stability C	1740.0 m
Stability D	1310.0 m
Stability E	880.0 m
Stability F	450.0 m

concentration at specified distances. Adjustment factors can be applied to estimate concentrations for longer averaging periods (i.e., up to 24 h). The SCREEN2 model is approved by the EPA for specific screening procedures and is designed to run on personal computers.

C1.2 RECEPTORS

Maximum ground-level pollutant concentrations for regulatory-significant time periods are reported at the maximally impacted receptor location. To capture this impact, ISC model runs have at least one receptor location in each of the 16 transport directions used by the model. Receptors are positioned at points of public access along publicly accessible roads within the boundaries of LANL, along the LANL fenceline, and in existing residential areas (figure C1-1).

To determine maximum short-term (i.e., exposure periods of from 1- to 24-h) impacts, pollutant concentrations are reported for the maximally impacted point of public access. This involves assessing impacts at receptors located within, along, and outside of the LANL fenceline. For long-term impacts (i.e., annual exposures), pollutant concentrations are reported for the maximally impacted point of unrestricted public access. This involves the assessment of impacts at receptor locations along and outside of the LANL fenceline. Onsite points of public access are not considered because of the limited time any member of the public would spend at an onsite location over the course of an entire year; however, receptor locations along large segments of the LANL fenceline are considered even though current land-use restrictions do not allow permanent residents in these areas.

ISC model runs indicate that the maximum short-term (i.e., 1-, 3-, 8-, and 24-h) pollutant concentrations would occur along the LANL fenceline at a point 1.0 mi (1.5 km) southwest of the proposed DARHT facility (receptor 18 on figure C-1). Maximum long-term (annual) pollutant concentrations would occur along the LANL fenceline at a point 1.1 mi (1.8 km) south of the DARHT facility (receptor 16 on figure C-1). Because of the close proximity of the DARHT and PHERMEX sites, emissions from both facilities are conservatively assumed to occur at the DARHT facility.

C1.3 SOURCE TERM

The increases in the airborne concentration of criteria pollutants, as described for each alternative in chapter 5, is assumed to result from construction activities and routine operation of the DARHT or PHERMEX facility. Construction activities release NO_2, SO_2, and PM_{10} as a result of the operation of diesel- and gasoline-powered construction equipment. PM_{10} emissions also occur, in the form of fugitive dusts, as a result of the movement of construction equipment over the disturbed ground. Operations activities release NO_2 and PM_{10} as a result of emissions during hydrodynamic testing and NO_2, SO_2, and PM_{10} as a result of the operation of the natural gas boiler used in heating the DARHT facility.

In all but one case, pollutants were assumed to be released from a ground-level point source located on flat terrain; the only exception to this is that fugitive dust emissions during construction are assumed to come from an area source. The use of more realistic pollutant release heights, accounting for buoyant and mechanical plume rise, and the consideration of initial plume spreading (e.g., as would result from

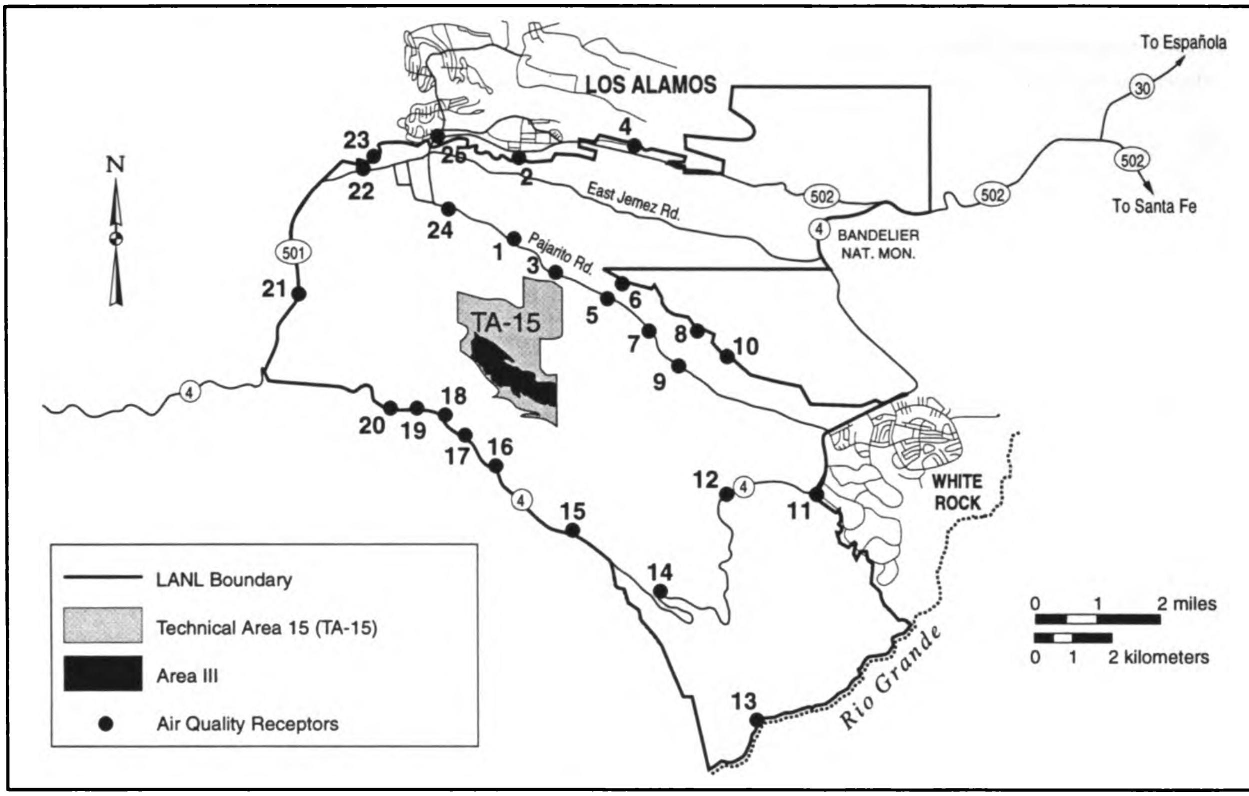

FIGURE C-1.—***Location of Receptors used in Air Quality Modeling.***

hydrodynamic testing) are factors that would tend to reduce maximized ground-level impacts, but were not included in this analysis.

To calculate annual pollutant concentrations using the ISCLT2 model, a joint frequency distribution of wind speed, wind direction, and atmospheric stability data from tower TA-6 were used (exhibit C1-1). The TA-15 area, where the proposed DARHT and PHERMEX facilities are located, does not have routine meteorologic monitoring. As described in appendix H, meteorologic data from TA-6 were also used to compute human health impacts from the airborne transport of pollutants.

The ISCLT2 model also required estimations of average mixing layer depth for the six stability classes (A-F). Because no mixing height data is available from Los Alamos, the annual morning mixing height of Albuquerque, 1,500 ft (450 m) is assumed to be the average mixing layer depth for stability class F (very stable), and the annual afternoon mixing height of Albuquerque, 8,500 ft (2,600 m) is assumed to be the average mixing layer depth for stability class A (very unstable) (Holzworth 1972). The mixing layer depths at stability classes between A and F are estimated by linear interpolating between the mixing heights at stability class A and F.

To calculate the short-term averaged concentration using the ISCST2 model requires hourly meteorological data of wind speed, wind direction, atmospheric stability, air temperature, and mixing heights. The hourly meteorological data for 1994 at tower TA-6 were used as meteorological input in the ISCST2 model. Because mixing layer depth is not measured at Los Alamos, a conservative estimate of the morning mixing height for Albuquerque for all stability classes was used (Holzworth 1972). The morning mixing height varied by season.

For estimating the short-term averaged concentration using the SCREEN2 model, no meteorological input is required. The worst case maximum concentration option is used in which the SCREEN2 model estimates the maximum concentration by examining a range of wind speed and stability classes to find the worst-case meteorological conditions. For a ground-level release, the worst case meteorological variables are a 2 mi/h (3 km/h) wind speed and a stability class of F.

C1.3.1 Fugitive Dust

Because it is nearly impossible to accurately predict the amount of dust emitted during construction, a default value of 1.2 ton/ac/mo of total suspended particulates is assumed (EPA 1993). This value was based on EPA measurements of suspended particulates (with aerodynamic diameters $\leq 30\ \mu$) made during the construction of apartments and shopping centers. It takes into account emissions during land clearing, blasting, ground excavation, cut and fill operations, and facility construction (EPA 1993).

The amount of PM_{10} emitted from the construction at the DARHT site should be less than 1.2 ton/ac/mo because many of the particulates suspended during construction are at the larger end of the 30 μ size range and will tend to rapidly settle out of the atmosphere at locations very close to the source (Seinfeld 1986). Experiments on dust suspension due to construction found that at 160 ft (50 m) a maximum of 30 percent of the particulates remaining suspended in the atmosphere were in the PM_{10} size range (EPA 1988). Thus, only 30 percent of 1.2 ton/ac/mo of total suspendable particulates or 0.4 ton/ac/mo are assumed to be emitted as PM_{10} from the construction site. Any active dust suppression activities at the DARHT construction site would further reduce PM_{10} emissions; however, no dust suppression activities are assumed in our analysis.

To estimate the annual and 24-h average PM_{10} concentration requires both the size of the area disturbed and the unit-area emission rate (0.4 ton/ac/mo). For all alternative except the No Action, a square-shaped area of 8 ac (3 ha) is assumed to be disturbed. For the No Action Alternative, the construction activities

are assumed to be negligible, so no area is disturbed. Table C1-3 presents the source term used to calculate the air quality impacts from fugitive dust emissions. Both the annual and 24-h maximum average concentration are calculated using the ISC2 models.

C1.3.2 Construction Equipment

The other major source of criteria pollutant emissions from construction is the operation of diesel- and gasoline-powered construction equipment. To obtain the emission rate for each pollutant from the construction equipment, it is assumed that all the diesel and gasoline are consumed by the heavy-duty construction equipment that emits the maximum amount of each pollutant for the given equipment type. The pollutant emission rate for heavy-duty construction equipment is found in EPA's AP-42 tables 2-7.1 and 2-7.2 (EPA 1991). Table C1-4 presents the estimated average monthly and the peak daily consumption of diesel and gasoline for construction of DARHT. Table C1-5 presents the kilograms of

TABLE C1-3.—*Source Term for the Fugitive Dust for the Various Alternatives*

Alternative	Pollutant	Averaging Time	Mass of Pollutant per Time Period per Area	Area of Source (ac)	Maximum Emission Rate (g/(m^2-s))
No Action	PM_{10}	Annual	0 kg/(yr-ac)	0	0
		24-h	0 kg/(24-h-ac)	0	0
All Others	PM_{10}	Annual	1.2×10^4 kg/(yr-ac)	8	3.4×10^{-5}
		24-h	210 kg/(24-h-ac)	8	3.4×10^{-5}

pollutant emitted per cubic meter (m^3) of fuel consumed by the construction equipment. For all pollutants but SO_2, the largest emitter is a wheeled tractor; the motor grader and the wheeled dozer are the largest emitters of SO_2, respectively.

The emission rate for the annual concentration is calculated from the average monthly emissions, assuming that the construction is year round. Annual concentrations are calculated using the ISCLT2 model.

The 3-h average emission rate assumes that all of the full workday ration of fuel is consumed in a 3-h period [i.e. 135 gal (0.5 m^3 of diesel fuel per 3 h]. All of the fuel is assumed to be burned by a vehicle that provides the highest level of emissions for nitrogen dioxide, sulfur dioxide, and PM_{10}. The 24-h average emission rate assumes that the same workday ration of fuel is consumed over a 24-h period. The

TABLE C1-4.—*Table of Estimated Average Monthly and Peak Daily Consumption of Diesel and Gasoline for Construction of the DARHT Facility*

Fuel	Average Monthly Consumption (gal/mo)	Daily Peak Consumption (gal/day)
Diesel	500	135
Gasoline	500	17
Source: Chastain 1995		

TABLE C1-5.—*Amount of Pollutant Released per m^3 of Fuel Consumed by Construction Equipment with Highest Emissions*

Pollutant	Diesel (kg of pollutant/m^3)	Gasoline (kg of pollutant/m^3)
NO_2	52.35	17.5
SO_2	3.73	0.636
PM_{10}	5.75	0.991

short-term average concentrations are calculated using the SCREEN2 model. Because there is no specific information on different fuel consumption rate for the various alternatives, the same annual, 24-h, and 3-h consumption are used for all the alternatives except the No Action Alternative, which has no appreciable construction-related emissions.

Table C1-6 presents the source term for the construction equipment emissions used for all alternatives except the No Action Alternative.

TABLE C1-6.—*Source Term for the Construction Equipment Emissions for the All Alternative Except the No Action Alternative*

Pollutant and Averaging Time	Averaging Time	Mass of Pollutant per Time Period	Maximum Emission Rate (g/s)
PM_{10}	Annual	150 kg/yr	4.7×10^{-3}
	24-h	3 kg/24 h	3.5×10^{-2}
NO_2	Annual	1,600 kg/yr	5.1×10^{-2}
	24-h	28 kg/24 h	3.2×10^{-1}
SO_2	Annual	95 kg/yr	3.0×10^{-3}
	24-h	1.9 kg/24 h	2.2×10^{-2}
	3-h	1.9 kg/3 h	1.8×10^{-1}

C1.3.3. Hydrodynamic Testing

Five ambient air pollutants, NO_2, and PM_{10}, beryllium, heavy metals (depleted uranium and lead), and lead are assumed to be emitted during hydrodynamic testing. These are products of detonation of high explosives and the resultant aerosolization of metals. It is assumed that the high explosives do not contain any significant amounts of sulfur, thus they are not a source of sulfur dioxide.

For purposes of this analysis, it was assumed that 10 percent of all the material (high explosive and other test metals) become respirable (PM_{10}) following a test. The remaining materials stay within 490 ft (150 m) of the firing point (see appendix B). Table C1-7 gives the estimated maximum amount of material used each year in the No Action and the Enhanced Containment Alternatives. With the exception of the Enhanced Containment Alternative, all the alternatives involve the same amount of material. Under the Enhanced Containment Alternative, the containment building or vessel limits the release of gases, fine particles, and fragments to 6 percent of the values used estimated for the other alternatives. The 6 percent release factor is a highly conservative assumption used to account for potential leakage of the containment structure and vessel/building failure. Annual concentrations are calculated using the ISCLT2 model.

For the 24-h concentration of PM_{10}, an estimate of the largest amount of material to be expended in 24 h is needed. This quantity was not known, but the largest test shot was assumed to be 500 lb (230 kg). To

TABLE C1-7.—*Estimated Material Released to the Environment During a Year of Testing for the No Action and Containment Alternatives.*

Alternative	DU (kg)	Be (kg)	Pb (kg)	Cu (kg)	Other Metal (kg)	HE (kg)	LiH (kg)	Total (kg)
No-Action	700	10	15	100	200	1500	100	2625
Containment	42	1	1	6	12	1400	6	1468

DU = Depleted uranium
Be = Beryllium
Pb = Lead
Cu = Copper
HE = High explosives
LiH = Lithium hydride

provide a rough estimate of the maximum amount of material that could be detonated in a 24-h period, the largest test device detonation was used, assuming detonation of 500 lb (230 kg) of material in a 24-h period. The same emission rate was used for all alternatives except the Containment alternative, for which the emission rate is assumed to be 6 percent of the No Action Alternative. The 24-h PM_{10} concentrations are calculated using the SCREEN2 model.

Nitrogen dioxide can be produced from the detonation of high explosives. Because the type of high explosives to be used during testing is variable, a bounding case is used. The high explosive used in this assessment was nitroglycerine (even though this specific explosive would not be used in hydrodynamic testing) because it has the highest emission rate of nitrogen dioxide, 53 lb/ton (26 kg/MT), of any of the explosives listed by the U.S. Environmental Protection Agency for stationary point and area sources (EPA 1993). Table C1-7 shows the yearly amount of high explosives to be used for the No Action and Containment alternatives.

The annual emission rate for nitrogen dioxide from hydrodynamic testing is the product of the number of tons of high explosive used per year and the amount of nitrogen dioxide released per ton of explosive. The emission rate for nitrogen dioxide is the same for all alternatives (in the Containment Alternative, nitrogen dioxide emissions might initially be contained but they are soon vented from the building or vessel). The annual concentrations are calculated using the ISCLT2 model.

For the 24-h emission rate of nitrogen dioxide from hydrodynamic testing, the largest amount of high explosive expended in a 24-h period is needed. This quality is not known. It is assumed that 500 lb (230 kg) of high explosive (nitroglycerine for purposes of nitrogen dioxide emission) will be the maximum amount detonated in a 24-h period. The same emission rate is used for all alternatives. The 24-hour concentrations are calculated using the SCREEN2 model.

The ambient air concentrations for beryllium, heavy metals (depleted uranium and lead), and lead were derived using one hour χ/Q factors and source terms as presented in table C1-8 The χ/Q factors were derived using the meteorological data presented in exhibit C1-1. Ten percent of the metals available for aerosolization are assumed to be respirable. These one hour concentrations were then adjusted for

TABLE C1-8.—*Data Used to Derive Ambient Air Concentrations of Metals During Testing*

Alternative	1 hr χ/Q′	Amount Available for Aerosolization		
		DU (g)	Pb (g)	Be (g)
Uncontained	12.82	50,000	4,000	500
Contained				
Building	360	8,600	180	120
Vessel Contained	360	35,000	800	500
Vessel Uncontained	360	6,400	200	100

TABLE C1-9.—*Source Term for Hydrodynamic Testing for the No Action and Enhanced Containment Alternatives*

Alternative	Pollutant	Averaging Time	Mass of Pollutant per Time Period	Maximum Emission Rate (g/s)
No Action	PM_{10}	Annual	260 kg/yr	8.3×10^{-3}
		24-h	23 kg/24-h	2.6×10^{-1}
	NO_2	Annual	39 kg/yr	1.2×10^{-3}
		24-h	5.2 kg/24-h	6.0×10^{-2}
Containment	PM_{10}	Annual	150 kg/yr	4.7×10^{-3}
		24-h	1.4 kg/24-h	1.6×10^{-2}
	NO_2	Annual	32 kg/yr	1.0×10^{-3}
		24-h	5.2 kg/24-h	6.0×10^{-2}

comparison to the standards for metals in the ambient air, 30 days for beryllium and heavy metals and 90 days (calendar quarter) for lead.

Table C1-9 gives the source term used to estimate the air quality impacts from PM_{10} and NO_2 due to hydrodynamic testing for the No Action and Containment alternatives. As stated before, all alternatives except the Containment Alternative are assumed to be the same as the No Action Alternative.

C1.3.4. Boiler Emissions

The only other primary pollutant source from operation of the facility is emissions from the natural gas boiler used for heating. The natural gas boiler is assumed to be a commercial boiler (80 hp) with an hourly gas input rate of 3,348,000 Btu/hr. The emission rate of each pollutant can be calculated from the emission factors for commercial natural gas boilers given in EPA's AP-42 document (EPA 1993). Table C1-10 gives these emission rates in units of kilograms of primary pollutant (nitrogen dioxide, sulfur dioxide, and PM_{10}) per million m^3 of natural gas. The rates are computed assuming a heating rate of 8,270 kcal per m^3 of natural gas (EPA 1993). To be conservative, the boiler is assumed to run continuously throughout the year. It is also assumed that the boiler has no emissions controls for nitrogen dioxide. Since the hourly gas input rate is known, there is no special requirement for finding the

TABLE C1-10.—*Emission of Primary Pollutants from Natural Gas Combustion, Heating Value, and Hourly Gas Input for a 80 hp Commercial Boiler*

Pollutant	Pollutant Emitted (kg of pollutant per 10^6 m^3 of fuel)	Heating Value ($kcal/m^3$)	Hourly Gas Input (10^3 Btu/hr)
NO_2	1,600	8,270	3,348
SO_2	9.6	8,270	3,348
PM_{10}	192	8,270	3,348

TABLE C1-11.—*Source Term for Emissions from the Natural Gas Boiler Used in Heating the Facilities*

Pollutant	Averaging Time	Mass of Pollutant per Time Period	Maximum Emission Rate (g/s)
PM_{10}	Annual	170 kg/yr	5.4×10^{-3}
	24-hr	4.7×10^{-1} kg/24-h	5.4×10^{-3}
NO_2	Annual	1,400 kg/yr	4.5×10^{-2}
	24-hr	3.8 kg/24-h	4.5×10^{-2}
SO_2	Annual	8.6 kg/yr	2.7×10^{-4}
	24-hr	2.4×10^{-2} kg/24-h	2.7×10^{-4}
	3-hr	2.9×10^{-3} kg/3-h	2.7×10^{-4}

short-term emission rates compared to annual emission rates. The emission rate is the same for all alternatives. Table C1-11 presents the source term used to estimate the air quality impacts due to emissions from the natural gas boiler. All the concentrations are calculated using the ISC2 models.

APPENDIX C2: NOISE

This evaluation of noise impacts focuses on three sources of noise: construction noise associated with each alternative, increases or decreases in traffic and resulting noise propagation in adjacent communities based on facility construction and operation, and effects of noise from the firing of test shots at the facilities. In support of the evaluation, this appendix reviews how meteorological conditions and terrain influence sound travel, summarizes noise measurements made at a series of testing firings at PHERMEX on March 11, 1995, and documents the tests or methods employed in the noise analysis.

C2.1 GENERAL INFORMATION

For this assessment, noise is expressed in two forms. A-weighted sound pressure levels (dBA) are adjusted values that are most indicative of adverse community responses to noise. Firing noise levels are reported as peak dBA levels. Noise derived from traffic estimates are reported as 1-h equivalent sound levels (L_{eq}). The L_{eq} (in dBA) is the equivalent steady state sound level that, if continuous during a specified time period, would contain the same energy as the actual time varying sound over the monitored or modeled time period (in this case, 1 h). Except for vehicles exceeding 10,000 lb (4,540 kg) Gross Vehicle Weight (GVW), vehicle noise on public thoroughfares is exempted from residential noise standards.

C2.2 NOISE ANALYSIS MARCH 1995 TEST SHOTS

On March 11, 1995, at the PHERMEX pad, a series of test shots was fired to obtain seismic and acoustic measurements at selected locations. The coordinates at the PHERMEX firing point were North 35°49.957′ and West 106°17.739′. Acoustic (sound pressure) readings were taken by instruments fitted with wind screens at three locations: Technical Area 49 (TA-49), Bandelier National Monument entrance, and the community of White Rock.

C2.2.1 TA-49

The sampling location was located approximately 3/4 mi (1 km) east of the TA-49 Gate along State Route 4 (coordinates for this site were North 35°49.133′ and West 106°18.518′.) A multi-spectral IVIE sound level meter (IVIE #677) was used to record maximum sound pressure levels at nine standard frequencies. This location was the shortest distance between the firing site and the site boundary.

C2.2.2 Bandelier National Monument Entrance

This sampling location was located just off State Route 4 in a turn-off on the east side of the highway about 100 yards west of the entrance to Bandelier National Monument. The coordinates were North 35°47.797′ and West 106°16.545′. A multi-spectral IVIE sound level meter (IVIE #436) was used to record maximum sound pressure levels at nine standard frequencies. This location represents the closest residence to the PHERMEX firing site.

C2.2.3 White Rock Community

This station was located about 100 to 150 ft (30 to 45 m) east of the intersection of State Route 4 and Karen Circle Road on LANL property just off State Route 4. The mean coordinates of two readings were North 35°82.026′ and West 106°22.182′. A-weighted sound levels were measured with a GenRad Precision Sound Level Meter at 250 Hz. On March 11, 1995, White Rock, which is generally ENE of PHERMEX, was not directly downwind of PHERMEX. Because of terrain and anticipated wind patterns, this location represents the community that is most likely to have the greatest noise levels resulting from blasts.

Acoustic measurements collected on March 11, 1995, measured air over pressure signals (frequencies from 2 to 200 Hz) with a microphone equipped with a wind screen. Measurements were collected at the TA-49 location from two duplicate sensors (Station C1 and Station C2), as shown in table C2-1. Air blast

TABLE C2-1.—*Acoustic (Airblast) Measurement at TA-49 Seismic and Acoustic Monitoring Stations, March 11, 1995*

Shot #	Load[a]	Time	Station B1			Station B2		
			AOP[b]	dB	Hz	AOP[b]	dB	Hz
0942	10	12:15	<0.04	NS	NS	<0.04	NS	NS
0943	25	12:38	<0.04	NS	NS	<0.04	NS	NS
0944	50	13:01	0.17	119	6.6	0.14	117	6.9
0945	50	13:33	<0.04	NS	NS	<0.04	NS	NS
0946	100	13:54	0.11	116	6.0	0.12	116	6.2
0958	150	14:16	0.21	121	7.1	0.20	120	5.0

[a] lb TNT used
[b] Air overpressure in millibars

dB = decibel
Hz = frequency, in Hertz
NS = not sampled

measurements were measured at frequencies (5 to 15 Hz) which do not contribute to the A-weighted measurements for evaluation of human noise impacts. Consequently, air blast measurements are not addressed further.

Meteorological and environmental factors significantly affected the March 11, 1995, noise measurements. Terrain and wind are discussed below.

C2.2.4 Terrain

LANL is situated on the Pajarito Plateau and supports a mixture of conifers, trees, and shrubs. This ground cover will attenuate sound as it travels over land. Generally, the higher frequency sound is more effectively attenuated than lower frequencies. The rate of attenuation through medium-dense woods at 250 Hz is 0.06 dB/m (EEI 1978); hence, attenuation in low frequency bands that characterize blast noise is significant. The mesas, which run in an east-southeasterly direction, are separated by valleys that may also channel and influence offsite noise measurements.

Portions of the community of Los Alamos are closer to PHERMEX than White Rock (Table C2-2), but they are located uphill over heavily forested terrain and beyond a hill. These factors would tend to significantly reduce noise levels at locations north and northwest of PHERMEX. Communities located to the east of LANL are lower in elevation and may have noise channeled into the community down through the valleys.

TABLE C2-2.—***Estimated Distances Between PHERMEX Firing Site and Sound Measurement Locations***

Location	Distance
TA-49 (off Route 4)	1.3 mi (2 km)
Bandelier National Monument Entrance	2.6 mi (4 km)
White Rock	4.0 mi (6 km)
Los Alamos	3.0 mi (5 km)

C2.2.5 Wind

Wind measurements are summarized from data collected at the TA-49 weather station (Table C2-3). As the firings progressed, wind velocity steadily increased; however, the winds varied and were gusty. The wind measurements do not indicate gusts of possible greater speed that may have occurred at the time of firing. Sound moving into the wind is bent upwards, producing a shadow zone and generally reducing sound levels measured at ground level in an upwind location (EEI 1978). The Bandelier location is located to the south of the firing site and the TA-49 location is located to the SW. The prevailing winds would, therefore, reduce the measurements recorded at these two upwind locations. Sound traveling with the wind is forced downward, which effectively negates any ground level attenuation that may result from trees, shrubs, terrain, or other sound-attenuating obstructions. This situation is further exacerbated by the general decrease in slope from the PHERMEX firing site to the White Rock location. Because White Rock is located generally east of PHERMEX, the prevailing wind conditions would tend to increase noise levels there. Daytime winds are generally westerly during the months of March, April, and May (Bowen 1990), hence the selection of the White Rock location. However, during the March 11, 1995, testing, the winds came from the south.

TABLE C2-3.—*Summary of Meteorological Data Collected at TA-49 Weather Station March 11, 1995*

Shot #	Approximate Time	Time	Wind Speed (mi/h)	Wind Direction (Degrees N=0)	Temperature (°F)	Relative Humidity (percent)
		12:00	9.7	183	54.1	37
942	12:16	12:15	12.1	182	57.0	33
		12:30	13.0	182	57.7	31
943	12:39	12:45	15.4	187	56.8	31
944	13:02	13:00	13.9	177	58.6	31
		13:15	16.1	180	59.0	30
945	13:33	13:30	17.4	190	58.1	30
		13:45	13.9	194	57.4	30
946	13:55	14:00	15.4	187	7.0	31
958	14:17	14:15	14.5	189	57.0	31
		14:30	11.0	183	56.5	32

Temperatures and relative humidity varied little over the duration of the firings (Table C2-3). The differential effects on noise travel would not significantly affect measured noise levels during the March 11, 1995, tests.

C2.2.6 Measured Sound levels at White Rock, Bandelier Entrance, and TA-49

During the testing, sound pressure recording generally increased with blast intensity (Table C2-4). The noise variation observed by frequency and intensity is caused by the fluctuating wind that changed, not only in direction, but by speed. Under ideal conditions of calm and optimum temperature and humidity, it is possible for sound pressure levels at the TA-49 Site boundary location to exceed 70 dBA with the larger blasts. The lower power firings will have a lower probability of exceeding the 75 dBA Los Alamos County daytime guideline. The nighttime standard imposed from 9:00 p.m. to 7:00 a.m. of 53 dBA can be exceeded at the closest site boundary locations. The diverse terrain, and frequency and directional variability of winds complicate routine noise estimation procedures and introduce a high level of uncertainty.

With a base schedule of 20 shots per year, blast noise impacts are considered equivalent for all alternatives except the Containment Alternative. In this option, containment may reduce blast noise by as much as 80 percent; however, uncertainties in the choice of a vessel or a building and the design of containment prevent a more specific evaluation of blast noise impacts. The county noise regulations restrict maximum noise levels to 75 dBA for a period of not more than 10 minutes in a single hour during daylight hours (7:00 a.m. to 9:00 p.m.). Monitoring results indicate that it would be extremely unlikely for this guideline to be exceeded as an instantaneous measurement of more than 75 dBA or for 10 min of blast-associated

TABLE C2-4.—*Noise Measurements Conducted at LANL on March 11, 1995*

		Frequency, in Hertz									
Firing No.	**Load (ib1 TNT)**	**31.5**	**63**	**125**	**250**	**500**	**1,000**	**2,000**	**4,000**	**8,000**	**dBA**
TA-49 (I)											
942	10	32	42	54	50	50	46	42	44	48	NR
943	20	<46	52	58	46	46	52	46	NR	NR	66
944	50	48	52	62	60	60	58	48	NR	NR	68
945	50	NR	54	54	54	54	50	48	NR	NR	64
946	100	48	50	64	62	62	60	50	50	NR	70
958	150	NR	62	64	64	64	58	54	48	NR	71
Bandelier (II)											
943	20	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
944	50	38	52	56	54	52	48	42	40	36	NR
945	50	36	42	50	50	54	56	48	40	42	62
946	100	40	46	54	52	48	42	38	36	40	61
958	150	40	48	54	56	52	54	52	36	<36	60
White Rock											
942	10	NR	NR	NR	60.9	NR	NR	NR	NR	NR	NR
943	20	NR	NR	NR	65.3	NR	NR	NR	NR	NR	NR
944	50	NR	NR	NR	69.1	NR	NR	NR	NR	NR	NR
945	50	NR	NR	NR	63.1	NR	NR	NR	NR	NR	NR
946	100	NR	NR	NR	71.6	NR	NR	NR	NR	NR	NR
958	150	NR	NR	NR	68.6	NR	NR	NR	NR	NR	NR
Background Measurements		31.5	63	125	250	500	1,000	2,000	4,000	8,000	dBA
BKG1-67749		41	34	30	31	25	25	NR	NR	31	NR
BKGII-436		42	40	38	34	32	30	28	30	28	35
White Rock		NR	NR	NR	38	NR	NR	NR	NR	NR	NR
White Rock (car noise)		NR	NR	NR	51	NR	NR	NR	NR	NR	NR

NR = data not recorded or lost
BKG1-67749 taken at TA-49
BKGII-436 taken at Bandelier entrance

noise to exceed 65 dBA in a given hour. (Under test shot operating procedures, it is not possible for more than three shots to be fired in one hour.) However, the likelihood of exceeding the 53 dBA county limit for nighttime noise imposed from 9:00 p.m. to 7:00 a.m. is high.

C2.3 WORKER PROTECTION

Construction workers are protected by administrative procedures and protective devices (such as ear plugs or muffs). Threshold limit values (ACGIH 1993) for impulse noise are 100 impulses per day at 140 dB. The maximum number of firings in an 8-h period, assuming 20 minutes between shots is 25, well below the limit. Safety procedures implemented during firing create an exclusion zone that would protect staff from excessive impulse noise due to intensity and frequency.

C2.4 WILDLIFE

Firing noise may potentially impact sensitive wildlife, such as nesting birds. A group of deer observed during the first test shot on March 11, 1995, had an unhabituated startle response to the first firing. This observation suggests that local wildlife have not habituated to routine firings. However, the general health and well-being of deer and elk herds in the area suggest that testing programs involving firings have not had an adverse effect on ungulate populations at LANL or Bandelier National Monument.

C2.5 ESTIMATION OF TRAFFIC NOISE

Traffic noise is exempted under Los Alamos County noise regulations; however, increases in traffic can result in complaints about associated noise or congestion. A regression equation was developed from modeled data of traffic volume (vehicles/h) and estimated noise levels (1-h L_{eq} in dBA). The modeled data was developed to assess traffic noise associated with the New Production Reactor Environmental Impact Statement (DOE 1991). The regression equation was:

$$Y = 48.35549 + 7.25929X$$

where Y is the predicted noise level in 1 h L_{eq} (dBA) and X is the log of the hourly traffic volume.

For the analysis, three baseline levels of traffic volume were used: 10, 100, and 1,000 vehicles/h. The 10-vehicle/h limit might approximate early morning traffic. The 1,000-vehicle/h value is a conservative estimate of rush hour traffic volume. The larger the baseline traffic volume, the less significant the potential impact on overall traffic noise in the community. Incremental increases of traffic for each of these standard traffic volumes were raised by the full-time equivalents (FTEs) associated with each alternative. The impact was then related to the base flow to define the range of impact (the change (Δ) in table C2-5). The same approach was used to estimate increases in traffic due to construction. A mean and maximum construction force of 50 and 75 staff, respectively, were used in the assessment and the differences between alternatives resulting from the length of the construction phase.

The increases in traffic noise associated with all alternatives, compared to the No Action Alternative, are inconsequential because, in the modeled assumptions, the expected increases in traffic noise would not increase residential noise levels above 5 dBA. Within Los Alamos County noise standards, operation of motor vehicles on public thoroughfares is exempted from the county noise code.

TABLE C2-5.—*Estimated Traffic Noise Increases by Alternative for Operation and Construction*

Volume (Vehicles/hr)	Log Volume	Estimated L_{eq}	Baseline L_{eq}	Change in L_{eq} (ΔL_{eq})
OPERATIONS				
Analysis Baseline Traffic Flow				
10	1	56		
100	2	63		
1000	3	70		
No-Action Alternative (based on 13.4 FTEs)				
23	1.4	58	56	2.7
113	2.1	63	63	0.4
1013	3.0	71	70	0.04
Preferred Alternative (based on 19.9 FTEs)				
30	1.5	59	56	3.5
120	2.1	63	63	0.6
1020	3.0	70	70	0.06
Containment Alternative (based on 28.5 FTEs)				
39	1.6	60	56	4.3
129	2.1	64	63	0.8
1029	3.0	70	70	0.09
Plutonium Exclusion Alternative (based on 19.9 FTEs)				
30	1.5	59	56	3.4
120	2.1	63	63	0.6
1020	3.0	70	70	0.06
Single-Axis Alternative (based on 17.34 FTEs)				
27	1.4	59	56	3.2
117	2.1	63	63	0.5
1017	3.0	70	70	0.05
PHERMEX Upgrade Alternative (based on 19.9 FTEs)				
30	1.5	60	56	3.4
120	2.1	63	63	0.6
1020	3.0	70	70	0.06
CONSTRUCTION				
Maximum				
85	1.9	62	56	6.8
175	2.2	65	63	1.8
1075	3.0	70	70	0.2
Mean				
60	1.8	61	56	5.7
150	2.2	64	63	1.3
1050	3.0	70	70	0.2

L_{eq} is the one-hour equivalent sound level.

C.3 REFERENCES CITED IN APPENDIX C

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EXHIBIT C1-1.—Joint Frequency Distribution of Atmospheric Stability, Wind Direction, and Wind Speed for LANL at tower TA-6

(Wind measurements were made onsite at 32 ft (10 m) above ground level. Data are based on measurements made from 1990 through 1993.)

STAB CLASS	WIND DIRECTION FROM WHICH THE WIND IS BLOWING	WIND SPEED CLASS (m/s) 0 - 1.8	1.8 - 3.3	3.3 - 5.5	5.5 - 8.5	8.5 - 11.5	> 11.5
A	NORTH	0.0014	0.0005	0.0000	0.0000	0.0000	0.0000
A	NORTH-NORTHEAST	0.0022	0.0006	0.0000	0.0000	0.0000	0.0000
A	NORTHEAST	0.0048	0.0019	0.0000	0.0000	0.0000	0.0000
A	EAST-NORTHEAST	0.0086	0.0023	0.0000	0.0000	0.0000	0.0000
A	EAST 0.0096	0.0031	0.0000	0.0000	0.0000	0.0000	
A	EAST-SOUTHEAST	0.0081	0.0044	0.0000	0.0000	0.0000	0.0000
A	SOUTHEAST	0.0086	0.0076	0.0001	0.0000	0.0000	0.0000
A	SOUTH-SOUTHEAST	0.0066	0.0074	0.0002	0.0000	0.0000	0.0000
A	SOUTH	0.0038	0.0039	0.0003	0.0000	0.0000	0.0000
A	SOUTH-SOUTHWEST	0.0017	0.0013	0.0001	0.0000	0.0000	0.0000
A	SOUTHWEST	0.0010	0.0007	0.0001	0.0000	0.0000	0.0000
A	WEST-SOUTHWEST	0.0007	0.0005	0.0000	0.0000	0.0000	0.0000
A	WEST 0.0007	0.0004	0.0001	0.0000	0.0000	0.0000	
A	WEST-NORTHWEST	0.0007	0.0003	0.0001	0.0000	0.0000	0.0000
A	NORTHWEST	0.0009	0.0006	0.0001	0.0000	0.0000	0.0000
A	NORTH-NORTHWEST	0.0007	0.0006	0.0001	0.0000	0.0000	0.0000
B	NORTH	0.0005	0.0004	0.0001	0.0000	0.0000	0.0000
B	NORTH-NORTHEAST	0.0008	0.0012	0.0002	0.0000	0.0000	0.0000
B	NORTHEAST	0.0019	0.0031	0.0004	0.0000	0.0000	0.0000
B	EAST-NORTHEAST	0.0029	0.0032	0.0001	0.0000	0.0000	0.0000
B	EAST 0.0029	0.0032	0.0000	0.0000	0.0000	0.0000	
B	EAST-SOUTHEAST	0.0020	0.0041	0.0001	0.0000	0.0000	0.0000
B	SOUTHEAST	0.0019	0.0055	0.0005	0.0000	0.0000	0.0000
B	SOUTH-SOUTHEAST	0.0021	0.0085	0.0022	0.0000	0.0000	0.0000
B	SOUTH	0.0016	0.0066	0.0035	0.0000	0.0000	0.0000
B	SOUTH-SOUTHWEST	0.0008	0.0026	0.0019	0.0000	0.0000	0.0000
B	SOUTHWEST	0.0005	0.0011	0.0010	0.0000	0.0000	0.0000
B	WEST-SOUTHWEST	0.0002	0.0008	0.0004	0.0000	0.0000	0.0000
B	WEST 0.0002	0.0007	0.0002	0.0000	0.0000	0.0000	
B	WEST-NORTHWEST	0.0002	0.0007	0.0002	0.0000	0.0000	0.0000
B	NORTHWEST	0.0002	0.0008	0.0004	0.0000	0.0000	0.0000
B	NORTH-NORTHWEST	0.0002	0.0005	0.0003	0.0000	0.0000	0.0000
C	NORTH	0.0008	0.0013	0.0005	0.0000	0.0000	0.0000
C	NORTH-NORTHEAST	0.0016	0.0037	0.0019	0.0000	0.0000	0.0000
C	NORTHEAST	0.0026	0.0058	0.0021	0.0000	0.0000	0.0000
C	EAST-NORTHEAST	0.0035	0.0031	0.0002	0.0000	0.0000	0.0000
C	EAST 0.0040	0.0041	0.0001	0.0000	0.0000	0.0000	
C	EAST-SOUTHEAST	0.0021	0.0046	0.0004	0.0000	0.0000	0.0000
C	SOUTHEAST	0.0018	0.0030	0.0007	0.0000	0.0000	0.0000
C	SOUTH-SOUTHEAST	0.0022	0.0087	0.0076	0.0000	0.0000	0.0000
C	SOUTH	0.0026	0.0141	0.0160	0.0000	0.0000	0.0000
C	SOUTH-SOUTHWEST	0.0014	0.0073	0.0090	0.0000	0.0000	0.0000
C	SOUTHWEST	0.0009	0.0039	0.0053	0.0000	0.0000	0.0000
C	WEST-SOUTHWEST	0.0004	0.0021	0.0046	0.0000	0.0000	0.0000
C	WEST 0.0004	0.0014	0.0026	0.0000	0.0000	0.0000	
C	WEST-NORTHWEST	0.0003	0.0013	0.0019	0.0000	0.0000	0.0000
C	NORTHWEST	0.0004	0.0016	0.0026	0.0000	0.0000	0.0000
C	NORTH-NORTHWEST	0.0004	0.0009	0.0007	0.0000	0.0000	0.0000

EXHIBIT C1-1.—Joint Frequency Distribution of Atmospheric Stability, Wind Direction, and Wind Speed for LANL at tower TA-6 – Continued

D	NORTH	0.0098	0.0083	0.0011	0.0003	0.0000	0.0000
D	NORTH-NORTHEAST	0.0079	0.0081	0.0031	0.0010	0.0000	0.0000
D	NORTHEAST	0.0067	0.0041	0.0007	0.0001	0.0000	0.0000
D	EAST-NORTHEAST	0.0046	0.0010	0.0001	0.0000	0.0000	0.0000
D	EAST	0.0055	0.0020	0.0001	0.0000	0.0000	0.0000
D	EAST-SOUTHEAST	0.0046	0.0024	0.0003	0.0000	0.0000	0.0000
D	SOUTHEAST	0.0040	0.0012	0.0000	0.0000	0.0000	0.0000
D	SOUTH-SOUTHEAST	0.0060	0.0044	0.0022	0.0002	0.0000	0.0000
D	SOUTH	0.0098	0.0131	0.0041	0.0013	0.0000	0.0000
D	SOUTH-SOUTHWEST	0.0099	0.0221	0.0101	0.0027	0.0000	0.0000
D	SOUTHWEST	0.0085	0.0204	0.0084	0.0019	0.0002	0.0000
D	WEST-SOUTHWEST	0.0065	0.0120	0.0089	0.0038	0.0001	0.0000
D	WEST	0.0062	0.0095	0.0145	0.0090	0.0012	0.0001
D	WEST-NORTHWEST	0.0058	0.0092	0.0147	0.0101	0.0020	0.0012
D	NORTHWEST	0.0080	0.0130	0.0095	0.0030	0.0002	0.0000
D	NORTH-NORTHWEST	0.0079	0.0071	0.0011	0.0002	0.0000	0.0000
E	NORTH	0.0056	0.0027	0.0000	0.0000	0.0000	0.0000
E	NORTH-NORTHEAST	0.0028	0.0011	0.0000	0.0000	0.0000	0.0000
E	NORTHEAST	0.0016	0.0003	0.0000	0.0000	0.0000	0.0000
E	EAST-NORTHEAST	0.0008	0.0000	0.0000	0.0000	0.0000	0.0000
E	EAST	0.0008	0.0001	0.0000	0.0000	0.0000	0.0000
E	EAST-SOUTHEAST	0.0008	0.0001	0.0000	0.0000	0.0000	0.0000
E	SOUTHEAST	0.0009	0.0001	0.0000	0.0000	0.0000	0.0000
E	SOUTH-SOUTHEAST	0.0015	0.0004	0.0000	0.0000	0.0000	0.0000
E	SOUTH	0.0026	0.0013	0.0000	0.0000	0.0000	0.0000
E	SOUTH-SOUTHWEST	0.0047	0.0036	0.0001	0.0000	0.0000	0.0000
E	SOUTHWEST	0.0063	0.0076	0.0001	0.0000	0.0000	0.0000
E	WEST-SOUTHWEST	0.0047	0.0151	0.0007	0.0000	0.0000	0.0000
E	WEST	0.0039	0.0093	0.0029	0.0001	0.0000	0.0000
E	WEST-NORTHWEST	0.0038	0.0096	0.0050	0.0005	0.0000	0.0000
E	NORTHWEST	0.0062	0.0231	0.0010	0.0000	0.0000	0.0000
E	NORTH-NORTHWEST	0.0063	0.0070	0.0000	0.0000	0.0000	0.0000
F	NORTH	0.0058	0.0011	0.0000	0.0000	0.0000	0.0000
F	NORTH-NORTHEAST	0.0031	0.0005	0.0000	0.0000	0.0000	0.0000
F	NORTHEAST	0.0019	0.0001	0.0000	0.0000	0.0000	0.0000
F	EAST-NORTHEAST	0.0005	0.0000	0.0000	0.0000	0.0000	0.0000
F	EAST	0.0008	0.0000	0.0000	0.0000	0.0000	0.0000
F	EAST-SOUTHEAST	0.0009	0.0001	0.0000	0.0000	0.0000	0.0000
F	SOUTHEAST	0.0009	0.0001	0.0000	0.0000	0.0000	0.0000
F	SOUTH-SOUTHEAST	0.0011	0.0001	0.0000	0.0000	0.0000	0.0000
F	SOUTH	0.0020	0.0002	0.0000	0.0000	0.0000	0.0000
F	SOUTH-SOUTHWEST	0.0032	0.0003	0.0000	0.0000	0.0000	0.0000
F	SOUTHWEST	0.0058	0.0013	0.0000	0.0000	0.0000	0.0000
F	WEST-SOUTHWEST	0.0078	0.0068	0.0000	0.0000	0.0000	0.0000
F	WEST	0.0101	0.0307	0.0028	0.0000	0.0000	0.0000
F	WEST-NORTHWEST	0.0100	0.0308	0.0035	0.0000	0.0000	0.0000
F	NORTHWEST	0.0111	0.0149	0.0000	0.0000	0.0000	0.0000
F	NORTH-NORTHWEST	0.0078	0.0030	0.0000	0.0000	0.0000	0.0000

Appendix D

Geology and Soils (Soils Contamination)

APPENDIX D
GEOLOGY AND SOILS (SOILS CONTAMINATION)

This appendix describes the soils contamination resulting from firing-site activities. The description is presented both in terms of the level of soils contamination evident at firing sites, and in terms of the distance from the firing point (i.e., the soil contamination circle radius) at which levels of contamination cannot be distinguished from known background concentrations of metals.

Observed contamination of the soils surrounding the PHERMEX firing point provides the basis for a reasonable estimate of future soil contamination levels at the PHERMEX or DARHT sites, and the soil contamination circle radius applicable to either site. Data from the E-F firing sites, located on the watershed for Potrillo Canyon and also within TA-15, provide additional insight into the maximum soil contamination levels and the levels of contamination as a function of soil depth. Results from an aerial radiological survey provide an integrated assessment of surface soil contamination levels and show that the land area surrounding the PHERMEX firing point exhibits uranium-238 contamination above background levels. Finally, operational aspects of the cleanup of depleted uranium are summarized.

D.1 ABSTRACT

With respect to the soils environment, the existing PHERMEX firing site is an appropriate analogue for future contamination of firing sites located at either the PHERMEX or DARHT sites. PHERMEX is located approximately 2,300 ft (700 m) southeast of DARHT in TA-15 on Threemile Mesa. Soils, precipitation, and vegetation of the two sites are similar. A similar inventory of depleted uranium, i.e., 35,000 lb (~16,000 kg) depleted uranium (Anderson 1995), has been used at PHERMEX, as is planned for the No Action or Preferred Alternative, i.e., 46,000 lb (~21,000 kg) depleted uranium. Lesser amounts of beryllium and lead are forecast to be used in future tests than have been used in the past 32 years of testing at the PHERMEX firing site (Anderson 1995). Soils contamination observed at the E-F firing sites provides an upper bound to what might be expected under either a No Action (implying continued use of the PHERMEX site) or Preferred Alternative (implying use of the DARHT site) because of the higher inventory used at the E-F firing sites between 1943 and 1973. Based on soils contamination data from PHERMEX and E-F firing sites and the ratio of inventory planned for use versus that used at PHERMEX, the maximum average soil contamination level for depleted uranium at the firing point of the DARHT site is not anticipated to be greater than 5,300 ppm, (i.e., 4,000 ppm x 46,000 lb (21,000 kg) depleted uranium/35,000 lb (16,000 kg) depleted uranium). Similarly, the maximum average soil contamination level observed at PHERMEX in the vicinity of the firing point under either the No Action or Upgrade Alternatives would be approximately double that observed currently at PHERMEX or 9,300 ppm, (i.e., 4,000 ppm x 82,000 lb (37,000 kg) depleted uranium/35,000 lb (16,000 kg) depleted uranium).

The amount of explosive used in individual tests would be no greater than that used at PHERMEX in the past 32 years. The general pattern and number of tests (i.e., large and small explosives amounts) would be virtually the same over the next 30 years (under any of the proposed alternatives) as that used during the past 32 years. Thus, the radius of a circle defining the area with soils contamination above background (soils contamination circle) at PHERMEX should be virtually the same for either continued operation at PHERMEX or operation of DARHT. That soil contamination circle radius at the PHERMEX site is approximately 460 ft (140 m).

Approximately 70 percent of the depleted uranium used at PHERMEX is cleared off the firing point and disposed during periodic cleanup operations. However, all beryllium, lead, copper, and aluminum used at the firing point in each alternative is assumed to be released to and remain in the environment within the soil contamination circle. Cleanup of these materials has not been documented. Surface soil concentrations of beryllium and lead indicate they drop to background levels with 200 ft (61m), well within the soil contamination circle radius of 460 ft (140 m). No information was found on the distribution of copper and aluminum in firing site soils; however, it is assumed that they, like the other metals, remain initially within the soil contamination circle.

D.2 PHERMEX FIRING SITE SOIL CONTAMINATION

Results of a soil sampling survey conducted at the PHERMEX firing site have been reported (Fresquez 1994). Over 20 soil surface samples were collected from the 0 to 3 in (0 to 7.5 cm) depth at six distances along the length of four transects radiating outward from the center of the detonation area towards the NE, E, SE, and SSE. Two sediment samples were also collected; one located in a drainage channel about 240 ft (73 m) northeast of the detonation pad and the other located approximately 200 ft (61 m) south of the pad. Results of this sampling effort are summarized in table D-1, showing mean values at various distances from the firing point.

TABLE D-1.—***Average Uranium, Beryllium, and Lead Concentrations in Surface Soils at PHERMEX***

Sample Locations or Description – Distance ft (m)	Mean Concentrations (ppm)		
	Total Uranium	Beryllium	Lead
0	161.5	0.6	230.0
20 (6.1)	1746.9	18.5	93.9
40 (12.2)	3789.8	1.6	68.4
80 (24.4)	315.4	3.0	24.5
160 (48.8)	165.7	73.3	39.0
200 (61)	26.8	1.0	13.7
Simple Average	1210	18	52
NE Drainage Channel	105	—	—
S Drainage Channel	11.5	—	—
Background (mean + 2 std dev)	3.4	2.88	28.4

Total uranium (i.e., the sum of all uranium mass regardless of the isotope mix) in individual soil samples ranged in concentration from 0.8 to 13,398 ppm. The highest concentration, 13,398 ppm, is well above the other observations, and resulted from a soil sample taken at the base of a building wall near the firing point. The wall was exposed to fragments and aerosolized fractions during shots and apparently acts to concentrate depleted uranium in the soils immediately beneath the wall. Most samples were above the upper limit background (mean + 2 standard deviation) uranium concentration of 3.4 ppm for the firing site. Total beryllium (i.e., the sum of all beryllium mass regardless of the isotope mix) in individual surface soil samples ranged from 0.2 to 218 ppm, and total lead (i.e., the sum of all lead mass regardless of the isotope mix) concentrations ranged from 2.9 to 230 ppm. Most beryllium and lead data were also above the upper limit background concentrations of 2.88 and 28.4 ppm, respectively. However, soil concentrations of both beryllium and lead dropped to background levels at the maximum sampling radius of ~200 ft (~61 m). Simple averages of uranium, beryllium, and lead samples were 1,210, 18, and 52 ppm.

Using the radial measurement point as the center of an annulus having constant contaminant concentration, an area-weighted integration of total uranium concentration was performed. The integration considered only the upper 3 in (7.5 cm) of soil and assumed a dry bulk soil density of 1.4 g/cm^3. If measured surface soil depleted uranium contamination levels were applied to a full circle of radius 200 ft (61 m), the total uranium inventory in the soil would be 1,300 lb (568 kg) uranium. The area-weighted average total-uranium concentration, which takes into account the radial pattern of material deposition, was 456 ppm.

While measured values of beryllium and lead fell to background levels within the ~200 ft (~61 m) radial distance sampled, the total uranium levels did not. A regression analysis on the full (natural log-transformed) total uranium data set (Fresquez and Mullen 1995) showed the distance from the detonation pad to a point where total uranium concentrations would drop to upper limit background levels (i.e., 3.4 ppm) was 279 $\pm$ 83 ft (85 $\pm$ 25.3 m). The 95 percent upper confidence level of this one-sided estimate was 422 ft (128.6m). This is an estimate of the soil contamination circle radius enclosing total uranium soil concentrations above background levels.

The drainage channel located northeast of the detonation pad yielded sediments containing 105 ppm total uranium. The channel to the south of the firing pad yielded sediments with only 11.5 ppm total uranium. No TCLP or total heavy metals were detected above EPA or background concentrations in any of the drainage channels. No traces of high explosive materials were detected in any of the soil or sediment samples.

A previous sampling study conducted at the PHERMEX site in 1987 (Fresquez 1995) showed levels of total uranium up to 3,593 ppm and of beryllium up to 470 ppm. A simple average concentration of surface soil samples yielded average uranium and beryllium concentrations for the site of 432 ($\pm$ 647) ppm and 31.7 ($\pm$ 83) ppm. Note, these are simple averages of all data and are not area-weighted mean values that would take into account the radial pattern of contaminant distribution.

D.3 E-F FIRING SITES SOIL CONTAMINATION

The E-F firing sites are located within TA-15, in the watershed for Potrillo Canyon. It has been estimated that between 1943 and 1973 up to 150,000 lb (66,500 kg) of uranium (a combination of natural and depleted uranium) was used in tests at the E-F firing sites (Hanson and Miera 1977). This is nearly four times the inventory used at PHERMEX. The amount of explosive charge in individual tests at the E-F firing sites exceeds that proposed under the DARHT EIS. This implies that both the level of soil contamination and the spatial spread of debris at the E-F firing sites would be greater than has occurred at PHERMEX and is expected to occur under the alternatives examined in this EIS.

In 1976 a polar coordinate sampling pattern was used to collect soil samples at the E-F site for total uranium analysis (Hanson and Miera 1976; Hanson and Miera 1977; Hanson and Miera 1978). Samples were taken at nine distances from 33 to 660 ft (10 to 200 m) on transects that extended outward from the detonation pad every 45 degrees. Total uranium concentrations were determined for six depth increments ranging from 0 to 1 in to 0.66 to 1 ft (0–2.5 to 20–30 cm) depths. The variation in total uranium concentration with horizontal distance from the firing point for the surface soils (0 to 1 in; 0 to 2.5 cm) is presented in table D-2. The area-weighted mean uranium concentration for surface soils in the sampling area was 542 ppm.

Data on the vertical distribution of uranium in site soils were presented in Hanson and Miera (Hanson and Miera 1977). Data collected at the E-F firing sites indicated that uranium had migrated into the soil to the maximum sampling depth; however, sample analyses were incomplete when Hanson and Miera published their work in 1977 and samples from 0.66 to 1 ft (20 to 30 cm) were not reported for all sample distances. Available results are presented in table D-3. The anomaly observed in the 33-ft (10-m) sample from 0.6 to 1 ft (20 to 30 cm) was attributed to a single observation of 22,000 ppm. Deletion of this datum from the mean value calculation resulted in a decreasing uranium concentration with increasing depth for all profiles. Extending the slope of the 33-ft (10-m) sample line in figure 5 of the Hanson and Miera report (Hanson and Miera 1977) results in an approximate value of 1,000 ppm total uranium in the 0.66 to 1 ft (20 to 30 cm) depth interval 33 ft (10 m) from the firing point.

The uranium in the top 2 in (5 cm) ranges between 86 and 43 percent of the total uranium at a sample point, with a regular decrease beyond 66 ft (20 m). Total uranium concentrations presented by Hanson and Miera (1977 CTJ5) show a general decrease with increasing depth. However, even at the maximum sample depths reported, total uranium concentrations were above background.

The E-F firing sites operated over a 30-year period and used on the order of 150,000 lb (66,500 kg) of uranium. The estimate of depleted uranium used at PHERMEX during the past 32 years is 35,000 lb (16,000 kg). The forecasted depleted uranium usage over the next 30 years is 46,000 lb (21,000 kg). Thus, if the No Action Alternative is implemented, the quantity of depleted uranium used at PHERMEX would increment from 35,000 lb (16,000 kg) to 82,000 lb (37,000 kg) depleted uranium over a 30-year period. This represents slightly more than half (57 percent) of the inventory used at E-F during its 30-year operation. Thus, future soil-contamination levels at PHERMEX firing site should not exceed and would likely be less than those observed at the E-F firing sites. If deposition is a linear function of inventory, soil contamination at PHERMEX would be approximately double the levels currently observed at the PHERMEX firing point, (e.g., 9,300 ppm = 4,000 ppm x 82,000 lb (37,000 kg)/35,000 lb (16,000 kg)).

The maximum explosive charge used in tests at the E-F firing sites exceeds that forecast for testing under any DARHT EIS alternative. As a result of tests involving larger explosive charges, uranium contamination in soils is spread over a larger area at the E-F firing sites than is observed at PHERMEX. The amount of explosive used in individual tests under any DARHT EIS alternative would be no greater than that used at PHERMEX in the past 32 years. Additionally, the general pattern and number of tests

TABLE D-2.—*Uranium Distribution in E-F Firing Site Surface Soils [0 to 1 in (0 to 2.5 cm)]*

Distance ft (m)	Mean Concentration (ppm)
0	4,650
33 (10)	4,520
66 (20)	1,000
98 (30)	1,800
130 (40)	745
160 (50)	395
250 (75)	350
330 (100)	520
490 (150)	725
660 (200)	165

Source: Hanson and Miera 1977

TABLE D-3.—*Distribution of Total Uranium with Depth in Surface Soils at the E-F Firing Site*

Distance ft (m)	Percent of total uranium in top 2 in (5 cm) of the column	Lowest Reported Depth ft (cm)[a]	Concentration[b] (ppm)
0	86	0.33-0.5 (10-15)	650
33 (10)	48	0.66-1 (20-30)	~5000[c]
66 (20)	86	0.33-0.5 (10-15)	80
98 (30)	71	0.33-0.5 (10-15)	250
130 (40)	62	0.33-0.5 (10-15)	450
160 (50)	43	0.66-1 (20-30)	100

[a] Lowest depth presented in Figure 5 of the Hanson and Miera report.
[b] Estimate from Figure 5 of the Hanson and Miera report.
[c] Includes a value of 22,000 ppm.

Source: Hanson and Miera 1977

(i.e., large and small explosives amounts) would be virtually the same over the next 30 years (under any of the proposed alternatives) as that used during the past 32 years at PHERMEX. Based on the size of explosive forecast for use in the DARHT EIS alternatives, the current areal extent of contamination at PHERMEX is a better analogue than the E-F firing sites for estimating the areal extent of future soils contamination at either PHERMEX or DARHT.

The E-F firing sites data does reveal that surface soil contamination levels at the PHERMEX firing point can be expected to increase for alternatives that involve continued use of the PHERMEX firing site. Still, average surface-soil total-uranium concentrations local to the firing point do not exceed 5,000 ppm at the E-F firing sites. The depth profile data suggest that uranium concentrations in soil ~1 ft (30 cm) or more below the surface can be expected to exceed background levels within 160 ft (50 meters) of the firing point. However, contaminant concentrations at depth were measured to be a factor of 2 to 10 below surface soil contamination levels. Thus, with regard to soils contamination levels, average surface-soil total-uranium concentration levels at the E-F firing sites represent maximums.

D.4 AERIAL RADIOLOGICAL SURVEY

An aerial radiological survey of TA-15 was conducted in 1982 to estimate the extent of uranium (uranium-238) contamination in the vicinity of firing sites (Fritzsche 1989). The survey monitored levels of protactinium (protactinium-234m), a granddaughter of uranium-238. Surface contamination was seen to decrease radially as the distance from the test-firing area increased. A surface area of 630,000 ft^2 (58,600 m^2) around PHERMEX was estimated to be contaminated above background. The contaminated area can be represented by a circular area with radius of 450-ft (137-m) centered at the PHERMEX firing point (LATA 1992). The 450 ft (137 m) radius circle is rounded to 460 ft (140 m) for convenience.

D.5 MATERIAL RELEASES AND SITE CLEANUP DURING OPERATIONS

During the 32 years of PHERMEX operations, a total of about 35,000 lb (16,000 kg) of depleted uranium has been used. This amount of depleted uranium represents a volume of about 35 ft^3 (1 m^3). Most of the depleted uranium was used in the form of experimental assemblies of simulated nuclear weapons. Approximately 50 percent of the depleted uranium was contained in simulated secondaries and blast pipes of pin experiments. This depleted uranium is ejected as relatively large fragments. These large fragments remain in the immediate vicinity of the firing point. An estimated 40 percent of the total was dispersed as relatively small, platelet-shaped fragments having surface areas ranging from 0.08 to 1.1 in^2 (0.5 to 7 cm^2). Approximately 10 percent of the depleted uranium was released as an aerosol. Only about 20 percent of the aerosol (about 2 percent of the total depleted uranium) was released as respirable particles, i.e., having an average mean aerodynamic diameter of 3.94×10^{-4} in (10 microns) (McClure 1995). This particle range is important for air quality assessment and is termed PM_{10}.

At least 70 percent of the depleted uranium remains on or near the firing point and is removed and disposed of (see Waste Management in appendix B) during routine housekeeping. This 70 percent consists of all of the large fragments, half of the small fragments (i.e., those ejected downward), and some portion of the aerosol. The other half of the small fragments fell within a 4,100 ft (1,250 m) circle. The aerosol fraction having an average mean aerodynamic diameter greater than 3.94×10^{-4} in (10 microns) is known to be deposited within a few hundred meters of the firing point. Therefore, only two percent of the total amount of depleted uranium involved in the experiments is a candidate for downwind dispersion (McClure 1995). Based on the projected amount of materials to be used, this would amount to 30 lb (14 kg) annually.

In addition to depleted uranium, the only other materials of regulatory concern for the firing area are beryllium and lead. Materials released during open-air tests at the PHERMEX facility have resulted in observable quantities of beryllium and lead on or near the firing site. The soil sampling mentioned above indicate that no beryllium or lead are observed at levels above background beyond 460 ft (140 m) from the firing point.

When containment would be used for a test shot, the blast products would remain in the containment vessel that would be taken to another LANL facility for cleaning and refurbishing. The contained blast debris would be taken to appropriate LANL facilities according to the nature of the debris. For the containment option, containment vessels are described by two conservative performance assumptions that are relevant to this discussion: no more than one percent of blast byproducts could escape a normal test, and no more than five percent of the tests could cause a rupture of the containment vessel. While containment vessels are designed not to fail and they are not expected to fail, these assumptions address the possibility of failure. A rupture of a containment vessel means the development of a crack, not a catastrophic explosion of the entire containment vessel. Hence, it is assumed that 70 percent of the inventory of depleted uranium dispersed to the firing point in the Containment Alternative [93 lb (42 kg) depleted uranium/yr; 6 percent of the No Action and Preferred Alternative inventory] is also cleaned up during routine housekeeping.

D.6 SOIL CONTAMINATION CIRCLE RADIUS AND SOIL CONTAMINATION LEVELS

The estimate of the soil contamination circle radius from the aerial radiological survey (i.e., 460 ft or 140 m) is comparable to the 420-ft (128-m) radius calculated by Fresquez and Mullen (1995) as defining the 95 percent upper-confidence level of enclosing all above-background total-uranium soil contamination. The soil survey conducted by Fresquez (1994) only characterized an ~200 ft (~61 m) radius circle centered on the firing point, and may reflect only a portion of the fragment and aerosol size fractions. However, the aerial radiological survey takes into account uranium (uranium-238) concentration levels associated with the complete range of fragments sizes as well as the aerosol fraction. Based on the similarity of tests to be run in the future as compared to past PHERMEX operations (e.g., explosive charges, the range and pattern of large and small tests), we conclude that the soil contamination area around PHERMEX (defined approximately by a circle with radius 460 ft (140 m) centered on the firing point) is appropriate for application to alternatives involving either PHERMEX or DARHT sites.

The inventory of depleted uranium used at PHERMEX over the last 32 years is ~35,000 lb (~16,000 kg). Of this 30 percent, or 11,000 lb (4,800 kg) of depleted uranium, is estimated to remain within the soil contamination circle. Clearly, this is greater than the estimated 1,300 lb (568 kg) uranium accounted for in the surface soils (i.e., to 3 in or 7.5 cm depth) within 200 ft (61 m) of the firing point at PHERMEX. However, a circle of radius 200 ft (61 m) represents only ~20 percent of the area 460 ft (140 m) radius soil contamination circle. If 11,000 lb (4,800 kg) of depleted uranium were uniformly distributed in the upper ~1 ft (30 cm) of soil within an ~460 ft (~140 m) radius soil contamination circle, the resulting uranium concentration would be ~190 ppm.

Under the No Action Alternative, the total inventory of depleted uranium used at PHERMEX after an additional 30 years would be 82,000 lb (37,000 kg) depleted uranium. Of this, 30 percent, or ~24,000 lb (~11,000 kg), depleted uranium would remain onsite within the soil contamination circle and contribute to soil contaminant concentrations. If initially distributed uniformly in the upper ~1 ft (30 cm) of the soil contamination circle, the resulting uranium concentration would be 430 ppm.

While total uranium concentration in soils in the immediate vicinity of firing points are known to be significantly higher (e.g., average values of 3,789 and 4,650 ppm values calculated for PHERMEX and E-F firing sites), these areas represent a relatively small fraction of the overall soil contamination circle in an area-weighted average. Area-weighted average concentrations calculated at E-F (542 ppm for a 660 ft or 200 m radius) and PHERMEX (456 ppm for a 200 ft or 61 m radius) are comparable to those calculated for the uranium inventory forecast to be within the soil contamination circle of PHERMEX operations (i.e., 190 ppm current and 430 ppm future).

The soil contamination circle radius of current PHERMEX operations, 460 ft (140 m), is assumed to apply to alternatives involving either the PHERMEX or DARHT sites. Based on soils contamination data from PHERMEX and E-F firing sites and the ratio of inventory planned for usage versus that used at PHERMEX, the maximum average soil contamination level for depleted uranium at the firing point of the DARHT site is not anticipated to be greater than 5,300 ppm (i.e., 4,000 ppm x 46,000 lb (21,000 kg) depleted uranium/35,000 lb (16,000 kg) depleted uranium). Similarly, the maximum average soil contamination level observed at PHERMEX in the vicinity of the firing point under either the No Action or Upgrade Alternatives would be approximately double that observed currently at PHERMEX or 9,300 ppm (i.e., 4,000 ppm x 82,000 lb (37,000 kg) depleted uranium/35,000 lb (16,000 kg) depleted uranium).

It is apparent from the recent surface soil survey of PHERMEX (Fresquez 1994) that beryllium and lead contamination drops to background levels inside of the soil contamination circle for depleted uranium. However, no information is available on site cleanup and removal of beryllium and lead. Therefore, the entire original inventory of both beryllium and lead is assumed to be dispersed within the soil contamination circle and available for migration in hydrologic pathways.

There is no information on the distribution of copper and aluminum in the soils surrounding the PHERMEX firing point. Nor is there information about periodic cleanup activities at the firing point removing either copper or aluminum. Consequently, total inventories of copper and aluminum are assumed to be in the soils and available for migration via surface water and ground water pathways.

D.7 REFERENCES CITED IN APPENDIX D

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Appendix E

Water Resources

APPENDIX E
WATER RESOURCES

This appendix provides background information on 1) estimates of recharge at the mesa top, (i.e., firing sites), 2) the solubilities and distribution coefficients associated with the metals of interest when associated with LANL site sediments, 3) the approach taken to model surface water pathway, and 4) the approach taken to model the vadose zone and ground water pathways.

APPENDIX E1: DEEP DRAINAGE BENEATH THE DARHT AND PHERMEX SITES

E1.1 ABSTRACT

Meteoric water that drains well below the lowest level of plant roots is called deep drainage and can transport solubilized contaminants through vadose zone deposits to ground water. This pathway for contaminant migration to the accessible environment must be evaluated to understand the potential for surface soil contamination to migrate through the mesa and underlying vadose zone to ground water. The objective of this study was to estimate the deep drainage rates at two locations, the DARHT and PHERMEX sites. Estimates of deep drainage were performed using the UNSAT-H computer code, daily weather data from 1980 to 1994, and, in lieu of site-specific data, surrogate information for the hydrologic properties of vegetation and soils. Drainage rates were determined for a variety of soil and vegetation scenarios; the actual rates depend explicitly on the site-specific surface conditions. For the scenarios studied, the drainage rates ranged from 4.7 to 520 mm/yr. For the center of the DARHT site, the rates for an unvegetated surface were 265 and 360 mm/yr depending on the soil type. Modifying the surface with a gravel cover increased the drainage rate to 520 mm/yr. For the center of the PHERMEX site, the rate was 124 mm/yr for the unvegetated surface. Allowing shrubs and grasses to grow on the sites reduced, but did not eliminate, deep drainage. The potential exists for deep drainage at both sites. Whether deep drainage actually exists can only be determined with site-specific measurements.

E1.2 INTRODUCTION

One component of the DARHT EIS is an analysis of the potential for deep drainage beneath the DARHT and PHERMEX sites to carry contaminants to the main aquifer. At other DOE sites, deep drainage has transported solubilized contaminants to underlying ground-water systems. While such transport is not apparent beneath Threemile Mesa on which DARHT and PHERMEX are located, it does represent a pathway of interest and must be evaluated. The objective of this portion of the EIS was to estimate the deep drainage rate beneath the DARHT and PHERMEX sites.

E1.3 PRIOR ESTIMATES

Information on the rates of deep drainage beneath the DARHT and PHERMEX sites was unavailable. However, occasional monitoring at other locations at LANL indicates that deep drainage rates are highly variable, ranging from near zero to more than the annual precipitation rate, depending on the surface conditions at each of the specific locations.

Abeele et al. (1981) and Nyhan (1989a) (Abeele et al. 1981; Nyhan 1989). Water content profiles measured with neutron probes in several deep access wells have been reported. Some wells had low water contents in the tuff, indicating little if any deep drainage. Other wells had high water contents, particularly in the upper zones of tuff, possibly indicative of recent deep drainage. In one well, the high water contents implied that water was added in excess of precipitation rates. Nyhan (1989) speculated that an unlined drainage ditch routed surface water to the vicinity of the well, where the water subsequently infiltrated. Abeele et al. (1981) also alluded to the influence of surface topography as a factor in affecting infiltration rates and thus deep drainage rates.

Abeele et al. (1981) reported that the flux in the overburden above a waste disposal pit was always directed downward below a depth of about 13 ft (4 m) during a two-year period. In 1978, it was 3.5 in/yr (90 mm/yr); in 1979, it was 6 in/yr (150 mm/yr). The difference was attributed to extremely high precipitation at the end of 1978 and the beginning of 1979. At another location at LANL, Abeele et al. (1981) estimated a downward rate of 0.01 in/yr (0.3 mm/yr). It has been summarized as follows:

> "Where the soil cover has not been disturbed, little if any water from precipitation infiltrates the underlying tuff (Purtymun and Kennedy 1971). Where the soil cover was disturbed, as in the waste disposal areas, the moisture content of the tuff indicates a much higher degree of infiltration than the one that might have been implied by the moisture content fluctuations found in the undisturbed tuff (Abeele et al. 1981)."

Rogers and Gallaher (Rogers 1995) reviewed the hydraulic properties of the Bandelier Tuff as well as other units. Their review included core data from several areas at the LANL facility; the data came from both mesa tops and canyon bottoms. They concluded that "[t]he canyon bottom and mesa top hydraulic head profiles suggest that downward flow of water occurs beneath the surface of the Pajarito Plateau" (Rogers 1995). They noted two exceptions where there was the suggestion of upward flow, one of which they speculated was caused by "increased external air circulation through the mesa sides."

Core data were unavailable for the DARHT and PHERMEX sites. In lieu of site-specific data, data reported by Rogers and Gallaher (Rogers 1995) for other mesa tops were used to estimate deep drainage. Assuming a hydraulic gradient close to unity, one can equate the in situ hydraulic conductivity to the drainage rate. Rogers and Gallaher lumped core data together to calculate mean in situ conductivity values. In their table 5, Rogers and Gallaher report both harmonic and arithmetic mean values of hydraulic conductivity. For Area TA-54, Rogers and Gallaher reported values ranging from 1.7×10^{-6} to 0.06 in/yr (4.3×10^{-5} to 1.5 mm/yr) for the harmonic and arithmetic means, respectively. For Area TA-16, the rates ranged from 3 to 55 in/yr (79 to 1,390 mm/yr). For Area TA-53, the rates ranged from 7 to 3,660 in/yr (180 to 93,000 mm/yr). While not from the DARHT or PHERMEX sites, these ranges indicate clearly that deep drainage can vary greatly from site to site.

The impact of early and recent LANL operations may not always be reflected in core data – and this makes interpretation difficult. For example, Allison et al. (1994) related the case of land clearing in Australia in which the recharge rate increased from 0.003 to 1.8 in/yr (0.08 to 45 mm/yr). The pressure front generated by the increase in recharge took nine years to reach the 25-ft (7.5-m) depth.

Foxx and Tierney (1984) related the historical occurrence of grazing and logging as well as the impact of recent disturbances from LANL operations. Generally, such changes alter plant communities and reduce their ability to transpire water, thus increasing the potential for deep drainage. Depending on the pre-disturbance drainage rate, an increase in drainage may take decades or centuries to propagate downward through the tuff. Thus, core data collected today must be interpreted and used cautiously, especially if one does not know or account for the history of surface conditions at specific sites.

E1.4 METHOD

Deep drainage was estimated at the DARHT and PHERMEX sites using simulation modeling. Simulations were conducted using the UNSAT-H Version 2.02 computer code (Fayer and Jones 1990). The UNSAT-H computer code, developed for the Hanford site, was selected because it was developed for and has been applied to estimate deep drainage at DOE sites, in the arid and semi-arid western United States. The code models one-dimensional, deep drainage, accounting for the hydrological characteristics of soil media, climate, and vegetation. The exhibit E1-1 contains a listing of an example input file for UNSAT-H. The model requires information on the domain, soil properties, initial conditions, boundary conditions, and plants.

E1.4.1 Domain

The model domain extended to 16 ft (5 m). This depth is well below the zone of evapotranspiration for most species. Some roots have been observed at greater depths within fractures (Tierney and Foxx 1987), but these were not considered in this one-dimensional modeling exercise. Also, because of the one-dimensional nature of this analysis, processes such as interflow (subsurface lateral drainage) were not addressed. The node spacing ranged from 0.1 in (0.2 cm) at the soil surface to 20 in (50 cm) at the 16-ft (5-m) depth. At the transition between different materials, the node spacing was reduced to 0.8 in (2.0 cm).

E1.4.2 Soil Properties

The soil at the center of the DARHT site is mapped as Pogna sandy loam (Nyhan et al. 1978). Some of the soil samples collected at the DARHT site for a geotechnical investigation report (Korecki 1988) indicated that there is more clay than expected for a Pogna sandy loam. Nyhan et al. (1978) indicated that the Pogna sandy loam has small inclusions of other soil types. Based on the descriptions reported by Korecki (1988), a likely candidate for some of the soil at the DARHT site is the "Typic Eutroboralf, fine", which includes layers of sandy loam, sandy clay, and clay. In the blueprints for the DARHT facility (LANL 1993), several drawings indicate surface modifications that include stripping the soil off and building directly on the tuff as well as covering the surface near the firing point with gravel. At some distance from the center of the DARHT site is another soil type, the Seaby loam, which should be considered. Thus, five soil scenarios were envisioned for this analysis: 1) tuff, 2) gravel above tuff, 3) Pogna sandy loam, 4) Typic Eutroboralf, fine, and 5) Seaby loam. Table E1-1 shows the soil profile description for each scenario.

TABLE E1-1.—*Soil Profile Descriptions for the Computer Simulations*

Soil Profile	Depth Interval (cm)	Porous Material
Tuff	0 to 500	tuff
Gravel Above Tuff	0 to 30 30 to 500	gravel tuff
Pogna Sandy Loam	0 to 30 30 to 500	sandy loam tuff
Typic Eutroboralf, fine	0 to 18 18 to 51 51 to 94 94 to 500	sandy loam clay sandy clay tuff
Seaby Loam	0 to 13 13 to 25 25 to 30 30 to 66 66 to 500	loam clay loam, 40% gravel clay loam, 55% gravel gravel tuff
Nyjack Loam	0 to 8 8 to 61 61 to 99 99 to 500	loam clay loam sandy loam, 25% gravel tuff
Hackroy Sandy Loam	0 to 8 8 to 25 25 to 30 30 to 500	sandy loam clay clay, 25% gravel tuff

The soil type at the center of the PHERMEX site is mapped as Nyjack loam (Nyhan et al. 1978). Nearby soil types include the Seaby loam (included in the DARHT scenario list) and the Hackroy sandy loam. The Nyjack loam and Hackroy sandy loam were added to the list in table E1-1 to bring the total number of soil profile scenarios to seven.

Hydraulic properties were assigned to each porous material in table E1-1. Specifically, water retention and hydraulic conductivity were described using the van Genuchten (1980) retention function and the Mualem (1976) conductivity model; table E1-2 shows the parameters. Hydraulic properties specific to the site soils were unavailable. Instead, the particle size description (e.g., sandy loam, clay) was used to assign parameters based on the correlations reported by Carsel and Parrish (1988). For those materials with gravel, the hydraulic parameters reported by Carsel and Parrish (1988) were modified using the method proposed by Bouwer and Rice (1983). The actual properties of the tuff unit beneath the surface of the DARHT site were unknown. For this study, the properties of the Tshirege Unit 3 were used (Rogers 1995). This unit appears to be the highest in elevation for which hydraulic properties are available. All hydraulic properties were assumed to be isothermal and non-hysteretic. Soil freezing was not addressed.

TABLE E1-2.—*Parameters Used to Describe Hydraulic Properties in the Simulations*

Porous Material	Gravel (vol %)	θ_s --	θ_r --	α (1/cm)	n --	K_s (cm/h)
Tuff	0	0.469	0.045	0.0029	1.88	0.119
Gravel	100	0.419	0.005	4.93	2.19	1260.0
Sandy loam	0	0.410	0.065	0.075	1.89	4.42
Sandy loam	25	0.308	0.049	0.075	1.89	2.83
Sandy clay	0	0.380	0.100	0.027	1.23	0.12
Loam	0	0.430	0.078	0.036	1.56	1.04
Clay loam	0	0.410	0.095	0.019	1.31	0.26
Clay loam	40	0.246	0.057	0.019	1.31	0.122
Clay loam	55	0.185	0.043	0.019	1.31	0.0846
Clay	0	0.380	0.068	0.008	1.09	0.200
Clay	25	0.285	0.051	0.008	1.09	0.130

θ_s Saturated moisture content.
θ_r Residual moisture content.
α Fitted van Genuchten parameter, 1/cm.
n Fitted van Genuchten parameter.
K_s Saturated hydraulic conductivity, cm/h.

Note: The van Genuchten parameter m was set equal to 1-1/n. The standard value of 0.5 was used for the pore interaction term.

E1.4.3 Initial Conditions

There was no information on the 1980 matric suction distribution at the DARHT or PHERMEX sites. Therefore, the first year (1980) of every simulation was repeated until the water balance variables (i.e., evaporation, transpiration, drainage, and runoff) changed by less than 0.004 in (0.1 mm) from one year to the next. The reason for the iteration was to lessen the impact of the unknown initial conditions.

E1.4.4 Boundary Conditions

The surface boundary was described with weather data, which were summarized by Bowen (1990). The daily precipitation data were obtained for the TA-59 site for 1980 to 1990 and the TA-6 site for 1991 to 1994. During each day, the precipitation was added at the rate of 0.4 in/h (1 cm/h) until the day's total was applied to the surface. Snow was treated as an equivalent rainfall. No adjustment was made for delays in snowmelt.

Daily potential evapotranspiration (PET) values were calculated using the Penman Equation in Doorenbos and Pruitt (1977) and daily weather parameters from the TA-59 and TA-6 sites. These parameters included wind speed at 75 ft (23 m), maximum and minimum air temperature and dew-point temperature at 4 ft (1.2 m), solar radiation, and cloud cover. The dew-point temperature data set was sparse. When data existed, a comparison to measured minimum air temperature showed the dew-point temperature to be less than or equal to the minimum air temperature. Because a relatively complete record of daily minimum air temperature existed, the daily dew-point temperature was approximated as the minimum air temperature. Cloud cover data were not available. Instead, cloud cover was approximated using the measured solar radiation and calculations of the potential solar insolation for Los Alamos (Campbell 1985).

During the evaporation process, the matric suction of the surface node was not allowed to exceed a predetermined value. For most of the simulations, the value was 1,450 lb/in^2 a (10 MPa). For the gravel surface scenario, however, this limit increased the difficulty of the solution. Instead, a value of 14.5 lb/in^2 (0.1 MPa) was used.

The bottom boundary was described with a unit gradient condition. Observations at other sites indicate that unit gradient conditions exist in the tuff in certain zones at certain sites, but it is not universal. For these simulations, plant roots were assumed to be no more than 3.3-ft (1-m) deep. As long as the simulations indicated that deep drainage was greater than 0.04 in/yr (1 mm/yr), the unit gradient condition at 16 ft (5 m) was assumed to be valid.

E1.4.5 Plants

Plant information consisted of the method to partition potential evapotranspiration, active season, bare fraction, root length density, and maximum root depth during the year, as well as the effectiveness of plant water withdrawal as a function of soil matric suction. According to the Environmental Restoration Program (ERP), the plant community on the PHERMEX mesa is the piñon-ponderosa-juniper association (LANL 1993). In the vicinity of the facilities, however, this community has been eliminated and replaced by structures (e.g., roads, parking lots, buildings), bare ground, and shrubs and grasses. Data for those plants pertinent to the DARHT and PHERMEX sites were not available. Instead, literature parameters or reasonable estimates of parameters were chosen. Plant responses to precipitation and temperature variations, fire, disease, nutrient cycling, grazing, and land use changes were not addressed in the simulations.

The leaf area method was used to partition potential evapotranspiration into potential evaporation and potential transpiration. Leaf area as a function of season was described using values reported by Nyhan (1989b) for a 40 percent cover of shrubs and grasses.

The active season of the plants determined when to calculate transpiration and when roots started or stopped growing. The active season was specified with starting and ending days during the year. The shrubs and grasses were started on March 15 (day 74) and stopped on October 15 (day 288). These dates were estimates only but are reasonable given the monthly temperatures experienced at Los Alamos (Bowen 1990).

The bare fraction of soil was used to scale potential transpiration based on the amount of soil surface covered by the vegetation. If the bare fraction was zero, the cover percentage would be 100 percent and there would be no reduction in potential transpiration. For the grasses and shrubs cover, the bare fraction was assigned as 0.6. This means that the vegetation covered 40 percent of the ground surface (Nyhan 1989b); therefore, potential transpiration was appropriately reduced by 60 percent. Any reduction to potential transpiration caused by a less than 100 percent cover is added to potential evaporation. After all the manipulations, the sum of potential evaporation and potential transpiration must equal potential evapotranspiration.

Root length density data were unavailable. The roots of the grasses and shrubs were considered to be at their maximum depth throughout the growing season. The maximum depth was defined as the surface of the uppermost tuff unit. This depth ranged from 12 in (30 cm) in the Pogna sandy loam to 39 in (99 cm) in the Nyjack loam. Roots have been observed in cracks and fissures in the tuff (Tierney and Foxx 1987). For this one-dimensional analysis, however, cracks and fissures were not considered in the conceptual model.

Data on plant water uptake as a function of matric suction were also unavailable. A matric suction of 0.4 lb/in^2 (0.003 MPa) was assumed to be the limit below which plants ceased transpiration because of anaerobic conditions. From 0.4 to 14.5 lb/in^2 (0.003 to 0.1 MPa), plants were assumed to withdraw water at the potential rate. Above 14.5 lb/in^2 (0.1 MPa), but below the permanent wilting point, plants were assumed to withdraw progressively less water as the matric suction increased. Typically, the matric suction above which plants cease to transpire is 220 lb/in^2 (1.5 MPa) (i.e., the permanent wilting point). Sagebrush was reported to operate in soils with matric sections as high as 1,00 lb/in^2 (7.0 MPa) (Fernandez and Caldwell 1975; Branson et al. 1976). For this study, as an approximation, an intermediate value of 580 lb/in^2 (4.0 MPa) was chosen.

E1.5 RESULTS

Table E1-3 shows that the deep drainage rate is highly dependent on the soil profile and the presence of vegetation. Table E1-3 also shows that, for a given combination of soil profile and vegetation, the year-to-year rates [as estimated at the 16-ft (5.0-m depth)] can vary by more than a factor of two. Figures E1-1 to E1-6 illustrate the yearly variation more clearly.

The deep drainage rate at the center of the DARHT site was estimated to be 10 or 14 in/yr (265 or 360 mm/yr) depending on the soil type and assuming vegetation was not allowed to grow. Table E1-3 shows that the estimated rates were reduced by more than half when plants were included. If the immediate center of the site was covered with a layer of gravel (LANL 1993), the drainage rate would nearly double to 20 in/yr (520 mm/yr), or 95 percent of the precipitation. If the tuff were left exposed at any point, the results in table E1-3 suggest that the drainage rate would be only 1.3 in/yr (34 mm/yr), which is much lower than the rates estimated for the soils. The reason is that the tuff holds infiltrating water relatively near the surface, and its soil hydraulic properties are conducive to upward unsaturated flow. Thus, higher evaporation rates occur from exposed tuff surfaces.

At some distance from the center of the DARHT site is the Seaby loam soil. The simulation results indicate the drainage rate in this soil type is much less than for either the Pogna sandy loam or Typic Eutroboralf soils.

TABLE E1-3.—*Summary of Simulation Results for 1981 to 1994*

Soil[a] Profile	Max. Root Depth (cm)	Average Annual Rates (mm/yr)				Annual Drainage Rates (mm/yr)		Average Annual Mass Error	
		Evaporation	Transpiration	Runoff	Drainage	Max	Min	mm	% of drain
Tuff	na	505.5	0.0	0.4	33.8	44.3	16.5	0.1	0.3
Gravel	na	21.5	0.0	0.0	519.5	653.6	394.1	3.0	0.6
Pogna	na	183.5	0.0	0.0	359.9	449.2	261.4	0.5	0.1
Pogna	30	209.3	166.5	0.0	164.9	211.6	88.7	1.1	0.7
Typic Eutroboralf	na	272.6	0.0	3.7	265.3	328.1	192.4	1.5	0.6
Typic Eutroboralf	94	279.1	196.7	1.9	57.1	80.8	18.0	2.3	4.1
Seaby	na	464.8	0.0	30.0	32.4	54.1	5.1	0.5	1.5
Seaby	30	337.9	164.7	13.2	9.5	23.8	1.5	0.5	4.9
Nyjack	na	395.9	0.0	22.4	124.0	168.2	67.5	0.1	0.1
Nyjack	99	310.8	200.8	11.8	4.7	11.5	0.8	0.4	7.8
Hackroy	na	200.0	0.0	25.0	318.4	397.8	248.2	1.3	0.4
Hackroy	30	189.0	190.6	15.4	142.6	197.6	91.5	7.6	5.3

[a] Tuff, Gravel, Pogna sandy loam, Typic Eutroboralf (fine), Seaby loam, Nyjack loam, Hackroy sandy loam.

The deep drainage rate at the center of the PHERMEX site was estimated to be 5 in/yr (124 mm/yr) (assuming vegetation was not allowed to grow). At some distance from the center of the PHERMEX site are the Seaby loam, with rates slightly higher than the Nyjack loam, and the Hackroy sandy loam, with rates three times greater than the Nyjack loam without plants, and thirty times greater than the Nyjack loam with plants.

These results are in accord with previous simulation results (Nyhan 1989a) for seepage through covers over waste disposal areas. Nyhan estimated seepage rates of 2.4 and 4.8 in/yr (60 and 120 mm/yr) for a cover with range grass and a bare cover, respectively, assuming a saturated conductivity of 0.08 in/hr (0.2 cm/h) for the cover. For the years 1977 to 1987, Nyhan showed that the seepage rate varied between 0 and 6.3 in/yr (0 and 160 mm/yr) for the bare cover and for a cover with a poor range grass.

When the precipitation rate exceeds the ability of the soil to accept infiltration, water begins to accumulate on the soil surface. Once the storage capacity of the soil surface is exceeded, overland flow, or runoff, begins. The UNSAT-H model assumes zero surface storage, thus water that does not infiltrate is considered to be runoff. Table E1-3 shows the average annual runoff for each of the simulations. Only those soil profiles that had one or more clay layers had runoff. The Nyjack loam,

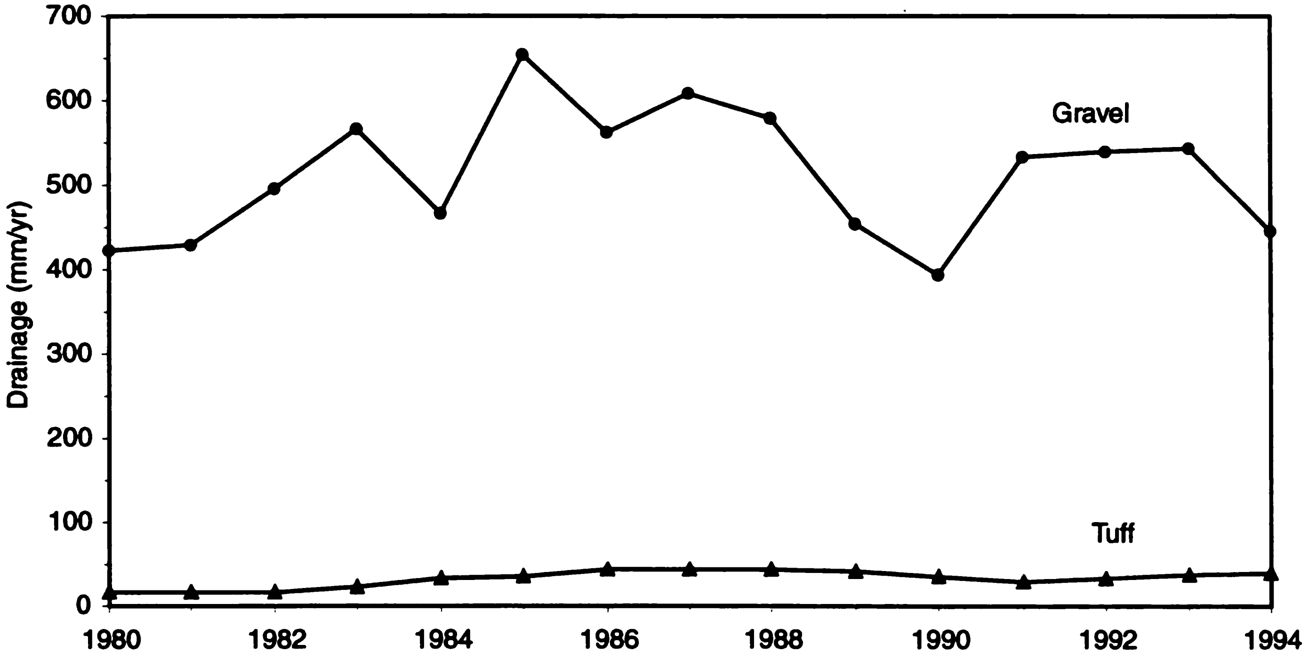

FIGURE E1-1.—*Simulation Results Showing Annual Drainage from the Tuff and Gravel Soil Profiles.*

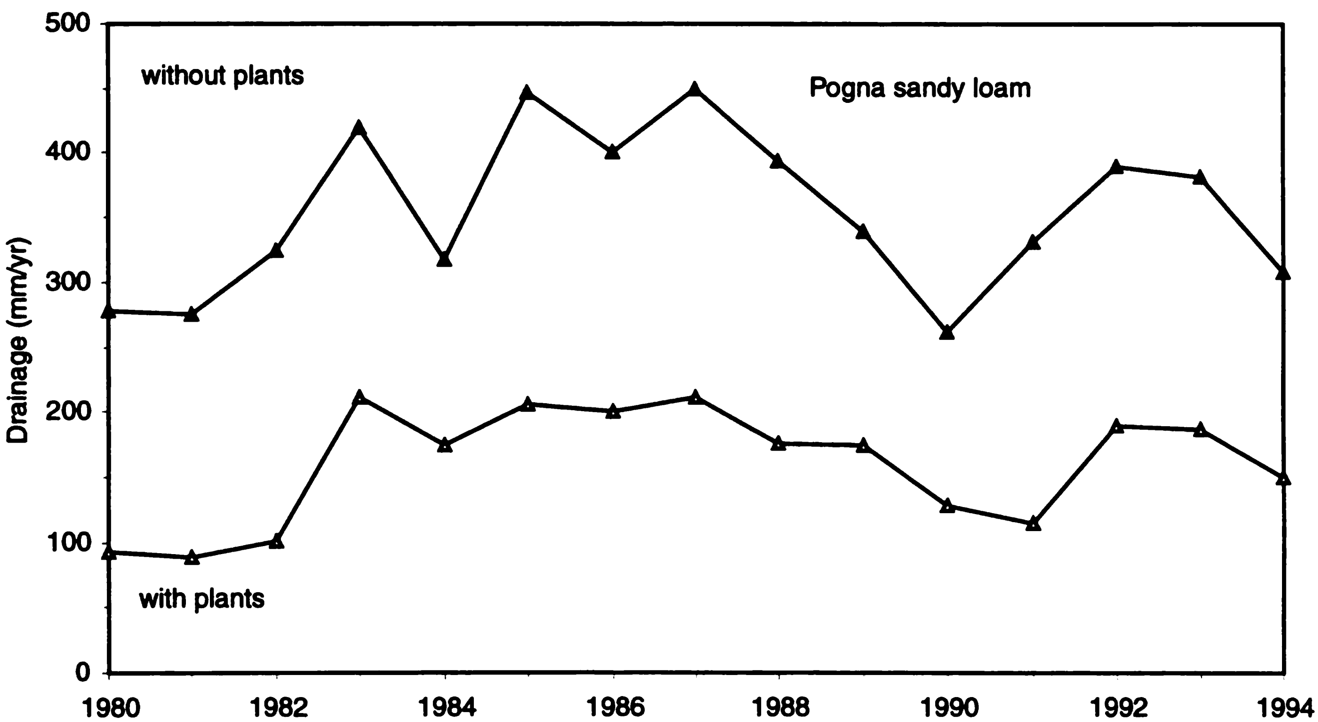

FIGURE E1-2.—*Simulation Results Showing Annual Drainage from the Pogna Sandy Loam Soil Profile.*

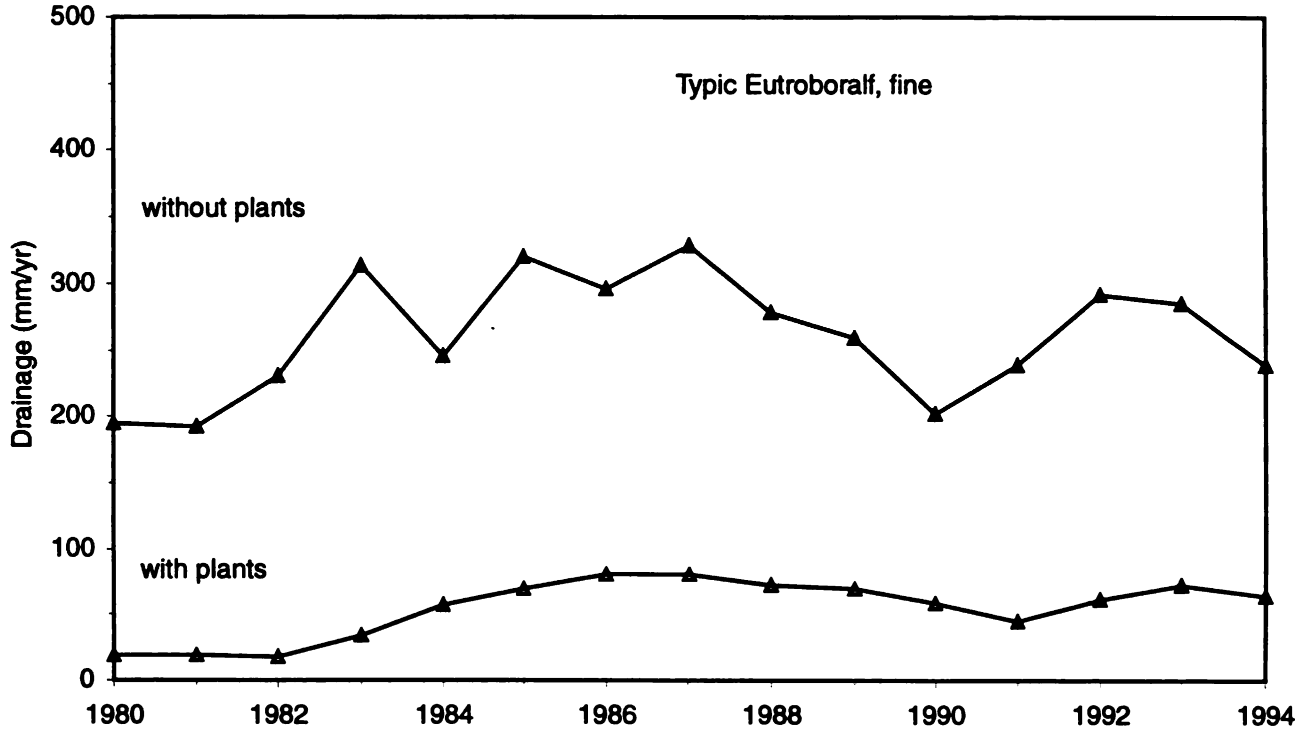

FIGURE E1-3.—***Simulation Results Showing Annual Drainage from the Typic Eutroboralf Soil Profile.***

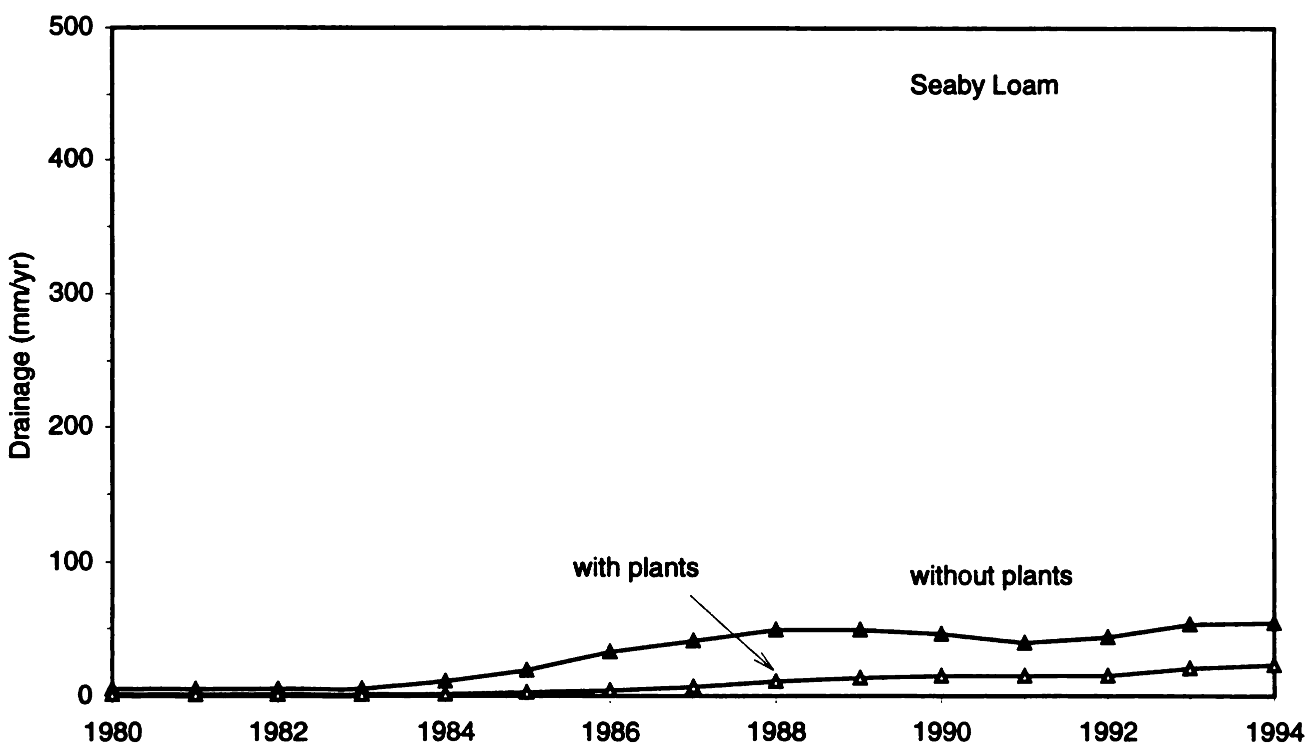

FIGURE E1-4.—***Simulation Results Showing Annual Drainage from the Seaby Loam Soil Profile.***

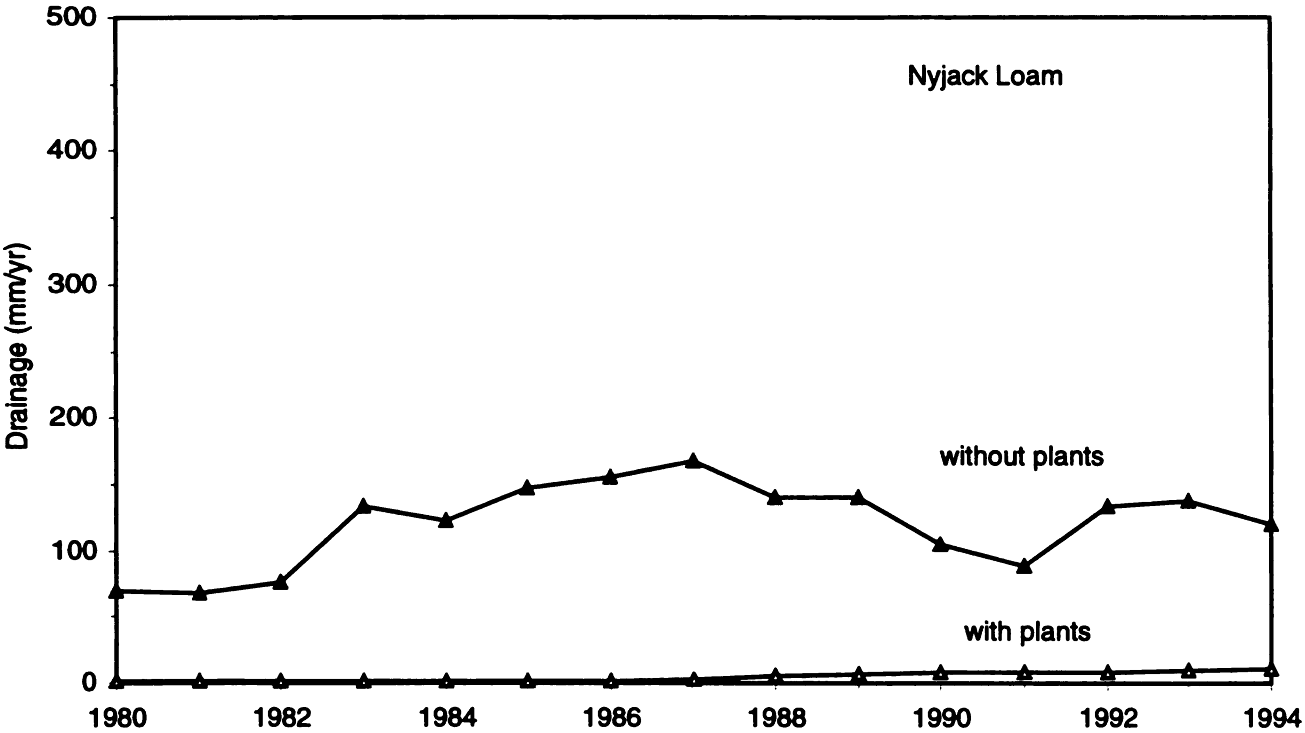

FIGURE E1-5.—*Simulation Results Showing Annual Drainage from the Nyjack Loam Soil Profile.*

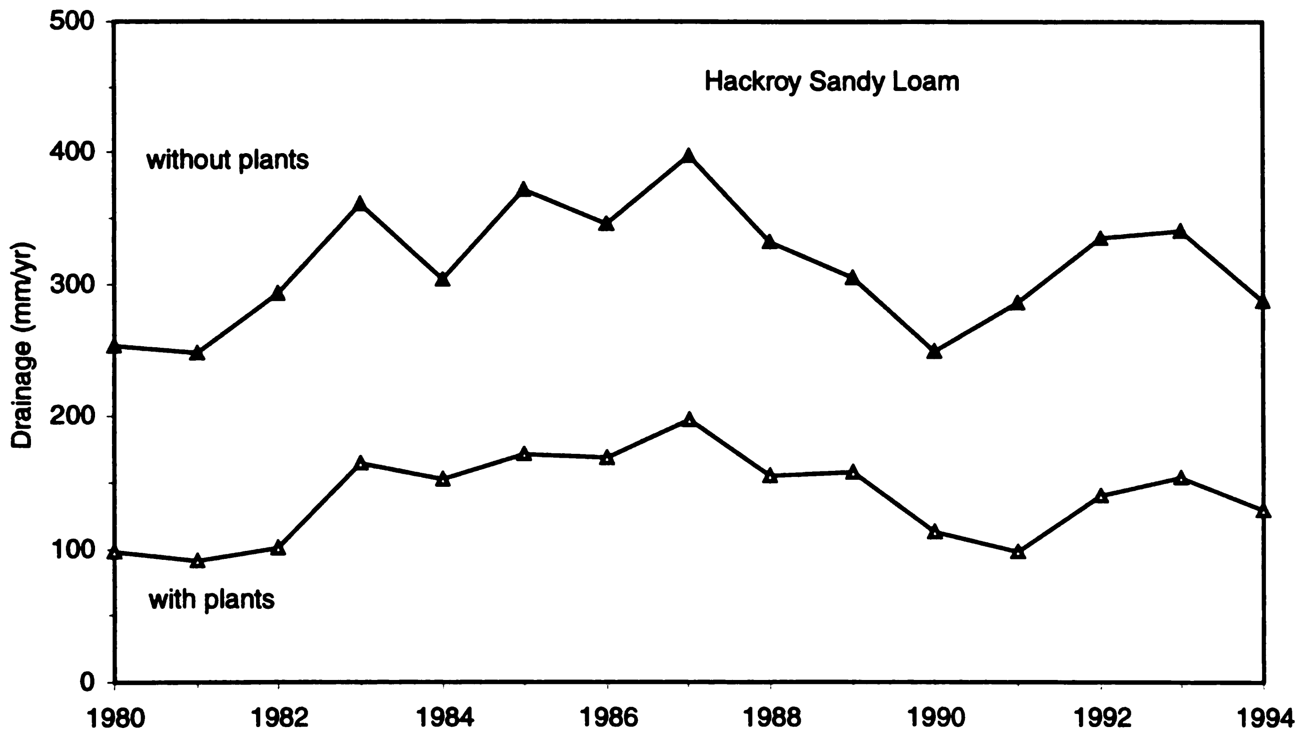

FIGURE E1-6.—*Simulation Results Showing Annual Drainage from the Hackroy Sandy Loam Soil Profile.*

Seaby loam, and Hackroy sandy loams had the highest rates; the Seaby loam was highest with 1.2 in/yr (30 mm/yr). Some of these high rates were comparable to the drainage rate. For the Nyjack loam, the runoff rate was actually twice the drainage rate [which, in this case, was quite low at 0.02 in/yr (4.7 mm/yr)]. The impact of frozen soil, snow, and rapid snowmelt on runoff and deep drainage was not evaluated.

At LANL, Wilcox (1994) reported that runoff accounted for 10 to 18 percent of the precipitation received during a two-year study of the intercanopy zone of a piñon-juniper woodland. The soil was from the Hackroy series and the slope was about 4.4 to 5.3 percent. While not directly applicable to the DARHT and PHERMEX sites, the results from Wilcox (1994) demonstrate that runoff can be a significant component of the water balance at LANL and thus impacts the estimation of deep drainage rates at these two sites. The Wilcox study did consider snow and snowmelt processes. If actual runoff is higher than predicted (table E1-3) at the two sites, the predicted drainage rates are higher than they should be.

E1.6 SENSITIVITIES

Several issues that arose during this study included hourly versus daily precipitation, the use of the 14-yr record versus the longer term precipitation record, the calculation of the daily average dew-point temperature, the calculation of internodal conductances, the effect of initial conditions, and mass balance. Most of these issues were evaluated by conducting additional simulations and comparing to the originals summarized in table E1-3.

E1.6.1 Hourly Precipitation

As configured, the UNSAT-H computer code applies daily precipitation at the rate of 0.4 in/hr (10 mm/h) starting at 0000 h until the day's amount has been applied to the soil surface. The concern is that the daily rates will underestimate runoff because they fail to represent the high intensities that sometimes occur. Four years (1991 to 1994) of 15-min precipitation data were used to provide hourly precipitation input for the UNSAT-H code. The Pogna sandy loam and Seaby loam profiles without plants were simulated. The Pogna sandy loam had no runoff using either daily or hourly precipitation data. In fact, the hourly precipitation resulted in a slight reduction in evaporation, mainly because hourly precipitation that occurred during the day reduced evaporation. Overall, estimated drainage increased by about 0.04 in/yr (1 mm/yr). For the Seaby loam, the hourly precipitation data resulted in a 13 percent reduction in runoff. The seemingly contradictory result is understandable. For the daily precipitation, all the rates were 0.4 in/hr (10 mm/h). For the hourly precipitation, most of the rates were far less than 0.4 in/hr (10 mm/h) while some rates were more. The net result of using hourly precipitation was a 0.05 in/yr (1.3 mm/yr) reduction in annual runoff.

E1.6.2 Precipitation Record

The drainage rate varies from year to year as a function of the precipitation distribution and amounts and the weather. The question that remains unanswered is whether the 14-yr record used for this study adequately represents the longer term weather that has been observed or can be reasonably expected to occur. Bowen (1990) reported precipitation extremes for LANL for the period from 1911 to 1988. The record shows that the largest annual precipitation amount was 30.3 in (770.6 mm), which occurred in 1941. That amount is about 17 percent greater than the highest value used in this study. Bowen (1990) also reported that the highest seasonal snowfall occurred in 1986-1987. That period is within the period used for this study. Both the highest annual precipitation and seasonal snowfall records are very near the estimated 100-yr values reported by Bowen (1990). If this analysis of deep drainage were to extend much beyond 100 years, consideration would have to be given to analyzing for greater precipitation amounts and intensities than used for this study.

E1.6.3 Dew-point Temperature

A clean and continuous record of daily average dew-point temperature was not available for the period 1980 to 1994. In lieu of actual data, daily dew-point temperatures were approximated as equivalent to the minimum daily air temperatures. Daily dew-point temperature from 1982 showed that the minimum air temperature may be roughly 9°F (5°C) higher than the dew-point temperature. The Pogna sandy loam scenario with and without plants was simulated using dew-point temperatures that were 9°F (5°C) lower than the minimum daily air temperature. In both cases, estimated evapotranspiration increased and drainage decreased (2 percent reduction without plants; 16 percent with plants). Similar results are expected for the other soil profiles.

E1.6.4 Internodal Conductance

For all of the simulations without plants, the geometric mean was used to approximate internodal conductances. The Pogna sandy loam simulation without plants was repeated with arithmetic averaging. The result was a much higher evaporation rate and a 24 percent reduction in the drainage rate. All of the simulations with plants were conducted using the arithmetic mean. The Pogna sandy loam simulation with plants was repeated with geometric averaging. The result was significantly reduced evaporation and a 25 percent increase in the drainage rate. One way to view the results overall, in the context of the averaging scheme, is that the simulations with plants and arithmetic averaging represent the lower estimate of deep drainage and the simulations without plants but with geometric averaging represent the upper estimate.

E1.6.5 Initial Conditions

To overcome the lack of initial conditions, the simulation of 1980 was repeated until there was less than a 0.004 in (0.1 mm) annual change in the water balance components and in the drainage flux through the tuff. This requirement was relaxed for some of the simulations with plants because the rates under the 1980 weather conditions were either so low or the flux was actually upward. Using these initial conditions, the simulation results for some soil profiles showed drainage rates that increased slowly during part or all of the 14-yr period, indicating some sensitivity to the initial conditions. To ascertain the degree of sensitivity to initial conditions, the Pogna sandy loam and Seaby loam profiles without plants were simulated with a uniform initial matric suction profile of 39 in (100 cm), which is very wet. Figure E1-7 shows that, after two years, the annual drainage rates from the initially wet (open triangles) Pogna sandy loam were nearly identical to what was predicted

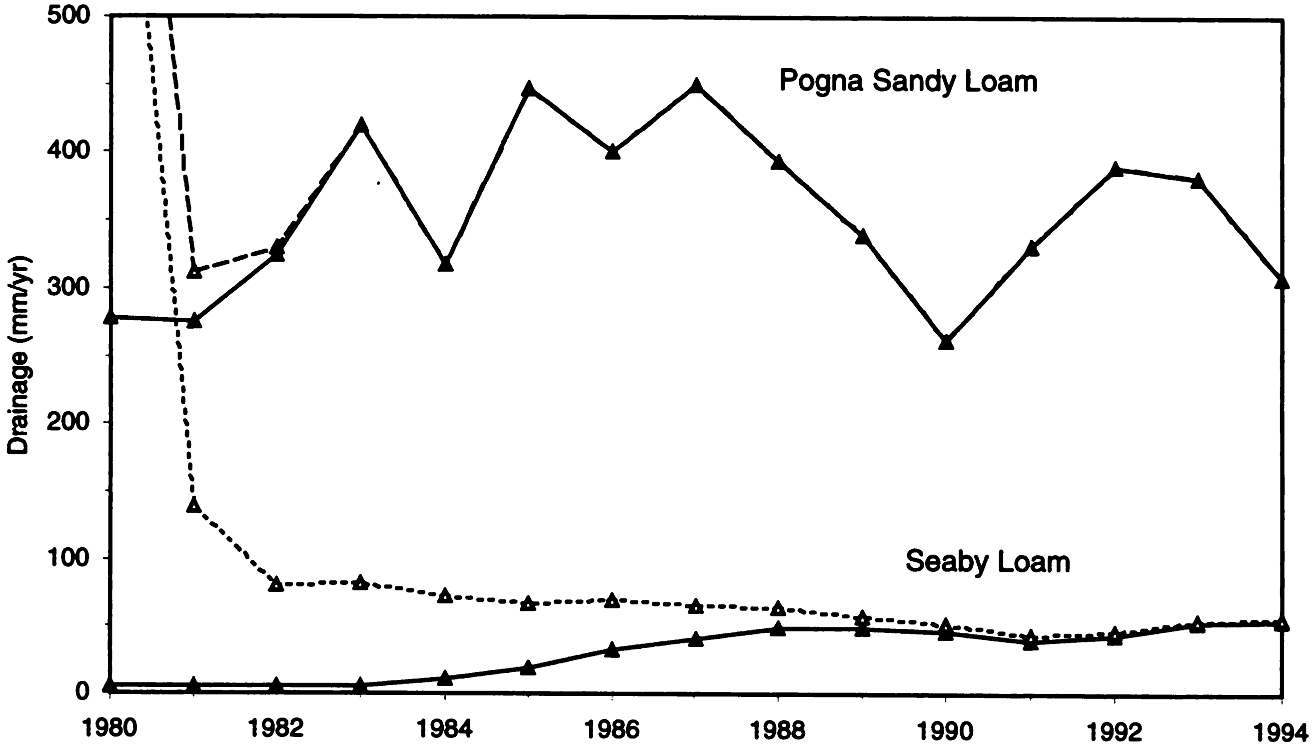

FIGURE E1-7.—*Simulation Results Showing the Impact of Initial Conditions on Annual Drainage from the Pogna Sandy Loam and Seaby Loam Soil Profiles.*

using the drier initial conditions (filled triangles). The 14-yr average rate was also nearly identical to the average rate predicted using drier initial conditions. In contrast, figure E1-7 shows that the annual drainage rates from the initially wet Seaby loam took the entire 14 years to come within 3 percent of the original simulation reported in table E1-3. Also, the 14-yr average rate was double the average rate predicted using drier initial conditions. When drainage rates are high, the initial conditions appear to become unimportant after only 1 to 2 years. When the rates are low, the initial conditions appear to influence the simulation results for at least as long as 14 years. The technique of conducting two simulations, one initially dry and one initially wet, can be used to illustrate the impact and provide bounding drainage predictions. Based on testing, the limited results suggest that the initial conditions used in the study caused an underestimate of deep drainage of no more than 12 to 16 in/yr (30 to 40 mm/yr).

E1.6.6 Mass Balance

The allowable mass balance error of a given simulation is controlled by the user. As more control is exerted, the simulation time requirement increases. Generally, the mass balance error was kept to less than 1 percent of the drainage rate. For the very low rates, this requirement was relaxed to 10 percent. In two cases, the Seaby loam and Nyjack loam, even this requirement was initially not met. These soil profiles with vegetation were simulated again with tighter convergence criteria. The estimated water balance components changed by less than 0.04 in/yr (1 mm/yr), but the mass balance errors were reduced to less than 10 percent relative to the drainage estimates. Further reductions in the mass balance errors could be obtained but the results and conclusions would not likely be affected.

E1.7 SUMMARY

The results of this study showed clearly that deep drainage at the DARHT and PHERMEX sites is possible. Estimated rates ranged from 0.2 to 14 in/yr (4.7 to 360 mm/yr) and could be as high as 20 in/yr (520 mm/yr) if the surface was graveled and unvegetated. These estimates are reasonably similar to other estimates (e.g, Abeele et al. 1981; Rogers 1995).

APPENDIX E2: SOLUBILITY AND SORPTION OF METALS

Mobilization of contaminants from the firing sites to and within Potrillo and Water canyons, and the associated subsurface environment is significantly affected by the contaminants' solubility in water and sorption onto soil and sediments. Thus, estimated solubility limits and distribution coefficients were determined for depleted uranium, beryllium, lead, nickel, copper, aluminum, iron, and silver at the LANL sites. The metals studied represent two classes; 1) those metals assigned annual expenditure rates, (e.g. depleted uranium, beryllium, lead and copper) (see chapter 3, table 3-4), and 2) those metals identified as included in the "other metals" category of the materials expended (see appendix B, table B-4) that were also listed in the primary and secondary drinking water standards, (i.e., 40 CFR 141 and 143), (e.g. aluminum, iron, nickel and silver). Note, aluminum and stainless steel (hence iron) make up the majority of the "other metals" category of materials expended during tests.

Because the numerical values for solubilities, distribution coefficients (K_d), and constants in the equations defining K_d are interrelated, these numerical values are given only in the metric units used by geochemists.

E2.1 METHODOLOGIES FOR ESTIMATION OF SOLUBILITY AND DISTRIBUTION COEFFICIENTS

Since no solubility experiments specific to the DARHT and PHERMEX sites were conducted previously, these values except for depleted uranium were obtained by running the geochemical model, MINTEQ (Felmy et al. 1983) with water quality data measured at Beta Hole in the Water Canyon and in Well PM-4 of the Pajarito Field (LANL 1988; LANL 1989; LANL 1990; LANL 1993; Purtymun et al. 1994). The MINTEQ computer code was selected because it is a state-of-the-art geochemical code capable of calculating complex geochemical equilibria for reactions involving gases, aqueous solutions, adsorbed species, and minerals within a wide range of geochemical conditions and constraints. The code has associated with it a thermochemical database containing aqueous speciation and solubility data. The code was developed in the mid-1980s for the EPA as part of a system to model the migration and fate of pollutant metals, the code was subsequently modified for the Nuclear Regulatory Commission and DOE. For depleted uranium, field data measured at the E-F site (Hanson and Miera

Exhibit E1-1
Example Input File for UNSAT-H Computer Code

```
DP1:  Typic Eutroboralf, fine, with grass-shrub cover 40%,
day 74 and 288
    1    1    1    1    0    0    0
iplant,lower,ngrav,iswdif,etc.
    0  365  365    1    1    0        0.0
nprint,dayend,ndays,nyears,etc.
    1    2    0    1    0
nsurpe,nfhour,itopbc,et_opt,icloud
    4    1    1    0    3    1
kopt,kest,ivapor,sh_opt,inmax,inhmax
       0.0  1.00e+05       0.0        0.0
hirri,hdry,htop,dhmax
   5.0e-05  1.00e+00   1.0e-08       24.0
dmaxba,delmax,delmin,stophr
      0.66    288.46      0.24        1.0
tort,tsoil,vapdif,qhtop
       0.0       0.0       0.0        0.0
tgrad,tsmean,tsamp,qhleak
       0.5       1.6   1.0e-06    0.0e-00
wtf,rfact,rainif,dhfact
    5   68                                     matn,npt
   1       0.0   1        0.2   1       0.4   1         0.6
   1       0.8   1        1.0   1       1.4   1         1.8
   1       2.4   1        3.0   1       4.0   1         5.5
   1       7.0   1        9.0   1      11.0   1        13.0
   1      15.0   1       17.0   5      19.0   5        21.0
   5      23.0   5       25.0   5      27.0   5        29.0
   5      31.0   5       33.0   5      35.0   5        38.0
   5      41.0   5       44.0   5      46.0   5        48.0
   5      50.0   4       52.0   4      54.0   4        56.0
   4      59.0   4       63.0   4      68.0   4        74.0
   4      80.0   4       84.0   4      86.0   4        89.0
   4      91.0   4       93.0   3      95.0   3        97.0
   3      99.0   3      102.0   3     106.0   3       110.0
   3     115.0   3      123.0   3     135.0   3       150.0
   3     175.0   3      200.0   3     225.0   3       250.0
   3     275.0   3      300.0   3     325.0   3       350.0
   3     375.0   3      400.0   3     450.0   3       500.0
 Sandy loam retention
    0.4100    0.0650    0.0750     1.8900
 Sandy loam conductivity
         2      4.43    0.0750     1.8900         0.5
 Gravel retention
     0.419    0.0050    4.9300       2.19
 Gravel conductivity
         2    1260.0    4.9300       2.19         0.5
 Tuff retention
    0.4690    0.0450    0.0029      1.884
```

```
 Tuff conductivity
         2    0.1188    0.0029     1.884       0.5
 Sandy clay retention
    0.3800    0.1000    0.0270     1.230
 Sandy clay conductivity
         2    0.1200    0.0270     1.230       0.5
 Clay retention
    0.3800    0.0680    0.0080     1.090
 Clay conductivity
         2    0.2000    0.0080     1.090       0.5

*** Initial matric suction values go here
```

Example Input File for UNSAT-H Computer Code (continued)

```
Plant information for shrubs and grasses
    1       1       1       1      74    288
leaf,nfroot,nuptak,nfpet,etc
   12  0.6                                            npoint,bare
    0 0.70    91 0.70   105 1.00   121 1.33   135 1.70 ngrow,flai
  213 1.70   227 1.60   244 1.50   258 1.28   274 1.08 ngrow,flai
  305 0.70   366 0.70                                  ngrow,flai
     0.000      0.0000      1.0000                     aa,b1,b2
    0    0    0    0    0    0    0    0    0    0 ntroot
    0    0    0    0    0    0    0    0    0    0
    0    0    0    0    0    0    0    0    0    0
    0    0    0    0    0    0    0    0    0    0
  366  366  366  366  366  366  366  366  366  366
  366  366  366  366  366  366  366  366  366  366
  366  366  366  366  366  366  366  366
   4.0e+04   1.0e+03       30.0                        hw,hd,hn
   4.0e+04   1.0e+03       30.0                        hw,hd,hn
   4.0e+04   1.0e+03       30.0                        hw,hd,hn
   4.0e+04   1.0e+03       30.0                        hw,hd,hn
   4.0e+04   1.0e+03       30.0                        hw,hd,hn

*** Meteorological data go here
```

1977), Aberdeen Proving Ground (APG) in Maryland (Erickson et al. 1993) and Yuma Proving Ground (YPG) in Arizona (Erickson et al. 1993) were used to estimate solubility. Water quality data for the surface and subsurface water used for the MINTEQ modeling are shown in table E2-1. Distribution coefficients for depleted uranium, beryllium, lead, nickel, copper, aluminum, iron, and silver were estimated by using laboratory experimental results from other sites (e.g., Yucca mountain in Nevada and the Hanford site in Washington).

TABLE E2-1.—*Water Quality at the Beta Hole in Water Canyon and Well PM-4 in the Pajarito Field*

Location	Calcium (mg/L)	Magnesium (mg/L)	Potassium (mg/L)	Sodium (mg/L)	Carbonate plus Bicarbonate (mg/L)	Chlorine (mg/L)	Sulfate (mg/L)	pH
Beta Hole	12	4	3.3	17	51	11	7.5	7.8
PM-4	14	4	3	15	60	2	2.5	7.85

E2.2 DEPLETED URANIUM

Depleted uranium is the isotopic form present in the studies cited here. The physical chemistry of various isotopic forms of uranium is essentially identical, so the general terms uranium is used in this section.

E2.2.1 Solubility of Uranium

Many studies have obtained data on uranium distributions at LANL and physical/chemical characteristics (Hanson 1974; Hanson and Miera 1976; Hanson and Miera 1978; Elder et al. 1977; and Becker 1993). Common oxidation states of uranium are designated as uranium(III), uranium(IV), uranium(V), uranium(VI), but in the LANL geologic environment uranium(IV) and uranium(VI) are the most important (Onishi et al. 1981). Uranium(VI) species control the total uranium concentration in oxidizing environments. The uranyl ion (UO_2^{+2}) ion is a dominant species under oxidizing conditions. This cation can form many soluble and stable complexes with common ground water anions such as carbonate and sulfate (Onishi et al. 1981). In reducing conditions, uranium (IV) dominates and generally precipitates as uranium dioxide. Uranium content in solution, and thus also a distribution coefficient K_d, are a function of oxidation-reduction potential (Eh), pH, solution carbonate content, sediment characteristics (particle size, carbonate, phosphorous and hydrous oxide contents), and organic matter content (organic carbon and humic substances) (Onishi et al 1981). Data reviewed by Onishi et al. (1981) indicate that the uranium K_d for sediments from the Great Miami River (Ohio) ranged between 1,000 and 1,600 mL/g, while K_d values for sediments in 40 Japanese rivers varied between 1,000 and 6,000 mL/g.

Erickson et al. (1993) performed a series of experiments and geochemical modeling to determine corrosion rate, solubility and adsorption potential for uranium at Aberdeen Proving Ground (APG) in

Maryland and the Yuma Proving Ground (YPG) in Arizona. Uranium pieces corrode with a corrosion rate of 0.02 to 0.04 in/yr (0.05 to 0.10 cm/y) to form uranium U(VI) hydrated oxides, mostly the yellowish mineral schoepite ($UO_3 \bullet H_2O$). The corrosion rate is fast enough that uranium is available for transport through dissolution of schoepite and subsequent surface and subsurface migration. The LANL E-F site exhibits a yellow corrosion product of uranium on the soil surface, a sign of schoepite. Soils (two types) at APG are predominantly silt with moderate cation exchange capacity (CEC), low calcium carbonate content, and low paste pH values (pH of 4 to 6). Soils (one set) at YPG are predominantly gravel and sand with higher CEC, high carbonate minerals and slightly basic (pH of 8 to 8.5) saturation paste. Erickson et al. (1993) reported that the solubility of uranium at APG and YPG is 10 to 280 mg/L, and 20 to 130 mg/L, respectively. They attributed the higher corrosion rate and uranium mobility measured at YPG as primarily controlled by the higher dissolved carbonate, derived from the dissolution of carbonate minerals in this soil. Soil characteristics (especially carbonate content) at the LANL site fall in between one of the APG soils and the YPG soil types (LANL 1995).

Furthermore, uranium concentrations in standing water at the detonation center of the E-F site were 86 and 235 mg/L in 1975 and 1976, respectively, with nearly all of the uranium being in solution as opposed to suspended as fine solids (Hanson and Miera 1977). The uranium concentration in standing water at 66 ft (20 m) to the southwest away from the detonation center was only 63 μg/L in 1975, i.e., three orders of magnitude less than the concentration measured in standing water at the detonation center. A uranium concentration in runoff water measured in 1975 at 330 ft (100 m) to the southwest (still on mesa top) away from the detonation center was 52 μg/L. These concentration differences between the detonation center and the short distances away imply that not enough uranium was transported from the firing point to maintain the uranium concentration in solution at the solubility limit of uranium even 20 m away.

Based on these studies, we selected uranium solubility limit to be 300 mg/L for the current study. We also assumed that corrosion of uranium is fast enough for uranium to be available for subsequent surface/subsurface migration.

E2.2.2 Sorption of Uranium

Erickson et al. (1993) also conducted adsorption experiments and geochemical modeling with the chemical code, MINTEQ (Felmy et al. 1983). Experimental values for uranium distribution coefficients on the two soil types at APG were reported to be 4360 and 328 mL/g. The YPG site has the lowest K_d value (54 mL/g) due to the high carbonate solution concentrations despite the YPG environment having the highest pH and CEC, two attributes that normally portend high adsorption. Since soil characteristics (especially carbonate concentrations) at the LANL site (LANL 1995) fall in between one of the APG soil types and the YPG soil type, an expected K_d value with soil at the LANL site is estimated to be between 54 and 328 mL/g. We selected distribution coefficient values for the LANL soil to be 50 mL/g, and 100 mL/g as conservative and more realistic estimates. Since suspended sediment in LANL canyon streams have finer particle size, and since it is generally believed that finer sediments exhibit greater K_d values (Onishi et al. 1981; Becker 1993), we selected K_d values of 100 and 200 mL/g to be conservative and more realistic estimates for the in-stream suspended sediment.

E2.3 LEAD

E2.3.1 Solubility of Lead

The release rate of lead from the metal compounds into water depends largely on the oxidation rate of metallic lead, the dissolution of secondary minerals (e.g., lead carbonates), and the amount of water available to react with lead (Rhoads et al. 1992). However, we are not aware of any solubility and adsorption data for lead in contact with LANL waters or tuff. Thus, we performed geochemical modeling with MINTEQ to obtain lead solubility estimates for the LANL sites. The water quality data shown in table E2-1 was used to represent the LANL surface water and ground water conditions. The mineral cerrusite ($PbCO_3$) was imposed as the solubility limiting solid in this case.

MINTEQ predicted lead solubility in canyon streams and ground water to be 48.2 and 45.7 μg/L, respectively. Hence, we selected the lead solubility to be 50 μg/L for both surface and subsurface waters at the LANL sites.

Rhoads et al. (1992) conducted experiments and chemical modeling to determine the lead solubility in Hanford ground water. Assuming lead was in equilibrium with cerrusite, they used the geochemical code MINTEQ (Felmy et al. 1984) to predict the lead solubility to be 287 μg/L, which is close to solubility limits of 236 to 482 μg/L which they obtained in laboratory experiments. This result confirms the general validity of the MINTEQ simulation with cerrusite limiting lead solubility.

E2.3.2 Sorption of Lead

Adsorption of dissolved lead depends on water and soil chemistry, and properties of the lead species in solution (Rhoads et al. 1992). However, a main factor affecting lead adsorption is the amount of iron oxides in the soil.

According to Rhoads et al. (1992), batch experiments with Hanford ground water and relatively fine sediment (sand, silt and clay mixture) yielded distribution coefficients varying from 1,190 mL/g at dissolved lead concentration of 200 μg/L to 56,000 mL/g at dissolved lead concentration of 0.005 μg/L, showing the following functional relationship:

$$K_d = 9550\ C^{-0.335}$$

where, C is a dissolved lead concentration in μg/L. This relationship yields K_d values of 2,580 mL/g at the dissolved lead concentration of 50 μg/L, 1,410 mL/g at the dissolved lead concentration of 300 μg/L, and 1,150 mL/g at the dissolved lead concentration of 550 μg/L.

Based on this Hanford study, conservative and realistic distribution coefficient values of 1,000 and 10,000 mL/g, respectively, for lead transport in the subsurface of the LANL site were selected. Because of the finer suspended sediment in canyon streams, their conservative and realistic distribution coefficient values were selected to be twice the values of ground water, e.g., 2,000 and 20,000 mL/g, respectively.

E2.4 BERYLLIUM

E2.4.1 Solubility of Beryllium

Beryllium solubility was calculated using the geochemical code MINTEQ (Felmy et al. 1983) by imposing beryllium hydroxide ($Be(OH)_2$) as the solubility limiting solid. Thermodynamic data used for this study on beryllium hydride were not a part of the original MINTEQ code but are incorporated in MINTEQA2 (Version 3.0) and are reported in Serne et al. (1993). Beryllium solubility was calculated for water from Water Canyon at the Beta Hole, and ground water from water supply Well PM-4 in the Pajarito Field (see table E2-1).

Beryllium solubility for Water Canyon at the Beta Hole and Well PM-4 predicted by the MINTEQ geochemical code are 3.95 and 3.62 μg/L, respectively. The MINTEQ simulation shows the strong dependency of beryllium solubility to pH. By using MINTEQA2, (i.e., with the same thermodynamic data base as those used under the current study), Serne et al. (1993) calculated beryllium solubility for Hanford ground water (pH of 8.1) to be 2.3 μg/L, which is comparable to the 3.62 to 3.95 μg/L range we estimated for the LANL waters.

Based on these model results, the beryllium solubility selected was 4 μg/L for both the canyon streams and subsurface flow.

E2.4.2 Sorption of Beryllium

Very few data are available for beryllium adsorption on soil (Serne et al. 1993), and we are not aware of any beryllium adsorption data for LANL soils and sediments. Beryllium adsorption data for 11 soils reviewed by Rai et al. (1984) show that beryllium adsorption is greater than adsorption of other divalent metals such as zinc, cadmium, nickel and the monovalent metal mercury.

Adsorption of divalent beryllium is expected to be somewhat similar to that of divalent strontium. Thus, we used a strontium distribution coefficient obtained from experiments on tuff deposits for beryllium adsorption values. Strontium adsorption is significantly influenced by calcium and magnesium ions. There are many strontium adsorption studies performed with Yucca Mountain tuff. These include strontium distribution coefficients of

- 50 to 84 mL/g obtained in batch tests and 30 to 52 mL/g obtained by column tests (Erdal et al. 1980),
- 50 to 300 mL/g with batch tests and 30 to 106 mL/g with column tests (Vine et al. 1980a)
- 51 to 283 mL/g with batch tests and 19 to 395 mL/g with column tests (Vine et al. 1980b).

Based on data from five samples of devitrified tuff, the range in strontium K_d values for the LANL soil was reported to be 53 to 190 mL/g with an average value of 116 mL/g (Wolfsburg 1980).

Based on these values, we selected conservative and realistic strontium distribution coefficient values to be 50 and 100 mL/g, respectively, for subsurface water. Because beryllium adsorption by soil is expected to be similar to that of strontium, these values were also used for the beryllium distribution coefficient for subsurface flow modeling.

Because the suspended sediments in canyon streams are expected to be finer than soils in the subsurface (Becker 1993), and the finer the sediment the greater the K_d values (Onishi et al. 1981), we selected conservative and realistic beryllium K_d values for canyon stream modeling to be 100 and 200 mL/g, respectively.

E2.5 NICKEL

E2.5.1 Solubility of Nickel

The solubility of nickel was estimated by using the MINTEQ code with its existing data base, and the LANL water quality data shown in table E2-1. Geochemical simulation indicates that the most stable solid phase of nickel in both surface and ground water is nickel hydroxide ($Ni(OH)_2$) as was found for a Hanford ground water case (Serne et al. 1993). The calculated nickel solubility for canyon streams and ground water were 1.16 and 0.904 mg/L, respectively, assuming equilibrium with nickel hydroxide. Thus, we selected the nickel solubility to be 1.0 mg/L for both surface and subsurface waters at the LANL sites.

E2.5.2 Sorption of Nickel

No nickel adsorption experiments have been conducted with LANL soils and water. Thus, we used Hanford Site nickel adsorption data to obtain an appropriate nickel distribution coefficient for this study. By using Hanford ground water with Trench-8 soil, Serne et al. (1993) obtained K_d values of 440 mL/g and 2350 mL/g after 5 and 44 days. With Trench-94 soil, they obtained K_d values of 48 and 337 mL/g at a dissolved nickel concentration of 2 and 1,000 μg/L, respectively. Serne et al. (1993) then derived the following empirical K_d expression:

$$K_d = 240\ C^{-0.155}$$

where C is the dissolved nickel concentration in μg/L, and the K_d is the distribution coefficient in mL/g. The above equation yields K_d values of 118, 167 and 240 mL/g at the dissolved nickel concentrations of 100, 10 and 1 μg/L, respectively. Note that a dissolved nickel concentration at the LANL sites is expected to be less than 100 μg/L.

In addition, Brookins (1984) and Serne (1994) reported the conservative nickel distribution coefficients to be 50 mL/g for devitrified tuff and 20 mL/g for sandy soil, respectively.

From these data, we selected conservative and realistic nickel distribution coefficients to be 20 and 200 mL/g, respectively, for the LANL ground water. For the LANL canyon streams suspended sediments, we selected conservative and realistic values of 40 and 400 mL/g, respectively.

E2.6 COPPER

E2.6.1 Solubility of Copper

The mineral malachite ($Cu_2CO_3(OH)_2$) was specified as the copper solubility controlling solid MINTEQ calculations of copper solubility in the canyon stream and ground water described in table E2-1. MINTEQ predicted the copper solubility to be 10.5 μg/L for both the LANL site surface and ground water. Thus, the copper solubility for this study was selected to be 10 μg/L for both canyon stream and subsurface modeling.

E2.6.2 Sorption of Copper

There are no copper adsorption data available for the LANL waters and soils or sediments. Since copper and nickel are both divalent and are expected to have similar sorption behavior, we elected to use the same K_d values for copper as for nickel. Serne (1994) reported the conservative copper K_d value for Hanford sandy soil to be 20 mg/L; the same as our conservative K_d value for nickel.

Thus we assigned the conservative and realistic K_d values for the LANL ground water to be 20 and 200 mL/g, respectively. The conservative and realistic K_d values for the canyon stream water were assigned 40 and 400 mL/g, respectively.

E2.7 ALUMINUM

E2.7.1 Solubility of Aluminum

Aluminum solubility was also calculated using the geochemical code MINTEQ (Felmy et al. 1983) by assigning the solubility limiting solid to be the mineral gibbsite ($Al(OH)_3$). With the water quality data shown in table E2-1 for Water Canyon and Well PM-4, MINTEQ predicted the aluminum solubility at equilibrium with gibbsite to be 1.22 and 1.36 μg/L for the canyon streams and ground water in the study area. Thus, we selected aluminum solubility to be 1 μg/L for both surface and subsurface flow modeling.

E2.7.2 Sorption of Aluminum

Since aluminum is a major constituent of soil, and the bulk of aluminum in the soil is not undergoing adsorption/desorption reactions with water, no meaningful adsorption experimental data for aluminum exist. Nonetheless, we selected the conservative aluminum K_d value to be 300 mL/g for the LANL ground water, as indicated by Serne (1994) for the Hanford sandy soil's conservative value. We selected a more realistic K_d value for aluminum to be 5,000 mL/g for the ground water. Because suspended sediment is finer than the bulk surface soil, we selected K_d values for the canyon streams to be twice the corresponding K_d values of the subsurface. Thus, the conservative and more realistic K_d values for canyon streams were assigned to be 600 and 10,000 mL/g, respectively.

E2.8 IRON

E2.8.1 Solubility of Iron

The solubility of iron was estimated using the MINTEQ code with its existing data base and water quality data shown in table E2-1. Because there were no redox data available for Water Canyon stream water and Well PM-4 ground water, we assumed that the water is oxidized. With this assumption, the geochemical simulation indicates that the most probable controlling solid phase of iron in both surface and ground water is amorphous iron hydroxide ($Fe(OH)_3$). The predicted iron solubility for both the canyon stream and ground water was 0.0022 μg/L. This value is very similar to the 0.002 μg/L value Morel (1983) reported for the ferric iron solubility at equilibrium with iron hydroxide at a pH of 7.8. Thus, we selected the iron solubility to be 0.002 μg/L for both surface and subsurface waters in the study area. Note that if the ground water of Well PM-4 is in a reduced condition, the iron solubility would be much higher than 0.002 μg/L due to the higher solubility of ferrous iron.

E2.8.2 Sorption of Iron

Similar to the aluminum case discussed above, iron is also a major constituent of soil and the bulk of the iron in the soil is not undergoing adsorption/desorption reactions with water. Thus, there is no meaningful adsorption experimental data for iron. However, Serne (1994) found a conservative K_d value for iron in sandy soil to be 15 mL/g, and we selected this value for subsurface flow modeling at the LANL sites. We assigned a realistic iron K_d value of 1,000 mL/g for the subsurface model. Conservative and realistic K_d values for iron in canyon streams were assigned to be 30 and 2,000 mL/g, respectively.

E2.9 SILVER

E2.9.1 Solubility of Silver

Silver chloride (AgCl) was specified as the silver solubility controlling solid for MINTEQ calculations of silver solubility in the canyon streams and ground water whose chemical quality is shown in table E2-1. MINTEQ predicted silver solubility to be 76.4 and 286 μg/L for the LANL sites' surface and ground water, respectively. Thus, the silver solubility for this study was selected to be 80 and 300 μg/L for canyon stream and subsurface models, respectively.

E2.9.2 Sorption of Silver

Serne (1994) stated that 1 mL/g may be taken as a conservative K_d value for silver in a sandy soil. Consequently, we selected the conservative K_d for the LANL subsurface water to be 1 mL/g. For canyon streams water we assigned a conservative silver K_d value of 2 mL/g. Since silver is monovalent, we assumed a realistic K_d value for silver to be a half of the divalent nickel K_d value. Thus, we selected realistic K_d values for silver in the subsurface environment and canyon streams at the LANL study area to be 100 and 200 mL/g, respectively.

E2.10 SUMMARY OF SOLUBILITY AND SORPTION OF METALS IN LANL SURFACE AND GROUND WATERS

Mobilization of contaminants released to surrounding surface and subsurface water environment from the firing sites is significantly affected by their solubility and affinity to sorb onto soils and sediments. Thus, the solubility and distribution coefficients of depleted uranium, beryllium, lead, nickel, copper, aluminum, iron, and silver were estimated here for LANL site surface and ground waters.

Except for depleted uranium, the solubility of the metals of interest were obtained by running the geochemical model, MINTEQ (Felmy et al. 1983). Water quality data from samples taken at the Beta Hole on Water Canyon and at Well PM-4 of the Pajarito Field (LANL 1988; LANL 1989; LANL 1990; LANL 1993; Purtymun et al. 1994) were assumed to be representative of surface and ground water quality for the study area (see table E2-1). For depleted uranium, solubility was estimated using field data measured at the E-F site at LANL (Hanson and Miera 1977), Aberdeen Proving Ground in Maryland (Erickson et al. 1993) and Yuma Proving Ground in Arizona (Erickson et al. 1993).

Table E2-2 shows a summary of both the solubility and sorption values estimated for the metals of interest in LANL surface and ground waters. Note that except for silver, solubility for each metal is the same for surface and ground waters of the LANL study area. Both conservative and realistic estimates of distribution coefficients, K_d, are shown in the table for depleted uranium, lead, beryllium, nickel, copper, aluminum, iron, and silver.

APPENDIX E3: SURFACE WATER MODELING

Contaminant movement in runoff, stream flow, and sediment transport from both PHERMEX and DARHT has been identified as a key set of processes leading to exposure and health effects. Pathways of interest include stream flow and sediment discharge through the Water and Potrillo Canyon watersheds leading to the Rio Grande and stream flow transmission losses to the underlying groundwater. This section of the appendix describes the modeling procedures used to estimate the transport and fate of depleted uranium and other contaminants in the Water and Potrillo Canyon watersheds.

E3.1 MODEL DESCRIPTION

The transport and fate of depleted uranium and other contaminants in the Water and Potrillo Canyon watersheds were estimated using one-dimensional event-based procedures (Lane et al. 1985) to simulate the movement of plutonium in the Los Alamos Canyon watershed. The procedures developed by Lane et al., hereafter referred to as the Lane model, were selected because they were specifically formulated to represent the hydrologic, hydraulic, sediment, and contaminant transport processes occurring in the Los Alamos region. The Lane model accounts only for the transport of contaminants sorbed to sediments and does not consider contaminant transport in the dissolved phase. Since this EIS is concerned with the transport of depleted uranium, beryllium, and lead which have significant solubilities, the Lane model procedures were extended to include dissolved phase transport and sorption/desorption with sediments using partition coefficients as described by Mills and others

TABLE E2-2.—*Estimated Solubilities and Distribution Coefficients for Metals in LANL Surface and Ground Waters*

Metals	Solubility, μg/L unless otherwise noted	Distribution Coefficients, K_d, (mL/g)			
		Subsurface Sediments and Ground Water		Suspended Sediment and Surface Water	
		Conservative	Realistic	Conservative	Realistic
Depleted Uranium	300 mg/L	50	100	100	200
Lead	50	1000	10,000	2000	20,000
Beryllium	4	50	100	100	200
Nickel	1000	20	200	40	400
Copper	10	20	200	40	400
Aluminum	1	300	5000	600	10,000
Iron	0.002	15	1000	30	2000
Silver	300 and 80 for surface and ground water	1	100	2	200

(Mills et al. 1985). The model was also extended to include the transport of dissolved contaminants from the firing sites into the neighboring canyon channels. The extended model transports contaminants sorbed to sediments or dissolved in the water column. The model also estimates dissolved contaminants that infiltrate to the subsurface from mesa top firing sites and through channel transmission losses.

It is important to note that the long term observations of precipitation, streamflow, and sediment yield necessary to calibrate and validate the model were not available for the Water and Potrillo Canyon watersheds. Although the numerical values produced by the model have uncertainty, the simulated concentrations leaving the LANL site are well below drinking water standards.

E3.2 MODEL APPLICATION

The extended Lane model was developed and applied to the Water and Potrillo Canyon watersheds. These watersheds were divided into a series of representative channel reaches. Figure E3-1 shows aschematic of the channel network and the individual reach identification numbers.

Total daily precipitation values used to drive the model for the 32-year historical period of PHERMEX operations were obtained from gage data collected at LANL (Bowen 1990). Snowmelt runoff was not explicitly included because there was not adequate information to characterize these events.

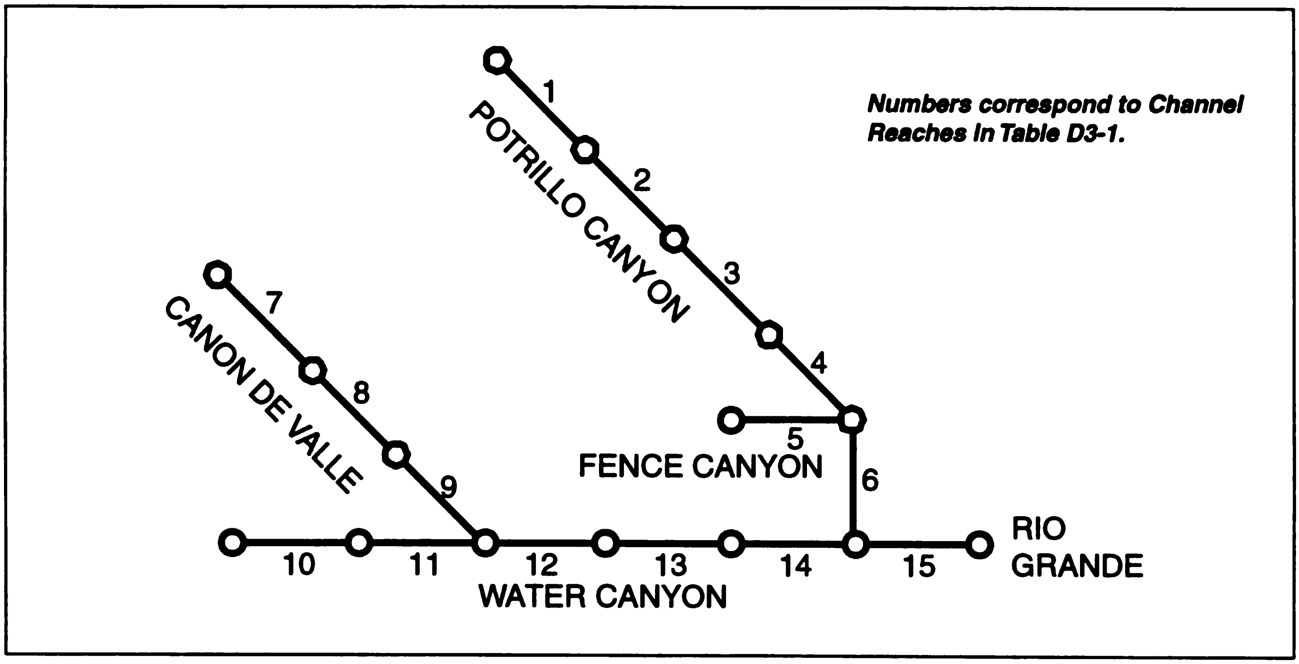

FIGURE E3-1.—*Schematic of Runoff-Sediment-Contaminant Transport Model Channel Network.*

Precipitation occurring as snow was simply applied as rainfall on the day of occurrence. Following Lane et al. (Lane et al. 1985), the daily average precipitation was converted to a 1-hour rainfall and used as the input to the hydrology model.

Because streamflow in Water and Potrillo Canyons is ephemeral, a very long time may be required for contaminants to be transported downstream from the release point and attain a maximum concentration. Since the model is driven entirely by rainfall events a hypothetical future precipitation record was required. A 5,000-year daily average precipitation record was created using the methods described by Sharpley and Williams (Sharpley and Williams 1990) and statistics computed from the measured daily rainfall record from 1947 through 1994.

Watershed subbasin areas, composite runoff curve numbers, channel widths, lengths, and slopes were obtained from McLin (McLin 1992) and are listed in table E3-1. Note that overbank areas (floodplains) were not included and the active channels were assumed to have a rectangular cross section. These assumptions are conservative in that they lead to increased rates of sediment and contaminant transport and thus an accelerated movement of contaminants toward the Rio Grande. Channel widths of 3 ft (0.91 m) have been used except for the section of Potrillo Canyon (reach 3) termed the "discharge sink" by Becker (Becker 1993). The discharge sink has been noted to be a wide area without a distinct channel with a high vertical infiltration rate (Becker 1993).

Additional channel characteristics used in the model (hydraulic conductivity, Manning's n, median grain size, and silt-clay fraction) were estimated using the values chosen by Lane, et al. (Lane et al. 1985) for Los Alamos Canyon as guidance. Only two sediment size classes were considered in the model; bedload was represented as material with a median grain size diameter (d_{50}) and suspended

TABLE E3-1.—*Channel Characteristics*

Canyon	Reach No	Drainage Area (mi^2)	Curve Number	Length (mi)	Average Width (ft)	Hydraulic Conductivity (in/hr)	Slope	Manning n	Median Grain Size (mm)	Silt-Clay Percentage
Water	10	4.07	54	3.41	3.0	1.5	0.13	0.040	1.3	2.5
	11	2.63	62	3.36	3.0	1.5	0.04	0.040	1.3	2.5
	12	0.52	72	1.33	3.0	1.5	0.02	0.040	0.8	0.5
	13	0.90	72	2.27	3.0	1.5	0.02	0.040	0.8	0.5
	14	1.97	72	2.60	3.0	1.5	0.04	0.040	0.8	2.5
	15	0.32	77	0.95	3.0	1.5	0.08	0.040	0.8	1.5
Canon De Valle	7	2.33	53	4.26	3.0	1.5	0.12	0.040	1.6	3.5
	8	0.78	63	1.42	3.0	1.5	0.05	0.040	1.6	3.5
	9	1.17	64	2.37	3.0	1.5	0.04	0.040	1.6	3.5
Potrillo	1	0.68	70	1.33	3.0	1.5	0.03	0.040	1.2	2.0
	2	0.68	70	1.33	3.0	1.5	0.02	0.040	1.2	2.0
	3	0.49	70	0.95	40.0	1.5	0.02	0.040	1.2	2.0
	4	0.93	70	1.80	3.0	1.5	0.02	0.040	0.9	2.5
	6	0.96	75	1.85	3.0	1.5	0.02	0.040	0.9	2.5
Fence	5	1.03	71	3.41	3.0	1.5	0.02	0.040	1.1	0.5

load was represented by the silt-clay size fraction. As recommended by Lane, et al. (Lane et al. 1985), a constant value of 5 was used for the suspended sediment transport coefficient in the model. To improve confidence in model results, future studies should be undertaken to characterize the channel sediments in Water and Potrillo Canyons. The values selected for channel reach are listed in table E3-1. The depth of channel bed sediments available for contaminant storage was assumed to be 11.81 in (30 cm) for all reaches which is consistent with the value selected by Lane, et al. (Lane et al. 1985).

For each reported simulation, the entire yearly contaminant mass release is assumed to be distributed uniformly over a 100-ft (30-m) radius circle centered at the firing site (PHERMEX or DARHT) at the start of each year. For days during which rainfall occurs, the contaminants are mobilized by assuming that they go into solution at the solubility limit. The volume of rainfall and associated contaminant mass is split between infiltration to the vadose zone and runoff to the canyons using the curve number method (Lane et al. 1985). Contaminants travel from the firing site to the canyon channel only through runoff; soil erosion and contaminant movement associated the eroded soil was not considered. This assumption was made in order to avoid the additional complexities and uncertainties associated with the simulation of soil erosion and overland contaminant transport from the firing sites to the channel system. The dissolved contaminants associated with rainfall runoff are input to Potrillo Canyon in reach number 1 and to Water Canyon in reach number 12 (see figure E3-1).

In all cases, the partition coefficients (Kd) and solubility limits for the depleted uranium, beryllium, and lead used were the conservative estimates for suspended sediments as given in appendix E, section 2.

E3.3 NO ACTION ALTERNATIVE SIMULATIONS

In this alternative, the transport by surface runoff during the past 32 years for releases of depleted uranium, beryllium, and lead and for releases during the next 30 years from the PHERMEX site were assumed to be evenly split between Water and Potrillo Canyons with 50 percent of the release going to each canyon. The amount of depleted uranium released is assumed to be 30 percent of total mass indicated in section 2 of appendix E. For the next 30 years in the No Action Alternative, the annual releases of depleted uranium, beryllium, and lead would be 460, 22 and 33 lb/yr (210, 10, and 15 kg/yr), respectively. Table 5-3 shows the simulated peak concentration of contaminants in the infiltrated water at the discharge sink in Potrillo Canyon (reach 3) and at Water Canyon channels below the source (reaches 12,13,14, and 15).

Because of their low solubility, the concentrations of beryllium and lead reach a plateau at the end of the 5,000 year simulation, but still remain well below drinking water standards. Using the average simulated transport rates, the inventories of beryllium and lead at the firing site will be exhausted in approximately 300,000 and 40,000 years, respectively. Although beryllium and lead have relatively low solubilities, depleted uranium has a relatively higher solubility in LANL surface and ground waters. Consequently, the source of depleted uranium in the upper 1 ft (30 cm) of soil would be completely removed from the firing site in less than 1,000 years.

Table 5-3 also lists the peak concentration of dissolved and sediment-sorbed contaminant concentrations entering the Rio Grande. The Rio Grande is the nearest off-LANL access point for surface water carrying contamination from the firing point. The quality of surface water entering the Rio Grande is forecast to be more than an order-of-magnitude below the proposed water quality standard for uranium and several orders-of-magnitude below the drinking water standard MCLs for beryllium and lead.

The long-term average annual water volume (over the 5,000-year simulation) infiltrating at the Potrillo Canyon discharge sink was computed to be 37,400 ft^3/yr (1,000 m^3/yr). This is lower, but in the range of the 183,600 ft^3 (5,200 m^3) volume that was reported for 1990 from the short-term measurements by Becker (Becker 1993). The average annual simulated water discharge and sediment discharges entering the Rio Grande from the Water-Potrillo Canyon watersheds were 237,000 ft^3/yr (6,700 m^3/yr) and 165 tons/yr (150,000 kg/yr), respectively. No direct measurements of streamflow volume and sediment discharge to the Rio Grande were available for Water Canyon.

E3.4 PREFERRED ALTERNATIVE SIMULATIONS

The annual expenditures from the DARHT site of depleted uranium, beryllium, and lead were 460, 22 and 33 lb/yr (210, 10, and 15 kg/yr), respectively. The amount of depleted uranium released is assumed to be 30 percent of total mass indicated in section 2 of appendix E. These annual expenditures from DARHT were released onto the firing site for the first 30 years of the simulation. All surface runoff from the firing site was directed to Water Canyon. Table 5-8 shows the peak concentration of contaminants and years to peak in the infiltrated water along Water Canyon (reaches 12, 13, 14, and 15).

Because of their low solubility, the concentrations of beryllium and lead reach a plateau at the end of the 5,000 year simulation, but still remain well below drinking water standards. Using the average simulated transport rates, the inventories of beryllium and lead at the firing site will be exhausted in approximately 74,000 and 9,000 years, respectively. Although beryllium and lead have relatively low solubilities, depleted uranium has a relatively high solubility in LANL surface and ground waters. Consequently, the source of depleted uranium in the upper 1 ft (30 cm) of soil would be completely removed from the firing site in less than 1,000 years.

Table 5-8 also lists the peak and time to peak for the dissolved and sediment-sorbed contaminant concentrations entering the Rio Grande. The Rio Grande is the nearest off-LANL access point for surface water carrying contamination from the firing point. The quality of surface water entering the Rio Grande is forecast to be more than an order-of-magnitude below the proposed water quality standard for uranium and several orders-of-magnitude below the drinking water standard MCLs for beryllium and lead.

E3.5 ENHANCED CONTAINMENT ALTERNATIVE SIMULATIONS

For a containment vessel, the annual expenditures from the DARHT site of depleted uranium, beryllium, and lead would be 28, 2.2 and 2.2 lb/yr (12.6, 1, and 1 kg/yr), respectively. The amount of depleted uranium released is assumed to be 30 percent of total mass indicated in section 2 of appendix E. These annual expenditures from DARHT were released onto the firing site for the first 30 years of the simulation. All surface runoff from the firing site was directed to Water Canyon.

Table 5-12 shows the peak concentration of contaminants and years to peak in the infiltrated water along Water Canyon (reaches 12, 13, 14, and 15). No depleted uranium is predicted to reach Water Canyon in this alternative. The inventory is sufficiently low and the solubility of uranium sufficiently high that the depleted uranium is carried into the mesa top at the firing point by a few storm events. These storm events generate infiltration but not surface runoff.

Because of its low solubility, the concentration of beryllium reaches a plateau at the end of the 5,000 year simulation, but still remains well below drinking water standards. Using the average simulated transport rates the inventory of beryllium at the firing site will be exhausted in approximately 7,400 years.

Table 5-12 lists the peak concentration and time to peak of the dissolved and sediment-sorbed contaminant concentrations entering the Rio Grande. The Rio Grande is the nearest off-LANL access point for surface water carrying contamination from the firing point. The quality of surface water entering the Rio Grande is forecast to be several orders-of-magnitude below the drinking water standard MCLs for beryllium and lead.

APPENDIX E4: VADOSE ZONE AND GROUND WATER MODEL

E4.1 INTRODUCTION

Ground water constitutes one potential environmental pathway by which contaminants originating at the DARHT and PHERMEX firing sites may, after centuries to millennia, become accessible to members of the public. Some canyons in the Los Alamos area (notably Los Alamos and Mortandad Canyons to the north of TA-15) have shallow alluvial and intermediate depth perched aquifer systems that provide a relatively fast path for contaminants leached through canyon bottoms to appear in ground water. However, the canyons of concern in this study, Water Canyon and Potrillo Canyon, do not appear to have such shallow aquifer systems. Potrillo Canyon is cut directly on the Bandelier Tuff, and there is little to no alluvial fill in the upper reaches of the watershed. Therefore, it is unlikely that a permanent alluvial aquifer exists in this canyon (ERP 1993). Water Canyon is a large canyon that heads on the flanks of the Sierra de Los Valles. A short distance downstream from the confluence of Water Canyon and Cañon de Valle, near the DARHT and PHERMEX sites, is Beta Hole, a dry well extending 187 ft (57 m) into the Bandelier Tuff (ERP 1993; Purtymun 1995). The lack of water in Beta Hole and two other shallow wells completed in the alluvium confirm that Water Canyon in the vicinity of TA-15 contains no permanent perched or alluvial aquifers, though there is a possibility of perched zones at intermediate depth (ERP 1993).

In the absence of a perched aquifer, water infiltrating through the vadose (unsaturated) zone may transport contaminants in liquid phase from the surface to the regional or main aquifer. However, this would occur over a long period of time, and has not been observed at LANL. Once in the main aquifer, contaminants may be transported down gradient through the saturated zone down gradient to the Rio Grande, where these contaminants may be discharged in springs or directly to the Rio Grande and become accessible in that surface water body to members of the public. Alternatively, once in the main aquifer, contaminated water might be pumped from wells for municipal and industrial use, again becoming accessible. Although no water supply wells currently exist in TA-15, which includes the DARHT and PHERMEX sites, Purtymun (Purtymun 1984) identified an area that included TA-15 as most suitable for additional water supply wells for Los Alamos County based on the desired attributes of high yield and low drawdown wells. It is surmised that these desirable attributes for well placement will make the area subject to future water well development. However, regulations would require testing before public use, and during subsequent use. The average yield from the five wells in the Pajarito Field [the PM wells are located in the zone identified by Purtymun (Purtymun 1995)] was 1215 gpm (0.08 m^3/s) (Purtymun 1984). Therefore, well extraction of dissolved contaminant mass from the regional aquifer, if transported to the aquifer, is a possible consideration.

In spite of the above considerations with regard to the main aquifer, it may be unnecessary to model the flow and transport of contaminants in the main aquifer depending on the results of vadose zone modeling. To reach the main aquifer, contaminant mass must i) be available at the surface for leaching into the soil profile and ii) be transported vertically downward from the surface to the water table. The travel time for recharge water through unsaturated volcanic tuffs in a semi-arid climate can be centuries to millennia. Sorption further extends the time required for contaminant to migrate to the main aquifer, and dispersion acts to reduce peak concentrations.

Ground water modeling and analysis for this study necessarily follows the assumptions made for the runoff-sediment-contaminant transport model (see appendix D, D.3 Surface Water Modeling). Water infiltration into the bottom sediments of Water Canyon and the contaminant mass loading associated with that water as predicted by the runoff-sediment-contaminant transport model constitute the inputs to the vadose zone model for Water Canyon.

The discharge sink in Potrillo Canyon identified by Becker (Becker 1991) is taken to be the controlling feature in that canyon. Evidence in Becker (Becker 1991) demonstrated that all surface water from the Potrillo Canyon watershed above this feature drains to the subsurface very rapidly via the discharge sink (except for flood events with a recurrence frequency greater than a 1-in-10 year event). The mechanism that enables such large water intake rates to the subsurface is not well characterized. Becker (Becker 1991) concluded that the discharge sink is an area of increased sedimentation, that it contains significant amounts of uranium adsorbed onto the surface soils with depth, and that leaching and deep infiltration transport uranium (dissolved phase) to groundwater. Becker (Becker 1991) could only hypothesize as to the feature that creates the discharge sink, an underlying fault with a 29 ft (9 m) offset. Because no defensible mechanism can be proposed to account for the discharge sink's hydrologic behavior at this time, no attempt was made to model the discharge sink. Instead, the approach to stream flow losses in Potrillo Canyon was to compute the concentrations of contaminants in water arriving at the sink (as all water in the upper reach of Potrillo Canyon usually collects at the discharge sink), and if those concentrations are low enough to meet regulatory criteria, the evaluation is completed. If not, we would make the conservative assumption that contaminated water from the discharge sink is transferred instantly to the main aquifer (i.e., no credit for time delay and dispersion vadose zone), and examine the consequences of water supply well uptake or surface water discharge of contaminated water at the Rio Grande.

Water Canyon does not appear to exhibit any feature analogous to the discharge sink Becker discovered in Potrillo Canyon. Nor does Water Canyon appear to have a perched aquifer system, based on the dry Beta Hole located in Water Canyon adjacent TA-15 (ERP 1991; Purtymun 1995).

Therefore, it was decided that modeling the vadose zone below Water Canyon might enable evaluation of the downward flow of water and transport of contaminants from stream losses to the stream bed as predicted by the surface water and sediment transport analysis model.

Finally, the vadose zone from the firing sites atop Threemile Mesa to the main aquifer was modeled. The mesa top in the vicinity of DARHT and PHERMEX is over 300 ft (91 m) above the bottom of Water Canyon. Thus, a model of vadose zone flow and transport from the bottom of Water Canyon to the main aquifer simulates a significantly shorter pathway. However, the contaminant loading at the firing sites into the soil is large enough (e.g., infiltration carrying contaminants at their solubility limit) to require vadose zone flow and transport modeling also.

E4.2 VADOSE ZONE STRATIGRAPHY

There are no deep wells in TA-15 that would provide certain knowledge of the geologic stratigraphy at the DARHT, PHERMEX, or nearby Water Canyon and Potrillo Canyon locations (ERP 1993; Purtymun 1995). The closest wells that penetrate to the regional aquifer are the test wells DT-5A, DT-9, and DT-10 to the south of TA-15, and the municipal and industrial supply wells PM-2 and PM-4 located to the northeast of TA-15. Figure E4-1 depicts the locations of these wells and the DARHT and PHERMEX firing sites. A cross-section from test well DT-5A to supply well PM-4, based on well log data reported in Purtymun (Purtymun 1995), is shown in figure E4-2. The Tshirege, Otowi, and Guaje members are all sequences within the Bandelier Tuff. Figure E4-2 illustrates the transition in geologic units expected over the area in the vicinity of DARHT and PHERMEX. Based on this cross-section, the location of the DARHT site, and the anticipated stratigraphy reported by the ERP (ERP 1993), the expected geologic stratigraphy for this EIS was developed, and is shown in figure E4-3. The elevation axis at the left of figure E4-3 shows how the expected stratigraphy corresponds to elevation above mean sea level, and includes arrows to show the elevations at the DARHT and PHERMEX sites, Water Canyon (near Beta Hole), and the Potrillo Canyon discharge sink location. The water table elevation at 6000 ft (1830 m) (Purtymun 1984; Volzella 1994; ERP 1993; Purtymun 1995) is shown on the stratigraphic column at 800 ft (244 m) below the well head surface. The depth of the alluvium is designated as 8 ft (2 m) based on the geologic log of the Beta Hole (Purtymun 1995). The fingered layers of Basalt Unit 2 shown in figure E4-2 are assumed not to be present based on the stratigraphy presented in ERP (ERP 1993) and the trend of basalt layers fingered into the Fanglomerate Member of the Puye Formation to decrease from east to west as a result of the geologic processes in which they were laid down.

E4.3 VADOSE ZONE HYDROLOGIC PROPERTIES

The expected stratigraphy for Water Canyon depicted in figure E4-3 shows five hydrogeologic units in the vadose zone for which hydrologic properties are required for modeling purposes: alluvium, three members of the Bandelier Tuff (Tshirege, Otowi, and Guaje), and the Puye Formation. The properties required for water flow modeling are saturated hydraulic conductivity, porosity or saturated moisture content, residual moisture content, and the empirical curve-fitting van Genuchten (van Genuchten 1980) water retention parameters α and n for use in the water retention and liquid relative permeability models chosen for this analysis.

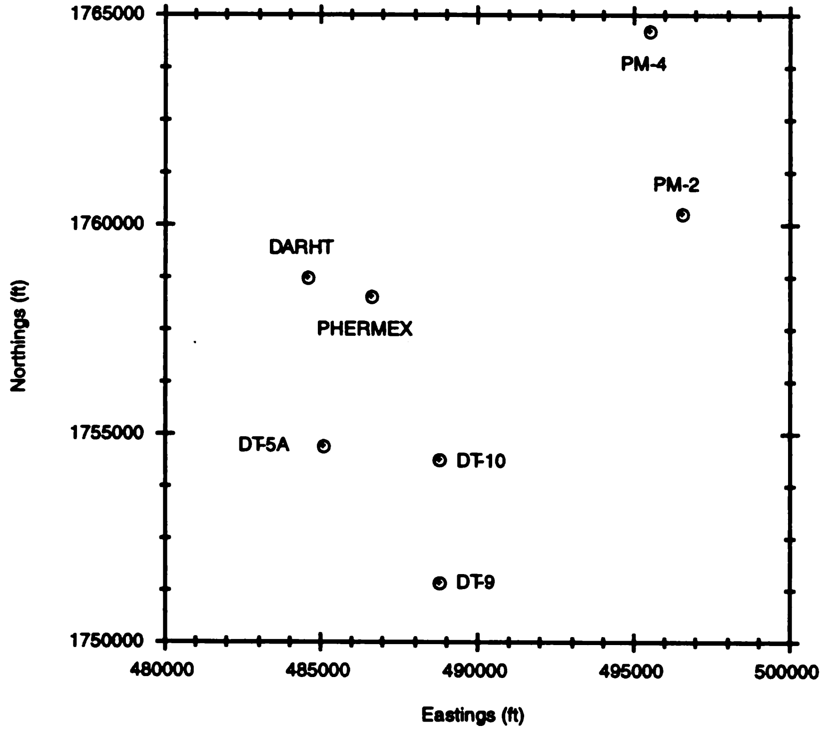

FIGURE E4-1.—*Locations of Deep Wells Relative to DARHT and PHERMEX Sites.*

TABLE E4-1.—*Hydrologic Properties for Vadose Zone Flow Modeling*

Stratigraphic Layer	Water Content Parameters		van Genuchten Model Parameters		Saturated Hydraulic Conductivity
	θ_r Residual	θ_s Saturated	α (1/m)	n	K_s (m/s)
Alluvium	0.038	0.433	3.85	1.558	4.40×10^{-6}
Tshirege	0.021	0.498	1.20	1.759	6.00×10^{-7}
Otowi	0.026	0.469	0.66	1.711	1.30×10^{-6}
Guaje	0.022	0.492	1.13	1.716	7.00×10^{-7}
Puye§	0.0283	0.4982	1.76	1.338	2.42×10^{-8}

θ_r Residual water content.
θ_s Saturated water content.
α Fitted van Genuchten parameter, 1/m.
n Fitted van Genuchten parameter.
K_s Saturated hydraulic conductivity, m/s.
§ Ringold Unit (WEN10 Rockhold et al. 1993) properties used as analogue for Puye Formation.

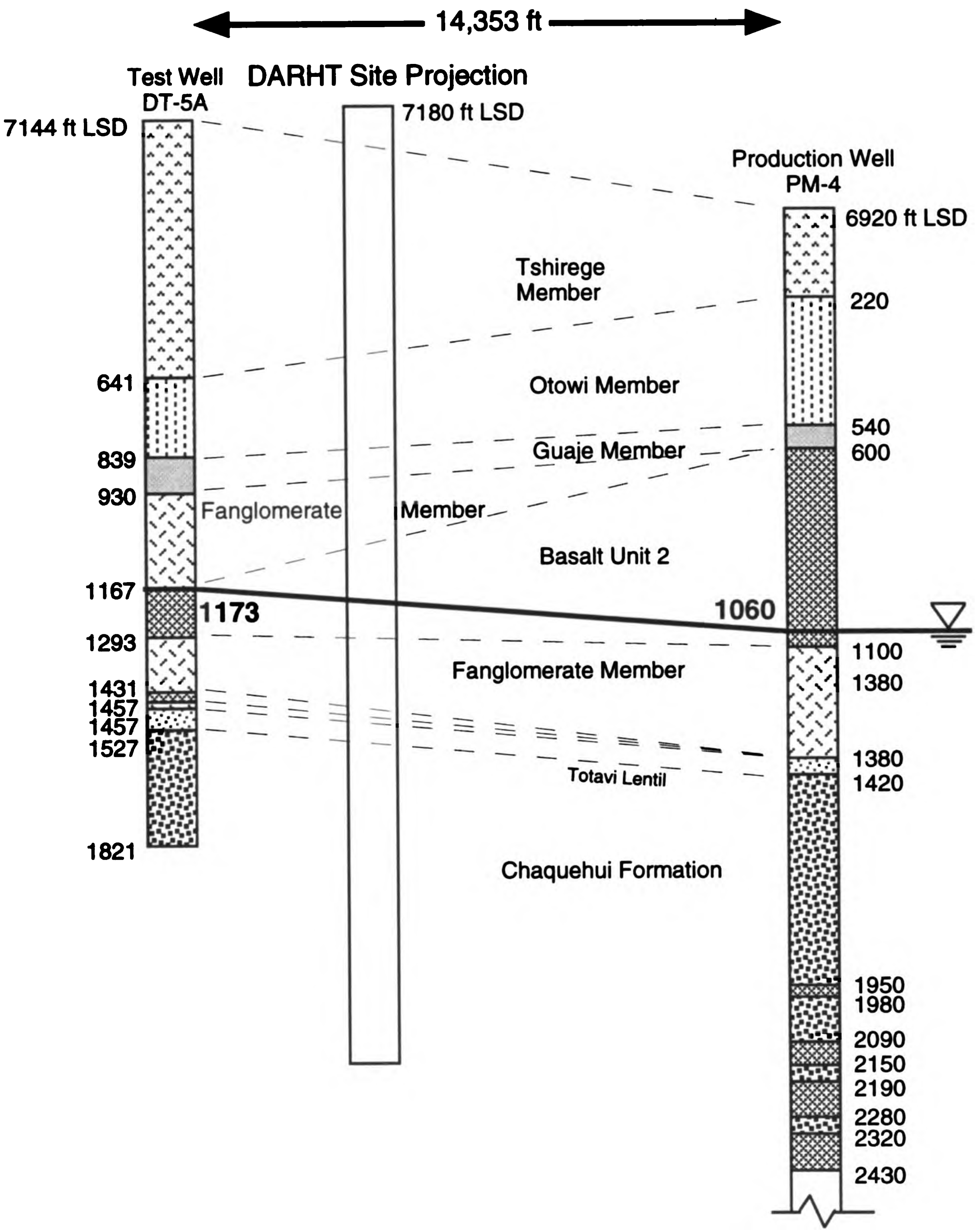

FIGURE E4-2.—*Stratigraphic Cross-Section from Test Well DT5A to Production Well PM-4, Indicating Projected Location of DARHT Site on the Cross Section.*

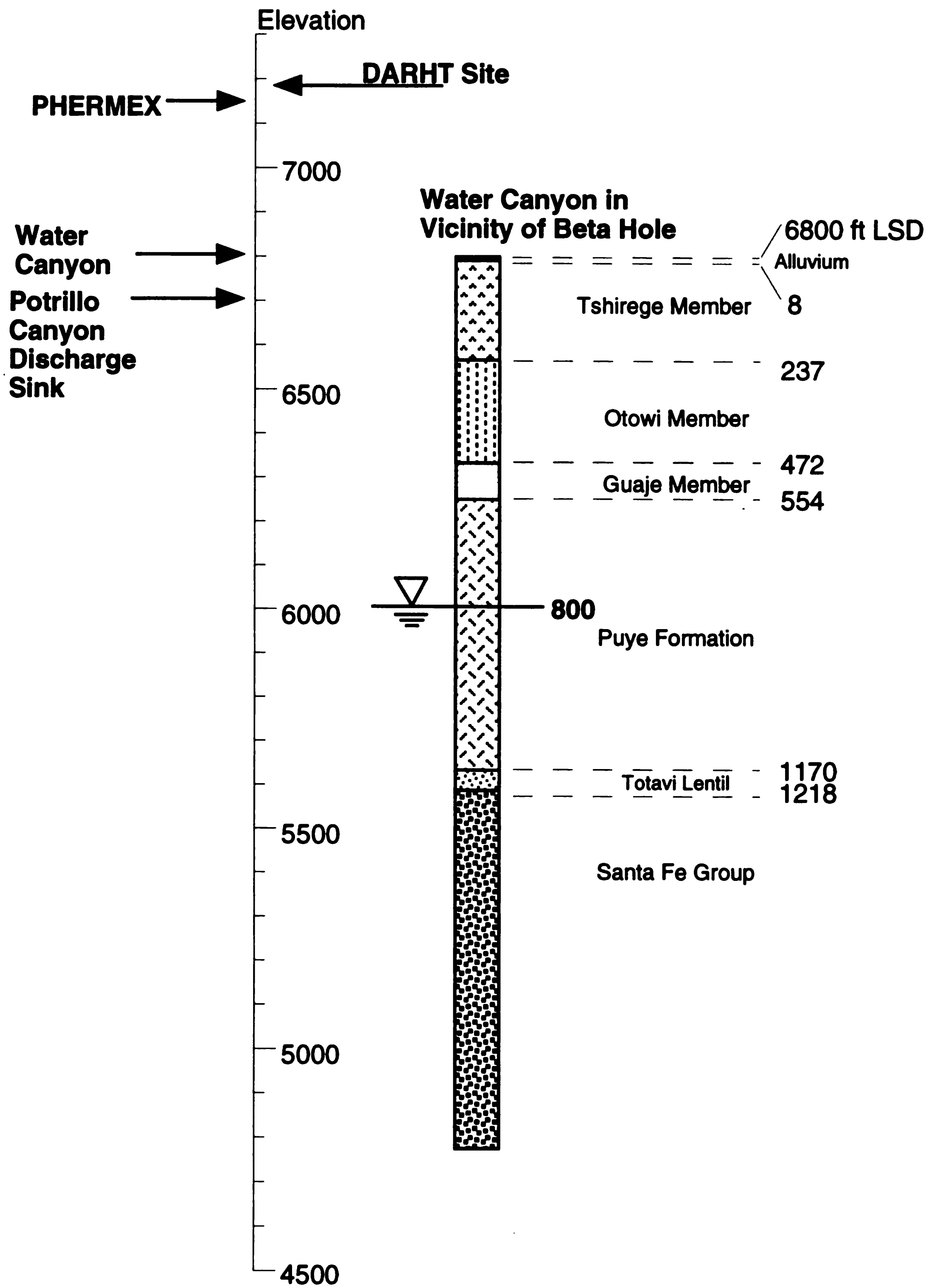

FIGURE E4-3.—*Expected Stratigraphy at Vicinity of Beta Hole in Water Canyon.*

Values for the vadose zone flow model parameters for each unit are reported in table E4-1. All values for the alluvium and Bandelier Tuff members are based on mean values reported in Rogers and Gallaher (Rogers and Gallaher 1995). No values were reported in that document directly for the Guaje Member, so the average of all Bandelier Tuff measurements was used to provide the hydrologic properties given in table E4-1 for the Guaje Member. Figure E4-4 provides the graphical interpretation of the water retention and relative permeability parameters by showing the retention and conductivity curves resulting from the use of the parameter values given in table E4-1.

No published hydrologic data, other than field coefficients of conductivity (Purtymun 1984), were found in the literature pertaining to the Puye Formation. The Puye Formation is derived from the Tschicoma volcanic centers located in the northeastern range of the Jemez Mountains. It consists of stream flow deposits, debris flow and block flow deposits, and ash fall and pumice fall deposits (ERP 1993). The hydrologic properties of a similar undifferentiated unit, the Ringold Unit found at the Hanford Site in Washington State, was chosen. The Ringold Unit is taken to be an analogue to the Puye Formation, and therefore properties used are largely approximate. Further precision will require a characterization and data collection program aimed at the Puye Formation and would only be necessary if the results of this analysis indicated that the unit imposed a significant control over the flow and transport results, which it did not. Properties for the Ringold Unit, reported in table E4-1, were taken from those reported in Rockhold et al. (Rockhold et al. 1993).

E4.4 VADOSE ZONE MODELING APPROACH

We modeled the vadose zone below Water Canyon and Threemile Mesa as one-dimensional vertical stratigraphic columns extending from the regional aquifer piezometric surface (water table) at the lower boundary to the surface of Water Canyon or Threemile Mesa at the upper boundary. The upper boundary was treated as a Neumann boundary with a constant water flux rate based on the average water infiltration predicted by the runoff-sediment-contaminant transport model. Temporal variation in water infiltration was neglected because such variation is greatly damped within a few meters of the surface. The lower boundary was treated as a Dirichlet boundary and assigned a constant atmospheric pressure to represent the presence of the water table. Fracture flow was neglected because published information on this flow mechanism is incomplete (Loeven and Springer 1992); fractures are sparse features where documented (Purtymun et al. 1978), and in the low-saturation regimes such as that modeled here, fractures constitute barriers to moisture flow rather than preferential pathways (Klavetter and Peters 1986).

A computer code was used to perform the flow and transport simulations. The code we chose was the Multiphase Subsurface Transport Simulator, or MSTS (White and Nichols 1993; Nichols and White 1993). The MSTS computer code was chosen based on the following considerations:

- MSTS solves the nonlinear water mass conservation equation for variably saturated media necessary to model the vadose zone
- MSTS was developed for the Yucca Mountain Site Characterization Project, a program concerned with deep vadose zone flow and transport in arid site volcanic tuff environments, characteristics similar to the site under consideration in this study

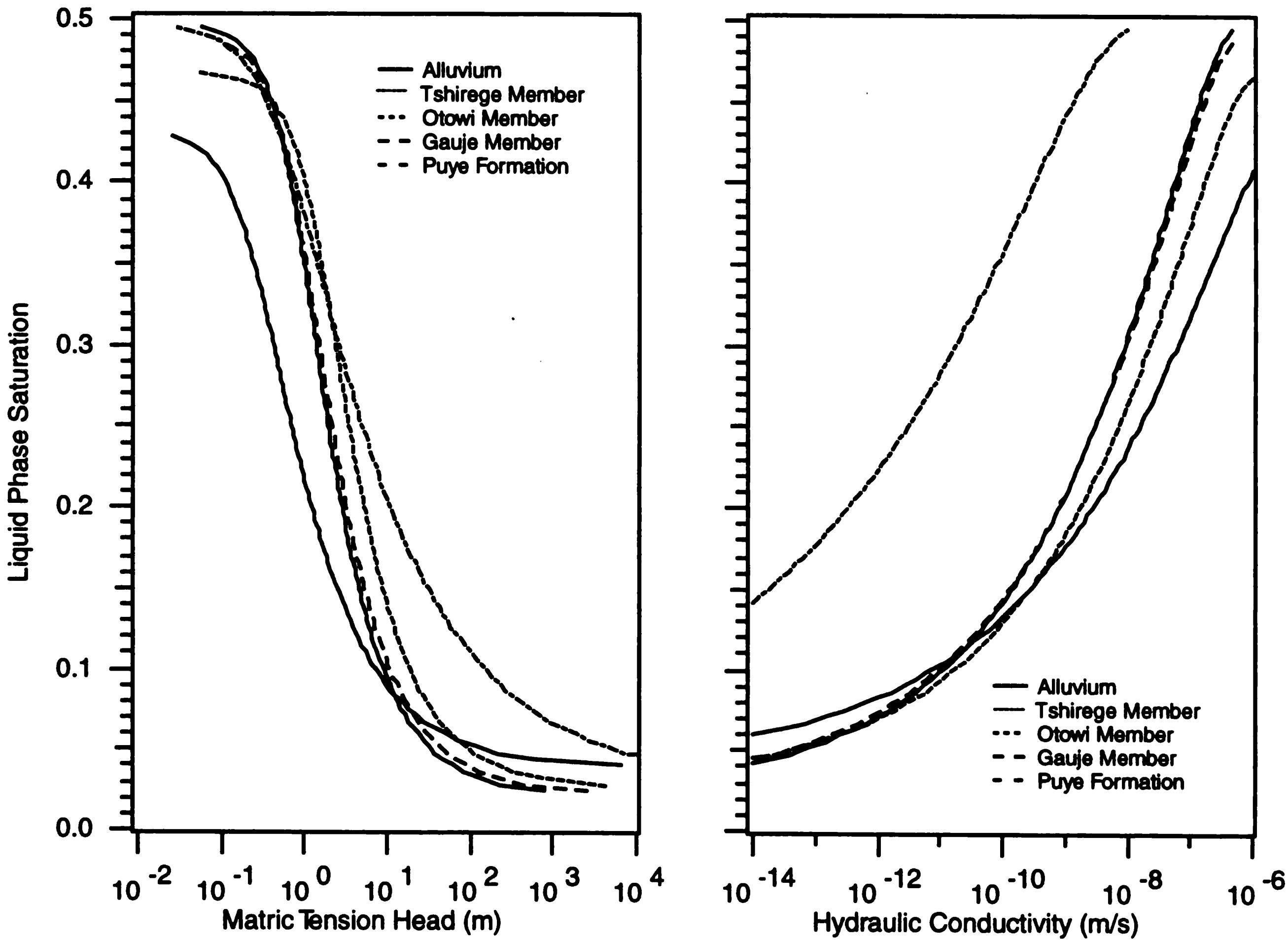

FIGURE E4-4.—*Unsaturated Water Retention and Relative Permeability Relationships for Vadose Zone Units.*

- MSTS simulates dilute species mass transport using a convection-dispersion model with linear sorption coupled with the water mass conservation simulation, providing an integrated capability for flow and transport modeling that is much simpler than using separate flow and transport models
- Radioactive decay in the transport equation (dilute species mass conservation equation) is accounted for by the MSTS code
- The code is well documented, has been favorably reviewed (Reeves et al. 1994), and has a proven track record for flow and transport simulation in the numerically difficult volcanic tuff environment (Eslinger et al. 1991).

Numerical stability criteria were examined to construct a grid of computational cells and enable stable simulation of water flow and contaminant transport for this vadose zone model. Calculations indicated that a grid discretization of 0.5 ft (0.15 m) or less would be required, yielding 1600 grid elements over the 800 ft (244 m) high stratigraphic column. Other calculations indicated that time steps for the transport simulations should not exceed 20 years to avoid numerical dispersion effects. Because the transport model was restricted to 1-yr time steps to match the temporal rate of contaminant mass loading resulting from the runoff-sediment-contaminant transport model, and 20-yr time steps after mass loading ended, this criteria presented no additional limitation.

E4.5 VADOSE ZONE FLOW MODEL RESULTS

Hydrologic conditions (e.g., water flow) in the unsaturated zone will depend on similar occurrences under any of the alternatives. For example, the presence of the DARHT and PHERMEX facilities does not affect the hydrology of Water Canyon appreciably, and infiltration would move water through Threemile Mesa at the either location of the firing point. Therefore, the results of the vadose zone flow simulations were performed first and the results reported here for all alternatives. Contaminant mass transport simulations that are based on the water pressure fields calculated here are reported with respect to individual alternatives in section 5.

A steady-state pressure field was simulated for Reach 12 of Water Canyon. Reach 12 in the surface water model is immediately downstream of the confluence of Cañon de Valle and Water Canyon (see appendix E3). Another was simulated for a location representative of the DARHT and PHERMEX elevations on Threemile Mesa. The surface elevation difference of the two sites was neglected; the firing sites differ in elevation by only 36 ft (11 m) (Fresquez 1994; Korecki 1988). The conditions vary in the different reaches of the Water Canyon model depending upon the water infiltration predicted in each reach by the runoff-sediment-contaminant transport model. The liquid-phase pressure and saturations predicted from the steady-state simulation with the MSTS code for Reach 12 are plotted in figure E4-5. The abrupt changes in pressure and saturation shown in figure E4-5 reflect the variations in hydrologic properties corresponding to the stratigraphic units identified. Liquid-phase mean travel time, that is, the mean time for water to travel from the base of Water Canyon to regional aquifer, was predicted with the MSTS code. Travel times for each reaches 12 and 13, and for the mesa-top-to-aquifer vadose zone model, are reported in table E4-2. Water travel times provide a upper bound on the arrival time of the mean concentration of a nonretarded, nondecayed contaminant. Retarded (sorbed) species, such as those under consideration in this study, will have even longer arrival times.

TABLE E4-2.—***Liquid Phase Vadose Zone Water Travel Times for Threemile Mesa and Water Canyon Reaches 12 and 13 Predicted by MSTS***

Vadose Zone	Water Travel Time (yr)
Threemile Mesa	298
Water Canyon Reach 12	179
Water Canyon Reach 13	174

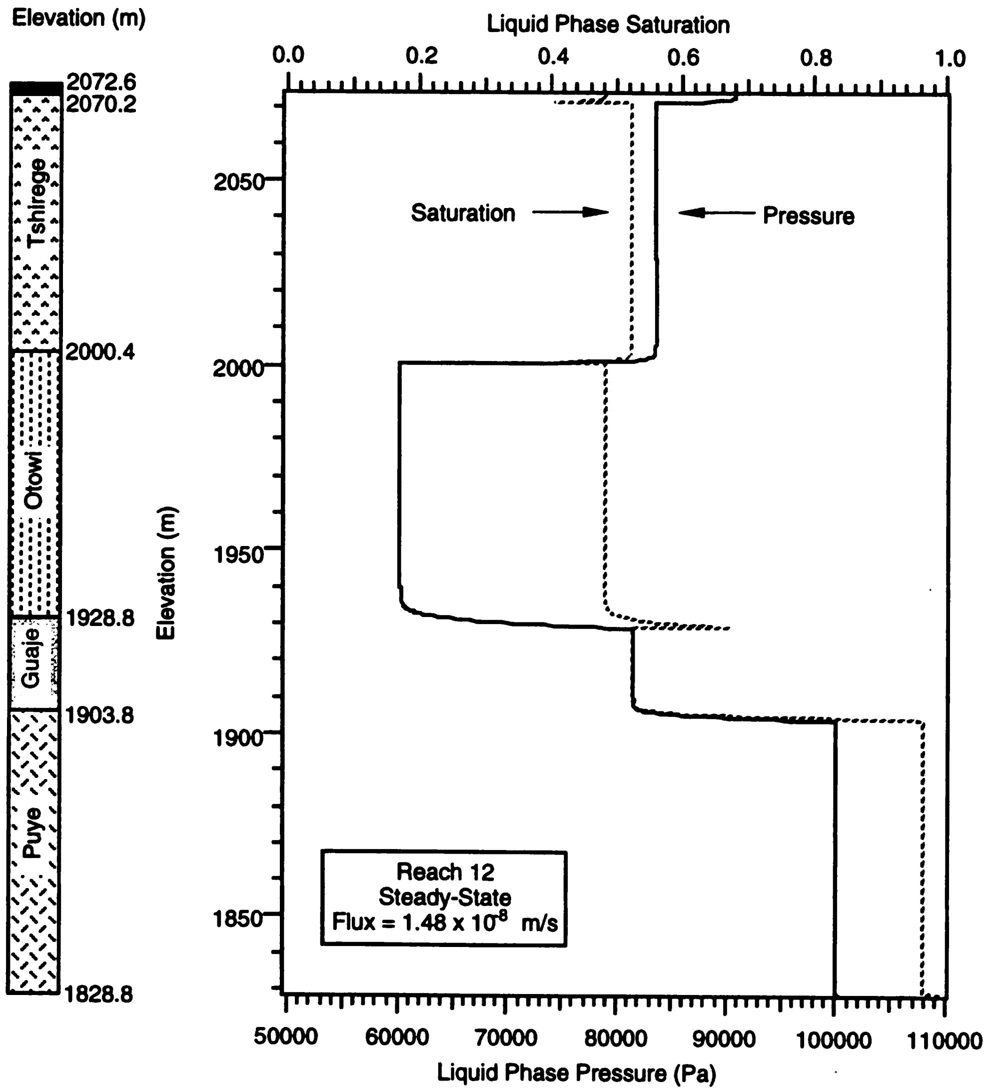

FIGURE E4-5.—*Liquid Phase Pressure and Saturation Profiles Predicted for Water Canyon Reach 12.*

E4.6 CONTAMINANT TRANSPORT SIMULATIONS

Review of the similarities between alternatives for the concentration of infiltration waters predicted by the runoff-sediment-contaminant transport model reduced the number of vadose zone contaminant transport cases that were necessary to simulate for this EIS. The ground-water impacts of the Plutonium Exclusion and Single-Axis Alternatives were the same as the Preferred Alternative; and the Upgrade PHERMEX Alternative was the same as the No Action Alternative. This review implied that simulations were necessary only under the No Action, Preferred, and Enhanced Containment Alternatives. For these three alternatives, the peak concentrations of depleted uranium, beryllium, and lead in water infiltrating into the vadose zone in the four reaches of Water Canyon downstream from the firing sites, and on Threemile Mesa at the firing sites, was compared to the proposed MCLs for these metals. Because transport and dispersion in the vadose zone will only further dilute the concentrations of these metals, it was necessary to simulate only those cases in which the concentration of infiltration water at the surface exceeded the MCL. Finally, comparison of concentrations of infiltration water in the four reaches of Water Canyon showed that the uppermost reach (Reach 12) was always subject to the highest infiltration contaminant concentration levels of the four reaches. Because no simulation of Reach 12 resulted in water concentrations at the regional water table exceeding a MCL for any contaminant, no simulation was necessary for the less-impacted reaches downstream. Thus, a total of 5 simulation cases were required: depleted uranium transport in Threemile Mesa for the No Action, Preferred, and Enhanced Containment Alternatives and depleted uranium in the uppermost reach of Water Canyon (Reach 12) for the No Action and Preferred Alternatives. We also simulated beryllium and lead transport on the mesa and in the uppermost reach of Water Canyon (though is was not necessary to do so) to examine the nature of environmental dispersion of these dissolved metal contaminants in the vadose zone.

Initial conditions for all simulations specified the liquid pressure field obtained for the respective reach or mesa top simulation (section E4.5, above) and zero contaminant concentration throughout the profile. Mass transport was simulated at 1-yr constant time steps (matching the temporal rate for which the contaminant mass input values were provided by the runoff-sediment-contaminant transport model) for 20 constant time steps for periods after mass input rates specified by the surface water model ceased (20 steps being the maximum permissible under the Courant Number stability criteria). Parameters related to dilute contaminant species mass transport include values of the sorption coefficient (K_d), longitudinal hydraulic dispersivity coefficient (α_L), and molecular dispersion coefficient ($D_{d,l}$). Sorption coefficient values were estimated in appendix E2 ("Solubility and Distribution Coefficients") where both conservative and best-estimate values were provided. We chose to use conservative (i.e., lesser sorption) values in all vadose zone modeling of contaminant transport. Hydrodynamic dispersion was estimated to be 262 ft (80 m). For moderate travel distances (on the order of kilometers), longitudinal dispersivity roughly varies between 0.01 and 0.1 of the mean travel distance of the solute. Choosing the more conservative values, with the travel distance through the vadose zone of 262 ft (800 m), we obtained the 262 ft (80 m) values. The molecular diffusion coefficient was that of water, 1.076×10^{-8} ft^2/s (1.0×10^{-5} cm^2/s).

Contaminant mass input rates were obtained from the results of the runoff-sediment-contaminant transport model. The infiltrated volume for each year reported by the runoff-sediment-contaminant transport model was multiplied by the corresponding water concentration of the infiltrated water, and divided by the channel reach area or the area for mass distribution around the firing point to obtain a value for annual mass flux per unit area. This value was converted to appropriate units for the vadose zone flow and transport code and treated as a mass source rate in the uppermost node of the model. For each simulated case, contaminant transport was modeled for 100,000 years. For depleted uranium, 1,000 years of mass input was provided, after which the surface supply of depleted uranium on the mesa surface and in the channel reaches was exhausted (the remainder of the simulation was carried out with no contaminant source term). For beryllium and lead 5,000 years of mass input was provided. For the simulation beyond 5,000 years, estimates (based on surface modeling) of the time to "plateau" for releases for beryllium and lead and average input concentrations thereafter were used to specify an average contaminant mass source rate and duration for the balance of the 100,000 year simulations. Table E4-3 presents the peak concentration of water arriving at the regional main aquifer for each simulated case and time of the peak occurrence, and the related MCL values. The

TABLE E4-3.—*Vadose Zone Numerical Transport Simulation Predicitions of Peak Concentrations (μg/L) and Associated Times for Water Arriving at the Regional Main Aquifer from the Vadose Zone for All Simulated Cases*

Alternative, Location	Contaminant		
	DU	**Be**	**Pb**
MCL	20 [56 FR 33050]	4 [40 CFR 141.62]	50 [40 CFR 141.11]
No Action, Threemile Mesa (PHERMEX)	145 (42,850 yr)	3.4 (>100,000 yr)	26 (55,740 yr)
No Action, Water Canyon Reach 12	0.017 (18,450 yr)	0.00069 (>100,000 yr)	2.6×10^{-6} (>100,000 yr)
Preferred, Threemile Mesa (DARHT)	81 (42,950)	3.1 (84,680)	6.3 (33,800)
Preferred, Water Canyon Reach 12	0.018 (18,430 yr)	0.0014 (>100,000 yr)	5.2×10^{-6} (>100,000 yr)
Enhanced Containment, Threemile Mesa (DARHT)	4.8 (42,940 yr)	0.43 (32,920 yr)	0.42 (29,320 yr)
Enhanced Containment, Water Canyon Reach 12	0	0.0014 (>100,000 yr)	5.2×10^{-6} (>100,000 yr)

significance of the arrival concentrations listed in table E4-3 is provided in the alternatives discussions in sections 5.1.4.2, 5.2.4.2, and 5.3.4.2.

E4.7 GROUND WATER ISSUES AT LANL

Two issues exist with respect to ground water resources in the vicinity of LANL. The first involves the recent discovery of tritium in the main aquifer at four points in the northern portion of the LANL site. The second involves the general observation that private ground water wells located north of Pojoaque can exhibit levels of alpha contamination in excess of drinking water standards.

E4.7.1 Tritium in the Main Aquifer

Since 1991, advanced techniques, not commonly applied to ground water samples, have been used to detect tritium at ultra-low levels and to determine that recent water (no more than a few decades old) has recharged the main aquifer from the land surface in several locations at LANL (Gallaher 1995). Many samples of well and spring water taken at LANL have shown only the natural background levels of tritium and no apparent recent recharge. However, four locations have indicated tritium migration to the main aquifer from overlying contaminated perched aquifers. The levels of tritium measured range from approximately one percent to less than a hundredth of a percent of current drinking water standards. Thus, measured levels of tritium are significantly below drinking water standards and below levels measurable using standard measurement techniques. All four confirmed main aquifer tritium measurements indicating young water are in Los Alamos, Pueblo, and Mortandad Canyons, all in the northern part of the Los Alamos site. No main aquifer samples from the southern portion of the site have shown tritium concentrations above natural background. LANL scientists are studying whether the communication between intermediate perched and deep aquifer formations is a result of poor well construction (leaks in well bore seals with casing) or recharge of the main aquifer through either fractures or faults. If the ongoing studies determine the old construction methods are resulting in communication, efforts may be undertaken to abandon and plug the older test wells (Gustafson 1995).

E4.7.2 Alpha Concentrations in Regional Ground Water

High alpha concentrations have been observed in ground water drawn from private wells in the vicinity of Nambe and Pojoaque, New Mexico (Nickeson 1994). These wells are located on the opposite side of the Rio Grande from LANL and to the north of Pojoaque. The relationship between LANL activities and the observed alpha concentrations was questioned at the DARHT public hearings. Nickeson noted there was no one to blame for the high alpha concentrations found in her well water. The levels found are related to the abundance of naturally occurring uranium deposits in the highly volcanic region of northern New Mexico. The Santa Fe Reporter (Bird 1995) presented a broader portrait of the high alpha contamination problem in the region, and its relation to natural uranium levels in the region. Bird indicated that the Ground Water Division of the Environment Department (State of New Mexico) was being asked to consider a study of the area's private wells. Such a study may relate the levels of natural uranium in the aquifer formation to levels observed in ground water, determine the origin of ground water in the Pojoaque area (i.e., origin to the east or west of the Rio Grande), or determine isotopic ratios of uranium species (i.e., identifying natural versus depleted uranium sources, man-made isotopes or other alpha emitters). Because it is a regional water quality issue and is acknowledged by State of New Mexico officials as being related to natural uranium levels, resolution of this issue is clearly beyond the scope of the DARHT EIS.

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Appendix F

Biotic Resources

APPENDIX F
BIOTIC RESOURCES

This appendix presents the plant and animal species found in the Los Alamos National Laboratory (LANL) area by biological surveys as reported by Dunham (1995) and Risberg (1995). The list may not be complete; some species in the LANL area may not have been found or identified during these surveys or, if listed, may not presently be found in the area.

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TABLE F-1.—*Checklist of Plants at TA-15 Proposed DARHT Site*

Family	Scientific Name[a]	Common Name
Aceraceae	*Acer glabrum* *Acer negundo*	New Mexico maple Boxelder maple
Amaranthaceae	*Amaranthus retroflexus*[c]	Pigweed
Anacardiaceae	*Rhus trilobata*	Skunk bush
Asclepiadaceae	*Asclepias asperula*	Immortal
Berberidaceae	*Berberis fendleri*	Colorado barberry
Boraginaceae	*Cryptantha fendleri* *C. jamesii* *Hackelia hirsuta* *Lappula sp.*[b] *Lithospermum incisum* *L. multiflorum*	Fendler cryptantha James hiddenflower Beggarlice Stickseed Fringed puccoon Puccoon
Cactaceae	*Echinocereus viridiflorus* *Opuntia polyacantha* *O. sp.*[c]	Strawberry cactus Starvation cactus Prickly pear cactus
Chenopodiaceae	*Atriplex canescens* *Chenopodium album* *C. graveolans* *Kochia scoparia* *Salsola kali*	Fourwing saltbush Lamb's quarters Goosefoot Summer cypress Russian thistle
Compositae	*Achillea lanulosa* *Ambrosia artemisiifolia* *A. confertiflora* *A. coronopifolia* *Antennaria parvifolia* *Artemisia carruthii* *A. dracunculus* *A. frigida*[c] *A. ludoviciana* *A. tridentata*[c] *Aster bigelovii* *A. novae-angliae* *Bahia dissecta* *Berlandiera lyrata* *Brickellia californica* *B. sp.* *Cichorium intybus* *Chyrsopsis foliosa* *C. villosa* *Chrysothamnus nauseosus* *Conyza canadensis*	Western yarrow Common ragweed Ragweed Ragweed Pussytoes Wormwood False tarragon Estafiata Wormwood Big sagebrush Bigelow aster Aster Wild chrysanthemum Lyre leaf California brickellia Bricklebush Chickory Golden aster Golden aster Chamisa, Rabbitbrush Horseweed

TABLE F-1.—*Checklist of Plants at TA-15 Proposed DARHT Site – Continued*

Family	Scientific Name[a]	Common Name
Compositae (Continued)	*Erigeron divergens*	Fleabane daisy
	Grindelia aphanactis	Gumweed
	Gutierrezia sarothrae	Snakeweed
	Haplopappus spinulosus	Spiny goldenweed
	Helianthus petiolaris	Sunflower
	Hymenopappus filifolius	White ragweed
	Hymenoxys argentea	Perky Sue
	H. richardsonii	Bitterweed
	Kuhnia chlorolepis	Kuhnia
	Lactuca sp.	Prickly lettus
	Machaeranthera bigelovii	Bigelow aster
	Pericome caudata	Taperleaf
	Psilostrophe tagetina	Paperflower
	Senecio eremophilus	Groundsel
	S. longilobus	Thread-leaf groundsel
	S. multicapitatus	Groundsel
	Stephanomeria tenuifolia	Skeleton weed
	Taraxacum officinale	Dandelion
	Thelesperma megapotamicum	Indian tea
	T. trifidum[c]	Greenthread
	Townsendia exscapa	Easter daisy
	Tragopogon dubius	Salisfy, Goatsbeard
	T. pratensis	Salsify
	Viguiera multiflora	Showy goldeneye
Cruciferae	*Capsella bursa-pastoris*	Shepherd's purse
	Descurania richardsonii	Tansy mustard
	Erysimum capitatum	Western wallflower
	Lepidium medium	Peppergrass
	Thlaspi alpestre	Mountian candytuft
Cupressaceae	*Juniperus monosperma*[c]	One-seed juniper
	J. scopulorum	Rocky Mountain juniper
Cyperaceae	*Carex sp.*	Sedge
Euphorbiaceae	*Croton texensis*	Doveweed
	Euphorbia serpyllifolia	Thymeleaf spurge
	E. sp.	Spurge
Fagaceae	*Quercus gambelii*	Gambel oak
	Q. undulata	Wavyleaf oak
	Q. sp.	Hybrid oak
Fumariaceae	*Corydalis aurea*	Golden smoke
Geraniaceae	*Erodium cicutarium*	Cranesbill
	Geranium caespitosum	James geranium

TABLE F-1.—*Checklist of Plants at TA-15 Proposed DARHT Site – Continued*

Family	Scientific Name[a]	Common Name
Gramineae	*Agropyron smithii* *Andropogon gerardii* *A. scoparius* *Aristida sp.* *Blepharoneuron tricholepis* *Bouteloua curtipendula*[c] *B. eriopoda* *B. gracilis* *Bromus anomalus* *B. tectorum* *Elymus canadensis* *Festuca sp.* *Koeleria cristata* *Lycurus phleoides* *Muhlenbergia montana* *Oryzopsis hymenoides* *Poa fendleriana* *Poa sp.* *Sitanion hystrix* *Sporobolus contractus* *S. cryptandrus* *S. sp.* *Stipa comata*	Western wheatgrass Big bluestem Little bluestem Three-awn Pine dropseed Side-oats grama Black grama Blue grama Nodding brome Downy Chess Canada wildrye Fescue Junegrass Wolftail Mountain muhly Indian rice grass Bluegrass Blue grass Bottlebrush squirreltail Spike dropseed Sand dropseed Dropseed Needle and thread grass
Hydrophyllaceae	*Phacelia corrugata*	Scorpionweed
Labiatae	*Monarda menthaefolia*[c] *M. pectinata* *Prunella vulgaris*	Beebalm Ponymint Selfheal
Leguminosae	*Astragalus sp.* *Lotus wrightii* *Lupinus caudatus* *Melilotus albus* *M. officinalis* *Petalostemum candidum*[c] *Robinia neomexicana*[c] *Trifolium sp.* *Vicia americana*	Milkvetch Deervetch Lupine Yellow sweet clover Yellow wild clover White prairie clover New Mexico locst Clover American vetch
Liliaceae	*Allium cernuum* *Yucca angustissima* *Y. baccata*[c]	Nodding onion Narrowleaf yucca Datil yucca
Linaceae	*Linum lewisii* *L. neomexicanum*	Blue flax New Mexico yellow flax
Loasaceae	*Mentzelia pumila*	Stickleaf

TABLE F-1.—*Checklist of Plants at TA-15 Proposed DARHT Site – Continued*

Family	Scientific Name[a]	Common Name
Malvaceae	*Sphaeralcea coccinea* *S. sp*	Red globe mallow Scarlet globe mallow
Nyctaginaceae	*Mirabilis multiflora* *Oxybaphus linearis*	Showy four-o'clock Desert four-o'clock
Oleaceae	*Forestiera neomexicana*	New Mexico olive
Onagraceae	*Oenothera albicaulis* *O. coronopifolia* *O. hookeri*	Evening-primrose Cutleaf evening-primrose Hooker's evening-primrose
Orobanchaceae	*Orobanche fasciculata*	Broomrape
Pinaceae	*Abies concolor*[c] *Pinus edulis*[c] *P. ponderosa* *Pseudotsuga menzesii*[c]	White fir Piñon pine Ponderosa pine Douglas fir
Plantaginaceae	*Plantago purshii*	Wooly Indian wheat
Polemoniaceae	*Ipomopsis aggregata*	Scarlet trumpet
Polygonaceae	*Eriogonum cernuum* *E. jamesii* *Rumex sp.*	Skelton weed Antelope sage Dock
Portulacaceae	*Portulaca oleracea*[c]	Common purslane
Primulaceae	*Androsace septentrionalis*	Western rock-jasmine
Ranunculaceae	*Clematis pseudoalpina* *Thalictrum fendleri*	Rocky Mountain clematis Meadowrue
Rosaceae	*Cercocarpus montanus*[c] *Fallugia paradoxa*[c] *Prunus virginiana var. melanocarpa* *Rosa woodsii*	Mountain mahogany Apache plume Western black chokecherry Fendler's rose
Rutaceae	*Ptelea trifoliata*	Narrowleaf hoptree
Salicaceae	*Populus angustifolia* *Salix sp.*[c]	Narrowleaf cottonwood Willow
Saxifragaceae	*Heuchera parvifolia* *Philadelphus microphyllus* *Ribes cererum* *R. inerme*	Alumroot Mockorange Wax Current Gooseberry

TABLE F-1.—*Checklist of Plants at TA-15 Proposed DARHT Site – Continued*

Family	Scientific Name[a]	Common Name
Scrophulariaceae	*Castilleja integra* *Penstemon barbatus* *P. virgatus* *Verbascum thapsus*	Indian paintbrush Scarlet bugler Beard tongue Mullein
Solanaceae	*Physalis foetens var. neomexicana*[c]	Ground cherry
Valerianaceae	*Valeriana acutiloba*	Valerian
Violaceae	*Viola adunca*	Western dog violet
Vitaceae	*Parthenocissus inserta*	Virginia creeper

[a] The scientific names presented here are based on information contained in *A Flora of New Mexico* (Martin and Hutchins 1980).
[b] Sp. indicates that the exact species has not been identified in the field.
[c] These plants have been known to be used historically by the Tewa Indians of New Mexico in the early part of the 20th century (Larson 1995).

Notes: This plant list was compiled from 1992 Level 2 surveys and the previous surveys listed below
1. *Long-term Ecological Effects of Exposure to Uranium* (Hanson/Miera 1976)
2. *Further Studies of Long-term Ecological Effects of Exposure to Uranium* (Hanson/Miera 1978)
3. *Water Canyon, Endangered Species Study* (Foxx and Tierney 1978)
4. *Status of the Flora of the Los Alamos National Environmental Research Park*, Vol. I (Foxx/Tierney 1980)
5. *Post Fire Recovery and Mortality* (Potter/Foxx 1981)
6. *Effects of Fire on Small Mammals* (Guthrie 1981)
7. *Effects of Clearing Fire-Killed Trees* (Moeur/Guthrie 1981)
8. *Floristic Composition and Plant Succession on Near Surface Radioactive Waste Disposal Sites* (Tierney/Foxx 1982)
9. *Status of the Flora of the Los Alamos National Environmental Research Park*, Vol. II (Foxx/Tierney 1984)
10. *Biological and Wetland Assessment for RCRA Mixed Waste Facility* (Cross 1993)
11. *Biological and Wetland Assessment for OU 1144* (Raymer 1993)

Source: Risberg 1995.

TABLE F-2.—*Fauna Found at TA-15*

Family	Scientific Name	Common Name
Amphibians		
Hylidae	*Hyla arenicolor*	Canyon treefrog
Reptiles		
Iguanidae	*Crotaphytus collaris*	Collared lizard
	Phrynosoma douglasii	Short-horned lizard
	Sceloporus undulatus	Eastern fence lizard
Scincidae	*Eumeces obsoletus*	Great Plains skink
Teiidae	*Cnemidophorus exsanguis*	Chihuahuan spotted whiptail
Viperidae	*Crotalus atrox*	Western diamondback rattlesnake
Birds		
Accipitridae	*Accipiter cooperii*	Cooper's hawk
	Buteo albonotatus	Zone-tailed hawk
	B. jamaicensis	Red-tailed hawk
Aegithalidae	*Psaltriparus minimus*	Bushtit
Apodidae	*Aeronautes saxatalis*	White-throated swift
Caprimulgidae	*Chordeiles minor*	Common nighthawk
	Phalaenoptilus nuttallii	Common poorwill
Carthartidae	*Cathartes aura*	Turkey vulture
Columbidae	*Zenaida macroura*	Mourning dove
Corvidae	*Aphelocoma coerulescens*	Scrub jay
	Corvus corax	Common raven
	Cyanocitta stelleri	Steller's jay
	Gymnorhinus cyanocephalus	Piñon jay
	Nucifraga columbiana	Clark's nutcracker
Emberizidae	*Aimophila ruficeps*	Rufous-crowned sparrow
	Coccothraustes vespertinus	Evening grosbeak
	Dendroica graciae	Grace's warbler
	D. nigrescens	Black-throated gray warbler
	Guiraca caerulea	Blue grosbeak
	Junco hyemalis	Dark-eyed junco
	Molothrus ater	Brown-headed cowbird
	Oporornis tolmiei	MacGillivray's warbler
	Pheucticus melanocephalus	Black-headed grosbeak
	Pipilo chlorurus	Green-tailed towhee
	P. erythrophthalmus	Rufous-sided towhee
	P. fuscus	Canyon towhee

TABLE F-2.—*Fauna Found at TA-15 – Continued*

Family	Scientific Name	Common Name
Emberizidae (continued)	*Piranga ludoviciana*	Western tanager
	Spizella passerina	Chipping sparrow
	Vermivora celata	Orange-crowned warbler
	V. virginiae	Virginia's warbler
Falconidae	*Falco sparverius*	American kestrel
Fringillidae	*Cardeulis pinus*	Pine siskin
	Carpodacus mexicanus	House finch
	C. psaltria	Lesser goldfinch
	Loxia curvirostra	Red crossbill
Hirundinidae	*Tachycineta thalassina*	Violet-green swallow
	Hirundo pyrrhonota	Cliff swallow
Miscicapidae	*Catharus guttatus*	Hermit thrush
	Myadestes townsendi	Townsend's solitaire
	Polioptila caerulea	Blue-grey gnatcatcher
	Regulus calendula	Ruby-crowned kinglet
	Sialia mexicana	Western bluebird
	Turdus migratorius	American robin
Paridae	*Parus gambeli*	Mountain chickadee
	P. inornatus	Plain titmouse
Phasianidae	*Callipepla gambelii*	Gambel's quail
Picidae	*Colaptes auratus*	Northern flicker
	Melanerpes formicivorus	Acorn woodpecker
	Picoides pubescens	Downy woodpecker
	P. villosus	Hairy woodpecker
Sittidae	*Sitta pygmaea*	Pygmy nuthatch
Strigidae	*Bubo virginianus*	Great horned owl
	Otus flammeolus	Flammulated owl
Trochilidae	*Archilocus alexandri*	Black-chinned hummingbird
	Selasphorus platycercus	Broad-tailed hummingbird
Troglodytidae	*Catherpes mexicanus*	Canyon wren
	Salpinctes obsoletus	Rock wren
	Thryomanes bewickii	Bewick's wren
Tyarannidae	*Contopus borealis*	Olive-sided flycatcher
	C. sordidulus	Western wood-pewee
	Empidonax hammondii	Hammond's flycatcher
	E. oberholseri	Dusky flycatcher
	E. occidentalis	Cordilleran flycatcher
	E. wrightii	Gray flycatcher
	Myiarchus cinerascens	Ash-throated flycatcher

TABLE F-2.—*Fauna Found at TA-15 – Continued*

Family	Scientific Name	Common Name
Tyarannidae (continued)	*Sayornis nigricans* *S. saya* *Tyrannus vociferans*	Black phoebe Say's phoebe Cassin's kingbird
Vireonidae	*Vireo gilvus* *V. solitarius*	Warbling vireo Solitary vireo
Mammals		
Canidae	*Canis latrans* *Vulpus vulpus*	Coyote Red fox
Cervidae	*Cervus elaphus* *Odocoileus hemionus*	Elk Mule deer
Muridae	*Neotoma mexicana* *Peromyscus boylei* *P. maniculatus* *P. truei* *Reithrodontomys megalotis*	Mexican woodrat Brush mouse Deer mouse Piñon mouse Western harvest mouse
Molossidae	*Tadarida brasiliensis*	Brazilian free-tailed bat
Vespertilionidae	*Antrozous pallidus* *Eptesicus fuscus* *Lasionycteris noctivagans* *Lasiurus cinereus* *Myotis californicus* *M. evotis* *M. leibi* *M. thysanodes* *M. volans* *M. yumanensis* *Pipistrellus hesperus* *Plecotus townsendi*	Pallid bat Big brown bat Silver-haired bat Hoary bat California myotis Long-eared myotis Small-footed myotis Fringed myotis Long-legged myotis Yuma myotis Western pipistrelle Townsend's big-eared bat

For bird habitats see Travis, J. R., Atlas of the Breeding Birds of Los Alamos County, New Mexico Pajarito Ornithological Survey.

Source: Dunham 1995

TABLE F-3.—*Wintering Birds of Potrillo Canyon, February and March 1986*

Family	Scientific Name	Common Name
Accipitridae	*Buteo jamaicensis*	Red-tailed hawk
Columbidae	*Zenaida macroura*	Mourning dove
Corvidae	*Aphelocoma coerulescens*	Scrub jay
	Corvus corax	Common raven
Fringillidae	*Carpodacus mexicanus*	House finch
	Junco hyemalis	Dark-eyed junco
	Pipilo erythrophthalmus	Rufous-sided towhee
	P. fuscus	Brown towhee
Meleagrididae	*Meleagris gallopavo*	Wild turkey
Paridae	*Parus gambeli*	Mountain chickadee
	P. inornatus	Plain titmouse
Picidae	*Colaptes auratus*	Yellow-shafted flicker
	Picoides pubescens	Downy woodpecker
	P. villosus	Hairy woodpecker
	Sphyrapicus thyroideus	Williamson's sapsucker
Sittidae	*Sitta carolinensis*	White-breasted nuthatch
	S. pygmaea	Pygmy nuthatch
Troglodytidae	*Catherpes mexicanus*	Canyon wren
	Troglodytes aedon	House wren
Turdidae	*Myadestes townsendi*	Townsend's solitaire
	Sialia currucoides	Mountain bluebird
	S. mexicana	Western bluebird
	Turdus migratorious	American robin

For Bird habitats see Travis, J. R., Atlas of the Breeding Birds of Los Alamos County, New Mexico, Pajarito Ornithological Survey.

Source: Dunham 1995

Appendix G
Socioeconomics

APPENDIX G
SOCIOECONOMICS

G.1 REGIONAL ECONOMIC MODELING

The IMPLAN (Impact analysis for Planning) regional economic modeling system was used to construct a baseline economic model for the region-of-interest, and to measure the possible impacts of EIS alternatives on regional employment, labor income, and output of goods and services. The stock regional IMPLAN model uses Standard Industrial Classification (SIC) information provided by the Bureau of Economic Analysis (BEA) on employment, income, and production activities within the region-of-interest, which in this case is Los Alamos, Santa Fe, and Rio Arriba counties of north-central New Mexico.

IMPLAN employs a static, non-survey, input-output model which uses a 528-sector adaptation of the 538-sector BEA national input-output transactions table otherwise known as the "national table". This table was derived by BEA based on information from its national income and product accounts (NIPA accounts) covering the production and sales of all commodities. The most recent national table was released by BEA in 1994 and represents the industrial technologies in place in 1987. These values have been price-updated to 1994 constant dollars. IMPLAN provides the flexibility to update the 1987-level technology of any industry, as represented in the national table, to an improved representation of the technology currently being employed. IMPLAN also performs adjustments to the national table to permit regional tables to be constructed for application to any region of the country.

Among the more important considerations in applying the stock IMPLAN model are that: 1) the model is static in the sense of reflecting economic conditions and production technologies in place at a given point in time, with no allowance for technological changes; 2) the model uses exogenous estimates of "regional repurchasing coefficients," (RPCs) critical parameters reflecting the locally produced portion of goods or services used by industry in the region-of-interest; 3) the model characterizes all industrial production processes as requiring fixed proportional use of factors of production, making no allowances for input substitutions due to relative-price changes.

This stock IMPLAN model was modified to reflect 1993 levels of economic activity specific to the tri-county area based on two additional data files: 1) ES-202 employment data obtained from New Mexico Department of Labor, which covers 1993 annualized employment levels at the two-digit SIC level; and 2) published information on regional consumption expenditures made by LANL during FY 1992, as described in a DOE-funded study (Lansford et al. 1993). The modified IMPLAN model of the region-of-interest reflects these additional county-level data files and, correspondingly, the recent experience underlying employment and expenditures within the tri-county region.

The stock IMPLAN model was also adjusted to better approximate the local economic impacts of incremental construction and operations expenditures under each EIS alternative. These adjustments bear on the accuracy of IMPLAN's RPCs for heavy construction (SIC 16) and facility operations (SIC 28). Based on DARHT's local construction expenditures during FY 1993, IMPLAN's RPC for heavy construction was adjusted downward to 0.15. This parameter adjustment provides a more realistic estimate of the RPC for heavy construction in the region-of-interest. On the contrary, IMPLAN's RPC for industrial facility operations was adjusted upward to 0.80. This upward adjustment reflects the understanding that most of PHERMEX's local expenditures are on specialized equipment made onsite at other LANL defense production facilities.

Given the above adjustments, the modified IMPLAN model was run with alternative expenditure scenarios in order to estimate the consequential impacts of the various EIS alternatives on regional employment, labor income, and output of goods and services. These alternative data sets reflect the following expenditures information provided by LANL: 1) annual capital and operating expenditures for the DARHT and PHERMEX facilities under each EIS alternative (tables G-1 and G-2); and 2) estimated duration of construction and timing of operations for the DARHT and PHERMEX facilities under each EIS alternative. Upon applying a DOE price escalation index for general construction and defense programs to these alternative expenditure projections, IMPLAN was run to estimate the consequential impacts of each DARHT alternative on employment, labor income, and output of goods and services in the region-of-interest for each year in the 1995 to 2002 period. These impacts are reported by year for that period (see table G-3).

G.2 ENVIRONMENTAL JUSTICE ANALYSIS

The geographic region underlying the analysis of environmental justice encompasses various Census tracts spanning four county boundaries, i.e., Los Alamos, Santa Fe, Rio Arriba, and Sandoval counties. Census tract boundaries within these counties are derived from a coverage of census block group boundaries provided by Geographic Data Technology, Lebanon, New Hampshire. This coverage was derived from the TIGER/Line Files of 1990 census geography provided by the U.S. Bureau of Census. In addition, the geographic region underlying the analysis of environmental justice encompasses the Native American reservations of the Cochiti, Santa Clara, Jemez, and San Ildefonso DOE/LANL accord tribes. The geographic boundaries of these reservations were derived from digital data provided by the Bureau of Indian Affairs.

Note that the scope of coverage used in the analysis excludes boundaries or locations of several categories of lands that are generally associated with tribal lands: 1) ceded lands (lands ceded to the U.S. Government to which some tribes retain treaty-protected rights); 2) possessory and usage areas that were established, in some cases, in the course of U.S. Land Claims Commission hearings; and 3) in-holdings within the tribal reservation boundaries. Such in-holdings are lands not held in trust for tribes. These may include fee lands owned by non-Indians, or public domain lands withdrawn from their former trust status (e.g., for National Park Service management or interstate highway rights-of-way).

Given the geographic coverage described above, the following demographic data were used to measure minority and low-income populations: total persons (100 percent count), total households, persons by race, persons by Race and Hispanic Origin, and household counts by income class. The data were extracted from Summary Tape File 3A of the 1990 decennial census, provided by the U.S. Bureau of Census for census block groups. Each block group is identified by its unique block group identifier and the Federal Information Procedures System (FIPS) identifier for American Indian and Alaska Native Area (AIANAFP). The block group data were then aggregated by tracts generally, and by tracts for the Cochiti, Jemez, San Ildefonso, and Santa Clara Reservation populations only.

Minority population distributions were derived using census tract data on race and Hispanic origin. The size of the minority population within a specific scope of coverage [10, 30, or 50 mi (16, 48, or 80 km)]

TABLE G-1.—*Capital-Funded Construction Costs by Alternative (in millions of 1994 dollars)*

Alternative	1995	1996	1997	1998	1999	2000	2001	2002
No Action	6.61	5.88	1.04	0	0	0	0	0
Preferred	6.61	18.93	18.38	22.81	20.29	0.70	0	0
PHERMEX Upgrade	6.61	26.89	29.23	11.61	8.57	10.84	3.37	0
Enhanced Containment (vessels)	6.61	19.13	33.38	37.81	21.18	0.70	0	0
Enhanced Containment (150-ton bldg.)	6.61	21.61	35.70	23.01	9.96	15.12	0.66	0
Enhanced Containment (500-ton bldg.)	6.61	22.54	39.41	27.04	10.62	15.21	0.67	0
Plutonium Exclusion	6.61	18.93	18.38	22.81	20.29	0.70	0	0
Single-Axis	6.61	18.93	17.71	5.83	0	0	0	0

Notes: The underlying capital funded cost data was provided by the DARHT field office (Burns 1995). The costs do not include any expenses associated with site cleanup, decontamination or decommissioning of either the DARHT or PHERMEX facilities.

TABLE G-2.—*Operations and Maintenance Costs by Alternative (in millions of 1994 dollars)*

Alternative	1995	1996	1997	1998	1999	2000	2001	2002
No Action	4.17	4.30	4.43	4.58	4.73	4.88	5.03	5.19
Preferred	4.17	4.30	4.43	4.58	6.96	7.18	7.40	7.63
PHERMEX Upgrade	4.17	4.30	4.43	4.58	4.73	4.88	5.03	8.11
Enhanced Containment (vessels)	4.17	4.30	4.43	4.58	11.50	11.86	12.22	12.60
Enhanced Containment (150-ton bldg.)	4.17	4.30	4.43	4.58	4.73	4.88	5.03	12.60
Enhanced Containment (500-ton bldg.)	4.17	4.30	4.43	4.58	4.73	4.88	5.03	12.60
Plutonium Exclusion	4.17	4.30	4.43	4.58	6.96	7.18	7.40	7.63
Single-Axis	4.17	4.30	4.43	4.58	6.26	6.46	6.66	6.86

Notes: The underlying O&M cost data were provided by the DARHT field office (Burns 1995). This primary data was adjusted using an escalation price change index for DOE defense-related construction projects (Pearman 1994). The resulting O&M cost estimates presented in the table recognize varying periods of operation of PHERMEX prior to operations at the DARHT facility based on the DARHT implementation schedule (Burns 1995).

TABLE G-3.—*Summary of Economic Impacts by Alternative (FY 1996 to FY 2002)*

Alternative	Employment (FTE-Equivalent)	Labor Income (in millions)	Output (in millions)
Preferred	total 169 direct 73 indirect 96	total $3.60 direct $1.55 indirect $2.06	total $6.23 direct $3.21 indirect $3.02
PHERMEX Upgrade	total 139 direct 63 indirect 76	total $3.26 direct $1.38 indirect $1.88	total $5.38 direct $2.58 indirect $2.78
Enhanced Containment (vessels)	total 326 direct 139 indirect 187	total $6.87 direct $2.91 indirect $3.96	total $12.42 direct $6.60 indirect $5.82
Enhanced Containment (150-ton bldg.)	total 200 direct 85 indirect 115	total $4.27 direct $1.83 indirect $2.45	total $7.21 direct $3.59 indirect $3.61
Enhanced Containment (500-ton bldg.)	total 217 direct 91 indirect 126	total $4.63 direct $1.96 indirect $2.67	total $7.77 direct $3.83 indirect $3.94
Plutonium Exclusion	total 169 direct 73 indirect 96	total $3.60 direct $1.55 indirect $2.06	total $6.23 direct $3.21 indirect $3.02
Single-Axis	total 87 direct 38 indirect 49	total $1.84 direct $0.80 indirect $1.04	total $3.28 direct $1.75 indirect $1.53

Notes: All monetary amounts are reported in 1994 dollar values.

was measured as the difference between the general population and the white Non-Hispanic subgroup of the general population. The ratio between the derived minority subgroup and the general population constitutes the percentage of "minority population" residing within the various scopes of coverage. This percentage is greater than one half in both the 30- (48-) and 50-mi (80-km) radius, reflecting the large number of Hispanic and Native American persons residing in the region-of-interest.

Similarly, the low-income population distribution was derived using census tract data on household income. Household income data reflects wages and salaries earned by persons of 15 years of age and beyond who reside in the same household. For the region-of-interest the income class of $15,000 or less was chosen as the poverty threshold measure for the low-income population. This income level is the reported 1990 poverty threshold for the average-sized household in the region-of-interest. The ratio between these households and the total number of households in a specific scope of coverage [10, 30 or 50 mi (16, 48, or 80 km)] constitutes the percentage of the "low-income" households in the region-of-interest.

Finally, the presentation of both the minority and low-income distributions of the population can take a variety of forms. In the present analysis, maps and tables were constructed taking into consideration that census tracts (or block) areas tend to sprawl across the varying scopes of coverage, e.g. certain census tracts tend to lie on both sides of the 10, 30, and 50 mi radius (16, 48, and 80 km). In these instances, a detailed atlas was used to apportion persons and households situated in these census tracts to one or the other side of the boundary.

G.3 REFERENCES CITED IN APPENDIX G

Burns, M.J., 1995, *Response to Initial DARHT EIS Data Request*, LANL Memorandum No. DX-DO:DARHT–95–16, January 30, Los Alamos National Laboratory, Los Alamos, New Mexico.

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Appendix H
Human Health

APPENDIX H
HUMAN HEALTH

This appendix presents the methods and results of calculations to estimate human health effects that could result from the airborne releases of test assembly detonations at the DARHT or PHERMEX sites under the six alternatives. The detonations would result in the aerosolization and atmospheric dispersal of a portion of the materials contained in each assembly. The hazardous components may include depleted uranium, tritium, beryllium, lead, and lithium hydride. Depleted uranium and tritium were evaluated for their radiological hazard, and uranium, beryllium, lead, and lithium hydride were evaluated for their chemical hazard. Unless otherwise stated, dose is the effective dose equivalent. Sums and products of numbers in this section may not appear consistent due to rounding.

This appendix addresses only the potential human health impacts from chronic exposures under routine operations. Appendix I (Facility Accidents) covers the health impacts from acute exposures that could result from accident events.

H.1 COMPUTER CODES

The potential health impacts of the atmospheric releases were evaluated with two computer codes. GENII (Napier et al. 1988a; Napier et al. 1988b; and Napier et al. 1988c) was used to calculate radiation dose from uranium and tritium. The Multimedia Environmental Pollutant Assessment System (MEPAS) (Droppo et al. 1989; Droppo et al. 1991; Whelan et al. 1987; Strenge et al. 1989; Buck et al. 1995) was used to calculate toxicological impacts of all constituents and cancer incidence risk from nonradioactive constituents, namely beryllium. The HOTSPOT code (Homann 1994) was used in a limited manner to compare explosive atmospheric dispersion to the point-source atmospheric dispersion estimates of GENII and MEPAS.

H.1.1 GENII

The GENII code was used to calculate radiation doses from depleted uranium and tritium releases. GENII models the environmental transport, accumulation, and radiation dose to an individual or population. It may be used for acute (less than 24 h) or chronic exposure scenarios. Atmospheric dispersion is modeled using a straight-line Gaussian-plume model, and the release point may be either ground level or elevated. Depleted uranium is modeled as a particulate, but GENII includes a special algorithm for modeling tritium vapor. The tritium model of GENII assumes that the tritium released is in the form of tritiated water (HTO), whereas tritium released from either the DARHT or PHERMEX facilities is in the form of tritium gas (T_2). Tritium gas is about 14,000 times less a radiological hazard than tritiated water because it is taken up by the body to a far lesser extent. GENII calculations were made assuming the tritium to be in the form of HTO for atmospheric dispersion and environmental accumulation. Radiation dose output was then corrected by replacing HTO dose factors with those for T_2.

H.1.2 MEPAS

The MEPAS code was used to model the release, atmospheric transport, and receptor exposure of test assembly constituents that could cause toxicological effects (uranium, beryllium, lead, and lithium hydride) or cancer risks (beryllium). Uranium, as a heavy metal, may cause toxicological effects as well as be a source of radiation dose. MEPAS has the capability to model only chronic releases. Like GENII, MEPAS uses a straight-line Gaussian-plume model for atmospheric dispersion modeling, from either ground-level or elevated release points.

The MEPAS code output for toxicological effects from uranium, beryllium, lead, and lithium hydride is in terms of hazard index (HI). Hazard index is used to estimate the potential occurrence of noncarcinogenic effects that may result from chronic exposure to a metal or chemical. Toxicological effects are nonprobabilistic and have an occurrence threshold. They are specific to a given substance because the toxicological endpoints differ for different substances. The HI is equal to the individual's estimated exposure divided by the U.S. Environmental Protection Agency (EPA) constituent-specific reference dose (EPA 1994b). This EPA reference dose is based on a contamination level where a deleterious effect is noted following chronic exposure. No toxicological effects would be expected where the HI was less than unity (1). The reference doses and their bases are provided in table H-1.

TABLE H-1.—*Reference Doses (Rfd) for Beryllium (Be), Lead (Pb), Lithium Hydroxide (LiOH), and Uranium (U) and Their Bases (EPA 1994)*

Element	Rfd (mg/kg/d)	Basis
Be	Ingestion Rfd = 0.005 Inhalation Rfd = undefined	Low confidence in Rfd which is based on soluble Be salts. The deleterious effect on which the Rfd is based on weight changes.
Pb	Ingestion Rfd = 0.0014 Inhalation Rfd = 0.00043	High level of confidence in Rfd. Health effect bases are changes in the levels of certain blood enzymes and in aspects of children's neurobehavioral development.
LiOH[a]	Ingestion Rfd = 0.14 Inhalation Rfd = 0.14	Low confidence in Rfd. Symptoms of lithium toxicity resemble those of sodium deficiency and include drowsiness, anorexia, nausea, tremors, blurred vision, coma, and death. Rfd is based on sodium hydroxide threshold limit values. The TLV, however, is most likely based on the caustic nature of sodium hydroxide.
U	Ingestion Rfd = 0.003 Inhalation Rfd = 0.0014	Medium confidence in Rfd. U is a classic nephrotoxin.

[a] LiOH used as surrogate for lithium hydride in test assemblies.

MEPAS output for carcinogens is presented as risk of cancer incidence. Beryllium is a potential carcinogen as well as a toxicological hazard. EPA (EPA 1994a) has published a beryllium slope factor, based on chronic exposure, that is used to estimate the probability that an individual will contract cancer in his or her lifetime. The carcinogenic effect results from the inhalation of beryllium. The inhalation slope factor is 8.4 (mg [beryllium]/kg [body wt]–d)$^{-1}$; slope factors for other exposure pathways are undefined.

H.1.3 HOTSPOT

HOTSPOT is a code developed for the initial assessment of accidents involving atmospheric releases of radioactive material. The code module used for these analyses was the "uranium explosion." HOTSPOT was used in one limited application to compare its explosive atmospheric dispersion estimates to the single-point atmospheric dispersion estimates of GENII and MEPAS. The initial plume of the postdetonation release modeled in HOTSPOT is more disperse and spacious than the point release modeled by GENII and MEPAS. The dispersion estimate comparison, while rather extensive in examining dispersion estimates at several different locations, for different quantities of high explosives, and under various meteorological conditions, was limited due to the relatively unsophisticated meteorological input used by HOTSPOT. HOTSPOT was not used for any consequence (dose, toxicological effect, or cancer risk) analysis.

H.2 METEOROLOGICAL DATA AND ATMOSPHERIC DISPERSION

This section presents an overview of the meteorological data used for the human health analyses, as well as a description of the atmospheric dispersion analyses and assumptions made in modeling human health impacts.

H.2.1 Meteorological Data

A comparison was made of available LANL site-specific meteorological data to determine which was most appropriate for use in atmospheric dispersion and transport calculations for releases from the DARHT and PHERMEX sites (Area III) in TA-15. TA-15 has no meteorological tower. Data were available for two nearby areas, TA-6 and TA-49, which are north-northwest and south, respectively, of TA-15. These two sets of meteorological data were selected for comparison because they were from towers closest to TA-15, approximately equidistance from TA-15, and from towers with topography similar to TA-15.

To make a determination on which data set to use, GENII code analyses were carried out using three alternative meteorological data sets: TA-6, TA-49, and the average of TA-6 and TA-49. Doses to three different receptor locations onsite (Los Alamos, Bandelier, and White Rock) were modeled using three different exposure scenarios (i.e., acute, chronic annual, and 30-yr cumulative exposure), as well as the 50-mi (80-km) population. Unit releases of depleted uranium and tritium were used as the source term and held constant among the different comparison cases.

The hourly meteorological data from TA-6 was selected as the input data set for modeling the atmospheric dispersion from the DARHT and PHERMEX sites in TA-15 because it consistently resulted in the highest dose estimates; therefore, potential impacts would not be underestimated. In the 3 of 13 cases where the TA-6 data did not result in the highest dose, the difference between the maximum and the TA-6 dose estimate was less than a factor of two.

Both GENII and MEPAS use the site-specific, hourly meteorological data in the form of joint frequency data. Joint frequency data are shown in appendix C, Exhibit C1-1. Ninety-fifth-percentile, $\overline{\chi}/Q'$ atmospheric dispersion values were calculated by GENII and MEPAS and used for chronic release calculations. GENII calculates 95th-percentile E/Q values for acute releases. Where hand calculations were necessary for acute release calculations, these 95th-percentile E/Q values were used as the atmospheric dispersion input.

H.2.2 Atmospheric Dispersion

The GENII and MEPAS codes are routinely used for point (e.g., a building vent) or area (e.g., buried waste near the soil surface) source releases. However, material from the DARHT and PHERMEX sites would be released via explosive detonations. Initial post-detonation source term plumes for open-air detonations (as described below for the five uncontained alternatives) are roughly a vertical cylinder or stem-and-cap shape. Several analyses were performed to compare the impacts of using the GENII and MEPAS point sources release models to simulate the explosive detonation releases.

The initial analysis used the HOTSPOT code (Homann 1994) to compare post-detonation dispersion to point-source dispersion estimates used in GENII and MEPAS. HOTSPOT models five plumes stacked vertically for its model of nonnuclear detonations of uranium. The dispersion estimates for HOTSPOT and GENII/MEPAS were compared at several different receptor locations, for different quantities of high explosives, and under various meteorological conditions. The comparison was limited due to the relatively unsophisticated, generic meteorological input used by HOTSPOT.

This analysis determined that the GENII and MEPAS point-source estimates could significantly *under-estimate* atmospheric dispersion of explosive dispersal and therefore *over-estimate* the human health impacts. HOTSPOT has only limited air dispersion and dose modeling capabilities and was not used for any consequence analysis. However, HOTSPOT proved useful by providing an equation for effective release height that would allow GENII and MEPAS to more realistically simulate atmospheric dispersion from uncontained detonations. The effective release height is defined by the following empirical equation (Church 1969, cited by Homann 1994):

$$eff_{ht} = 0.6(76w^{0.25})$$

where eff_{ht} = effective release height (m) and
w = amount of high explosives (lb).

This equation defines the mid-point of the explosively dispersed plume, with approximately 50 percent of the aerosolized source term above and 50 percent below the effective release height. The height of release is dependent on the amount of high explosives used; larger amounts of high explosives result in greater initial dispersion and a higher effective release height. The amounts of high explosives used in hydrodynamic tests may range from approximately 10 to 500 lb (5 to 225 kg), with corresponding effective release heights of 270 to 700 ft (80 to 215 m). The release height used for all uncontained detonations of chronic exposure scenarios is 400 ft (120 m) corresponding to the use of 50 lb (22 kg) of high explosives.

A second evaluation compared the single-point release and dispersion model to the stem-and-cap (mushroom-shaped) atmospheric dispersion model. This comparison was made to ensure that the single-point release model was adequate to represent the explosive atmospheric dispersion that may be more appropriately represented by the stem-and-cap model.

Stem-and-cap releases are most accurately represented by double plume releases, with cap and stem sections modeled at a different release elevations (Shinn et al. 1989). This evaluation was performed for a variety of high explosive amounts with unit releases of depleted uranium. Using effective release height information gained from the initial comparison, dose consequences were calculated for a dose receptor in Los Alamos, [2.7 mi (4.4 km) NNW of TA-15]. For large amounts of explosives, the estimated dose from the stem-and-cap, double-plume release could be a maximum of 40 percent higher than that modeled for an elevated, single-point release. The dose from a representative test, using 20 lb (9 kg) of high explosives, could be up to 10 percent higher. Considering the ordinarily assumed factor of 10 uncertainty in atmospheric dispersion model results, a 10 to 40 percent difference (i.e., factor of 1.1 to 1.4) in dose estimates did not warrant the additional effort of stem-and-cap modeling. Table H-2 presents atmospheric dispersion data typical of that used in the above evaluations.

TABLE H-2.— *Atmospheric Dispersion Values Used to Compare Different Explosive Dispersion Models*

Location	$\bar{\chi}/Q'$		
	GENII/MEPAS	HOTSPOT[a]	Stem & Cap
10 lb (4.5 kg) of HE			
Los Alamos	4.0×10^{-8}	4.6×10^{-10}	4.5×10^{-8}
Bandelier	3.5×10^{-8}	3.6×10^{-10}	5.5×10^{-8}
White Rock	4.3×10^{-8}	2.6×10^{-10}	7.3×10^{-8}
500 lb (230 kg) of HE			
Los Alamos	1.6×10^{-8}	1.1×10^{-10}	2.3×10^{-8}
Bandelier	2.9×10^{-9}	7.1×10^{-11}	1.1×10^{-8}
White Rock	4.2×10^{-9}	1.1×10^{-10}	1.4×10^{-8}

[a] $\bar{\chi}/Q'$ values for HOTSPOT are the most conservative (nighttime)

For the Enhanced Containment Alternative, materials from 6 percent of the contained detonations were assumed to be released to the environment, based on previous operational experience at LANL. The bounding assumption of 6 percent containment release is used to account for potential leakage or failure of the vessel or building containment in a nonaccident scenario. Accidents are examined separately in appendix I. These leakage releases were modeled as ground-level point source releases using MEPAS and GENII. There would be no over-estimation of impacts from the ground-level releases.

H.2.3 Summary

Site-specific hourly meteorological data was evaluated and data from TA-6 was selected for use in atmospheric dispersion estimates. Several different atmospheric dispersion models were evaluated and it was determined that estimates made using the single-point release model in GENII and MEPAS were acceptable to conservatively represent the explosive dispersal of material from detonations. The single-point release model may overestimate potential impacts by up to a factor of 100. Ground-level dispersion estimates would not be affected.

H.3 SOURCE TERM

The constituents of test assemblies that may be released to the atmosphere and have potential adverse effects to humans include uranium, tritium, beryllium, lead, and lithium hydride. At detonation, test assembly material is dispersed in various size fractions ranging from large pieces or chunks to very small, micron or sub-micron size particles. Of particular interest is the aerosolized fraction of the material with particles sizes that are considered respirable, 10 μm or less aerodynamic diameter (see appendix C).

H.3.1 Usages and Environmental Releases

The estimated releases of materials to the environment from detonation activities are indicated in table H-3. The annual usages of materials in uncontained detonations under the No Action, Preferred, Upgrade PHERMEX, Plutonium Exclusion, and Single Axis alternatives are identical. The impacts of each of these alternatives are identical as well. The impacts of the Enhanced Containment Alternative were evaluated separately. The values listed are the largest foreseeable annual releases. The releases listed for the Vessel Containment scenario represent 25 percent of the annual inventory used during uncontained detonations and the use of a containment vessel for the remaining 75 percent of the inventory. It was conservatively assumed, based on operating experience, that six percent of the inventory detonated in a vessel annually would be released to the atmosphere. The Building Containment scenario similarly assumes six percent of the total annual inventory is released from the building.

The radionuclide source term used in the health effects evaluation is based on the radionuclides present in 10-year-old Rocky Flats depleted uranium, containing, by mass, 99.8 percent uranium-238, 0.22 percent uranium-235, and 0.00057 percent uranium-234. Depleted uranium is a usable residual product left after extracting some portion of uranium-235 from uranium ore. Naturally occurring uranium has a typical uranium isotope mass fractions of 99.3 percent uranium-238, 0.7 percent uranium-235, and minute quantities of uranium-234 and uranium-236. The mass percentage and activity of the 10-yr old Rocky Flats constituents are presented in table H-4. Radionuclides other than uranium in this table are the radioactive progeny produced by decay of the parent uranium radionuclides.

Lithium hydroxide (LiOH) was used in MEPAS as a surrogate for lithium hydride (LiH), which was not part of the MEPAS database. Lithium hydride readily converts to LiOH upon contact with water. A stoichiometric correction was made in the modeled release of the LiH because the LiOH surrogate has

TABLE H-3.—*Maximum Anticipated Annual Environmental Releases of Materials from Test Assemblies*

Constituent	Uncontained Alternatives	Vessel Containment Scenario	Building Containment Scenario
Deleted uranium lb (kg)	1540 (700)	385 (175) uncontained 70 (32) contained	92 (42) contained
Tritium Ci (TBq)	3 (0.1)	3 (0.1)	3 (0.1)
Be lb (kg)	22 (10)	5.5 (2.5) uncontained 1.1 (0.5) contained	1.3 (0.6) contained
Pb lb (kg)	33 (15)	9 (4) uncontained 2 (1) contained	2 (0.9) contained
LiH lb (kg)	220 (100)	55 (25) uncontained 11 (5) contained	13 (6) contained

TABLE H-4.—*Radionuclide Constituents of Depleted Uranium, by Mass Activity*

Radionuclide	Mass Percent	Activity of Depleted Uranium Constituents (Ci/g)[a]
Uranium-234	0.00057	3.7×10^{-8}
Uranium-235	0.22	4.9×10^{-9}
Uranium-238	99.8	3.4×10^{-7}
Protactinium-234	(negligible)	3.4×10^{-7}
Thorium-231	(negligible)	4.9×10^{-9}
Thorium-234	(negligible)	3.4×10^{-7}

[a] Activity of constituents is based on 10-year-old Rocky Flat Plant Depleted Uranium

three times the mass of LiH because of the addition of the oxygen molecule. Therefore, the release source terms of LiOH used in the risk evaluation are three times those listed in table H-3.

H.3.2 Aerosolization

Upon detonation of the test assembly, the depleted uranium is ejected in the form of large fragments, small fragments (from 0.08 to 1.1 m^2 [0.5 to 7 cm^2], and aerosols as discussed in appendix C (McClure 1995). The amount of depleted uranium aerosolized and available for atmospheric dispersion beyond the firing site could range from 0.2 to 10 percent of the test assembly inventory (Mishima et al. 1985; Dahl and Johnson 1977; McClure 1995). Respirable-size particles (less than 10 μm AMAD) may comprise 20 to 90 percent of the aerosolized fraction (2 to 9 percent of the total source term); however, for the purposes of these analyses the aerosolized depleted uranium fraction was assumed to be 100 percent respirable (10 percent of the total source term).

There is uncertainty about the aerosolization fraction of the detonated hazardous constituents. Much of the uncertainty results from the difficulty in sampling close to high explosive detonations (Baskett and Cederwall 1991). Dahl and Johnson estimated that two percent of the beryllium is aerosolized, whereas Shinn et al. estimate eight percent based on their re-analysis of the Dahl and Johnson results (Dahl and Johnson 1977; Shinn et al. 1989). Little information was available on the aerosolization of the lead and lithium hydride. Due to the lack of a strong basis for constituent-specific aerosolization fractions, an aerosolization fraction of 10 percent was used for all constituents, the same as for depleted uranium.

H.4 EXPOSURE SCENARIOS

Human health impacts resulting from routine, chronic exposure of the public and workers were evaluated by making exposure assumptions about the individuals and population. Annual chronic exposures consider impacts from routine releases over a one-year period. Cumulative exposures, an extension of the annual chronic exposure scenario, sum the annual exposures during the 30-yr operational life of the facility and exposure to any soil accumulation that had occurred as a consequence of the 30-yr operational period. The annual and cumulative radiological dose and risk, and the carcinogenic risk from beryllium exposure to the population residing within 50 mi (80 km) of TA-15 were also estimated. The potential impact to the 50-mi (80-km) population from toxicological effects due to chemical exposure (indicated by Hazard Index) were not calculated. These effects are nonprobabalistic and have an occurrence threshold, so low results for the maximally exposed individual were an adequate indication that population calculations were not needed.

Three residential locations around LANL (Los Alamos, White Rock, and Bandelier) were chosen at which to evaluate the maximally exposed individual (MEI) for radiation dose and chemical exposure. Residents were assumed to be at their homes continuously and to consume home-grown crops. Assessing impacts at multiple locations provided a better indication of possible impacts, and also provided allowance for slight differences in the atmospheric dispersion and deposition algorithms used in the two consequence assessment codes (GENII and MEPAS) to ensure that individuals with the highest potential impacts were identified.

H.4.1 Receptor Type and Location

The general categories of individual receptors evaluated included the annual-chronic MEI, cumulative (over 30 years of operations) MEI, and noninvolved worker (see table H-5). Both public MEI categories considered offsite residents nearest to TA-15 (i.e., Los Alamos, White Rock, and Bandelier). The noninvolved worker was assumed to be located on the road leading to DARHT or PHERMEX about 2,500 ft (750 m) away. This distance is based on a series of administrative hazard radii that LANL has established for protection of personnel from fragment injury and would be a typical exclusion for test assembly detonations. The hazard radius determinations are included in LANL operating procedures, based on principles presented in the DOE Explosives Safety Manual (DOE 1994). The above individual receptor locations are presented in the table H-5. Table H-6 presents the 1993 population distribution data for the 50-mi (80-km) area surrounding TA-15, used in population impact calculations.

TABLE H-5.—*Locations of Individuals Evaluated for Impacts from Chronic and Cumulative Exposures*

Category	Location name	Location
Maximally Exposed Individual (MEI) Chronic (Annual) and Cumulative (30 years of Operation)	Bandelier White Rock Los Alamos	3 mi (5 km) SSE 3.8 mi (6 km) ESE 2.7 mi (4.4 km) NNW
Noninvolved worker		2,500 ft (750 m) NW

Due to the close proximity of DARHT and PHERMEX sites [0.4 mi (0.6 km) apart], the MEI distances used for each site were assumed to be equivalent. The PHERMEX facility was modeled in the No Action Alternative as operational for an additional 30 years.

H.4.2 Exposure Pathways

Table H-7 lists the exposure pathways included in evaluating impacts of routine exposures. The annual chronic MEI's pathways included external exposure and dermal absorption, inhalation of airborne constituents and resuspended soil, ingestion of food crops, and the inadvertent ingestion of soil. The cumulative MEI and population included these same pathways as well as additional pathways of meat and milk ingestion. The noninvolved worker pathways were more limited. The noninvolved worker would be present onsite and only for a fraction of the year, during working hours. Exposure pathways included were external exposure (from radionuclides), dermal absorption and inhalation of the airborne plume, and inhalation of resuspended soil. Table H-8 presents the code input parameters of most interest that were used to evaluate the human health impacts.

TABLE H-6.—*The 1993 population distribution within the 50 mi (80 km) polar grid centered on TA-15*

Distance (mi)											
0-1	1-2	2-3	3-4	4-5	5-10	10-20	20-30	30-40	40-50	Sector Total	Direction (Sector)
0	0	0	0	1	0	1,295	3,511	697	6,195	11,699	S
0	0	1	0	1	0	216	38	4,310	114,102	118,668	SSW
0	0	1	0	1	0	0	37	1,048	45	1,132	SW
0	0	1	3	1	0	17	516	2,198	6	2,742	WSW
0	0	0	2	1	11	268	489	29	146	946	W
0	0	0	0	1	10	53	41	149	1,970	2,224	WNW
0	0	0	0	0	0	17	24	357	632	1,030	NW
0	0	5	3,961	148	0	10	42	231	206	4,603	NNW
0	0	39	4,459	65	0	56	232	1,038	655	6,544	N
0	0	39	1827	472	1	262	1,450	821	360	5,232	NNE
0	0	12	241	37	1	12,500	5,898	2,594	2,167	23,450	NE
0	0	0	6	2	865	5,591	5,057	1,332	1,147	14,000	ENE
0	0	0	220	3,631	1	1,179	1,175	74	186	6,466	E
0	0	0	498	1,518	1	481	41,322	1,955	2,782	48,557	ESE[a]
0	0	0	5	43	0	797	33,390	5,735	293	40,263	SE
0	0	0	49	0	3	9	1,161	2,291	202	3,715	SSE
Population Total											
0	0	98	11,271	5,922	893	22,751	94,383	24,859	131,094	291,271	
Distance Midpoint (km)											
0.8	2.4	4.0	5.6	7.2	12	24	40	56	72		

[a] The ESE sector was determined to be the maximally exposed population sector for accident analysis (Appendix I).

TABLE H-7.—*Exposure Pathways Evaluated for Impacts from Routine Chronic Releases*

Pathway	Chronic MEI	Cumulative MEI	Noninvolved Worker (chronic)	Population
External exposure from:				
plume	x	x	x	x
ground surface	x	x	x	x
dermal absorption	x	x	x	x
Inhalation of plume and resuspended soil/dust	x	x	x	x
Ingestion of:				
incidental soil	x	x	NA	x
crops (a)	x	x	NA	x
animal products (b)	NA	x	NA	x

[a] leafy vegetables, "other" vegetables, fruit, grains
[b] meat and milk

H.5 RESULTS

Results are presented for potential radiological, toxicological, and carcinogenic impacts of releases of uranium, tritium, lead, beryllium, and lithium hydride. Radiation dose estimates are presented in terms of effective dose equivalent (EDE). The radiation dose estimates were translated into a measure of latent cancer fatalities (LCFs) using recommendations of the International Commission on Radiological Protection in its Publication 60 (ICRP 1991). The ICRP estimated the risk of cancer from data based on populations exposed to relatively high doses and dose rates. A dose reduction factor of 2 was used when doses were below 20 rad, as is the case with all doses estimated in these analyses. The dose-to-risk conversion factors used for estimating cancer deaths from exposure to low dose rates of ionizing radiation were 500 cancer deaths (latent cancer fatalities) per million person-rem effective dose equivalent (5×10^{-4} deaths per person-rem) for the general population and 400 cancer deaths per million person-rem (4×10^{-4} deaths per person-rem) for workers. The difference is attributable to more diverse age groups in the general population. These values include the dose reduction factor. For purposes of explaining potential impacts to individual members of the public or individual workers, these dose-to-risk conversion factors have also been used to estimate the "probability" of contracting a latent cancer for the representative member of the public or worker.

The hazard index (HI) is used to estimate potential occurrence of toxicological effects resulting from chronic exposure to a chemical. The basis is the EPA's constituent-specific reference dose (EPA 1994) which is based on chronic exposure at a contamination level where a deleterious effect is noted. The HI for a specific contaminant is equal to the individual's estimated exposure divided by the EPA reference dose, and thus is a unitless measure. The critical value – 1.0 – indicates that the individual is exposed at a level equivalent to the reference dose and, therefore, would be expected to experience the health effect

TABLE H-8.—*Code Input Parameters and Values Used in Evaluating Human Health Effects of Routine, Chronic Releases*

Pathway/Parameter	Chronic MEI	Cumulative MEI[a]	Noninvolved Worker (Chronic)	Population
External exposure from:				
plume (h)	8766	8766	2000	8766
ground surface (h)	8766	8766	2000	8766
dermal absorption (h)	8766	8766	2000	8766
Inhalation (h)	8766	8766	2000	8766
Ingestion of:				
incidental soil (mg/d)	100	100	100	100
crops (kg)[b]				
leafy vegetables	16.5	16.5	0	16.5
other vegetables	34.9	34.9	0	34.9
fruit	55.7	55.7	0	55.7
grain	73.9	73.9	0	73.9
meat (kg)[c]	0	95	0	95
milk (kg)[c]	0	110	0	110

[a] For Hazard Index (HI) and post-operation calculations, 30 years of previous facility operation assumed
[b] all crops 1 d hold-up
[c] beef 20 d hold-up, 75 percent fresh forage consumption
milk 2 d hold-up, 75 percent fresh forage consumption

Note: Annual exposure times are shown unless otherwise indicated.

Miscellaneous parameters:

absolute humidity	0.0048 kg/m^3
soil density	1.6×10^3 kg/m^3
roots	60 percent upper soil, 40 percent deep soil
manual redistribution factor	0.15
surface soil density	240 kg/m^2
mass loading	7.2×10^{-5} g/m^3

upon which the reference dose is based. No deleterious effects would be expected when the hazard index is less than 1.0.

The risk of cancer incidence (as compared to cancer fatalities from radiation dose) from exposure to beryllium was also calculated, using the EPA slope factor for beryllium (EPA 1994a) as a basis.

Estimated impacts of expected normal releases under the uncontained detonation alternatives (No Action, Preferred, Upgrade PHERMEX, Plutonium Exclusion, and Single Axis) are described in section H.5.1.1. Analysis and results of these impacts were identical. The estimated impacts of the Enhanced Containment Alternative are shown in section H.5.1.2. Results are presented for individuals and population, for annual and cumulative exposures. Results of accident analyses are presented in appendix J.

For all six alternatives, the radiation dose from tritium, in the form of T_2, was determined to be approximately 1×10^{-7} (1/10,000,000) that of depleted uranium. An analysis was performed, using GENII, to compare dose consequences of the projected chronic annual releases of depleted uranium and tritium. Because it was determined to be an insignificant contributor to the radiation dose, tritium impacts were not explicitly calculated.

H.5.1 Uncontained Alternatives

Analysis of the uncontained alternatives – No Action, Preferred, Upgrade PHERMEX, Plutonium Exclusion, and Single Axis – involved only uncontained detonation and atmospheric releases of test assembly material, including depleted uranium, tritium, beryllium, lead, and lithium hydride.

H.5.1.1 Public

Health impacts would not be expected in the maximally exposed members of the public, located at Los Alamos, Bandelier, and White Rock, from routine annual releases under the uncontained alternatives (see tables H-9 and H-10). Neither would health impacts be expected in maximally exposed members of the public at these locations from exposure over the projected 30 years of facility operations (table H-11). This table includes values calculated from releases of uranium, tritium, and beryllium, as well as the dose and risk projected in the first year immediately following 30 years of operations from the deposition and accumulation of depleted uranium and beryllium in the soil. Table H-12 presents an estimate of the potential toxicological effects that would occur as a result of deposition and accumulation of uranium, beryllium, lead, and lithium hydride in the soil. The results are presented for the first year immediately following 30 years of operations, when buildup of the materials in the soil would be at a maximum. All values are well below 1.0; therefore, toxicological effects would not be expected. These results indicate that any environmental accumulation of released materials in the soil would create a negligible residual health risk to members of the public living around LANL after termination of DARHT or PHERMEX operations.

The projected annual dose to the population of 290,000 individuals living in the 50-mi (80-km) radius of TA-15 would be 0.91 person-rem. Latent cancer fatalities would not be expected among the population from this population dose (4.6×10^{-4} LCFs). Beryllium-induced cancer would not be expected in this population (4×10^{-7} cancers). Cumulative dose to the population over 30 years would be 27 person-rem; latent fatal cancers would not be expected (1×10^{-2} LCFs). Cancer from cumulative exposure to beryllium would not be expected (1×10^{-5} total cancers).

TABLE H-9.—*Estimated Annual Doses and Carcinogenic Risks for Members of the Public and the Noninvolved Worker for Routine Release From All Uncontained Alternatives*

Maximally Exposed Individual Location	Total dose (rem),[a] per year	Probability of Radiation-Induced LCF,[b] per year	Probability of Beryllium-Induced Cancer, per year
Los Alamos	2×10^{-5}	1×10^{-8}	3×10^{-11}
Bandelier	1×10^{-5}	7×10^{-9}	6×10^{-12}
White Rock	2×10^{-5}	8×10^{-9}	4×10^{-11}
Noninvolved Worker	2×10^{-5}	9×10^{-9}	3×10^{-11}

[a] Includes the sum of all applicable exposure pathways in table H-7
[b] LCF = latent cancer fatality

TABLE H-10.—*Estimated Toxicological Effects to Members of the Public and the Noninvolved Worker for Annual Routine Releases from All Uncontained Alternatives*

Individual Location	Hazard Index (HI)[a]			
	Uranium	Beryllium	Lead	Lithium Hydride
Los Alamos	1×10^{-7}	5×10^{-10}	8×10^{-9}	7×10^{-10}
Bandelier	3×10^{-8}	1×10^{-10}	2×10^{-9}	1×10^{-10}
White Rock	1×10^{-7}	1×10^{-9}	5×10^{-9}	4×10^{-10}
Noninvolved Worker	2×10^{-7}	0	1×10^{-8}	7×10^{-10}

[a] Toxicological effects would not be expected for a Hazard Index value less than 1.

H.5.1.2 Noninvolved Worker

Health impacts would not be expected in noninvolved workers as a result of releases to the atmosphere under the uncontained alternatives (see tables H-9 and H-10). Neither would any health impacts be expected from cumulative exposures over the 30-yr anticipated life of the project (table H-11). Toxicological effects would also not be expected, as Hazard Index values for all constituents are all far below 1.0 (table H-12).

TABLE H-11.—*Estimated Cumulative Dose and Probability of Cancer from Radiation and Beryllium Exposure from 30 Years of Operation for all Uncontained Alternatives*

Individual Location	Cumulative Dose (rem)	Probability of Radiation-Induced LCF[a]	Soil Buildup Dose[b] (rem)	Probability of Beryllium-Induced Cancer	Soil Buildup Probability of Beryllium-Induced Cancer[b]
Los Alamos	7×10^{-4}	4×10^{-7}	2×10^{-8}	9×10^{-10}	1×10^{-11}
Bandelier	4×10^{-4}	2×10^{-7}	1×10^{-8}	2×10^{-10}	2×10^{-12}
White Rock	5×10^{-4}	3×10^{-7}	1×10^{-8}	1×10^{-9}	9×10^{-12}
Noninvolved worker	7×10^{-4}	3×10^{-7}	–	9×10^{-10}	–

[a] LCF stands for Latent Cancer Fatality
[b] Reflects the potential impact from build-up of released material in soil; evaluated during the first year immediately following 30 years of operations

TABLE H-12.—*Estimated Toxicological Effects to Members of the Public After 30 Years of Facility Operation for All Uncontained Alternatives*[a]

Maximally Exposed Individual Location	Hazard Index[b] (HI)			
	Uranium	Beryllium	Lead	Lithium Hydride
Los Alamos	1×10^{-7}	4×10^{-10}	8×10^{-9}	7×10^{-10}
Bandelier	3×10^{-8}	9×10^{-11}	2×10^{-9}	1×10^{-10}
White Rock	9×10^{-8}	7×10^{-10}	4×10^{-9}	3×10^{-10}

[a] Reflects the potential impact from buildup of released material in soil; evaluated during the first year immediately following 30 years of operations.
[b] Toxicological effects would not be expected for a Hazard Index value less than 1.

H.5.1.3 Workers

The average dose to workers at the facility was estimated to be no more than 0.01 rem annually. The maximum probability of such a worker contracting a latent fatal cancer would be 4×10^{-6}. Over the 30-yr operating life of the facility an involved worker's maximum probability of contracting a latent fatal cancer would be 1×10^{-4}. An annual collective worker dose similar to that observed for PHERMEX in the past was assumed to be representative for future operation, or about 0.3 person-rem/year. Latent cancer fatalities would not be expected among the worker population (1×10^{-4} LCFs). Collective worker dose over the anticipated 30 years of operations would be about 9 person-rem. Latent cancer fatalities would not be expected among the worker population (4×10^{-3} LCFs). The collective dose estimate was based on a maximum of 100 workers at the facility each receiving an average of 0.003 rem per year. No operating information was available on exposure to chemicals or metals. The risks of exposure to these materials would be expected to be similarly low to those for radiation exposure.

H.5.2 Enhanced Containment Alternative

Under the Enhanced Containment Alternative two operational scenarios were evaluated: the Vessel Containment Scenario and the Building Containment Scenario. The vessel containment scenario assumed 25 percent of annual usages as uncontained detonations, and 6 percent of the contained detonations released routinely via ground-level leakage. The building containment scenario assumed that all annual usage was as contained detonations and that 6 percent was released routinely via ground-level leakage. The vessel containment scenario had higher potential impacts than the building containment scenario in all cases.

H.5.2.1 Public

Health impacts would not be expected in maximally exposed members of public, located at Los Alamos, Bandelier, and White Rock, from routine annual releases under the uncontained alternatives (see tables H-13 and H-14). Neither would health impacts be expected in maximally exposed members of the public at these locations over the projected 30 years of facility operations (see table H-15). This table includes

TABLE H-13.—***Estimated Annual Doses and Carcinogenic Risk for Members of the Public Under the Enhanced Containment Alternative***

Enhanced Containment Scenario	Maximally Exposed Individual Location	Total dose,[a] (rem) per year	Probability of Radiation-Induced LCF,[b] per year	Probability of Beryllium-Induced Cancer, per year
Vessel	Los Alamos	1×10^{-5}	5×10^{-9}	1×10^{-11}
	Bandelier	1×10^{-5}	6×10^{-9}	2×10^{-12}
	White Rock	2×10^{-5}	8×10^{-9}	1×10^{-11}
Building	Los Alamos	5×10^{-6}	2×10^{-9}	4×10^{-12}
	Bandelier	1×10^{-5}	5×10^{-9}	8×10^{-13}
	White Rock	2×10^{-5}	8×10^{-9}	4×10^{-12}

[a] Includes the sum of all applicable exposure pathways in table H-7
[b] LCF = latent cancer fatality

TABLE H-14.—***Estimated Toxicological Effects to Members of the Public for Annual Routine Releases Under the Enhanced Containment Alternative***

Enhanced Containment Scenario	Maximally Exposed Individual Location	Hazard Index (HI)[a]			
		Uranium	Beryllium	Lead	Lithium Hydride
Vessel	Los Alamos	5×10^{-8}	2×10^{-10}	4×10^{-9}	3×10^{-10}
	Bandelier	1×10^{-8}	4×10^{-11}	7×10^{-10}	5×10^{-11}
	White Rock	5×10^{-8}	4×10^{-10}	2×10^{-9}	2×10^{-10}
Building	Los Alamos	2×10^{-8}	7×10^{-11}	1×10^{-9}	1×10^{-10}
	Bandelier	4×10^{-9}	2×10^{-11}	2×10^{-10}	2×10^{-11}
	White Rock	2×10^{-8}	1×10^{-10}	9×10^{-10}	8×10^{-11}

[a] Toxicological effects would not be expected for a Hazard Index value less than 1.

TABLE H-15.—*Estimated Cumulative Dose and Probability of Cancer from Radiation and Beryllium Exposure from 30 years of Operation under the Enhanced Containment Alternative*

Enhanced Containment Scenario	Maximally Exposed Individual Location	Cumulative Dose (rem)	Probability of Radiation-Induced LCF[a]	Soil Buildup Dose[b] (rem)	Probability of Beryllium-Induced Cancer	Soil Buildup Probability of Beryllium-Induced Cancer[b]
Vessel	Los Alamos	3×10^{-4}	9×10^{-3}	8×10^{-8}	3×10^{-10}	3×10^{-12}
	Bandelier	3×10^{-4}	1×10^{-2}	8×10^{-8}	7×10^{-11}	6×10^{-13}
	White Rock	5×10^{-4}	1×10^{-2}	1×10^{-7}	3×10^{-10}	2×10^{-12}
Building	Los Alamos	1×10^{-4}	4×10^{-3}	4×10^{-8}	1×10^{-10}	3×10^{-13}
	Bandelier	3×10^{-4}	9×10^{-3}	8×10^{-8}	2×10^{-11}	7×10^{-14}
	White Rock	5×10^{-4}	1×10^{-2}	1×10^{-7}	1×10^{-10}	3×10^{-13}

[a] LCF stands for Latent Cancer Fatality.
[b] Reflects the potential impact from buildup of released material in soil; evaluated during the first year immediately following 30 years of operations.

the projected cumulative impact from releases of uranium, tritium, and beryllium, as well as the dose projected in the first year immediately following 30 years of operations from the deposition and accumulation of depleted uranium and beryllium in the soil. Table H-16 presents an estimate of the potential toxicological effects that would occur as a result of deposition and accumulation of uranium, beryllium, lead, and lithium hydride in the soil. The results are presented for the first year immediately following 30 years of operations, when buildup of the materials in the soil would be at a maximum. All values are well below 1.0; therefore, toxicological effects would not be expected. These results indicate that any environmental accumulation of released materials in the soil would create a negligible residual health risk to members of the public living around LANL after termination of DARHT or PHERMEX operations.

TABLE H-16.—*Estimated Toxicological Effects to Members of the Public After 30 Years of Facility Operation Under the Enhanced Containment Alternative*

Enhanced Containment Scenario	Maximally Exposed Individual Location	Hazard Index[b] (HI)			
		Uranium	Beryllium	Lead	Lithium Hydride
Vessel	Los Alamos	4×10^{-8}	1×10^{-10}	3×10^{-9}	2×10^{-10}
	Bandelier	7×10^{-9}	2×10^{-11}	5×10^{-10}	4×10^{-11}
	White Rock	3×10^{-8}	2×10^{-10}	1×10^{-9}	1×10^{-10}
Building	Los Alamos	6×10^{-9}	1×10^{-11}	4×10^{-10}	3×10^{-11}
	Bandelier	1×10^{-9}	3×10^{-12}	7×10^{-11}	5×10^{-12}
	White Rock	4×10^{-9}	1×10^{-11}	2×10^{-10}	2×10^{-11}

[a] Reflects the potential impact from buildup of released material in soil; evaluated during the first year immediately following 30 years of operations.
[b] Toxicological effect would not be expected for a Hazard Index value less than 1.

The projected annual dose to the population of 290,000 individuals living in the 50-mile (80-km) radius of TA-15 from the vessel containment scenario would be 0.44 person-rem. No latent cancer fatalities would be expected among the population from this population dose (2×10^{-4} LCFs). Beryllium-induced cancer would not be expected in this population (4×10^{-6} cancers). The projected annual population dose under the building containment scenario would be 0.27 person-rem. Latent cancer fatalities would not be expected among the population from this population dose (1.4×10^{-4} LCFs). Beryllium-induced cancers would not be expected in this population releases (2×10^{-6} cancers). Cumulative impacts over the anticipated 30-year life of the project would be about 13 person-rem and 8 person-rem for the vessel and building scenarios, respectively. Latent cancer fatalities would not be expected (6×10^{-3} and 4×10^{-3} LCFs, respectively). Cancers from cumulative exposure to beryllium would not be expected (1×10^{-4} and 6×10^{-5} total cancers, respectively.)

H.5.2.2 Noninvolved Worker

The annual radiation dose from chronic exposure of a noninvolved worker under the vessel containment scenario would be 2 x 10^{-5} rem. The maximum probability of this worker contracting a latent fatal cancer from this dose would be 6 x 10^{-9}. The cumulative dose over the 30-year operating life of the facility to the same worker would be 5 x 10^{-4} rem. The worker's cumulative maximum probability of contracting a latent fatal cancer from this dose would be 2 x 10^{-7}. The maximum annual probability of a beryllium-induced cancer in a noninvolved worker would be 2 x 10^{-11}. This worker's cumulative probability of contracting a beryllium-induced cancer over the 30-yr operating life of the facility would be 5 x 10^{-10}.

The annual radiation dose from chronic exposure of a noninvolved worker under the building containment scenario would be 1 x 10^{-5} rem. The maximum probability of this worker contracting a latent fatal cancer would be 5 x 10^{-9}. The cumulative dose over the 30-yr operating life of the facility to the same worker would be 4 x 10^{-4} rem. The worker's maximum probability of contracting a latent fatal cancer from this dose would be 2 x 10^{-7}. The maximum annual probability of a beryllium-associated cancer in a noninvolved worker would be 1 x 10^{-11}. This worker's cumulative probability of contracting a beryllium-associated cancer over the 30-yr operating life of the facility would be 3 x 10^{-10}.

Potential toxicological impacts to noninvolved workers under the vessel and building containment scenarios are presented in table H-17. Toxicological effects would not be expected, as Hazard Index values are all well below 1.0.

TABLE H-17.—*Estimated Toxicological Effect to Noninvolved Workers for Annual Routine Releases Under the Enhanced Containment Alternative*

Containment Alternative	Hazard Index (HI)[a]			
	Uranium	Beryllium	Lead	Lithium Hydride
Vessel	9 x 10^{-7}	0	8 x 10^{-8}	4 x 10^{-9}
Building	6 x 10^{-7}	0	4 x 10^{-8}	2 x 10^{-9}

[a] Toxicological effects would not be expected for a Hazard Index value less than 1.

H.5.2.3 Workers

Impacts to workers under the Enhanced Containment Alternative could be somewhat higher than those previously observed under PHERMEX operating conditions or projected for the uncontained alternatives because cleanup of contained space (vessels or buildings) could involve exposure to greater quantities and concentrations of materials. Worker exposures were projected to be higher than that previously observed at PHERMEX or those for other alternatives. The average annual worker dose would probably not exceed

0.020 rem. The maximum probability of a latent cancer fatality from this dose would be 8 x 10^{-6}. The annual collective worker dose, assuming a maximum of 100 workers, would probably not exceed 2 person-rem. No latent cancer fatalities would be expected from this dose (8 x 10^{-4} LCFs). The collective worker dose over the assumed 30-yr lifetime of the facility would probably not exceed 60 person-rem. No latent cancer fatalities would be expected from this dose (2 x 10^{-2} LCFs).

Involved worker exposures to radiation and radioactive materials under normal operations would be controlled under established procedures that require doses to be kept as low as reasonably achievable (ALARA). Any potential hazards would be evaluated as part of the radiation worker and occupational safety programs at LANL, and no impacts outside the scope of normal work activities would be anticipated.

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Appendix I
Facility Accidents

APPENDIX I
FACILITY ACCIDENTS

This appendix presents the approach used to determine and analyze impacts of accidents that might occur at the PHERMEX or DARHT facilities under all of the alternatives examined in this EIS. Section I.1 describes the Preliminary Hazards Analysis that identifies potentially hazardous conditions and potential accidents that might result. Section I.2 describes the identification of representative or bounding accidents selected for detailed evaluation. Section I.3 provides information on the consequence evaluation of these accidents, if they were to occur. Much of the technical basis for evaluating the human health impact of accidental releases is included in Appendix H, Human Health. These analyses do not include the impacts from accidents involving transportation of materials, which are included in appendix J Transportation. Unless otherwise stated, dose is the effective dose equivalent. Sums and products of numbers in this section may not appear consistent due to rounding.

I.1 PRELIMINARY HAZARDS ANALYSIS

The first step in the accident analysis process was to prepare a preliminary hazards analysis (PHA). The objective of a PHA is to identify the potentially hazardous conditions in a system and to determine the significance of the potential accidents. The PHA defines a set of abnormal operations and potential accidents that could occur at the PHERMEX or DARHT facilities. The PHA examined causes of potential accidents and qualitatively evaluated the possible consequences. A tabular summary of the PHA is shown in table I-1.

Potential hazards were identified using a modified energy barrier approach, in which abnormal events or potential accidents were selected by considering energy sources potentially capable of being released from control or containment barriers. Barriers between the source and the receptor may be present to prevent or restrict the release of energy. For example, major portions of the DARHT facilities are located below grade, using the earth as a barrier between the firing point and occupied areas. In this example, the high explosives on the firing point represents the energy source potentially capable of being released. Other examples of energy sources include radioactive materials and radiation, kinetic energy (e.g., moving vehicles, hoisting equipment), potential energy (hoisted loads), hazardous chemical materials, electrical energy, and flammable materials.

In the process described above, components associated with the PHERMEX and DARHT facilities under each alternative were analyzed using engineering judgment based on previous operating experience with PHERMEX and similar types of firing-site operations in Technical Area (TA) 15. Each of the major work locations or processes in the facilities was evaluated for potential hazards to the general public, onsite personnel, and the operating staff.

Safety features provided to prevent or mitigate hazards were also identified. Review of the hazards led to generating a list of potentially hazardous events and associated safety features.

The PHA is intended to identify hazards from which accidents are selected that may be bounding, and considers only accident pathways that for a given frequency category may have significant effects. The

TABLE I-1.—*Preliminary Hazards Analysis for DARHT and PHERMEX Facility Operations (All Alternatives)*

Facility Area	Hazardous Element	Event Description	Frequency Categorization[a]	Consequence	Mitigation/Control Measures
Firing Site	Explosives	Inadvertent detonation	U. procedures and training; lockout on firing set (detonators)	Fatal to all persons on the firing site (up to 15); **evaluate public impact**	Building design and location; firing site isolation; blast shadow of buildings; access control
Firing Site	Explosives/ radiation	Worker enters firing site during detonation sequence	E. interlocks on facility doors; cameras at firing site; access control; warning lights and sirens; procedures and training	Fatal to worker	Building design and location; firing site isolation; access control
General Facility	Explosives	Inadvertent detonation	E. HE & radioactive mat'l prohibited from facility; no storage or staging locations; procedures and training	Fatalities among facility personnel; evaluate public impact	Building design and location; firing site isolation; procedures and training
Exclusion Zone	Explosives	Worker inside the exclusion zone during detonation	U. access control; procedures & training; warning signs and sirens; physical lockouts	Inhalation of radioactive & other detonated mat'l; possible injury from fragments; **evaluate impact**	Access control; procedures & training; warning signs and sirens
Firing Site	Radiation	Exposure to accelerator beam on firing site	E. physical lockout of accelerator operation; limited accelerator keys; beam stop in place during testing; procedures & training	Possible large, localized radiation dose to a worker	Physical lockout of accelerator operation; limited accelerator keys; beam stop in place during testing; procedures & training

TABLE I-1.—*Preliminary Hazards Analysis for DARHT and PHERMEX Facility Operations (All Alternatives)—Continued*

Facility Area	Hazardous Element	Event Description	Frequency Categorization[a]	Consequence	Mitigation/Control Measures
accelerator bay	Hazardous Materials	Spill of insulator liquids or transformer oil	U. procedures and training; low frequency of change-out	Minimal impact to workers unless ingested; no offsite impacts	System design; berms around tanks and accelerators; dedicated drains and tanks for material spills
Entire Facility	Flammable	Facility is set afire internally: rags/paper ignite spontaneously; cable fire	Sprinklers; cable integrity and inspection; manual fire extinguishing; fire department response	Normal fire hazard for workers; no offsite impact	Alarms; emergency procedures and training
Entire Facility	Natural initiators - lightning - brush fire	Facility is set afire by a lightning strike or brush fire	A. high lightning area; explosive detonation oftens sets brush afire	Normal fire hazard for workers; no offsite impacts	Brush control; lightning control; canyons as natural fire breaks; fire department response capability; non-flammable facility construction (concrete); control of combustible loading
Entire Facility	Natural initiators - earthquake - tornado - high wind - heavy snowfall	Major structural damage to facility	U. infrequent occurrence of events; building structural integrity; little material at risk in facility	Significant for workers in facility; no offsite impacts	Building structural integrity; no HE or radioactive material in facility

TABLE I-1.—*Preliminary Hazards Analysis for DARHT and PHERMEX Facility Operations (All Alternatives)—Continued*

Facility Area	Hazardous Element	Event Description	Frequency Categorization[a]	Consequence	Mitigation/Control Measures
Entire Facility	Natural initiator - flood	Major structural damage to facility	I. Facility not sited in floodplain	Incredible event not requiring additional evaluation	Building siting
Entire Facility	Aircraft	Aircraft strikes facility causing detonation of assembly on firing site	I. distance from airport; direct overflights are limited; amount of aircraft traffic;	Incredible event not requiring additional evaluation	Amount of time assemblies at facility or on firing site
General Facility	Explosives/ radiation	Electrical power fails at facility	A. normal electrical failures; no back-up power for facility except data back-up	No impact	Detonation system de-energized when power fails; accelerator de-energized; recovery plans; procedures and training
Containment Structure or Vessel	Explosive	Catastrophic loss of containment	E. design specifications of vessel or building; administrative controls on HE quantities; procedures and training	**Evaluate impact**	Building design and location; firing site isolation; access control

[a] A is anticipated; U is unlikely; E is extremely unlikely.

initial estimate of safety significance is based on historical experience with similar hazards and engineering judgment. Not all of the events described in the PHA were analyzed in detail to assign frequency categories or to determine expected consequences. Instead, conservative estimates were made to select a limited number of accident scenarios for detailed review (evaluation or analysis) as potentially bounding accidents.

Frequency categories are based on the entire set of events included in the accident scenario, not just the initiating event frequency. The entire event includes the initiating event and any subsequent equipment failures or human errors. As a result, it is possible for accidents with similar (or identical) initiating events to have greatly different frequency assignments. This is due to the assumptions regarding subsequent events and system failures.

The form of the PHA does not allow a detailed listing of all of the specific event assumptions. The PHA summary table succinctly describes the overall event or scenario and initiating event. Where lack of historical data or prior experience forces frequencies to be estimated based on engineering judgment, conservative assumptions were made.

The frequency categorization column of the table lists those items considered in assigning a frequency category and consequence to the event. The last column, mitigation/control measures, lists measures present principally for limiting the consequences of the event. An event in the anticipated frequency category may be constrained by physical systems (e.g., shielding walls) and administrative controls (e.g., procedures and training). Another event may be in the unlikely or extremely unlikely frequency category based on the same considerations, but may also consider the failure of one or more of the mitigation/ control measures. The event frequency determination may consider the existing or planned administrative control to limit frequency or to limit consequences.

Frequency categories used in the PHA are the following:

- Anticipated (A) (1 to 10^{-2} per year) – accidents and natural phenomena that may occur a few times during the lifetime of the operation or facility.
- Unlikely (U) (10^{-2} to 10^{-4} per year) – accidents and natural phenomena that will probably not occur during the lifetime of the operation or facility.
- Extremely Unlikely (EU) (10^{-4} to 10^{-6} per year) – accidents and natural phenomena that are credible buy very unlikely to occur during the lifetime of the operation or facility.
- Incredible (I) ($<10^{-6}$ per year) – scenarios of exceedingly small probability. By definition, scenarios determined to occur less than once every 1,000,000 years are not credible.

The PHERMEX and DARHT facilities are rather unique from a hazard analysis and accident selection perspective in that the source of potential consequences to the general public from the normal operation, that is, detonation of high explosives and dispersal of depleted uranium and other materials from the site, is also the source of bounding consequences for accidents. Consequences of most accidents impact only the involved workers. For this reason, hazards and potential accidents that impact only involved workers are included in table I-2.

TABLE I-2.—*Preliminary Hazards Analysis of Hazards and Potential Accidents Which Would Affect Facility Workers (Involved Workers) Only*

Facility Area	Hazardous Element	Event Description	Frequency Categorization[a]	Consequence	Mitigation/Control Measures
Accelerator Rooms	electrical energy	workers contacts accelerator injector power supply	U. procedures and training	Potentially fatal to involved workers	
Accelerator Bay & Laser Room	electrical energy	worker contacts with laser power supply	U. procedures and training	potentially fatal to involved workers	
General Facility Areas	potential/ kinetic energy	failure of mechanical lift	U. periodic inspections; preventive maintenance; procedures & training	potentially fatal to involved workers	first aid available; hospital nearby
General Facility Areas	toxic	worker spills solvents used in facility	A. frequent but small usage	minor inhalation or uptake	room ventilation
Camera Room	potential/ kinetic energy	high-speed camera flies apart, producing fragments	U. camera construction and reliability	worker could be injured by fragment	camera room is an exclusion area when cameras operating
Accelerator Hall	inert gas	confined-space entry into accelerator during maintenance	U. procedures and training; confined space entry program	possible asphyxiation due to SF_6 inhalation	SF_6 required to be vented from area prior to accelerator entry
Laser Room	radiation (non-ionizing)	exposure to laser beam during maintenace or operations	U. procedures and training	possible eye injury or skin burn	
Accelerator Rooms	radiation (ionizing)	exposure to accelerator beam scattered radiation or bremsstrahlung	U. exclusion area; shielding	radiation exposure within LANL administrative guidelines	procedures and training

[a] A is anticipated; U is unlikely; E is extremely unlikely.

I.2 BOUNDING ACCIDENT SELECTION

As noted in section I.1, the source of potential impacts to the public from PHERMEX or DARHT accidents is identical to normal operations, namely the detonation of high explosives and dispersal of materials from the firing site. Most of the differences between accidents are noted in potential impacts to involved workers, and less difference in impacts to noninvolved workers and members of the public.

The PHA provided the basis for selecting bounding accidents. Bounding accidents are those which, if they occurred, would result in the highest potential consequences (impacts) to members of the public and noninvolved or involved workers. Bounding accidents were selected from the PHA based on potential consequences, with little or no consideration of the frequency of occurrence; that is, they were considered as "what if" accidents, although the likelihood of occurrence would be small. Accidents with expected smaller consequences than the bounding accidents were eliminated from further consideration. The accident selected for more detailed analysis under the uncontained alternatives (No Action, Preferred Action, PHERMEX Upgrade, Plutonium Exclusion, and Single-Axis) was the inadvertent uncontained detonation of high explosives. This accident was also considered for the vessel containment scenario of the Enhanced Containment Alternative. For the Enhanced Containment Alternative, vessel containment scenario, the accident selected was the catastrophic failure of a containment vessel. Under the building containment scenario the bounding accident was the cracking and loss of integrity of the containment walls or major failure of the HEPA-filtered overpressure release system.

For involved workers at and around the firing site, inadvertent detonation is clearly the bounding case for all alternatives. The number of workers and observers on the firing site when explosives are present is limited to 15; under an inadvertent detonation scenario all of these individuals could be killed. Other accidents, mainly industrial-types accidents, could also result in worker fatalities. However, only an explosives-type accident has the capability of injuring or killing a large number of workers. In addition, for all alternatives, the direct exposure of a worker to the accelerator beam pulse was selected because it falls well outside the scope of hazards typically encountered in an industrial or laboratory setting.

I.3 ACCIDENT ANALYSIS

This section presents the methods used to analyze the human health impacts from facility accidents, and also presents the detailed results of the analyses. Some of the of technical basis for evaluating the impacts of accidents is the same as for evaluating impacts from normal operations. Therefore, some of the technical basis for these analyses is contained in appendix H, Human Health.

The detonation of a test assembly results in the aerosolization and atmospheric dispersal of a portion of the materials contained in the assembly. Depleted uranium and tritium were evaluated for their radiological hazard and uranium, beryllium, lead, and lithium hydride were evaluated for their chemical hazard. The potential for carcinogenesis from exposures to uranium, tritium, and beryllium was evaluated, as well as the potential occurrence of toxicological effects from exposure to uranium, beryllium, lead, and lithium hydride.

An inadvertent uncontained detonation was evaluated as the bounding accident for all uncontained alternatives, that is, the No Action, Preferred, PHERMEX Upgrade, Plutonium Exclusion, and Single-Axis alternatives, as well as the uncontained detonations under the vessel containment scenario of the Enhanced

Containment Alternative. This accident considered the impact from uncontained inadvertent detonation of a test assembly with release of all assembly materials to the environment.

Two accident scenarios, one for each operating scenario, were evaluated under the Enhanced Containment Alternative. The vessel containment accident scenario considered a catastrophic failure of a containment vessel, releasing all test assembly materials to the environment. The building containment accident scenario considered a building wall cracking or a HEPA-filter failure during a detonation, allowing the release of a portion of the detonated inventory.

I.3.1 EXPOSURE MODELING

The GENII code, spreadsheet, and hand calculations were used for the health impact evaluation. A description of the GENII code and model approach can be found in appendix H, Human Health. Whereas the MEPAS code was used in the evaluation of the chronic exposures in appendix H, it was not appropriate to use this code for acute exposure scenarios resulting from postulated accidental releases. Therefore, the hand calculations were used to estimate the intake of the nonradioactive hazardous releases.

Hazard indexes (HI) are to be used to describe potential toxicological effects only in situations of chronic exposures; they are inappropriate to use for acute exposure evaluations. Therefore, only the acute intake of nonradioactive constituents via the inhalation pathway over the plume passage period was evaluated. GENII acute-scenario atmospheric dispersion estimates (95th percentile E/Q values) were used in the spreadsheets to determine the amount of nonradioactive constituent inhaled. Air concentrations were then calculated and compared to the NIOSH Immediately Dangerous to Life or Health (IDLH) values (NIOSH 1990 JCL16).

A test assembly inventory was established for each of the accident release cases that would be within the operating limits of the facility, represent normal assembly configuration, but would maximize possible consequences. Each inventory has the same quantity of potentially hazardous constituents as presented in table I-3. The radionuclide composition of the depleted uranium is presented in appendix H, table H-4. The high-explosive content for the uncontained detonation case was assumed to be relatively low to decrease dispersion and therefore *increase* potential impacts. The high-explosive content of assemblies under the containment breech cases would be higher, to effect the loss of containment.

For the uncontained detonation accident case, the effective point of material release is based on the amount of explosives used in the detonation (see appendix H). The amount of explosives detonated in the test assembly was assumed to be 22 lb (10 kg), with a effective midpoint release height of 330 ft (100 m). As discussed in appendix H for chronic releases, the single-point release assumption used in the modeling may cause potential impacts to be overestimated by up to a factor of 100.

For both of the containment-breech accident scenarios under the Enhanced Containment Alternative a ground-level release was modeled because the containment was assumed to diminish the upward pressure of the blast. This assumption would reduce atmospheric dispersion and, as a consequence, increase calculated potential impacts.

For the uncontained detonation and vessel containment breech cases, 100 percent of the test assembly inventory was assumed to be released to the environment. For the building containment breech case, only

TABLE I-3.—*Assumed Inventory of an Individual Test Assembly for Accident Analysis*

Accident Release Scenario	Inventory				
	DU	tritium	Be	Pb	LiH
Uncontained Detonation	50	0.75	0.5	4	25
Enhanced Containment Vessel Containment Breech Building Containment Breech	50	0.75	0.5	4	25
Note: All inventories in kg, except for tritium, which is in Ci.					

10 percent of the test assembly inventory was assumed to be released. For all accident cases, only a portion of the released hazardous constituents would be of respirable size. An aerosolization fraction of 0.1 (10 percent) was assumed for this EIS (see appendix H); the entire aerosolized portion was assumed to be respirable. Therefore, the percentage of the test assembly inventory available for intake by human receptors would be 10 percent for uncontained detonations and the vessel containment breech, and 1 percent for the building containment breech.

Potential impacts to the maximally exposed individual (MEI) were evaluated at three points of public access near the PHERMEX and DARHT facilities: the nearest point of State Road 4, Pajarito Road, and Bandelier National Monument. A nearby noninvolved worker was evaluated in each case for onsite impacts. For the uncontained alternatives impacts to noninvolved workers were evaluated at hazard radius boundary 2,500 ft (750 m), a typical hazard radius for hydrodynamic tests. For the Enhanced Containment Alternative, the impacts to a noninvolved worker were evaluated at 1,300 ft (400 m), assuming that under contained testing the hazard radius criteria would be relaxed. This case would also be bounding for a noninvolved worker inside the hazard radius during an uncontained detonation. Involved workers were assumed to be near the blast and killed or seriously injured by overpressure or fragments. Table I-4 presents the locations of these individuals.

TABLE I.4—*Locations of Individuals Evaluated for Accidental Release Cases*

Category	Location Description	Location
MEI[a]	State Road 4 (SR4)	0.9 mi (1.5 km) SW
Public Individual	Pajarito Road	1.7 mi (2.7 km) NE
Public Individual	Bandelier	3 mi (5 km) SSE
Uninvolved worker Uncontained Detonation		2,500 ft (750 m) NW
Uninvolved worker Containment Breech		1,300 ft (400 m) NW
[a]MEI is the maximally exposed individual		

The basis for selecting the public access locations was the frequented points of closest approach by offsite individuals. These individuals are assumed to remain at that point for a brief period of time; for example, an individual changing a tire located on State Road 4 or Pajarito Road or a hiker in the Bandelier National Monument at the time of the acute release.

The uninvolved worker was located on the roadway just outside the hazard radius, approximately 2,500 ft (750 m) away for uncontained detonations. The hazard radius was assumed to be smaller for the contained detonations under the Enhanced Containment Alternative, with the uninvolved worker 1,300 ft (400 m) away. These distances are based on administrative hazard radii that LANL has established for protection of personnel from fragment injury and would be a typical exclusion for test assembly detonations. The hazard radius determinations are included in LANL operating procedures, based on principles presented in the DOE Explosives Safety Manual (DOE 1994 SFS21).

The exposure pathways and parameters values for those of greatest importance and interest are presented in table I-5. For radioactive material the exposure pathways considered under the acute accidental release scenarios included inhalation and external exposure from the material in the plume and deposited on the ground surface. This was principally depleted uranium because for all six alternatives, the radiation dose from tritium, in the form of T_2, was determined to be about 1×10^{-8} (about 1 in 100 million) that of depleted uranium. An analysis was performed, using GENII, to compare dose consequences of the acute releases of depleted uranium and tritium. Because it was determined to be an insignificant contributor to the radiation dose, tritium impacts were not explicitly calculated. To evaluate the potential toxicological effects of uranium, beryllium, lead, and lithium hydride, and the carcinogenic risk from beryllium, only the inhalation exposure pathway was considered.

I.3.2 ACCIDENT ANALYSIS RESULTS

The estimated radiation dose and carcinogenic risk impacts to members of the public and noninvolved workers from exposure to radioactive material and beryllium released during an accident are presented in table I-6. The maximum radiation dose to a member of the public was estimated to be 0.011 rem to the maximally exposed individual (MEI), located at State Road 4, in the event of a catastrophic failure of a containment vessel during a detonation. The maximum probability of a latent cancer fatality (LCF) from this dose would be 6×10^{-6}. Dose to members of the public at Pajarito Road, Bandelier, and other locations would be lower than those at the State Road 4 location. The estimated maximum dose to the surrounding population within 50 mi (80 km), also from a containment vessel failure, would be about 17 person-rem. No latent cancer fatalities would be expected among the population from this dose (9×10^{-3} LCFs).

The maximum probability of a beryllium-induced cancer, again to the MEI at the State Road 4 location from a containment vessel failure, would be 4×10^{-10}. Inhalation intakes of material released during the accidents is presented in table I-7, and calculated air concentrations and comparison to the Immediately Dangerous to Life and Health (IDLH) values are presented in table I-8. The transitory air concentrations that would be experienced by the MEI at the State Road 4 location would be, at the greatest, less than one percent of the IDLH values.

A noninvolved worker would receive the highest dose from the vessel containment failure, receiving a dose of about 0.05 rem (table I-6). The maximum probability of a latent cancer fatality from this dose

TABLE I-5.—*Code Input Parameters Used to Evaluate Accident Release Consequences*

Pathway	Dose Receptor/Applicable Accident Scenario		
	Public Individual All Accident Scenarios	Noninvolved Worker Uncontained Detonation	Noninvolved Worker Containment Breech
External exposure			
external plume	plume passage[a]	plume passage	plume passage
ground surface (hours)	1	0.25	0.25
Inhalation	plume passage	plume passage	plume passage
Miscellaneous parameters: soil density 100 lb/ft^3 (1.6 x 10^3 kg/m^3) surface soil density 50 lb/ft^3 (240 kg/m^2) mass loading 4.5 x 10^{-9} lb/ft^3 (7.2 x 10^{-5} g/m^3)			

[a] Individuals are located in the plume centerline during the entire time of its passage.

would be 2 x 10^{-5}. The maximum probability of a beryllium-induced cancer would be about 3 x 10^{-8}. Inhalation intakes of material released during the accidents are presented in table I-7, and calculated air concentrations and comparison to the Immediately Dangerous to Life and Health (IDLH) values are presented in table I-8. Under the containment vessel failure a noninvolved worker 1,300 ft (400 m) away, would be exposed to transitory air concentrations that could be as high as 10 percent of IDLH value for uranium only. Air concentrations for other materials would be a lower fraction of the IDLH values. Air concentrations under the other release scenarios would be lower as well.

In the past, DOE has conducted dynamic experiments at LANL with plutonium. Such experiments may be conducted in the future. Experiments with plutonium would always be conducted in double-walled containment vessels, and these experiments could not reasonably be expected to result in any release of plutonium to the environment. However, some individuals may wish to explore potential human health consequences of hypothetical accidental releases of plutonium from proposed PHERMEX or DARHT activities. Estimates of the potential health consequences from unit releases of plutonium isotopes are provided in tables I-9, I-10, and I-11 for ground-level, 330 ft (100 m), and 400 ft (120 m) releases, respectively. Doses can be correlated to LCFs by reference to table I-6.

I.4 REFERENCES CITED IN APPENDIX I

NIOSH (National Institute for Occupational Safety and Health), 1990, *NIOSH Pocket Guide to Chemical Hazards*, June, Washington, D. C.

DOE (U.S. Department of Energy), 1994, *DOE Explosives Safety Manual*, DOE/EV/06194, August, Washington, D.C.

TABLE I-6.—*Estimated Doses and Carcinogenic Risk from Bounding Case Accidents*

Accidental Release Case	Total dose (rem EDE)	Probability of Radiation-Induced LCF[1][c]	Probability of Beryllium-Induced Cancer
Uncontained Detonation			
Public MEI[b], State Road 4	6×10^{-4}	3×10^{-7}	4×10^{-10}
Public, Pajarito Road.	3×10^{-4}	2×10^{-7}	2×10^{-10}
Public, Bandelier	3×10^{-4}	1×10^{-7}	2×10^{-10}
Noninvolved worker	7×10^{-4}	3×10^{-7}	5×10^{-10}
Population (ESE)[a] (number of LCFs)	13 person-rem	none (0.007 LCFs)	none (9×10^{-7} total cancers)
Vessel Containment Breech			
Public MEI, State Road 4	1×10^{-2}	6×10^{-6}	8×10^{-9}
Public, Pajarito Road	8×10^{-3}	4×10^{-6}	5×10^{-9}
Public, Bandelier	3×10^{-3}	2×10^{-6}	3×10^{-9}
Noninvolved worker	5×10^{-2}	2×10^{-5}	3×10^{-8}
Population (ESE) (number of LCFs)	17 person-rem	none (0.009 LCFs)	none (1×10^{-5} total cancers)
Building Containment Breech			
Public, MEI, State Road 4	1×10^{-3}		8×10^{-10}
Public, Pajarito Road	8×10^{-4}	6×10^{-7}	5×10^{-10}
Public, Bandelier	3×10^{-4}	4×10^{-7}	3×10^{-9}
		2×10^{-7}	
Noninvolved worker	5×10^{-3}		3×10^{-9}
		2×10^{-6}	
Population (ESE)[a]	1.7 person-rem		none (1×10^{-6}
(number of LCFs)		none (9×10^{-4}	total cancers)
		LCFs)	

[a] The east-southeast (ESE) sector was where the maximum population dose occurred.
[b] MEI is the maximally exposed individual
[c] LCF is latent cancer fatality

TABLE I-7.—*Inhalation Intakes (μg) of Materials Released in the Accident Release Cases*

Accidental Release Case	E/Q[a] (s/m^3)	U	Be	Pb	LiH
Uncontained Detonation					
Public MEI, State Rd 4	7.5×10^{-6}	9	0.09	0.7	4
Public, Pajarito Rd.	4.4×10^{-6}	5	0.05	0.4	4
Public, Bandelier	3.5×10^{-6}	4	0.04	0.3	2
Noninvolved worker	8.9×10^{-6}	10	0.4	0.8	5
Vessel Containment Breech					
Public MEI, State Rd 4	1.4×10^{-4}	200	2	10	80
Public, Pajarito Rd.	9.6×10^{-5}	100	1	9	60
Public, Bandelier	4.7×10^{-5}	50	0.5	4	30
Noninvolved worker	6.2×10^{-4}	700	7	60	400
Building Containment Breech					
Public MEI, State Rd 4	1.4×10^{-4}	20	0.2	1	8
Public, Pajarito Rd.	9.6×10^{-5}	10	0.1	0.9	6
Public, Bandelier	4.7×10^{-5}	5	0.05	0.4	3
Noninvolved worker	6.2×10^{-4}	70	0.7	6	40

[a] The E/Q (E over Q) is a measure of atmospheric dispersion for short-term (acute) atmospheric releases using gaussian dispersion plume modeling, with units of s/m^3. For a given point or location at some distance from the source, it represents the time-integrated air concentration (e.g., $Ci\text{-}s/m^3$) divided by the total release from the source (e.g., Ci). Integrated air concentrations used are usually plume centerline values. E/Qs are typically used for releases lasting no longer than 8 to 24 hours.

TABLE I-8.—*Air Concentration (mg/m³) of Materials Released in the Accident Release Cases*

Accidental Release Case	E/Q[a] (s/m³)	U	Be	Pb	LiH
Uncontained Detonation					
Public MEI, State Rd 4	7.5×10^{-6}	9×10^{-3}	9×10^{-5}	7×10^{-4}	4×10^{-3}
Public, Pajarito Rd.	4.4×10^{-6}	5×10^{-3}	5×10^{-5}	4×10^{-4}	3×10^{-3}
Public, Bandelier	3.5×10^{-6}	4×10^{-3}	4×10^{-5}	3×10^{-4}	2×10^{-3}
Noninvolved worker 2,500 ft (760 m)	8.9×10^{-6}	5×10^{-2}	5×10^{-4}	4×10^{-3}	3×10^{-2}
Vessel Containment Breech					
Public MEI, State Rd 4	1.4×10^{-4}	2×10^{-1}	2×10^{-3}	2×10^{-2}	1×10^{-1}
Public, Pajarito Rd.	9.6×10^{-5}	1×10^{-1}	1×10^{-3}	1×10^{-2}	7×10^{-2}
Public, Bandelier	4.7×10^{-5}	7×10^{-2}	7×10^{-4}	5×10^{-3}	3×10^{-2}
Noninvolved worker 1,300 ft (400 m)	6.2×10^{-4}	3	3×10^{-2}	3×10^{-1}	2
Building Containment Breech					
Public MEI, State Rd 4	1.4×10^{-4}	2×10^{-2}	2×10^{-4}	2×10^{-3}	1×10^{-2}
Public, Pajarito Rd.	9.6×10^{-5}	1×10^{-2}	1×10^{-4}	1×10^{-3}	7×10^{-3}
Public, Bandelier	4.7×10^{-5}	7×10^{-3}	7×10^{-5}	5×10^{-4}	3×10^{-3}
Noninvolved worker 1,300 ft (400 m)	6.2×10^{-4}	3×10^{-1}	3×10^{-2}	3×10^{-2}	2×10^{-1}
Applicable IDLH[b] Levels, mg/m³		30	10	700	55

[a] The E/Q (E over Q) is a measure of atmospheric dispersion for short-term (acute) atmospheric releases using gaussian dispersion plume modeling, with units of s/m³. For a given point or location at some distance from the source, it represents the time-integrated air concentration (e.g., Ci-s/m³) divided by the total release from the source (e.g., Ci). Integrated air concentrations used are usually plume centerline values. E/Qs are typically used for releases lasting no longer than 8 to 24 hours.

[b] IDLH (Immediately Dangerous to Life and Health) values taken from NIOSH 1990.

TABLE I-9—Plutonium Isotope Unit Dose Factors for Evaluation of Potential Human Health Impacts from Acute, Ground-Level Releases[a]

Accident Release Case Dose Receptor	Pu-236	Pu-238	Pu-239	Pu-240	Pu-241	Pu-242	Pu-244
Public (rem/μCi released)[b]							
MEI, State Road 4	6.2×10^{-6}	1.3×10^{-5}	1.4×10^{-5}	1.4×10^{-5}	2.3×10^{-7}	1.3×10^{-5}	1.3×10^{-5}
Pajarito Road	4.3×10^{-6}	9.2×10^{-6}	9.7×10^{-6}	9.7×10^{-6}	1.6×10^{-7}	9.3×10^{-6}	9.2×10^{-6}
Bandelier	2.0×10^{-6}	4.3×10^{-6}	4.6×10^{-6}	4.6×10^{-6}	7.4×10^{-8}	4.4×10^{-6}	4.3×10^{-6}
Population (person-rem per μCi released)							
East-southeast	9.6×10^{-3}	2.0×10^{-2}	2.2×10^{-2}	2.2×10^{-2}	3.6×10^{-4}	2.1×10^{-2}	2.1×10^{-2}
Noninvolved Worker (rem/μCi released)							
1,300 ft (400 m)	2.7×10^{-5}	5.7×10^{-5}	6.1×10^{-5}	6.1×10^{-5}	9.8×10^{-7}	5.8×10^{-5}	5.8×10^{-5}
2,500 ft (760 m)	9.8×10^{-6}	2.1×10^{-5}	2.2×10^{-5}	2.2×10^{-5}	3.6×10^{-7}	2.1×10^{-5}	2.1×10^{-5}
Specific Activity (μCi/g)	5.3×10^{8}	1.7×10^{7}	6.2×10^{4}	2.3×10^{5}	1.0×10^{8}	3.9×10^{3}	1.8×10^{1}

[a] Includes all applicable exposure pathways described in table I-5.
[b] Release can be estimated as follows: inventory x fraction released x respirable fraction.

TABLE I-10—*Plutonium Isotope Unit Dose Factors for Evaluation of Potential Human Health Impacts from Acute, 330 ft (100 m) Releases*[a]

Accident Release Case Dose Receptor	Pu-236	Pu-238	Pu-239	Pu-240	Pu-241	Pu-242	Pu-244
Public (rem/μCi released)[b]							
MEI, State Road 4	3.4×10^{-7}	7.2×10^{-7}	7.6×10^{-7}	7.6×10^{-7}	1.2×10^{-8}	7.3×10^{-7}	7.2×10^{-7}
Pajarito Road	2.0×10^{-7}	4.3×10^{-7}	4.6×10^{-7}	4.6×10^{-7}	7.4×10^{-9}	4.4×10^{-7}	4.3×10^{-7}
Bandelier	1.6×10^{-7}	3.4×10^{-7}	3.6×10^{-7}	3.6×10^{-7}	5.9×10^{-9}	3.5×10^{-7}	3.5×10^{-7}
Population (person-rem per μCi released)							
East-southeast	1.1×10^{-3}	2.3×10^{-3}	2.4×10^{-3}	2.4×10^{-3}	4.06×10^{-5}	2.3×10^{-3}	2.3×10^{-3}
Noninvolved Worker (rem/μCi released)							
1,300 ft (400 m)	7.0×10^{-7}	1.5×10^{-6}	1.6×10^{-6}	1.6×10^{-6}	2.6×10^{-8}	1.5×10^{-6}	1.5×10^{-6}
2,500 ft (760 m)	3.9×10^{-7}	8.3×10^{-7}	8.8×10^{-7}	8.8×10^{-7}	1.4×10^{-8}	8.5×10^{-7}	8.4×10^{-7}
Specific Activity (μCi/g)	5.3×10^{8}	1.7×10^{7}	6.2×10^{4}	2.3×10^{5}	1.0×10^{8}	3.9×10^{3}	1.8×10^{1}

[a] Includes all applicable exposure pathways described in table I-5.
[b] Release can be estimated as follows: inventory x fraction released x respirable fraction.

TABLE I-11—*Plutonium Isotope Unit Dose Factors for Evaluation of Potential Human Health Impacts from Acute, 400-ft (120-m) Releases*[a]

Accident Release Case Dose Receptor	Pu-236	Pu-238	Pu-239	Pu-240	Pu-241	Pu-242	Pu-244
Public (rem/μCi released)[b]							
MEI, State Road 4	2.4×10^{-7}	5.2×10^{-7}	5.5×10^{-7}	5.5×10^{-7}	8.9×10^{-9}	5.2×10^{-7}	5.2×10^{-7}
Pajarito Road	1.1×10^{-7}	2.4×10^{-7}	2.6×10^{-7}	2.6×10^{-7}	4.2×10^{-9}	2.5×10^{-7}	2.5×10^{-7}
Bandelier	1.1×10^{-7}	2.3×10^{-7}	2.4×10^{-7}	2.4×10^{-7}	3.9×10^{-9}	2.3×10^{-7}	2.3×10^{-7}
Population (person-rem per μCi released)							
East-southeast	7.3×10^{-4}	1.6×10^{-3}	1.6×10^{-3}	1.6×10^{-3}	2.7×10^{-5}	1.6×10^{-3}	1.6×10^{-3}
Noninvolved Worker (rem/μCi released)							
1,300 ft (400 m)	4.7×10^{-7}	1.0×10^{-6}	1.1×10^{-6}	1.1×10^{-6}	1.7×10^{-8}	1.0×10^{-6}	1.0×10^{-6}
2,500 ft (760 m)	3.1×10^{-7}	6.6×10^{-7}	7.0×10^{-7}	7.0×10^{-7}	1.1×10^{-8}	6.7×10^{-7}	6.6×10^{-7}
Specific Activity (μCi/g)	5.3×10^{8}	1.7×10^{7}	6.2×10^{4}	2.3×10^{5}	1.0×10^{8}	3.9×10^{3}	1.8×10^{1}

[a] Includes all applicable exposure pathways described in table I-5.
[b] Release can be estimated as follows: inventory x fraction released x respirable fraction.

Appendix J
Transportation

APPENDIX J
TRANSPORTATION

This appendix discusses the methods, data and results used to analyze the impacts of transporting test assemblies from the assembly facility to the firing site. With respect to transportation impacts there are only two different transportation scenarios and analyses. The No Action Alternative and Upgrade Alternatives, in which activities at the DARHT site would be terminated, are slightly different from the other alternatives, which would take place at the DARHT site. The No Action and Upgrade Alternatives are discussed as the No Action Alternative, while the other alternatives are discussed collectively as the Preferred Alternative.

J.1 SHIPPING SCENARIOS

The options for shipping test assemblies from the assembly facility to firing sites are discussed in this section. All scenarios assume that the test assembly is assembled by the WX division, and that the fully assembled test assembly would be transported via truck to the magazine for interim storage, and following interim storage would be transported via truck to the firing site. It was further assumed that only one test assembly would be transported at a time and all testing apparatus would be installed at the firing site. There may be up to six supporting equipment shipments associated with each test assembly detonation. These would not involve hazardous materials and would occur within the facility boundary; therefore, these supporting shipments have not been included in this analysis.

The test assembly would consist of a steel frame work, high explosive, and depleted uranium. Although the quantity of high explosives may vary per test assembly, it is assumed that the quantity of depleted uranium will remain constant. The test assemblies were assumed to be transported on a flat bed truck. Once the device is assembled, all testing equipment, consisting of x-ray triggering devices and the high explosives detonators, would be installed at the firing site. In accordance with U. S. Department of Transportation (DOT) regulations, the detonators would not be transported on the same vehicle as the high explosives.

The following subsections discuss the shipping scenarios, transportation and packaging systems, and the affected facilities.

J.1.1 Facilities

The facilities that would be used during the shipping of the test assembly from the assembly facility to the firing sites are discussed in the following subsections.

J.1.1.1 No Action Alternative and Preferred Alternative

For both transportation scenarios, the test assembly would be assembled at the WX facility (TA-16-410) and transported to a magazine (Building R242), which is used for interim storage. From the magazine, the test assemblies would be transported to the PHERMEX or FXR facility (No Action Alternative) or to the DARHT facility (Preferred Alternative). These facilities were identified to estimate the consequences to LANL facility workers during normal or incident-free shipping and during shipping accidents.

J.1.2 Transport Scenario

The test assembly would be fully assembled, without detonators, by the WX division in TA-16-410 and transported to the PHERMEX, FXR or the DARHT facility via truck on roads internal to TA-16 and TA-15. The fully assembled device would be loaded and secured at TA-16-410 on a flat bed truck and transported to a magazine (Building R242). If required, the device could be staged at the magazine on the transport vehicle for a few hours with attending personnel before being shipped from the magazine to the receiving facility where it would be unloaded.

J.2 SHIPPING SYSTEM DESCRIPTION

This section describes the shipping container and the truck used to transport the test assembly. The information presented in this discussion focuses primarily on the parameters that would affect the analysis results, that is, the shipping container, the radionuclide inventory, the hazardous chemical inventory, and the quantity and characteristics of the high explosives.

The test assembly would be secured to a flat bed truck and would not be transported in a shipping container. The estimated radionuclide and hazardous chemical inventories for depleted uranium, beryllium, lead, copper, tritium, and lithium hydride are presented in section 3.11, table 3-4. It is anticipated that there would be 20 shipments per year, with a maximum of 110 lb (50 kg) depleted uranium per test assembly and a maximum annual usage of 1,540 lb (700 kg). The high explosives used in test assemblies may be sensitive to heat and impact. Three bounding test assemblies have been identified: Test Assembly 1 containing 22 lb (10 kg) high explosive, Test Assembly 2 containing 500 lb (230 kg) explosive, and Test Assembly 3 containing 1,010 lb (460 kg) high explosives. These larger high explosives tests were assumed not to contain any additional depleted uranium.

J.3 TRANSPORTATION ROUTE INFORMATION

The assembled test assemblies would be transported from TA-16-410 to the PHERMEX or the DARHT facility using roads internal to TA-16 and TA-15. The truck would be loaded at TA-16-410 and transported nonstop approximately 5 mi (8 km) to the magazine (Building R242). From the magazine, the test assembly would be transported nonstop approximately 1.2 mi (2 km) to the PHERMEX gate or 1 mi (1.5 km) to the DARHT gates. At each of the facilities, the test assembly would be transported approximately 1,600 ft (490 m) from the facility gate to the firing site. It was assumed that 10 people would be exposed to the shipment at each of the stops (i.e., magazine, and facility gates), and that approximately 60 percent of the route is through LANL open space (~5 workers/km^2) and 40 percent of the route is past occupied buildings (~360 workers/km^2). These assumptions were based on an examination of a LANL site map.

J.4 DESCRIPTION OF METHODS USED TO ESTIMATE CONSEQUENCES

This section describes the methods used to estimate the impacts to individuals at the LANL site due to transporting test assemblies for both incident-free and accident conditions. Any impacts would be due to exposures to radiological and hazardous materials and physical traumas from explosion of the high explosives. The RADTRAN 4 (Neuhauser and Kanipe 1992) and GENII (Napier et al. 1988) computer codes were used to estimate radiological consequences. The hazardous material consequences were calculated by hand using the same site meteorological characteristics data used in the GENII analyses. The consequences associated with explosions of the high explosives were calculated using explosion modeling data presented in Rhoads et al. (1986).

J.4.1 RADTRAN 4 Computer Code

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 of the test assembly. RADTRAN was developed by Sandia National Laboratories (SNL) to calculate the risks associated with the transportation of radioactive materials. The original code was written by SNL in 1977 in association with the preparation of NUREG-0170, *Final Environmental Statement on the Transportation of Radioactive Material by Air and Other Modes* (NRC 1977). The code has since been refined and expanded and is currently maintained by SNL under contract with 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 following seven models (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 from 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.

J.4.1.1 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 is conservatively assumed to be a line source. For all other cases, the source is 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 that are used in the calculation of dose. The user can add isotopes not in the RADTRAN library by creating a data table in the input file consisting of eleven parameters.

J.4.1.2 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 (e.g., trailer truck or ship), accident rate, vehicle speed, road type, vehicle density, and link length. Alternatively, the transportation route also can 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.

J.4.1.3 Health Effects Model

The health effects model in RADTRAN 4 is outdated and is replaced by hand calculations. The health effects are determined by multiplying the population dose (person-rem) supplied by RADTRAN 4 by a conversion factor (ICRP 1991).

J.4.1.4 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 (such as urban, suburban, and rural), each increasing in magnitude. Eight severity categories for Spent Nuclear Fuel containers that are related to fire, puncture, crush, and immersion environments are defined in NUREG-0170 (NRC 1977). Various other studies also have been performed for small packages (Clarke et al. 1976) and large packages (Dennis et al. 1978) that also can 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. The source term for RADTRAN 4 is adjusted to account for the presumed explosion in an accident scenario.

J.4.1.5 Meteorological Dispersion Model

RADTRAN 4 allows the user to choose two different methods for modeling 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 meteorological data acquired in TA-6.

J.4.1.6 Routine Transport

The models described above are used by RADTRAN 4 to determine dose from routine transportation or risk from potential accidents. The public and worker doses calculated by RADTRAN 4 for routine transportation are dependent on the type of material being transported and the transportation index (TI) of the package or packages. The TI is defined in 49 CFR 173.403(bb) as the highest package dose rate in millirem per hour at a distance of 3.3 ft (1 m) from the external surface of the package. Dose consequences are also dependent on 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.

J.4.1.7 Analysis of Potential Accidents

The 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 frequencies for accidents in each category and summed to give a total point estimate of risk for a radiological accident.

J.4.2 GENII

GENII (Napier et al. 1988), which is also referred to as the Hanford Environmental Dosimetry Software System, was developed and written by the Pacific Northwest Laboratory to analyze radiological releases to the environment. GENII is composed of seven linked computer programs and their associated data libraries. This includes user interface programs, internal and external dose factor generators, and the environmental dosimetry programs. GENII is capable of calculating:

- Doses resulting from acute or chronic releases, including options for annual dose, committed dose, and accumulated dose
- 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
- Initial contamination of soil or surfaces
- Radionuclide decay

The pathways considered in this analysis include inhalation, submersion (in explosive cloud), and external exposures due to ground contamination.

J.4.3 Explosives Model

The explosive effects model was taken from Rhoads et al. (1986), which evaluated the effects produced by TNT explosions. The physical effects of explosions are related to the blast pressure, which will decrease with distance from the point of explosion. The assessment contained in Rhoads et al. assumed that a 27 lb/in^2 (186 kPa) peak overpressure was 100 percent fatal. Assuming that the blast wave expands equally from the center point, the distance to the peak overpressure for an unconfined explosion can be calculated using the following formula:

$$D = ZW^{1/3}$$

Where D is the distance from the blast, Z (ft/lb$^{1/3}$) (m/kg$^{1/3}$) is the scaled range and W is the TNT equivalent of the explosion. For this assessment, Z was assumed to be equal to 5.5 ft/lb$^{1/3}$ (3.7 m/kg$^{1/3}$), which corresponds to a peak overpressure of 27 lb/in^2 (186 kPa).

J.4.4 Microshield

Microshield (Grove Engineering 1988) was used to analyze the shielding of gamma radiation in such areas as shielding design, container design, temporary shielding selection, source strength inference from radiation measurements, ALARA planning, and teaching. This program is a microcomputer adaptation of the main frame code ISOSHLD, a public domain "point kernel" code first written in the early 1960s. Microshield was used in this analysis to calculate the TI or estimated dose rate (mrem/h) at one meter from the test assembly. This estimated dose rate is required in RADTRAN to calculate doses to truck crews and onsite and offsite individuals during routine transportation. The depleted uranium was modeled as a solid spherical source, approximately 8 in (20 cm) in diameter, shielded by plastic (high explosives). Table J-1 presents the input data used to determine the dose rate at one meter.

J.4.5 Analysis Input Parameters

Table J-2 presents the input parameters used to perform the incident-free and accident analysis using the RADTRAN computer code.

J.5 ANALYSIS OF INCIDENT-FREE (ROUTINE TRANSPORTATION) IMPACTS

The following section discusses the radiological and nonradiological impacts to the truck crew and the public during incident-free or routine transportation of the test assembly. The impacts due to interim storage of the test assembly at the magazine, if necessary, are not addressed in this analysis. The results of the analyses are presented in section 5.7.

J.5.1 Radiological Impacts due to Routine Transportation Activities

The radiological doses to the truck crew, onsite worker, and the public due to transportation activities were calculated using RADTRAN 4 (see section J.4.1). As discussed in section J.4.1, RADTRAN 4 uses a

TABLE J-1.—*Microshield Input Data*

Input Parameter	Value
Sphere radius, in (cm)	25 (10)
Shielding material[a] - Plastic, in (cm)	2.5 (1)
Distance to receptor, in (cm)	250 (100)
Radionuclides (Ci)[b]:	
Th-231	2.5×10^{-4}
Th-234	1.7×10^{-2}
Pa-234	1.7×10^{-2}
Pa-234m	1.7×10^{-2}
U-234	1.9×10^{-3}
U-235	2.5×10^{-4}
U-238	1.7×10^{-2}

[a] Modeled as water.
[b] Appendix H.

combination of meteorological, demographic, health physics, transportation, packaging, and material factors to analyze the risk due to incident-free transport activities. Input data used to perform the analysis are shown in section 5.7 and tables J-1 and J-2.

The calculated annual dose is based on 20 shipments per year. The dose to the truck crew for the No Action Alternative would be 6×10^{-6} person-rem for each shipment or 1×10^{-4} person-rem annually. The calculated dose to the public would be less than 1×10^{-10} person-rem and for this analysis is considered zero. The total dose to the onsite worker population for the No Action Alternative would be 2×10^{-4} person-rem for each shipment or 3×10^{-3} person-rem annually.

The potential health effects or latent cancer fatalities (LCFs) were calculated using the methodology described in ICRP 60 (1991), i.e., 4.0×10^{-4} LCFs/person-rem to the onsite worker and truck crew respectively. The annual health effects for truck crews, were estimated to be 4×10^{-8} (No Action Alternative) and 4×10^{-8} (Preferred Alternative). The annual health effects for the onsite worker, were estimated to be 1×10^{-6} and 1×10^{-6} for the No Action and Preferred Alternatives, respectively.

J.5.2 Nonradiological Impacts due to Routine Transportation Activities

Impacts to the public from nonradiological causes were also evaluated. This included 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

TABLE J-2.—*Input Parameters for RADTRAN and Explosives Model*

Parameter	Value
Fraction of travel time, rural population zone[a]	60
Fraction of travel time, suburban population zone[b]	40
Fraction of travel time, urban population zone	0
Dose rate at 3.3 ft (1 m) from package (mrem/hr)[c]	5.9×10^{-1}
Length of package ft (m)	13 (4)
Velocity mi/h (km/h)	35 (56.3)
Number of crewmen	2
Distance from source to crew	10
Stop time per mi (km) h/mL (h/km) (1hr/stop 2 stops/trip)	.27 (0.44)
Persons exposed while stopped	10
Average exposure distance while stopped ft (m)	66 (20)
Shipments per year	20

a Data taken from Romero and Jolly (1989)
b Estimated percentages based on a review of site layout drawings. For the purposes of this analysis the suburban population zone is used to characterize onsite activities.
c The dose rate from the package at 1 m calculated using microshield (Grove Engineering 1988)

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 densities (1.0×10^{-7}/km for truck). Although, this unit risk factor is for urban population densities, it was combined with the total shipping distance past occupied buildings [40 percent of the total distance of 2.5 and 2.4 mi (4 and 3.8 km) for the No Action and Preferred Alternatives, respectively] to calculate the nonradiological routine impacts to the public. Based on travel distances per shipment or per year, the estimated number of fatalities due to routine nonradiological impacts, as presented in section 5.7, table 5-17, are very low (roughly 4.0×10^{-7} per shipment or 8×10^{-6} annually).

J.6 ANALYSIS OF TRANSPORTATION ACCIDENTS

The following section discusses the potential radiological and nonradiological impacts due to transportation accidents. Radiological accident impacts to the collective population (public) were calculated using the RADTRAN 4 computer code (Neuhauser and Kanipe 1992). The radiological impacts to a nearby individual, and the maximally exposed onsite and offsite individual, were performed using GENII (Napier

1988). For analysis purposes, the nearby individual was assumed to be located 330 ft (100 m) from the point of release, the maximally exposed onsite individual was assumed to be located at the nearest occupied facility, and the maximally exposed offsite individual was assumed to be located at the site boundary. This scenario assumes that the high explosives detonate and the depleted uranium is released to the environment.

J.6.1 Radiologieal Impacts to the Public from Transportation Accidents

This section describes the analyses performed to assess radiological impacts to the public from transportation accidents.

J.6.1.1 Radiological Impacts to the Public

For these analyses the impacts were expressed as maximally exposed individual doses or as integrated population risks. The integrated population risk was determined by multiplying the expected consequences by the accident frequency integrated over the entire shipping campaign or estimated number of shipments annually. The potential consequences to the population from transportation accidents were expressed in terms of radiological dose and latent cancer fatalities. Typically these impacts can result from breaches in the shipping cask or damage to the cask shielding; however, in this analysis these impacts would be due to detonation and release of the radiological materials.

Once the material is released to the environment it would be dispersed and diluted by weather action and a small amount would be deposited on the ground due to plume depletion. Access to the area adjacent to the transportation accident would be controlled by emergency response personnel until the area could be remediated and the radiation monitoring personnel have declared the area safe.

The input data used to calculate the radiological dose to the public (i.e., population densities, travel times and distances) were the same as the inputs used to calculate the incident-free dose to the population and are discussed in section J.4.1. The accident frequency used in the analysis was based on a review of local or state specific accident data. It was assumed, because of the characteristics of the high explosives, that all transportation accidents were severe enough to detonate the high explosives and result in a release to the environment. This was a conservative assumption that would tend to overstate the expected consequences. The initial accident data [or rates expressed as accidents/mi (accidents/km)] used in this analysis were taken from Saricks and Kvitek (1994) for the state of New Mexico. The accident rate used, 3.78×10^{-7} accidents/mi (2.35×10^{-7} accidents/km), was a combination of accident rates for rural and urban federally aided highway systems.

It was assumed that 10 percent of the material in a test assembly was aerosolized and respirable (appendix H).

Radiological doses were calculated using RADTRAN for the two population densities of interest (i.e., LANL open space and occupied buildings). The calculated dose, on a per shipment basis, to the two populations was estimated to be 2.4×10^{-1} person-rem and 1.7×10^{1} person-rem, respectively. The integrated risk to the public (i.e., consequences times accident frequency integrated over the entire shipping distance) was estimated to be 9.8 x 10^{-5} person-rem and 9.3 x 10^{-5} person-rem for the No Action Alternative and Preferred Alternative, respectively.

J.6.1.2 Radiological Impacts to Individuals

In addition to the radiological dose to the collective population, the LANL site was reviewed to identify a maximally exposed onsite individual, i.e., an individual located at the nearest occupied facility, and maximally exposed offsite individual, i.e., an individual located at the site boundary. For this analysis, based on the location of the site boundary and the nearest public roadway, and the meteorological data, the maximally exposed offsite individual was assumed to be located approximately 1 mi (1.5 km) to the northwest and north-northwest. The location is dependent on the median effective release height (see appendix H.1). Meteorological data for TA-6 at LANL is used in the dose consequence analyses.

The location of the maximally exposed onsite worker, was determined by reviewing the LANL site drawings with respect to the location of the PHERMEX and DARHT facilities. It was assumed that the maximally exposed onsite individual is located 0.50 mi (0.75 km) to the northwest and north-northwest.

Radiological accident impacts to the maximally exposed offsite and onsite individual and the maximally exposed individual were calculated using GENII (Napier 1988). The source term for GENII is adjusted to account for the presumed explosion in an accident scenario; the adjustment takes the form of specifying a median effective release height. To calculate the impacts to the receptor, a median effective release height of 327 ft (99 m), 713 ft (216 m), and 848 ft (257 m) was used for Test Assembly 1, Test Assembly 2, and Test Assembly 3, respectively. This was calculated using the methodology described in appendix H. The results of the radiological analyses to the maximally exposed individuals are presented in section 5.7, table 5-19.

J.6.2 Nonradiological Impacts to the Public from Transportation Accidents

This section describes the analyses performed to assess nonradiological impacts to the public and the maximally exposed individuals.

J.6.2.1 Nonradiological Impacts

The vehicle travel speed is limited to 35 mi/h (56 km/h); therefore, vehicle impacts are not considered severe enough to cause fatalities to the truck occupants or occupants of other vehicles involved in the accident. For the purposes of this analysis it was assumed that the transport vehicle impacted a stationary object with sufficient force to detonate the high explosive.

The lethal limits due to the blast wave were estimated using the formula and assumptions discussed in section J.4.3 and the high explosive inventories discussed in section 5.7. The impacts due to explosions were modelled for each of the test assemblies. Assuming that a peak overpressure of 27 lb/in^2 (186 kPa) is fatal, all individuals within an approximate radius of 15 ft (5 m), 43 ft (13 m), and 53 ft (16 m) for test assemblies 1, 2, and 3, respectively, would be subjected to potentially fatal overpressures. This would include the truck crews which are assumed to be located within 33 ft (10 m) of the test assembly. In addition to impacting the truck crew, depending on the quantity of high explosive involved, 50 percent of the individuals at distances up to 80 ft (24 m) could be killed due to the blast wave. Individuals located further away may not be impacted by overpressure but could be seriously injured or killed by fragments ejected by the detonation.

In addition to evaluating the impacts from a detonation of the high explosives, an assessment of the consequences of a release of the hazardous materials identified in section 5.7, was performed. The release fraction and percentage respirable was the same release fraction used for the depleted uranium; 10 percent of the total material in the device was assumed respirable. The results, based on the meteorological data for the LANL site, are shown in section 5.7, table 5-18. For comparison, although plume passage times are very short in duration, the immediately dangerous to life and health (IDLH) exposure limits are also provided in table 5-18.

J.7. REFERENCES CITED IN APPENDIX J

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About NEPA

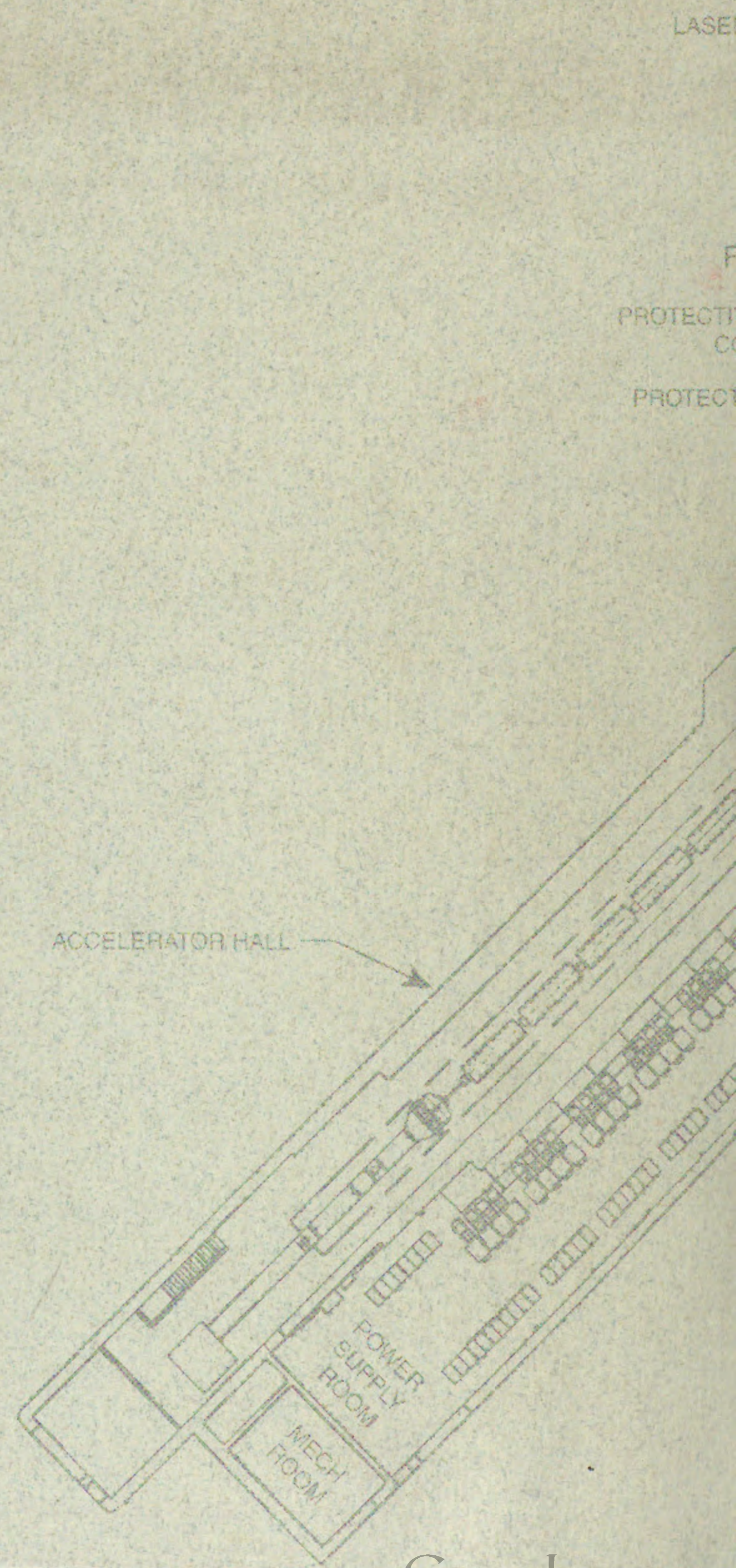
The National Environmental Policy Act (NEPA) was enacted to ensure that Federal decision-makers consider the effects of proposed actions on the human environment and to lay their decision-making process open for public scrutiny. NEPA also created the President's Council on Environmental Quality (CEQ) to establish a NEPA review process. DOE's NEPA regulations (10 CFR 1021) augment the CEQ regulations (40 CFR 1500).

An environmental impact statement (EIS) documents a Federal agency's analysis of the environmental consequences that might be caused by major Federal actions, defined as those proposed actions that might result in a significant impact to the environment. An EIS:

- Explains the purpose and need for the agency to take action
- Describes the proposed action and the reasonable alternative courses of action that the agency could take to meet the need
- Describes what would happen if the proposed action were not implemented – the "No Action" (or Status Quo) Alternative
- Describes what aspects of the human environment would be affected if the proposed action or any alternative were done
- Analyzes the changes, or impacts, to the environment that would be expected to take place if the proposed action or an alternative were implemented, compared to the expected condition of the environment if no action were taken

The DOE EIS process follows these steps:

- Notice of Intent, published in the *Federal Register*, identifies potential EIS issues and alternatives and asks for public comment on the scope of the analysis
- Public scoping period, with at least one public meeting
- Implementation Plan, which gives the results of public scoping and provides a "roadmap" of how the EIS will be prepared
- Draft EIS, issued for public review and comment, with at least one public hearing
- Final EIS, which incorporates the results of the public comment period on the draft EIS
- Record of Decision, which states:
  - The decision
  - The alternatives that were considered in the EIS and the environmentally preferable alternative
  - All decision factors, such as cost and technical considerations, that were considered by the agency along with environmental consequences
  - Mitigation measures designed to alleviate adverse environmental impacts
- Mitigation Action Plan, which explains how the mitigation measures will be implemented and monitored.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