ATSDR
AGENCY FOR TOXIC SUBSTANCES
AND DISEASE REGISTRY

Public Health Assessment for

LIBRARY COPY

LOS ALAMOS NATIONAL LABORATORY
U.S. DEPARTMENT OF ENERGY
LOS ALAMOS, LOS ALAMOS COUNTY, NEW MEXICO
EPA FACILITY ID: NM0890010515
APRIL 26, 2005

AUGUST 8, 2005

13937

THE ATSDR PUBLIC HEALTH ASSESSMENT: A NOTE OF EXPLANATION

This Public Health Assessment-Public Comment Release was prepared by ATSDR pursuant to the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA or Superfund) section 104 (i)(6) (42 U.S.C. 9604 (i)(6), and in accordance with our implementing regulations (42 C.F.R. Part 90). In preparing this document, ATSDR has collected relevant health data, environmental data, and community health concerns from the Environmental Protection Agency (EPA), state and local health and environmental agencies, the community, and potentially responsible parties, where appropriate. This document represents the agency's best efforts, based on currently available information, to fulfill the statutory criteria set out in CERCLA section 104 (i)(6) within a limited time frame. To the extent possible, it presents an assessment of potential risks to human health. Actions authorized by CERCLA section 104 (i)(11), or otherwise authorized by CERCLA, may be undertaken to prevent or mitigate human exposure or risks to human health. In addition, ATSDR will utilize this document to determine if follow-up health actions are appropriate at this time.

This document has previously been provided to EPA and the affected state in an initial release, as required by CERCLA section 104 (i) (6) (H) for their information and review. Where necessary, it has been revised in response to comments or additional relevant information provided by them to ATSDR. This revised document has now been released for a 30-day public comment period. Subsequent to the public comment period, ATSDR will address all public comments and revise or append the document as appropriate. The public health assessment will then be reissued. This will conclude the public health assessment process for this site, unless additional information is obtained by ATSDR which, in the agency's opinion, indicates a need to revise or append the conclusions previously issued.

Agency for Toxic Substances and Disease Registry ..... Julie L. Gerberding, M.D., M.P.H., Administrator
Thomas Sinks, Ph.D., M.S., Acting Director

Division of Health Assessment and Consultation.....William Cibulas, Jr., Ph.D., Director
Sharon Williams-Fleetwood, Ph.D., Deputy Director

Community Involvement Branch .....Germano E. Pereira, M.P.A., Chief

Exposure Investigations and Consultation Branch.....Donald Joe, M.S., Deputy Branch Chief

Federal Facilities Assessment Branch.....Sandra G. Isaacs, B.S., Chief

Superfund and Program Assessment Branch .....Richard E. Gillig, M.C.P., Chief

Use of trade names is for identification only and does not constitute endorsement by the Public Health Service or the U.S. Department of Health and Human Services.

Please address comments regarding this report to:

Agency for Toxic Substances and Disease Registry
Attn: Division of Health Assessment and Consultation (E-60)
1600 Clifton Road, N.E., Atlanta, Georgia 30333

You May Contact ATSDR TOLL FREE at
1-888-42ATSDR or
Visit our Home Page at: http://www.atsdr.cdc.gov

PUBLIC HEALTH ASSESSMENT

LOS ALAMOS NATIONAL LABORATORY
U.S. DEPARTMENT OF ENERGY

LOS ALAMOS, LOS ALAMOS COUNTY, NEW MEXICO

EPA FACILITY ID: NM0890010515

Prepared by:

Energy Section
Federal Facilities Assessment Branch
Division of Health Assessment and Consultation
Agency for Toxic Substances and Disease Registry

Foreword

The Agency for Toxic Substances and Disease Registry (ATSDR) is an agency of the U.S. Department of Health and Human Services. Congress created ATSDR in 1980 as part of the Comprehensive Environmental Response, Compensation, and Liability Act, also known as the Superfund law. Among other things, the Superfund law established a fund to identify and clean up our country's hazardous waste sites. The U.S. Environmental Protection Agency (EPA) and the individual states regulate the investigation and cleanup of those sites.

In 1986, amendments to the Superfund law directed ATSDR to conduct a public health assessment at each of the sites on the EPA National Priorities List. The legal definition of a health assessment is included on the inside front cover of this document. A health assessment determines whether people are being exposed to hazardous substances. If the health assessment finds an exposure pathway by which people are so exposed, the health assessors then determine whether that exposure is harmful and should be stopped or reduced. If appropriate, ATSDR can also conduct public health assessments when petitioned by concerned individuals. Public health assessments are carried out by ATSDR environmental and health scientists and scientists from those states with which ATSDR has cooperative agreements.

Exposure: As the first step in the evaluation, ATSDR scientists review environmental data to determine the extent of contamination at a site, where that contamination is located, and how people might come into contact with it. Generally, ATSDR does not collect its own environmental sampling data; we review information provided by EPA, other government agencies, businesses, and the public. When available data are insufficient, ATSDR will specify what further sampling data are needed.

Health Effects: If the review of the environmental data shows that people have or could in the future come in contact with hazardous substances, ATSDR scientists will evaluate the risk of harmful effects from these exposures. This evaluation focuses on public health, or the health impact on the community as a whole, rather than on individual risks. ATSDR generally uses existing scientific information. That information can include the results of medical, toxicological, and epidemiologic studies and the data collected in disease registries. The science of environmental health is still developing; sometimes scientific information on the health effects of certain substances is not available. When this is the case, the report will suggest what further research is needed.

Conclusions: The health assessment presents conclusions about the level of health threat, if any, posed by a site. Additionally, the health assessment's public health action plan recommends ways to stop or reduce exposure to that threat. ATSDR is primarily an advisory agency; generally, its health assessments will identify actions appropriately undertaken by EPA, other responsible parties, or the research or education divisions of ATSDR. If, however, ATSDR finds an urgent health threat, we can issue a public health advisory warning people of the danger. ATSDR can also authorize health education or pilot studies of health effects, full-scale epidemiology studies, disease registries, surveillance studies, or research on specific hazardous substances.

Interactive Process: The health assessment process is interactive. ATSDR solicits and evaluates information from numerous city, state, and federal agencies, from the individuals or business entities responsible for cleaning up the site, and from the community. ATSDR then shares its conclusions with all interested parties. To ensure that the data they have provided are accurate and current, government agencies are asked to comment on an early draft of the health assessment. This also gives the agencies, when informed of ATSDR's conclusions and recommendations, the opportunity to act before the health assessment is released in final form.

Community: ATSDR must learn what people in the area know about the site and what concerns they have about its impact on their health. Consequently, throughout the health assessment process ATSDR actively gathers information and comments from those who live or work near a site, including area residents, civic leaders, health professionals, and community groups. To ensure the report responds to the community's health concerns, ATSDR also distributes an early version to the public for their comments. In the final version of the health assessment ATSDR responds to all of the comments received from the public.

Comments: If after reading this health assessment you have questions or comments, we encourage you to send them to us.

Addressed your letters to

Attention: Chief, Program Evaluation, Records, and Information Services Branch, Agency for Toxic Substances and Disease Registry, 1600 Clifton Road (E-60), Atlanta, GA 30333.

Table of Contents

Foreword ii
List of Figures vi
List of Tables vi
List of Abbreviations vii
Summary ix
Background 1
Purpose and Scope 1
Site Description and Operational History 2
Environmental Setting 4
Demographics and Land Use 5
Environmental Management and Restoration Activities 5
ATSDR Involvement 6
Environmental Contamination, Exposure Pathways, and Potentially Exposed Populations 8
Introduction 8
Evaluating Environmental Data 8
Evaluating Exposure 9
Groundwater 10
Hydrogeology 10
Groundwater Use 11
Groundwater and Drinking Water Monitoring Programs 11
Nature and Extent of Groundwater Contamination 12
Potential Groundwater/Drinking Water Exposure Scenarios 14
Surface Soil 15
Background, Geology, and Meteorology 15
Soil Monitoring Program 15
Nature and Extent of Soil Contamination 16
Possible Soil Exposure Pathways 16
Surface Water and Sediment 16
Hydrology 16
Waste Received 17
Surface Water Use 17
Surface Water and Sediment Monitoring Program 18
Nature and Extent of Surface Water and Sediment Contamination 19
Surface Water and Sediment Exposure Pathways 20
Air 20
Air Monitoring Program 21
Nature and Extent of Ambient Air Contamination 23
Air Exposure Pathways 23
Biota 23
Background 23

Biota monitoring program 23
Nature and Extent of Biota Contamination 24
Biota Exposure Pathways 24
Public Health Implications 25
Introduction 25
Special Considerations of Women and Children 26
Groundwater 26
Surface Soil 27
Surface Water and Sediment 27
Air 28
Biota 28
Health Outcome Data Evaluation 29
Community Health Concerns 32
Conclusions 39
Recommendations 41
Public Health Action Plan 42
Authors, Technical Advisors 45
References 46
Appendices 49
Appendix A : Figures A-1
Appendix B : Tables B-1
Appendix C : Evaluation of Technical Areas (TAs) of Concern at Los Alamos National Laboratory (LANL) C-1
Appendix D : Detailed Site Descriptions of Technical Areas and Canyons Evaluated by ATSDR D-1
Appendix E : Regional Hydrogeology E-1
Appendix F : ATSDR Glossary of Environmental Health Terms F-1
Appendix G : Comparison Values G–1
Appendix H : Estimates of Human Exposure Doses and Determination of Health Effects H–1

List of Figures

Figure 1: Los Alamos National Laboratory Area Map A-1
Figure 2: Los Alamos National Laboratory Technical Areas A-2
Figure 3: Los Alamos National Laboratory 5- and 10-Mile Radii from Site Boundary A-3
Figure 4: ATSDR Exposure Evaluation Process A-4
Figure 5: Los Alamos National Laboratory Surface Water Bodies and Sediment Sampling Locations A-5

List of Tables

Table 1. Exposure Situation and Hazard Summary Table B-1
Table 2: Summary of Groundwater Monitoring by Groundwater Zone B-4
Table 3: Contaminants Detected Above Comparison Values in Alluvial and Perched Groundwater Monitoring Wells B-2
Table 4: Contaminants Detected Above Comparison Values in Regional Aquifer Groundwater Monitoring (Test) Wells B-4
Table 5: Contaminants Detected Above Comparison Values in Drinking Water Wells B-5
Table 6: Contaminants Detected Above Comparison Values in Surface Soil B-6
Table 7: Contaminants Detected Above Comparison Values in Surface Water and Sediment: Acid Pueblo Canyon B-7
Table 8: Contaminants Detected Above Comparison Values in Surface Water and Sediment: Los Alamos Canyon B-8
Table 9: Contaminants Detected Above Comparison Values in Surface Water and Sediment: Mortandad Canyon (San Ildefonso Pueblo and White Rock) B-9
Table 10: Contaminants Detected Above Comparison Values in Surface Water and Sediment: Cañada del Buey B-10
Table 11: Summary of Biota Monitoring B-11
Table 12: Maximum Detected Contaminant Concentrations in Honey B-12
Table 13: Maximum Detected Contaminant Concentrations in Alfalfa Forage, Produce, Navajo Tea, Prickly Pear, Wild Spinach, Overstory, and Understory B-13
Table 14: Maximum Detected Contaminant Concentrations in Eggs, Milk, Goat's Milk, Mushrooms, Piñon Shoot Tips, Small Mammals, Deer, Elk, and Steer/Cattle B-17
Table 15: Maximum Detected Concentrations in Fish B-23

List of Abbreviations

ATSDR	Agency for Toxic Substances and Disease Registry
bgs	below the ground surface
CAA	Federal Clean Air Act
CDC	Center for Disease Control and Prevention
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980
CFR	Code of Federal Regulations
CLL	Chronic Lymphocytic Leukemia
CMR	Chemistry and Metallurgy Research
CREG	ATSDR's Cancer Risk Evaluation Guide
CSF	Cancer slope factor
CV	comparison value
CWA	Clean Water Act
DOE	U.S. Department of Energy
EM	DOE Office of Environmental Restoration and Waste Management
EMEG	Environmental Media Evaluation Guide
ES	Environmental Surveillance Report
EPA	U.S. Environmental Protection Agency
EPCRA	Emergency Planning and Community Right-to-Know Act
ER	Environmental Restoration
°F	degrees Fahrenheit
FIFRA	Federal Insecticide, Fungicide, and Rodenticide Act
ft	feet
ft^2	square feet
HSWA	Hazardous and Solid Waste Amendments
in	inches
km	kilometer
LAHDRA	Los Alamos Historical Document Retrieval and Assessment Project
LAMPF	Los Alamos Meson Physics Facility
LANL	Los Alamos National Laboratory
LANSCE	Los Alamos Neutron Science Center
LOAEL	Lowest-observed-adverse-effect level
LTHA	Lifetime Health Advisory
m^2	square meter
mi	mile
MCL	EPA's maximum contaminant level
MOU	Memorandum of Understanding

List of Abbreviations

MRL	ATSDR's oral minimal risk level
NCEH	National Center for Environmental Health
NCRP	National Council on Radiation Protection and Measurements
NEPA	National Environmental Policy Act
NFA	no further action
NIOSH	National Institute for Occupational Safety and Health
NMAC	New Mexico Administrative Code
NMAQCA	New Mexico Air Quality Control Act
NMDWR	New Mexico Drinking Water Regulations
NMED	New Mexico Environment Department
NOAEL	No-observed-adverse-effect level
NPDES	National Pollutant Discharge Elimination System
OSHA	Occupational Safety and Health Administration
PCB	Polychlorinated biphenyl
pCi/g	picocurie(s)/gram
pCi/L	picocurie(s)/liter
PHA	Public Health Assessment
PHAP	Public Health Action Plan
ppb	parts per billion
ppm	parts per million
QA/QC	Quality assurance/quality control
RBC	Risk-based concentration
RCRA	Resource Conservation and Recovery Act
RfC	EPA's reference concentration
RfD	EPA'S oral reference dose
RMEG	ATSDR's Reference Dose (or Concentration) Media Evaluation Guide
SARA	Superfund Amendments and Reauthorization Act
SDWA	Safe Drinking Water Act
SVOC	Semivolatile Organic Compound
SWMU	Solid Waste Management Unit
TA	Technical Area
TSCA	Toxic Substances Control Act
UC	University of California
USGS	United States Geological Survey
UST	underground storage tank
VOC	Volatile organic compound

Summary

Los Alamos National Laboratory (LANL) is a 28,000-acre, active facility owned by the U.S. Department of Energy (DOE) and operated by the University of California (UC). LANL is in north central New Mexico, 25 miles northwest of Santa Fe. Much of the land surrounding LANL is undeveloped, with National Forest along the northwest, north, and southeast boundaries. The communities of Los Alamos and White Rock are adjacent to the northern and southeastern LANL boundaries, and the San Ildefonso Pueblo is to the east. Approximately 22,100 persons live within a 10-mile radius of LANL. As a whole, access to LANL is unrestricted, but security fences, guard stations, and clearance requirements limit access to individual facilities and areas.

In 1943 the federal government established LANL as the Los Alamos Laboratory (renamed the Los Alamos Scientific Laboratory in 1947 and LANL in 1981). As the development site for Project Y of the Manhattan Project, the laboratory's original mission was to develop the world's first atomic weapons. Los Alamos also housed a small weapons research facility. After World War II, laboratory scientists continued to focus on nuclear defense research and development, but they also expanded their research to nuclear energy and other technology projects. Currently, LANL's mission includes four focus areas: national security, energy resources, environmental quality, and science.

Past activities have released radioactive and chemical wastes to the soil, air, and water surrounding the LANL. Historically, laboratory personnel discharged liquid wastes into canyons, buried solid wastes in the ground, and released air emissions into the atmosphere. On occasion, accidental spills also occurred. Different programs and work activities lead to organizing LANL into 49 Technical Areas (TAs). Each TA has unique activities and contamination issues.

Since 1980, LANL has followed a number of environmental regulations to minimize releases of hazardous materials to the environment. Nevertheless, spills and accidents can still occur and minute quantities of materials can still be released—even with the many environmental regulations and permits under which LANL currently operates. Today, LANL operations and waste disposal practices are carefully planned and monitored, both to restore the environment and to mitigate threats to human health from past operations. In addition to restoration activities, LANL regularly tracks and assesses ongoing releases to groundwater, soil, surface water, sediment, air, and biota (i.e., the region's plant and animal life).

For this PHA, ATSDR reviewed monitoring data gathered from 1980 to 2001, which may report information about long-lived contamination resulting from releases that occurred before 1980 as well as information about releases occurring after 1980. Data on LANL from before 1980 is currently being gathered through a document retrieval process conducted by the Center for Disease Control and Prevention's National Center for Environmental Health. After completion of the document retrieval process, ATSDR will determine if additional actions need to be taken to evaluate past potential exposures (pre-1980) and determine follow-up action.

ATSDR's purpose was to assess possible exposures to chemical contaminants and radionuclides in groundwater, surface soil, surface water and sediment, air, and biota. ATSDR reviewed past (i.e., post-1980), current, and potential future exposure situations. *This review provided the basis*

for ATSDR's determination that no harmful exposures are occurring or are not expected to occur in the future because of chemical or radioactive contamination detected in groundwater, surface soil, surface water and sediment, air, or biota. The following is a summary of the conclusion for each potential exposure pathway.

The public is not ingesting contaminants at levels of concern, either in the community or in LANL water supplies. Groundwater from the deep aquifer provides the majority of the public drinking water for the Los Alamos community and for LANL. Regular monitoring of the water supply identified chloride, fluoride, sodium, perchlorate, 11 metals, and gross alpha at maximum concentrations greater than ATSDR health-based comparison values (CVs) for drinking water. To evaluate the possible adverse health effects of consuming groundwater, ATSDR used conservatively derived doses associated with daily consumption of drinking water containing the maximum detected concentrations of the above-referenced chemicals. ATSDR identified no doses at levels of concern. Those following a low-sodium diet, however, should be aware of the elevated levels of sodium found during monitoring and should consult with their health care providers to monitor properly their sodium intake. We also note that under the Safe Drinking Water Act, LANL water suppliers and the community regularly monitor the water supply.

Accidental ingestion of surface soil containing site contamination is not expected to result in adverse human health effects. On-site monitoring from 1980 to 2001 identified only arsenic, cesium-137, plutonium-238, and strontium-90 at concentrations above CVs. Assuming the maximum detected concentrations found within restricted areas of LANL could also be present in residential yards, ATSDR estimated exposure doses that were both below health-based standards and below the doses identified in the scientific literature as causing adverse health effects.

Exposure to surface water and sediment contaminants during recreational use of the canyons surrounding LANL is possible, but is not expected to result in adverse human health effects. Hunters, hikers, and bikers now use canyons that were historically used for waste disposal. Monitoring from 1980 to 2001 identified contaminants above CVs in surface water (bis(2-ethylhexyl)phthalate, methylene chloride, 15 inorganics, gross alpha, and total uranium) and sediment (benz(a)anthrcene, benzo(a)pyrene, arsenic, iron, manganese, americium-241, cesium-137, plutonium 239/240, and strontium-90). ATSDR estimated potential exposure doses using conservative assumptions about how often, how long, and how much exposure to contaminants could occur. This exposure evaluation, a review of site data, and observations of site conditions allowed ATSDR to conclude that potential contact with surface water and sediment during recreation is not expected to result in adverse health effects.

Inhalation of contaminants is not expected to result in adverse health effects. Monitoring for airborne contaminants at on site, at perimeter, and at regional air-monitoring stations detected no contaminants at concentrations above health-based CVs.

Adverse health effects are not expected from the consumption and use of locally harvested or grown foods. Monitoring between 1980 and 2001 included sampling a number of different biota (i.e., the plants and animals of a particular region). In the various biota sampled, researchers found polychlorinated biphenyls (PCBs), 16 metals, 21 pesticides, and 23 radionuclides. No CVs

are available for biota; thus ATSDR estimated exposure doses using conservative assumptions regarding daily consumption or use of local foods. Using these conservative assumptions about how often and how long exposures occur and how much of a contaminant might be ingested, together with a review of the scientific literature, led ATSDR to conclude that consumption of locally harvested and locally grown foods is not expected to result in adverse human health effects.

Background

Purpose and Scope

The Agency for Toxic Substances and Disease Registry (ATSDR) conducts public health assessments (PHAs) primarily to determine whether people are exposed to contaminants and whether this exposure might be of health concern to them. To make such determinations in this PHA, ATSDR evaluated available environmental data—both to assess exposures and to assess the possible public health impact of releases—from the Los Alamos National Laboratory (LANL) in Los Alamos County, New Mexico.

To determine the extent of releases from LANL, ATSDR reviewed monitoring data for groundwater, surface soil, surface water, sediment, air, and biota. ATSDR also reviewed site conditions to identify potential exposure pathways such as

- consumption of groundwater as drinking water,
- accidental ingestion and inhalation of surface soil as windblown dust,
- recreational contact with surface water and sediment,
- inhalation of airborne contaminants, and
- consumption and use of biota.

ATSDR also identified and addressed the community concerns regarding specific exposure scenarios. In that regard, while determining the possibility of adverse health effects, ATSDR also considered environmental data, plausible exposure scenarios, and chemical toxicity information, as well as remedial actions planned to reduce, prevent, or further investigate possible exposures.

In this PHA, ATSDR limited its possible-exposure evaluations to members of the public living and working in communities surrounding LANL. ATSDR did not specifically evaluate exposures to LANL employees. Employees could be exposed to hazardous materials at higher levels than the general public, but employees are trained in the safe use of those hazardous materials—and LANL supplies radiological personal dosimeters to monitor employee exposures. Since its creation in 1971 the Occupational Safety and Health Administration (OSHA) has regulated employee safety and health. At LANL, however, DOE must grant OSHA jurisdiction to regulate worker safety. A regulation allowing this process is currently proposed. Information about health activities involving employees is available at the Centers for Disease Control and Prevention's (CDC) National Institute for Occupational Safety and Health (NIOSH).

To prevent duplication of CDC's National Center for Environmental Health (NCEH) Los Alamos Historical Document Retrieval and Assessment Project (LAHDRA), ATSDR has limited this PHA to exposures occurring from 1980 to 2001. ATSDR recognizes, however, that sampling data collected from 1980 to 2001 may represent past releases of long-lived contaminants as well as releases occurring after 1980. The University of California (UC), the U.S. Department of Energy (DOE), the New Mexico state agencies, and numerous pueblos in the region are also involved in this project. LAHDRA plans to review—from LANL's inception in 1943 onward—historical documents pertaining to operations and releases (e.g., of chemicals and radionuclides). LAHDRA will summarize data regarding environmental releases and prioritize them by their

potential for off-site health effects. CDC will then determine the necessity for further investigations, such as screening-level evaluations or detailed dose reconstructions. The LANL data retrieval process is a large undertaking—the summary of releases is not scheduled until 2005. Further information regarding LAHDRA is at the project Web site http://www.shonka.com/ReConstructionZone/default.htm (LAHDRA 2000; 2003).

In summary then, ATSDR has reviewed readily available environmental surveillance data collected from 1980 to 2001 and prepared this PHA to provide an initial, focused assessment of the potential impact of LANL on the surrounding communities. Upon completion of LAHDRA activities, ATSDR will decide what actions should be taken to evaluate pre-1980 exposures and determine follow-up activities as appropriate.

Site Description and Operational History

LANL covers approximately 28,000 acres in north central New Mexico. Most of the laboratory lies within Los Alamos County; a smaller portion is in Santa Fe County. Albuquerque is approximately 60 miles to the southwest and Santa Fe is approximately 25 miles to the southeast. The Bandelier National Monument borders LANL's southwestern boundary. Los Alamos is adjacent to LANL's northern boundary and White Rock is adjacent to the southeastern boundary. The San Ildefonso Pueblo is to the east; national forest lands border the northwestern, the northern, and the southeastern LANL boundaries (Figure 1). Large parts of these areas remain undeveloped (LANL 1999a).

Although DOE owns LANL, UC operates it under an agreement with DOE's National Nuclear Security Administration. The laboratory includes 2,043 structures, of which 1,835 are buildings (covering 7.3 million square feet [ft^2]). The remaining structures (covering 0.6 million ft^2) include meteorological towers, pumphouses, water towers, manhole covers, and small storage sheds. LANL's building sites, experimental areas, support facilities, roads, and utility rights-of-way are divided into 49 Technical Areas (TAs) (figure 2). Although the TAs are identified by number, they are not numbered sequentially. Each TA is unique—thus not all areas are equally likely to cause off-site contamination. For each of the TAs and canyons at LANL, ATSDR reviewed information about past and current to land use, potential contaminant sources, waste disposal practices, and available environmental data to identify the areas with the greatest potential to produce off-site contamination, contain contamination released from LANL, or provide a path for transport of LANL contamination off site. Based on this review, ATSDR selected the following TAs and canyons for detailed evaluation under this PHA:

- TA-2 (Omega West Reactor)
- TA-3 (Chemistry and Metallurgy Research [CMR] building and main laboratories)
- TA-21 (tritium facilities)
- TA-50 (waste management site)
- TA-51 (radioactive waste research)
- TA-53 (Los Alamos Meson Physics Facility [LAMPF])
- TA-54 (waste disposal site)
- Acid Canyon
- Los Alamos Canyon
- Mortandad Canyon
- Cañada del Buey

Appendix C contains a brief description of each TA. Appendix D contains a detailed description of the TAs and of the areas of concern for this PHA.

In 1943 the Los Alamos Laboratory (subsequently renamed the Los Alamos Scientific Laboratory in 1947 and LANL in 1981) was established as a small weapons research and development site for the Manhattan Project's Project Y. During the Cold War years (1949–1989) the facility underwent considerable expansion. Although the U.S. government owns the LANL, since 1943 UC has been responsible for its management and for the operation of its facilities. After World War II, Congress created the Atomic Energy Commission (AEC), giving it the authority to direct all research of radioactive materials. In 1946, President Harry Truman transferred all of the government property in Los Alamos to the AEC. The AEC eventually became DOE and DOE's National Nuclear Security Administration eventually became responsible for LANL (Emelity 1991; LANL 1999a).

When LANL was first established, scientists worked to achieve the laboratory's original mission—developing atomic weapons. The successful completion of this mission has influenced subsequent activities and research at LANL. Following World War II, although scientists continued to focus on nuclear defense research and development, they also branched out into other nuclear energy projects and other technology projects. Today LANL's mission is divided into four focus areas: national security, energy resources, environmental quality, and science. Under the national security mission, LANL monitors the safety and reliability of nuclear weapons stockpiles, tracks the international use and spread of nuclear weapons, materials, and technologies, and produces nuclear propulsion plant components for the U.S. Navy. The energy resources mission covers research and development of energy resources, including renewable fuels, fossil fuels, and nuclear fuels. The environmental quality mission focuses on the treatment, storage, and disposal of DOE wastes (both chemical and radiological), as well as research and development of remedial technologies. As part of the science mission LANL conducts fundamental research in physics, materials science, chemistry, nuclear medicine, energy sciences, computational sciences, environmental sciences, and biological sciences (LANL 1999a).

Past research and development activities at LANL have caused releases of radioactive and chemical wastes into the air, the water, and the soil. Historically, these releases occurred in a number of ways, including direct discharge of liquid wastes to canyons, burial of solid wastes, direct release of air emissions to the atmosphere, and accidental spills. Currently, LAHDRA is in the process of characterizing releases prior to 1980. Since 1980, to minimize the release of hazardous materials to the environment, LANL has followed all applicable environmental regulations. Nevertheless, spills and accidents can still occur and cause the release of materials—even with the environmental laws, regulations, and permits governing LANL's activities, some of which include:

- the Clean Water Act (CWA),
- the Safe Drinking Water Act (SDWA),
- the Federal Clean Air Act (CAA),
- the New Mexico Air Quality Control Act (NMAQCA),
- the Toxic Substances Control Act (TSCA),
- the Resource Conservation and Recovery Act (RCRA),

- the National Environmental Policy Act (NEPA), and
- the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) (LANL 1981, 1999a).

Environmental Setting

The Jemez Mountains to the west and the Sangre de Cristo Mountains to the east dominate the vast, naturally beautiful landscape in which LANL is situated. The Rio Grande flows north to south, dividing the mountain ranges and, over geological time, contributing to the creation of the Pajarito Plateau, a volcanic shelf on the eastern slope of the Jemez Mountains on which LANL is situated. The plateau comprises finger-like mesas separated by steeply sloped canyons. Cut by intermittent streams, the canyons are oriented east-to-west, at right angles to the Rio Grande. The mesa elevations range from 7,800 feet (ft) at the base of the Jemez Mountains to 6,200 ft at their eastern end, where they rise above the Rio Grande Valley (LANL 1999a).

The area's complex topography affects local wind patterns. Winds follow a daily cycle over the plateau—except when cyclones move through the area. During the day the winds have a major southeasterly component; during the night they flow lightly from west and northwest. Wind flow within the canyons is more complex and very different from the wind flow over the plateau. Annual wind roses show that most of the time the wind blows from the south and west and travels across LANL to the north and east (LANL 1996).

The climate is semi-arid, with only 10 to 20 inches (in) of precipitation annually (LANL 1999a). During the day temperatures can vary as much as 23 degrees Fahrenheit [°F]), depending on the season and altitude. Winter temperatures range from 5 to 50°F; summer temperatures range from 50 to 90°F (LANL 1999a, 2001). Despite such variations the area supports a diverse ecosystem with six vegetation types: montane grasslands, spruce-fir forest, mixed conifer forest, ponderosa pine forest, pinyon-juniper woodlands, and juniper savannah. These habitats are home to hundreds of bird, mammal, plant, reptile, amphibian, and arthropod species living at or near LANL (LANL 1999a).

Within LANL surface water is limited to intermittent streams that cross laboratory property and flow into the canyons. Although rainfall, snowmelt, springs, and laboratory effluent create seasonal flow, these streams are dry most of the year. During heavy rainstorms surface water in the intermittent streams can discharge to the east, into the Rio Grande. Snowmelt springs and effluent are, however, usually minimal. Typically, through transpiration, evaporation, or infiltration, surface water from these sources never reaches the Rio Grande (LANL 1981). More information about surface water flow is provided in the *Surface Water and Sediment* section of this PHA.

Groundwater underneath LANL and in the region is in a complex system of groundwater zones and aquifers, which are not fully characterized. Generally, groundwater is contained in three zones: a shallow alluvial zone in stream sediments, an intermediate perched zone between the alluvial zone and a low permeable layer of soil, and a regional aquifer underlying the entire region. However, the alluvial and intermediate perched groundwater zones may not yield useful quantities of water to wells. The regional aquifer is typically 600 to 1200 ft below ground surface (bgs) and is separated from the overlaying groundwater zones by a low permeability layer of tuff

and volcanic sediments. This low permeability is mainly due to the rock being unsaturated, which causes a lower flow rate. Groundwater in the regional aquifer tends to flow toward the Rio Grande (LANL 1999b, 2001). Additional information about groundwater is provided in the *Groundwater* section of this PHA; a detailed description of the groundwater and hydrogeology is provided in Appendix E.

Demographics and Land Use

The communities of Los Alamos and White Rock—as well as the San Ildefonso Pueblo—border LANL. Other pueblos within a 10-mile radius of LANL are the Santa Clara, Cochiti, San Juan, and Pojoaque Pueblos. The Nambe, Tesuque, and Jemez Pueblos are more that 10 miles from LANL. The population within a 5-mile radius of the LANL boundary (including Los Alamos, White Rock, and the San Ildefonso Pueblo) is approximately 18,400. Within a 10-mile radius of the LANL boundary the population is approximately 22,100 (Figure 3) (ATSDR 2003).

LANL is the largest employer in Northern New Mexico. In 2003, the total LANL-affiliated work force included approximately 7,500 UC employees and approximately 3,200 contractor personnel (LANL 2003).

Northern New Mexico was originally selected for LANL because of the relative isolation of the area. Today the area remains mostly undeveloped. National forest and the Bandelier National Monument surround most of LANL.

San Ildefonso Pueblo lands along the eastern boundary of LANL are also mainly undeveloped, with most inhabitants living about 2.75 miles northeast of the LANL boundary. Land use within the San Ildefonso Pueblo includes gardening, farming, cattle grazing, hunting, fishing, food and medicinal plant gathering, and firewood production. The majority of the local population resides in the communities of Los Alamos to the north and White Rock to the east. Although small, these communities include necessary infrastructure and support systems, such as residential housing, schools, commercial businesses, and light industry (LANL 1999a). Community members say they have used the area canyons for recreational activities, such as hiking (Silver 1996).

To provide isolation and security for LANL activities, most land within the laboratory is also undeveloped (LANL 1992). Access to LANL as a whole is unrestricted—no perimeter fence is in place. Still, security fences, guard stations, and clearance requirements limit access to individual facilities and areas. Anyone requiring access needs a security clearance and to receive such clearance, visitors must make prior arrangements. Visitors must wear a badge or an escort must at all times accompany them (LANL no date). Some areas, including Mortandad and Pueblo Canyons, are open to hikers, rafters, and hunters. Archaeological sites at LANL are also open to the public (LANL 1992).

Environmental Management and Restoration Activities

Early in its history LANL did not observe the same environmental precautions it does today. Indeed, throughout the United States burying solid waste or releasing liquid wastes directly into surface waters was once considered appropriate. Over time, however, as knowledge of

radioactive and hazardous materials increased, safe handling and disposal practices changed accordingly.

Today LANL operations and waste disposal are carefully planned and monitored. For example, LANL is obligated to comply with all federal and state environmental and health laws and directives regarding environmental management and monitoring. Some of these laws were previously listed and include CWA, CAA, SWDA, RCRA and its Hazardous and Solid Waste Amendments (HSWA), CERCLA, TSCA, NEPA, the Emergency Planning and Community Right-to-Know Act (EPCRA), the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA); the Endangered Species Act; the Cultural Resource Compliance Acts; and the New Mexico Administrative Code (NMAC) (LANL 1999 ES). The U.S. Environmental Protection Agency (EPA), DOE, and the New Mexico Environment Department (NMED) administer these laws.

LANL currently operates under a RCRA and HSWA permit. RCRA and HSWA regulate the generation and disposal of hazardous waste and require cleanup of non-radiological hazardous materials released during prior operations. LANL follows other regulatory frameworks, such as the Mixed Waste Federal Facility Compliance Order, for the remediation of radiological and mixed wastes. At LANL, over 2,000 solid waste management units (SWMUs) have been identified for investigation. As needed, environmental restoration has been conducted or will be conducted at SWMUs to reduce possible environmental damage or human exposure to contaminants. Environmental restoration can include covering and containing a source of contamination to prevent its spread, placing controls on land use, treating the contamination sources, or a combination of these measures (LANL 1999b). Decisions on when and how to conduct environmental restoration are made primarily within RCRA's framework (DOE 1999). LANL continues to conduct environmental restoration to mitigate threats to human health from past operations (LANL 1999b).

In addition to restoration activities, LANL conducts monitoring to track and assess ongoing releases. The LANL Risk Reduction and Environmental Stewardship Division (formerly the Environmental, Safety, and Health Division) is responsible for an extensive monitoring program. Under the 2000 program LANL conducted more than 250,000 analyses for radioactive and nonradioactive contaminants on more than 12,000 samples of groundwater, soil, surface water, sediment, air, and biota (LANL 2001). For over 20 years LANL has published results of its monitoring efforts. These environmental surveillance reports provide a detailed overview of the environment and of LANL. They are a principal source of the data reviewed for this PHA.

ATSDR Involvement

ATSDR's involvement at LANL began in 1992. ATSDR conducted site visits and met with community members to identify their concerns regarding possible public health effects resulting from LANL operations. Residents surrounding LANL requested that ATSDR assess possible adverse health effects in their communities. These residents suspected that LANL releases contaminated surrounding areas. From 1994 to 1996, as part of this assessment, ATSDR conducted environmental sampling of groundwater, soil, surface water, sediment, vegetation, fish, and produce. Samples were analyzed for radionuclides. ATSDR's review of the data found no contaminants at levels of concern (ATSDR no date).

In 1995, ATSDR released a health consultation addressing concerns about tritium contamination in drinking water wells. Community members were concerned that sampling conducted by LANL was inaccurate. Because these documents were unavailable, ATSDR was unable to assess the methods and quality assurance program followed by LANL. A review of the reported concentrations, however, found that the reported tritium concentrations did not pose a public health threat (ATSDR 1995).

In August 1996, ATSDR released a health consultation entitled "Air Monitoring for Radionuclides in San Ildefonso Reservation, New Mexico." ATSDR conducted the health consultation because of community concerns that LANL air monitoring was inadequate. ATSDR concluded that most releases from LANL were radionuclides with short half-lives. ATSDR recommended locating gross gamma environmental monitors at the most frequented areas of the pueblo—areas that also happened to coincide with contaminant migration paths (ATDSR 1996).

In 2001, ATSDR completed a health consultation addressing concerns regarding radionuclides and chemicals possibly released from the 2000 Cerro Grande Fire. ATSDR reviewed available air sampling data collected during the fire. After its review ATSDR concluded that when the Cerro Grande Fire was burning it posed short-term hazards such as heat, burning, and smoke-inhalation. Extinguishing the fire finally eliminated these hazards. No short- or long-term hazards associated with releases of radionuclides or chemical contaminants were identified. Contaminants that were detected were not found at levels of public health concern. The fire left a large area shorn of vegetation and subject to wind and water erosion. ATSDR concluded that erosion could uncover previously buried contaminants, but erosion control measures taken by a number of agencies would minimize this possibility (ATSDR 2001).

Environmental Contamination, Exposure Pathways, and Potentially Exposed Populations

Introduction

In this section ATSDR reviews information about releases of contaminants from LANL and evaluates how people might contact or might be exposed to contaminated media. The *Public Health Implications* section of this PHA analyzes whether health effects could be associated with any of the identified exposure scenarios.

To acquaint the reader with terminology and methods used in this PHA, Appendix F provides a glossary of environmental and health terms used in the discussion.

Evaluating Environmental Data

ATSDR scientists review environmental data collected for a site to determine whether and to what extent chemical or radioactive substances released from a site are present in water, soil, air, or biota (i.e., plants and animals in the region). Environmental levels are then compared against media-specific comparison values (CVs). CVs are used by ATSDR as part of the PHA process and do not necessarily represent site-specific regulatory or monitoring requirements. Generally, if a contaminant's concentration exceeds one or more media-specific CVs, then ATSDR evaluates the contaminant further. For inorganic compounds (metals) and radionuclides ATSDR might also consider background values—some of these substances occur naturally or are the result of global radionuclide fallout.

With regard to CVs, it should be noted that they are not thresholds for adverse health effects; contact with contaminants at concentrations above the CVs will not necessarily make anyone sick. ATSDR sets its CVs at concentrations many times lower than those levels at which no effects have been observed in experimental animals or human epidemiological studies. If several CVs are available for a specific contaminant, ATSDR generally selects the CV that is derived from the most conservative or protective exposure assumptions. This generally protects the most sensitive segment of the population. If contaminant concentrations are above CVs, ATSDR further analyzes exposure variables (e.g., duration and frequency), the toxicology of the contaminant, epidemiology studies, and the weight of evidence for health effects. In this PHA, such analyses appear in the *Public Health Implications* section.

Some of the CVs used for screening by ATSDR include ATSDR's Environmental Media Evaluation Guides (EMEGs), Reference Dose Media Evaluation Guides (RMEGs), and Cancer Risk Evaluation Guides (CREGs); ATSDR also uses EPA's Maximum Contaminant Levels (MCLs) for drinking water, Lifetime Health Advisory (LTHA) for drinking water, media-specific Risk Based Concentrations (RBCs). When no final standards or guidelines are available, ATSDR may use proposed or draft standards (e.g., perchlorate in drinking water). MCLs are enforceable drinking water regulations developed to protect public health. CREGs, EMEGs, RMEGs, LTHAs, and RBCs are non-enforceable, health-based CVs developed by ATSDR and EPA as a method for screening environmental contamination for further evaluation. Proposed and draft standards are also non-enforceable CVs. CVs used by ATSDR for screening radionuclides in water and air were the water-effluent concentrations and air-effluent concentrations presented in Table 2 of Code of Federal Regulations (CFR) 10, Part 20, Standards

for Protection against Radiation. For soil and sediment, ATSDR used CVs from the National Council on Radiation Protection and Measurements (NCRP) Publication No. 129 *Recommended Screening Limits for Contaminated Surface Soil and Review of Factors Relevant to Site-Specific Studies.* Appendix G discusses the CVs used in this evaluation.

Evaluating Exposure

After identifying any contaminants measured above ATSDR's CV screening values, ATSDR evaluates whether and how people have been or are currently exposed to them. It is important to add that a release of a hazardous substance does not always result in human exposure. *People can only be exposed to a contaminant if they come in contact with that contaminant.* Exposure might occur by breathing, eating, or drinking a substance containing the contaminant or by skin contact with a substance containing the contaminant. Figure 4 illustrates ATSDR's exposure pathway evaluation.

ATSDR either identifies an "exposure pathway" as completed or potential or it eliminates that pathway from further evaluation. Prior to its decision ATSDR carefully studies and identifies elements of an exposure pathway that might lead to human exposure. These elements include

1. a source of site-related contamination, such as drums or waste pits,
2. an environmental medium in which the contaminants might be present or from which they might migrate, such as groundwater, surface soil, surface water and sediment, air, and biota,
3. points of human exposure, such as drinking water wells or work areas,
4. routes of exposure, such as breathing, eating, or skin contact; and
5. a receptor population, such as nearby community members or visitors to a site.

A *completed exposure pathway* exists for a past, current, or potential future exposure if contaminant sources can be linked to a receptor population. A *potential exposure pathway* is one which ATSDR cannot rule out, even though not all of the five elements described above are identifiable.

ATSDR analyzed available data for *groundwater*, *soil*, *surface water* and *sediment*, *air*, and *biota* for LANL to determine the nature and extent of contamination and the likelihood of past (1980 to 2001), current, or future exposures. ATSDR's evaluation of possible exposure situations is summarized in Table 1 and presented in greater detail in the following discussion. The primary exposure pathways (past, current, and potential future) identified for populations at or near LANL include

- consumption of groundwater as drinking water,
- accidental ingestion and inhalation of windblown dust from surface soil,
- accidental ingestion and contact with surface water and sediment during recreation,
- inhalation of air borne contaminants, and
- consumption and use of biota.

To characterize possible exposures, ATSDR relied on environmental data presented in the environmental surveillance reports produced by LANL for the years 1980 through 2001. Environmental surveillance reports for the years 1991 and 1993, were, however, unavailable. Although only sampling data from 1980 to 2001 are considered, these data can report information about long-lived contamination resulting from releases that occurred before 1980. In addition, sampling data can only be used to assess contaminant concentrations in site media and usually cannot be used to determine the contamination source. As such, data may also report contamination from above ground nuclear tests. To fully assess exposures to the public, ATSDR evaluated detected contaminant concentrations without attempting to determine the percent contribution from LANL versus other sources. Discussions of the nature and extent of contamination in each media (i.e., groundwater, surface soil, surface water and sediment, air, and biota) are based on data presented in the 19 environmental surveillance reports available to ATSDR.

Groundwater

Groundwater is water that lies beneath the earth's surface. It is found almost everywhere—in cracks and spaces in soil, in sand, and in rocks, all of which hold groundwater in much the same way a sponge holds water. The area where water fills spaces in the soil and rock is the saturated zone. The top of the saturated zone is the water table. The water table might be only a foot, or it might be hundreds of feet below ground surface. Heavy rains or melting snow can cause the water table to rise, just as an extended period of dry weather can cause it to fall.

Groundwater is stored in—and moves slowly through—layers of soil, sand, and rocks known as aquifers. The velocity of groundwater flow depends on the size of the spaces in the soil or rock and on how closely the spaces are connected. Some rock has a large or numerous spaces and can hold a large volume of water; other rock has few spaces, making water flow difficult. When saturated soil is located above such a low permeability layer, water can move down only very slowly and is trapped in an isolated pocket of groundwater known as a "perched" groundwater zone. Water from aquifers rises to ground surface naturally, as in springs, or artificially, as in drilling wells and pumping the water to the surface (Groundwater.com 2003).

Hydrogeology

As stated, LANL sits on a plateau between the Jemez Mountains to the west and the Rio Grande to the east. A number of east-west canyons that extend from the mountains to the Rio Grande divide the plateau. In and around the plateau three groundwater zones underlie LANL: a shallow groundwater zone found in alluvial sediments in the canyons, intermediate perched groundwater, an unsaturated zone, and the regional aquifer.

The canyons are lined with 1- to 100-ft thick alluvial or river sediments deposited by stream flow. This alluvium can hold water and contains the shallowest of the three groundwater zones. The amount of groundwater present in the alluvial sediments depends upon effluent releases, storm water runoff, precipitation, springs, evapo-transpiration, and seepage into the volcanic rocks beneath. Because this zone is closest to the surface, it has the greatest potential for contamination by LANL-related effluent. The second zone, known as the intermediate perched groundwater zone, is at deeper levels—ranging from 90 to 450 ft beneath Pueblo, Los Alamos, and Sandia Canyons. This layer interacts with the overlying alluvial groundwater and discharges at Basalt Spring in Los Alamos Canyon. The vadose zone is a layer of lower permeability tuff

and volcanic sediments between the intermediate perched groundwater above and the regional aquifer below. The moisture content of the 350- to 620-ft thick vadose zone is less than 10%, thereby making recharge of the regional aquifer from the intermediate perched groundwater zone difficult. The water table for the regional aquifer is between 600 and 1,200 ft bgs and is separated from the other groundwater zones by the low-moisture vadose zone. Groundwater in the regional aquifer under LANL generally flows easterly toward the Rio Grande. Groundwater from the regional aquifer discharges into White Rock Canyon from 27 springs, a few of which flow to the Rio Grande (LANL 1999b). Further information regarding the LANL hydrogeology is provided in Appendix E.

Groundwater Use

Groundwater in the alluvial and intermediate perched groundwater zones is not used as a water supply for human consumption. Over time, however, water from these two groundwater zones can potentially filter down to the regional aquifer. In addition, springs cause much of the water from these groundwater zones to discharge to surface waters. Wildlife and cattle grazing in the area use this surface water as a drinking water source.

Groundwater from the regional aquifer serves as the area's industrial and municipal water supply. In the western portion of the plateau, wells pump groundwater 1,100 ft to the surface. The number of wells and well fields providing water to LANL and the community has varied over the years. In 1980, 15 water supply wells and one gallery (a basin which collects underground spring discharge) in three well fields (Guaje, Pajarito, and Los Alamos well fields) produced water for LANL activities and the surrounding communities. The Los Alamos well field was retired in 1991 when the Otowi well field opened with two new operating wells (LANL 1996a). Two wells in Los Alamos Field continue to be used by the San Ildefonso Pueblo for drinking water; LANL retains one other as a monitoring well.

Historically, LANL operated the water supply serving the facility and surrounding communities (LANL 1996a). In September 1998, a lease agreement transferred operation of the Los Alamos water supply from LANL to Los Alamos County. The agreement left LANL responsible for operating the distribution system only within the laboratory boundaries. The county assumed the responsibilities of operating the remainder of the system, providing water to the surrounding communities, and ensuring compliance with the SDWA (LANL 2001). For its water supply system Los Alamos County currently uses groundwater pumped from 12 wells in the regional aquifer (LADPW 2001).

Groundwater and Drinking Water Monitoring Programs

Groundwater studies beneath LANL began in 1945 when the United States Geological Survey (USGS) oversaw groundwater planning. In 1949, USGS, together with the Atomic Energy Commission and LANL, began protecting and monitoring the groundwater. Initially, monitoring focused on Pueblo and Los Alamos Canyons—areas which at the time received waste discharge from the LANL. In 1987, a Memorandum of Understanding (MOU) provided for annual sampling of 13 wells and 4 springs on the San Ildefonso Pueblo land.

Because the region surrounding LANL is—as a result of the local geology—naturally rich in radioactivity, groundwater samples collected within the LANL boundary must be compared to natural background. As a result, the current monitoring program includes regional stations used

to identify background radioactivity and monitoring areas located within LANL boundaries. The samples collected on site are generally located near areas receiving past or current radioactive effluent (LANL 1998).

Groundwater Protection Management Program Plan

Following DOE Order Number 5400.1 (which was superceded by DOE Order 450.1 in 2003), LANL initiated a Groundwater Protection Management Program Plan. The plan established procedures to monitor and document groundwater quality to comply with environmental laws, support resource management, and manage groundwater protection and remediation. Under this plan the environmental surveillance reports provide annual documentation of groundwater monitoring activities and results. Although formal documentation for the plan was not issued until 1990 (and revised in 1995), certain elements of the Groundwater Protection Management Program Plan have been in place since 1949. Groundwater sampling is grouped into the three groundwater zones (alluvial zone, intermediate perched zone, and regional aquifer). The regional aquifer is the only aquifer used for drinking water and is the focus of sampling efforts, although the other two zones are also monitored (LANL 1998).

In accordance with the LANL Environmental Surveillance and Compliance Program groundwater grab samples are typically collected one to two times a year from designated regional, perimeter, and on-site locations. Wells outside the LANL boundary (regional and perimeter) are sampled to determine radioactivity beyond LANL. To ensure the samples are representative they are collected from discharge points of springs and from pumped monitoring wells (LANL 1985). The LANL RCRA permit specifically requires annual monitoring to determine compliance with standards for radionuclides, water quality chemistry, and inorganics (DOE 1999). The monitoring program for each groundwater zone is outlined in Table 2.

Hydrogeologic Workplan

LANL created the hydrogeologic workplan to further investigate groundwater in the region surrounding LANL. The plan was finalized in April 1998 and proposes a multi-year drilling and hydrogeologic analysis program (DOE 1999; LANL 2001). Because the recharge mechanism for the regional aquifer is not well understood, the workplan calls for additional wells to detect hydraulic gradients, groundwater flow and recharge, and water quality. One goal is to characterize the Pajarito Plateau and other areas within the LANL boundary to determine the migration potential of contaminants from disposal areas and the effect of LANL activities on groundwater. Workplan activities are expected to be completed in 2005. In 2000, five new regional aquifer wells and one intermediate-depth perched groundwater well were installed. Three additional regional aquifer wells were also completed. Quarterly sampling began at five of these new wells, but these wells were not part of LANL's groundwater monitoring plan in 2000 (LANL 2001).

Nature and Extent of Groundwater Contamination

Although past waste disposal practices at LANL have resulted in the contamination of the various groundwater zones beneath the site, only a few contaminants have actually been detected in the drinking water wells. However, groundwater monitoring wells within LANL and in the immediate vicinity have contained elevated concentrations of additional contaminants. The water from the monitoring wells is not being consumed; nevertheless, the potential exists for

contaminated water in the alluvial and intermediate groundwater zones to travel to the regional aquifer—from which people do obtain drinking water. ATSDR evaluated groundwater data collected from on-site monitoring (or test) wells installed in the alluvial/perched and regional aquifers, as well as from drinking water wells. The following text and Tables 3 to 5 contain monitoring results from each groundwater zone and from the drinking water supply.

Alluvial and Intermediate Perched Groundwater (Non-potable)

Pueblo, Los Alamos, and Mortandad Canyons receive effluent discharges. Monitoring has detected laboratory-related contaminants in the shallow groundwater located in the alluvial sediments. Additionally, contaminants have been detected in the intermediate perched groundwater below. Neither the alluvial nor the intermediate perched groundwater zones are tapped as a water supply; still, groundwater from these zones discharges as surface water from springs. Similarly, the vadose zone underlying the perched groundwater zones limits contaminant migration to the regional aquifer, but infiltration from the alluvial to the intermediate zone and regional aquifer below has been shown to occur relatively quickly in parts of Pueblo Canyon (LANL 1994). Table 3 lists the radionuclides, water quality parameters, and inorganics found above CVs in the alluvial and intermediate perched groundwater zones at least once during the 19 years of monitoring data reviewed.

The highest concentrations of radionuclides found in alluvial and intermediate perched groundwater were detected in Mortandad Canyon. The following were found above their CVs: cesium-137, plutonium-238, plutonium-239/240, total uranium, and gross alpha. Plutonium-239/240 (to 1,493 picocurie(s)/liter [pCi/L]) and gross alpha (to 6,700 pCi/L) were found at maximum detected concentrations in the greatest amounts above their CVs: 20 pCi/L and 15 pCi/L, respectively. Radionuclides were detected at their highest concentrations in the early 1980s but have decreased since then.

Of the 22 chemical contaminants detected above CVs, five were considered measures of water quality (chloride, fluoride, nitrate, perchlorate, and sodium). Samples from Mortandad Canyon also recorded the highest readings of the water quality parameters. Three of the five parameters exceeding CVs reached maximum levels in the 1980s. Sodium and chloride exceeded CVs most frequently.

The remaining 17 inorganics found above CVs were detected throughout each of the four canyons monitored. Arsenic, boron, cadmium, chromium, iron, lead, manganese, and molybdenum were detected above CV most frequently (at least 12 times each). Chromium (to 7.7 ppm) was detected at the greatest amount above its CV (0.03 ppm).

Regional Aquifer (Monitoring Wells)

Although researchers had previously believed the vadose zone would prevent contaminant migration, monitoring indicates that contaminants from LANL activities have reached the regional aquifer, particularly beneath Los Alamos and Pueblo Canyons (LANL 1996a). Contamination—likely from sewage treatment plant effluent and radiological industrial effluent—has been found in the upper portions of the regional aquifer. Table 4 lists water quality parameters and inorganics detected above CVs in the regional aquifer at least once during the 19 years of monitoring data reviewed.

In the monitoring wells evaluated (Test Wells 1, 2, 3, 4, 8 and Deep Test Wells 5A, 9, 10), no radionuclides were detected above their CVs. Fluoride (to 0.88 ppm) and sodium (to 135.4 ppm) were the two water quality parameters found above their CVs (0.5 ppm and 20 ppm, respectively). Arsenic (to 0.012 ppm), cadmium (to 0.014 ppm), lead (to 9 ppm), and molybdenum (to 0.72 ppm) were the inorganics detected above CVs. Lead concentrations were highest in 1993; subsequent measurements were generally well below 1 ppm.

Additionally, in 1998, in the southeastern part of LANL property, high explosives were found in the regional aquifer at concentrations above EPA health advisory guidance levels for drinking water. Although the extent of the explosive contamination is unknown, none of these contaminants have been found in the drinking water wells. LANL is currently conducting studies to determine the contamination extent (LANL 2001).

Regional Aquifer (Drinking Water)

Contaminants detected above CVs in drinking water wells from the Los Alamos well field (wells LA1B through LA-6), Guaje well field (wells G-1A through 4aA, and G-1 through G-6), the Pajarito well field (wells PM-1 through PM-5), and the Ottowi well field (wells O-1 and O-4) are presented in Table 5. Gross alpha was the only radiological test result detected above its CV in drinking water well samples. At the Los Alamos well field in 1985, the maximum gross alpha concentration (30 pCi/L) was detected slightly above its CV (15 pCi/L). Overall, gross alpha was detected above its CV in only 4 of the hundreds of samples collected between 1980 and 2001.

Non-radiological contaminants detected above CVs in drinking water wells consisted of fluoride, perchlorate, sodium, and 11 metals. Perchlorate, a byproduct of nuclear chemical research at LANL, has been found in the Ottowi water supply wells to 0.005 ppm. The source is thought to be early cold war-era radioactive liquid waste treatment facilities that discharged into Acid Canyon prior to 1964 (LANL 2000). Arsenic (to 0.11 ppm) was the only contaminant detected at a maximum concentration more than 100 times greater than its CV (Arsenic also was detected once up to 0.274 ppm in a Los Alamos stand-by well). Sodium (to 221 ppm) and boron (to 10 ppm) were the only contaminants detected greater than 10 times their CV. Other than arsenic, contaminants detected above their CVs infrequently.

Potential Groundwater/Drinking Water Exposure Scenarios

Groundwater from the alluvial and intermediate perched zones is not used as a water supply; thus no public exposure to this water occurs. (Contact with groundwater discharged in springs is evaluated under the *Surface Water and Sediment* section of this PHA.) Only groundwater from the regional aquifer serves as the community and as the LANL water supply. The water supply wells furnish a variety of municipal, industrial, and household uses. People utilize the water for irrigation, drinking, cooking, showering, and bathing. Exposure can occur through each of these uses. During cooking and drinking, people are exposed by ingestion. Bathing can result in incidental ingestion, dermal contact, and inhalation exposure. An evaluation of the potential public health affects associated with exposure from using the regional aquifer as a water supply is provided in the *Public Health Implications* section of this PHA.

Surface Soil

Background, Geology, and Meteorology

Soil is the upper layer of the earth; it is composed of eroded rock and mineral and decomposed plant and animal matter. Soil serves as a natural medium for the growth of plants (SSSA 2003). Soil is also an integrating medium. Contaminants can attach to soil particles via ion exchange (when a chemical bonds with soil) or adsorption (when a gas or a liquid chemical adheres to liquids or solids in soil). Additionally, soil is fairly immobile—contaminated soil usually stays put. That said, however, weather can move soil: precipitation (e.g., rain, hail, or snow) can carry soil in runoff and wind can disperse soil as dust.

The landscape at LANL was formed by a volcanic eruption approximately 1.4 million years ago; that eruption also formed the Bandelier Tuff. As a result, the soil at LANL is of eolian origin or derived from colluvium or alluvium as well as other volcanic rock such as dacite. Volcanic ash is hard and porous; uncompressed volcanic ash is susceptible to relocation by runoff and wind. Because LANL is located in a semi-arid region, runoff is minimal. LANL receives an annual average of 10 to 20 in of precipitation as rain and hail in the summer and as snow in the winter (which melts into runoff in the spring). The terrain at LANL slopes from west to east, so precipitation that falls in the western part of the laboratory flows easterly as runoff. Yet because of evaporation, transpiration and infiltration, runoff only reaches the Rio Grande several times a year. Soil contaminants transported to canyon streams in runoff are evaluated in this PHA as part of the surface water and sediment exposure pathway.

Due to the complicated terrain, winds at LANL are fairly diverse. On average, one might see a light southeasterly upslope wind during the day and a light westerly and northwesterly drainage wind at night. Annual wind roses show that most wind comes from the south and west, traveling across LANL to the north and east, with spring being the windiest season. Soil contamination transported as windblown dust is evaluated in this section of the PHA.

Soil Monitoring Program

As required by the DOE environmental compliance order 5400.5 (1990), soil testing is performed annually at LANL. There are no federal standards directly applicable to radionuclides in soil, other than 5 pCi/g for Radium-226/228, from the Uranium Mill Tailings Radiation Control Act of 1978 (UMTRCA) (42 U.S.C. 7918). Periodic soil monitoring provides information on possible exposures and on long-term accumulation trends. Monitoring is therefore considered an essential part of environmental surveillance.

Soil samples have been collected at designated soil sampling stations at and around LANL at the three types of stations: regional, perimeter, and on site. Regional stations are considered beyond the range where LANL activities could potentially impact the area. Still, they provide important information about background levels of radionuclides and inorganics that are naturally a part of soil. Perimeter stations are located within 4 kilometers (km) (2.3 miles [mi]) of LANL, mainly within surrounding residential and community areas. They provide information about the possible impacts of LANL activities in these areas. On-site stations are within LANL boundaries where public access is restricted. These stations tend to be near and downwind of facilities which could have released radionuclides and chemical contaminants. Monitoring these stations provides information about possible releases.

The soil samples collected at LANL are composite samples; that is, they are a mixture of soil collected from a single area considered representative of that area and its environs. Specifically, five soil plugs are collected from the corners and center of a 10-square meter (m^2) plot and mixed to form a composite sample.

Between 1980 and 2001 samples were analyzed for radionuclides. Inorganic analyses were most likely added in 1991 and continued from 1992 to 2001. (Data from 1991 were unavailable; thus ATSDR could not confirm the commencement of inorganic analysis in 1991.)

Nature and Extent of Soil Contamination

Soil data from TA-21, TA-50, TA-51, TA-53 and TA-54 were evaluated as part of this PHA. TA-50, TA-51 and TA-54 are waste management areas, research sites, or a combination of both. TA-50 treats and manages industrial and radioactive liquid waste, TA-51 is used for research on waste disposal, and TA-54 is a radioactive and chemical disposal site. The soil at these sites could have become contaminated by accidental spills, leaking containers, or inadequately treated waste and effluent. TA-21 and TA-53 are active research sites—radionuclides and chemicals employed in experiments at these sites could have been inadvertently released to the surrounding soil.

In reviewing data available from 1980 to 2001, the radionuclides cesium-137, plutonium-238 and strontium-90 were found above their CVs. Cesium-137 exceeded its CV at TA-53 in 1980 (of 3.5 picocuries/gram [pCi/g] uncertainty [±] 0.40) and in TA-54 plutonium-238 exceeded its CV on two occasions (in 1985 at 11.9 pCi/g ± 0.475 and in 1994 at 16.683 pCi/g no uncertainty reported). Strontium-90, however, was found above its CV in each of the technical areas reviewed. The maximum concentration detected was in 1998 at 1.55 pCi/g ±0.79 in TA-50. Similarly, arsenic was found above its CV in each of the technical areas reviewed (to a maximum of 6.0 ppm in TA-21 in 1994). Table 6 summarizes the locations and years in which contaminants exceeded their respective soil CVs.

Possible Soil Exposure Pathways

Los Alamos County is home not only to LANL, but also the San Ildefonso Pueblo, two residential communities, and their associated commercial areas. If contaminated soil finds its way (via runoff or wind) into these communities, residents could be exposed to soil contaminants through dermal contact and incidental ingestion. The *Public Health Implications* section of this PHA provides a detailed evaluation of the potential public health impacts from possible exposures to cesium-137, plutonium-238, strontium-90, and arsenic in soil.

Surface Water and Sediment

Hydrology

Hydrology describes how water is carried into, through, and away from a site. At LANL, surface water is found in intermittent streams in the canyons that cut through the Pajarito Plateau. The eight main canyons intersecting LANL property run parallel to each other from the northwestern to the southeastern section of the property. From north to south, the main canyons at LANL are Pueblo, Los Alamos, Sandia, Mortandad, Cañada del Buey, Pajarito, Water, and Ancho Canyon (Figure 5).

Although the streams within these canyons remain dry throughout most of the year, rainfall, snowmelt, springs, and laboratory effluent create seasonal surface water flow across LANL. The Jemez Mountains to the west are the primary surface water source. The rainfall from these highlands flows across the Pajarito Plateau and into the canyons from west to east, eventually reaching the Rio Grande southeast of LANL. Usually, however, the surface water flow in the streams has dried from evaporation, transpiration, and infiltration prior to reaching the Rio Grande. Spring snowmelt from the Jemez Mountains can provide stream flow that lasts for days or weeks in some of the canyons. The amount of water flowing in the canyons during the snowmelt is minimal and does not transport large amounts of sediment. Springs also discharge groundwater to streams as surface water. During the summer, thunderstorms create short (several hours), high-volume, run-off events. This type of flow can transport a greater amount of sediment than usual (LANL 1999). As a result of thunderstorms and heavy rainstorms, water in several of the canyons discharges to the Rio Grande several times a year (LANL 1981).

Sediments are intimately tied with surface water—the two media continually exchange components. As water flows in a river or lake, the particles of soil or organics that do not readily dissolve slowly sink to the bottom and deposit in the form of sediment. Additionally, when water flows over sediments, depending upon the volume and force of the flow, sediment particles can re-suspend and travel downstream. Because surface water and sediment occur together and can easily exchange particles and contaminants, the two media are most easily evaluated together. Many of the sediments adjacent to LANL contain the contaminants historically released into the canyons as a constituent of industrial effluent. Contaminants found in surface water from effluent, air deposition, or other releases have the ability to adsorb and become attached to sediments.

Waste Received

In addition to the natural run-off produced by precipitation and springs, surface water flow in the canyons is augmented by effluent from LANL activities. Since LANL's opening in the 1940s the canyons adjacent to LANL have received treated and untreated radioactive and sanitary waste. Acid, Pueblo, and Los Alamos Canyons were the primary recipients of untreated radioactive liquid waste. In the 1950s, newly constructed treatment plants processed the effluent before its release into the canyons. During the 1980s, retention evaporation lagoons decreased potential migration of contamination off site. Over the years LANL has held permits for as many as 124 National Pollutant Discharge Elimination System (NPDES) outfalls (LANL 1996a) for releasing effluent. In response to the Waste Stream Characterization Program and Corrections Program and the NPDES Outfall Reductions Program, LANL has been steadily reducing the number of NPDES permits. The 2001 NPDES permit listed 21 outfalls: 1 sanitary and 20 industrial (9 of which are targeted for elimination) (LANL 2001). Acid, Pueblo, Los Alamos, Sandia, and Mortandad currently receive or have received effluent waste (LANL 1981). Today effluent discharged to the canyons is treated before release.

Surface Water Use

Pueblo Canyon, Los Alamos Canyon, Sandia Canyon, Mortandad Canyon, Pajarito Canyon, Cañada del Buey, Water Canyon, and Ancho Canyon carry seasonal water across LANL to the Rio Grande. None of the intermittent streams held in these canyons are used by humans for drinking water or agricultural irrigation. Area residents and passers-by may come into contact

with some of these streams during recreation such as hiking or hunting, but public access to most areas on the LANL property is restricted. Access is most likely in the northern portions of the property and to the east of LANL. Wildlife may use the streams for drinking water. In addition, effluent from Pueblo Canyon is used for golf course irrigation during the summer months (LANL 1996a). Because the streams on LANL property contain no fish, they are not used for sport fishing (LANL 1999).

Surface Water and Sediment Monitoring Program

Historically, releases of effluents have left the sediments on many of the canyon floors contaminated with various site-related substances. LANL established surface water and sediment monitoring programs to assess the extent to which contamination was migrating off site. Surface water sampling points are located at on-site and at perimeter stations to monitor the surface water in streams on the Pajarito Plateau. Sampling points have also been established at regional sampling stations to monitor background concentrations of radionuclides, inorganics, and water quality parameters. Surface water sampling stations are placed where effluent discharge or natural runoff allows the stream to flow for several weeks or months of the year, thus allowing evaluation of the effects of industrial outfall or of soil contamination (LANL 2001). Canyons monitored each year include Acid Pueblo, DP Los Alamos, Mortandad, Pajarito, Sandia, Water, and Cañada del Buey.

Historically, surface water samples were collected as grab samples during or after a runoff event (either during the spring snow melt or after a summer thunderstorm). Often, no water flows through a canyon, making sampling impossible. Beginning in 1996, LANL established stream-gaging stations, some of which have automated samplers. Currently, surface water samples are collected at effluent discharge points or where stream flow is maintained. Grab samples of runoff samples are also collected (LANL 1999). Sampling also occurs in the two reservoirs in Guaje and Los Alamos Canyons upstream of LANL. These reservoirs are used for recreation and landscape irrigation. In 1999, LANL monitored 22 on-site and perimeter and 8 regional surface water sampling locations (LANL 1999).

Similar to the surface water sampling program, LANL measures sediment contamination by collecting annual sediment samples from canyons such as Pueblo, Los Alamos, and Mortandad Canyons and others that cross the LANL property, many of which in the past have received waste from LANL activities. Since the beginning of the sediment sampling program sediment samples have been analyzed for radionuclides. Analysis for trace metals began in 1990; polychlorinated biphenyl (PCB) and semivolatile organic compound (SVOC) analyses began in 1993 (LANL 2001). In addition to canyon stations, sediment sampling is conducted downstream of two waste disposal areas: Area G (an active waste storage facility at TA-54) and Area AB (an area at TA-49 where underground subcritical nuclear testing occurred from 1959 to 1961). Sediment samples are collected to establish whether contaminants are migrating from these two locations. A total of 53 sediment sampling locations on the Pajarito Plateau were monitored in 1999 (LANL 1999). As with surface water, LANL also collects regional sediment samples to compare contaminant concentrations on and off site (LANL 2001).

Special sediment studies have also been conducted over the years in response to unexpectedly high contaminant concentration measurements or in areas not usually tested. These studies have been conducted by LANL and by other agencies, such as the US EPA.

Nature and Extent of Surface Water and Sediment Contamination

To evaluate the nature and extent of surface water and sediment contamination at LANL, ATSDR reviewed surface water and sediment monitoring data from 1980 to 2001 for publicly accessible areas of Acid Pueblo Canyon, Los Alamos Canyon, and Mortandad Canyon (San Ildefonso and White Rock) and Cañada del Buey. These areas were selected because many have received effluent in the past, they are somewhat accessible, and/or they are typically able to maintain surface water flow during some part of each year. Radionuclides, water quality parameters, and inorganics were detected above CVs in the surface water in at least one of the canyons. Because no surface water CVs are available ATSDR used drinking water CVs to screen contaminant concentrations. Drinking water CVs are derived from assumptions about daily water consumption. Because at LANL surface water is not used as a drinking water supply, this method provides a particularly conservative initial screen.

ATSDR also examined sediment sampling data from publicly accessible areas of Acid Pueblo Canyon, Los Alamos Canyon, and Mortandad Canyon (San Ildefonso and White Rock) and Cañada del Buey. Four radionuclides, three inorganics, and two organics were detected above soil CVs in sediments. Again, because no CVs specific to sediment are available, soil CVs were used to screen sediment contamination. Soil CVs are derived assuming daily contact with surface soil at a home. As such, using these CVs also provide a particularly conservative initial screen. Of the contaminants detected, iron and manganese were found above their CVs only once during the sampling period. Arsenic was the only chemical consistently measured above its CV.

The highest levels of radioactivity for surface water were found in Los Alamos Canyon (total uranium and gross alpha). For sediment, the highest levels were typically detected in Los Alamos Canyon (americium-241, cesium-137, strontium-90, and total uranium). Acid Pueblo Canyon had the highest level of plutonium-239/240. The highest values of water quality parameters and inorganics (in surface water and sediment) were distributed primarily throughout Los Alamos and Acid Pueblo Canyon. Overall, strontium-90, chloride, fluoride, sodium, and arsenic were detected above CVs with the greatest frequency. Acid Pueblo Canyon had the only detections of organics in surface water and Los Alamos Canyon had the only detections of organics in sediment. Specific contaminants found in each area is discussed below and summarized in Tables 7 to 11.

Acid Pueblo Canyon

From this canyon, gross alpha radiation was the only radiological test result detected above its CV in surface water. At least twice in the sediment cesium-137, plutonium-239/240, and strontium-90 were all detected above their CVs. Strontium-90 (to 5 pCi/g) was the only radionuclide to exceed its CV by more than a factor of 10. Three organics, five water quality parameters, and eight inorganics were also detected above CVs in the surface water. Chloride (to 300 ppm) and arsenic (to 0.019 ppm) were the only two to exceed their CV by more than a factor of 10. Fluoride, nitrate, sodium, and boron were detected above their CVs with the greatest frequency (more than three times). Three inorganics were also detected above CVs in the sediment, but only arsenic was detected more than once. None of the inorganics detected in the sediment exceeded their CV by more than a factor of seven.

Los Alamos Canyon

In the surface water, both total uranium (to 576 pCi/L) and gross alpha (to 470 pCi/L) were detected above their CVs. Four water quality parameters and seven inorganics were also measured above CVs. The maximum detected concentration of all four water quality parameters exceeded CVs by at least 30 times. Arsenic (to 0.017 ppm) was the only inorganic with the maximum detected concentrations greater than 10 times its CV. In sediment, americium-241, cesium-137, plutonium-239/240, and strontium-90 were detected above CVs. Arsenic, benz(a)anthracene, and benzo(a)pyrene were also found above CVs.

Mortandad Canyon (San Ildefonso and White Rock)

No radionuclides were detected in surface water samples from accessible areas of Mortandad Canyon (San Ildefonso and White Rock). Only fluoride, sodium, arsenic, and boron were found about CVs. In sediment, only strontium-90 and arsenic were detected above CVs.

Cañada del Buey

Strontium-90, with a maximum concentration of 1.29 pCi/g in sediment, was the only radionuclide found above its CV in either media. In surface water, chloride, fluoride, sodium, and five inorganics were found above drinking water CVs. Of these contaminants, chloride (to 40 ppm), fluoride (to 9.3 ppm), arsenic (to 0.0058 ppm), and molybdenum (to 0.5 ppm) were found above their CVs in more than 50% of the monitoring years. In sediment, arsenic was the only non-radiological contaminant found above its CV.

Surface Water and Sediment Exposure Pathways

Monitoring conducted in the canyons adjacent to LANL found contamination present in the surface water and sediment. Persons in the area use these canyons for recreational purposes such as hiking, walking, and hunting. As a result, ATSDR identified dermal contact and incidental ingestion of contaminated surface water and sediment during recreation by adults and children as a possible exposure scenario. The *Public Health Implications* section of this PHA contains an evaluation of the potential public health effects from using the canyons for recreational purposes.

Air

The air we breathe comprises many gases, most of which can neither be seen, smelled, nor tasted. Nitrogen (approximately 78%) and oxygen (approximately 21%) are the primary gases in air. The remaining 1% of the air includes water vapor, carbon dioxide, ozone, and hundreds of other chemicals found only at very low levels.

Activities at LANL's research laboratories, waste management areas, and other facilities have released additional gases—including radionuclides—to the air. These gases, or airborne contaminants, are primarily transported from LANL to surrounding areas by the wind. Wind patterns, which are fairly diverse and are described in the *Background* section of this PHA, affect where contaminants migrate. A daily pattern, however, exists with winds blowing southeasterly during the day and northwesterly during the night. Wind strength affects how quickly contaminants move, and at what concentrations. Strong winds disperse contaminants rapidly over large areas, resulting in lower contaminant concentrations. Light winds transport contaminants slowly in smaller areas, resulting in relatively higher concentrations.

Air Monitoring Program

LANL monitors stack emissions and ambient air to track possible releases of and exposures to airborne contaminants. Air monitoring stations which collect emissions directly from stacks or other on-site release points (e.g., within an exhaust stream) provide some information about potential releases. That said, however, these stations do not represent accurate exposure conditions because their locations are often inaccessible to the public. Additionally, during transport though the air contaminant concentrations and characteristics change. Thus only ambient air monitoring stations can provide information about potential exposures. These stations are often located in areas with public access and provide information about the components in the air that people breathe. As such, data from ambient air monitoring stations are the focus of this evaluation.

LANL's ambient air monitoring network is called AIRNET. AIRNET is composed of reference stations, perimeter stations, and on-site stations. Data gathered from the reference stations provide information about conditions beyond the range of potential influence from normal LANL operations. LANL uses data from these stations to determine regional background and fallout levels of atmospheric radioactivity. The reference locations, which LANL calls "regional" stations, are located within the five counties surrounding Los Alamos County, at distances up to 80 km (50 mi) from LANL (LANL 2001). From 1980 through 1999, LANL sampled three regional stations: Espanola, Pojoaque, and Santa Fe. In 2000 a second Santa Fe ambient air sampling station was added and the Pojoaque station was replaced by the El Rancho station. Between 1994 and 1997 LANL sampled additional air monitoring stations within the Pueblo of San Ildefonso, Taos Pueblo, and Jemez Pueblo. LANL has designated these as "pueblo" stations. Because of their distance from the LANL boundaries ATSDR included the pueblo stations with the regional stations when conducting evaluations. The pueblo stations were established as part of a MOU that DOE entered into with the Pueblo of San Ildefonso and the Bureau of Indian Affairs to conduct environmental sampling on pueblo land (LANL 1996a).

Perimeter stations include air monitoring stations located just outside the boundaries of LANL. These stations are within approximately 4 km (2.5 mi) of the LANL boundary, in residential and community areas potentially affected by LANL operations (LANL 2001). The number of perimeter stations has varied over the years from 11 stations in 1980 to 16 stations in 1992 and 24 stations in 2000.

On-site air monitoring stations monitor for LANL air emissions are located where public access is limited (LANL 2001). The number of on-site ambient air monitoring stations has varied over the years—from 11 stations in 1980 to 20 stations in 1992, 31 stations in 1994, and 23 stations in 2000. ATSDR focused its evaluations on the technical areas most likely to report elevated levels of contaminants, including TA-2, TA-3, TA-21, TA-53, and TA-54. TA-2 included the Omega West Reactor, which operated from 1956 through 1992. The reactor produced radioisotopes used in research laboratories. TA-3 and TA-21 support a number of active research laboratories. TA-53 houses the LAMPF, a proton accelerator and research facility. The LAMPF produces most of the radioactive emissions from LANL. A portion of TA-54 has served as the primary waste disposal area for radioactive, hazardous, and mixed wastes produced throughout LANL.

To assess the potential transport of LANL air emissions to the surrounding environment, LANL monitors meteorological conditions in addition to conducting ambient air monitoring (LANL

2001). LANL collects data on the directions of daytime and nighttime winds from five meteorological stations—four atop mesas and one on Pajarito Mountain (LANL 2001). LANL also periodically evaluates whether airflow around the ambient air monitoring stations are affected by nearby obstacles or topography and relocates or modifies stations when necessary (LANL 1996a). Statistics on wind at LANL and around LANL have not varied significantly from year to year (LANL 1994)

Between 1980 and 2001 LANL analyzed samples collected from ambient air monitoring stations for radionuclides, beryllium, criteria pollutants (six common air pollutants regulated by EPA) or for a combination of both. The radiological contaminants sought included gross alpha, gross beta, americium-241, tritium (as tritiated water), iodine-131, plutonium-238, plutonium-239/240, total uranium, uranium-234, uranium-235, and uranium-238. Four of the six criteria pollutants sought included nitrogen dioxide, ozone, sulfur dioxide, and particulate matter. Continuously operating air sampling stations are used to collect samples. In 1980 and 1981, air filters from these stations were collected monthly (LANL 1981, 1982). Between 1982 and 1992, air filters were collected monthly and analyzed for gross alpha and gross beta. Analyses for other radionuclides were conducted quarterly. Beginning in 1992, for all parameters LANL changed to biweekly sampling and analysis (LANL 1994).

But not every sample is analyzed for each radionuclide or criteria pollutant during each sampling event—the sampling and analysis program is affected by a number of factors. First, LANL seeks some contaminants not requiring monitoring by law; the sampling program for these contaminants is, therefore, flexible. Second, in several cases LANL or other agencies have determined that emissions are low enough to forgo sampling. For example, LANL discontinued criteria pollutant monitoring in 1995 after several years without detections above typical regional background levels (LANL 1996a). Sampling for particulate matter, however, resumed in 1998 to assess releases during wildfires. In 2000, LANL also sampled on-site stations for volatile organic compounds (VOCs) and metals during the Cerro Grande wildfire (LANL 2001). Third, by tracking certain measurements, such as gross alpha and gross beta, LANL can determine whether additional measurements for specific radionuclides are necessary. If the gross alpha and beta activity in a sample is consistent with past observations and background, additional analyses for specific radionuclides are not necessary (LANL 1996a). Lastly, on occasion, when a facility is suspected of releasing more than usual levels of a contaminant, LANL only tracks that specific contaminant.

In conducting air monitoring, LANL has instituted a number of activities as part of their quality assurance/quality control (QA/QC) plan. The QA/QC plan provides LANL and others with insurance that data collected represent actual site conditions and that the data are not under- or over-reporting contaminant concentrations. QA/QC activities at LANL include

- Creating and implementing project-specific QA/QC plans for different aspects of the air monitoring program.
- Collecting duplicate quality assurance samples at two on-site stations (beginning in 1995).

In addition, DOE and the State of New Mexico have entered into an agreement-in-principle for an Environmental Oversight and Monitoring program which funds state monitoring activities of

LANL air emissions. In 1998, the DOE Oversight Bureau of the NMED published a report concluding that the LANL air data quality is good (LANL 1998).

Nature and Extent of Ambient Air Contamination

Between 1980 and 2001, LANL collected ambient air samples from regional, perimeter, and on-site (TA-2, TA-3, TA-21, TA-53, and TA-54) stations. At one or more times during at least a 1 year period between 1980 and 2001 LANL sampled for gross alpha, gross beta, americium-241, tritium (as tritiated water), plutonium-238, plutonium-239/240, total uranium, uranium-234, uranium-235, and uranium-238 at the regional, perimeter, and on-site stations. In each sampling event these contaminants were detected at concentrations below their CVs. LANL also analyzed ambient air samples from TA-21 and perimeter stations for iodine-131 in 1992 and 1994 and TA-3 in 1994. Detected concentrations were below the CV for iodine-131 in each sampling event. Beryllium sampling occurred at TA-3 in 1992, 1994, and 1998; at TA-21 and TA-53 in 1992; at TA-54 in 1989 and 1990; and perimeter and regional stations in 1989, 1990, 1992, 1994, and 1998. In each sampling event detected concentrations were below the CV for beryllium.

Air Exposure Pathways

When contaminants move in air they are not restrained by fences and barriers. Wind can transport contaminants beyond LANL boundaries, into surrounding communities. As such, anyone at or near LANL could breathe air containing contaminants released from LANL facilities, including residents in communities adjacent to LANL, employees at LANL, or visitors to LANL and the surrounding communities. The *Public Health Implications* section of this PHA provides a detailed evaluation of the potential public health impacts from possible exposures to airborne contaminants.

Biota

Background

Biota includes wildlife (e.g., deer, fish, and wild plants) or domestic animals (e.g., cattle) and plants (e.g., tomatoes and apples) in a particular region. Biota contamination of animals can occur through inhalation of contaminants in the air, dermal contact with contamination in water or soil, and through ingestion of contaminated water, soil, or other biota (i.e., food web transfer). Biota contamination of plants occurs through uptake of contaminants in groundwater, soil, surface water, and sediment. Deposition of airborne contaminants on plant surfaces or soil is another source of contamination. In evaluated monitoring data for biota ATSDR considered how that biota is used as food or used in tribal practices.

The climate in and around LANL is semi-arid and the terrain is complicated. The range of elevations, the steep canyons and the area's various wetlands and water bodies in provide a variety of habitats that produce a biologically diverse region. Thus in and around LANL a variety of wild and domestic edible plants, fruits, animals, and animal products are grown, harvested or both.

Biota monitoring program

The biota monitoring program at LANL (mandated by DOE environmental compliance orders DOE 5400.1 and DOE 5400.5) is diverse and expansive. This program's three main objectives

are 1) to determine radioactive and nonradioactive contaminants in biota collected from LANL, perimeter, and regional monitoring stations; 2) to determine potential contamination trends over time; and 3) to assess radiological doses contributed by biota exposures.

The monitoring program focuses on biota associated with the human food chain and with tribal practices. From 1980 to 2001, LANL sampled a variety of items from on-site locations and compared them to samples from perimeter and regional sites. The years and the biota sampled are summarized in Table 13.

Biota sampling is constrained by a number of factors. For example, because deer and elk are not purposely killed for monitoring purposes, the program relies on chance events to collect deer and elk data. These events (e.g., road deaths or natural deaths) dictate when and where the samples are collected. Furthermore, because animals move from place to place, where they die might not represent where they lived or what their exposures were. Natural disasters, such as the Cerro Grande fire in May 2000, can destroy or alter biota that would have been sampled. As such, the LANL monitoring program cannot provide a controlled picture of biota contamination over time.

Nature and Extent of Biota Contamination

For a number of reasons, a year-to-year assessment of the nature and extent of biota contamination is difficult to accomplish. Although biota, except deer and elk, can be collected from a consistent set of locations each year, migration, movement, and climate can affect the available biota samples and result in inconsistent data. Because of the inconsistency of the data, drawing conclusions about the nature and extent of contamination is problematic. Tables 14 through 17 summarize the maximum detected concentrations of chemical contaminants and of radionuclides found during biota monitoring at LANL. No CVs are available for food items; therefore, all contaminants detected in biota are presented in these tables. Each type of the biota sampled was analyzed for a unique list of chemical contaminants, radionuclides, or both. For example, honey, produce, Navajo tea, wild spinach, prickly pears, overstory, understory and alfafa forage were analyzed for radionuclides and inorganics. The remaining biota (eggs, milk, tea, mushrooms, piñon nuts and shoots, cattle, deer, elk, steer and small mammals) were only analyzed for radionuclides.

Biota Exposure Pathways

Residents in the communities surrounding LANL consume and otherwise use the region's biota. Exposure to potentially contaminated foodstuff and biota could occur through consumption or dermal contact. The *Public Health Implications* section of this PHA provides a detailed evaluation of potential public health impacts from possible exposures to contaminants in biota.

Public Health Implications

Introduction

In this section of the PHA, ATSDR further evaluates contaminants detected at levels above CVs. As part of this evaluation, ATSDR estimated hypothetical exposure doses using assumptions about the frequency, duration, and magnitude of site-specific exposures. These assumptions are intentionally selected to overestimate potential health effects, and, accordingly, to ensure protection of public health. The exposure estimates allow ATSDR to evaluate the likelihood, if any, that the evaluated contaminants are associated with adverse health effects. ATSDR then compared the estimated exposure dose for a contaminant to either its ATSDR minimal risk level (MRL) or EPA reference dose (RfD). ATSDR calculates MRLs and RfDs using the available scientific literature on exposure and health effects for a chemical. Generally, these values are established at concentrations *many times lower* than levels at which no effects were observed in experimental animals or human epidemiologic studies. A description of the methods and assumptions used in estimating exposures is presented in Appendix H.

> Human exposure does not always result in adverse health effects. Determining public health implications involves carefully studying what is known overall about the toxicity of the chemical or radioactive contaminant of concern and the likelihood of it causing harm under site-specific exposure conditions.

In addition to comparing estimated doses against MRLs or RfDs, ATSDR also closely examined relevant scientific literature from toxicological and epidemiological studies to assess the contaminant's (and sometimes the related substances') potential for health effects at the detected levels. In addition, ATSDR examined whether characteristics of the exposed populations—such as age, sex, nutritional status, genetics, lifestyle, and health status—could influence how a person absorbs, distributes, metabolizes, and excretes contaminants. ATSDR also reviewed the scientific literature to evaluate the likelihood that detected contaminant levels might result in cancer effects.

As discussed in the previous section, ATSDR identified contaminants in five exposure situations that required evaluation:

1. Consumption of groundwater as drinking water.
2. Accidental ingestion and inhalation of wind blown dust from surface soil.
3. Accidental ingestion and contact with surface water and sediment during recreation.
4. Inhalation of airborne contaminants.
5. Consumption of biota as food and contact with biota in tribal practices.

Special Considerations of Women and Children

Contaminants in the environment can sometimes affect women and children differently from the general population. Women and children tend to be smaller than the average person, which means smaller quantities of contaminants can affect them. Hormonal variations, pregnancy, and lactation can change the way a woman's body responds to some substances. A mother's past exposures as well as exposure during pregnancy and lactation, can result in a fetus or infant ingesting chemicals through the placenta or in its mother's milk. Depending on the stage of pregnancy, the nature of the chemical involved, and the dose of that chemical, fetal exposure can result in problems such as miscarriage, stillbirth, and birth defects.

ATSDR recognizes that young people—whether fetuses, infants, or children—have unique vulnerabilities. Children are not small adults; a child's exposure can differ from an adult's exposure in many ways. A child drinks more fluids, eats more food, and breathes more air per kilogram of body weight than does an adult. A child has a larger skin surface area in proportion to body volume. A child's behavior and lifestyle also influence exposure. Children crawl on floors, put things in their mouths, play close to the ground, and spend more time outdoors. These behaviors can result in longer exposure durations and higher intake rates.

Children's metabolic pathways, especially in the first months after birth, are less developed than those of adults. In some cases, children are better able than adults to deal with environmental toxins, but in others, they are less able to deal with such exposures and more vulnerable than adults to their effects; for example, some chemicals that are not toxins for adults are highly toxic to infants.

Children grow and develop rapidly in the first months and years of life. Some organ systems, especially the nervous and respiratory systems, can become permanently damaged if exposed to high concentrations of certain contaminants during this period. Also, young children have less ability to avoid hazards because they might lack the knowledge necessary to avoid them and because they depend on adults for decisions that affect children but do not affect adults.

In the following discussions, ATSDR will indicate whether women and children were, are, or could be exposed to contaminants of concern and will discuss the possible health concerns related to these exposures.

Groundwater

No adverse health effects are expected from consumption of water from the community and LANL water supplies.

A review of the community and LANL water supply monitoring data from 1980 though 2001 revealed chloride, fluoride, sodium, perchlorate, 11 metals, and gross alpha at maximum concentrations greater than ATSDR health-based CVs for drinking water. To evaluate the potential for adverse health effects when adults and children drink water from these supplies, ATSDR applied conservative assumptions to estimate exposure doses. Conservative assumptions included, for example, assuming daily consumption of water from these supplies, exposure to only the maximum detected contaminant concentrations, and ingestion rates for the 90th percentile of the population (only 10% of the population is likely to drink more water than

assumed). To create a protective estimate of exposure and to allow ATSDR to evaluate safely the likelihood, if any, that contaminants in the water supply could cause harm to its users, ATSDR intentionally calculated conservative doses.

ATSDR compared these conservatively derived doses against health-based standards and reviewed relevant scientific literature from toxicologic and epidemiologic studies. The estimated doses were below levels at which health effects had been seen in laboratory studies of animals or in human epidemiological studies. Doses were also based on maximum detected concentrations rather than average concentrations—the latter would provide a closer estimate of actual exposures. Often the doses were based on single high detections, or outlier data, that would overestimate actual risks. For these reasons, ATSDR concluded that no adverse health effects were expected. Detailed information regarding ATSDR's methods and conclusions are provided in Appendix H.

Surface Soil

Accidental ingestion of surface soil is not expected to result in adverse health effects.

In surface soil, arsenic was the only chemical contaminant found above CVs and cesium-137, plutonium-238, and strontium-90 were the only radionuclides found above CVs. The highest detected levels were found within restricted areas of LANL. To be conservative when estimating exposure doses, however, ATSDR assumed that these levels of contaminants could reach residential yards. Adults and children living in these homes were assumed to have contacted the highest levels of contamination every day. Based on actual site conditions and monitoring data from 1980 through 2001, this level of exposure is highly unlikely. Regardless, ATSDR compared the conservatively derived exposure doses to health-based standards, to the toxicological literature, and to epidemiological literature. ATSDR found that estimated doses were below those health-based standards representing exposure doses below which no adverse health effects are expected. Detailed information regarding ATSDR's methods and conclusions are provided in Appendix H.

Surface Water and Sediment

Contact with surface water and sediment during recreational use of the canyons surrounding LANL is not expected to result in adverse health effects for adults or children.

Residents living in the Los Alamos community have reported that the canyons have served as recreational areas. People hunt, bike, hike, and otherwise use these areas. Children have also used the canyons as a short cut for walking to different places (e.g., school) in the community. As such, ATSDR estimated doses for adults and children exposed to contaminants found above CVs in surface water and sediment. In surface water bis(2-ethylhexyl)phthalate, methylene chloride, 15 inorganics, gross alpha, and uranium were detected at maximum concentrations above CVs. Arsenic, iron, manganese and the radionuclides americium-241, cesium-137, plutonium 239/240, and strontium-90 were detected in sediment at maximum concentrations above ATSDR CVs.

Assuming daily contact with surface water—when present—and with sediment, ATSDR estimated doses that were below health-based standards, below doses reported in the

toxicological and epidemiological literature to cause adverse health effects, or below both. Combined with the conservative assumptions used to derive these exposure doses, ATSDR concluded that during recreation no adverse human health effects were expected from contact with surface water and sediment. Detailed information regarding ATSDR's methods and conclusions are provided in Appendix H.

Air

No adverse human health effects are expected from contaminants released to the air surrounding LANL.

In reviewing monitoring data collected from 1980 through 2001, ATSDR found no contaminants detected above their health-based CVs. The health-based CVs are concentrations that represent levels at which no adverse health effects are expected assuming chronic, daily contact. As such, it was unnecessary for ATSDR to estimate exposure doses to conclude that no adverse human health effects were expected from contaminants in the air.

Biota

Consumption and use of locally grown and harvested food is not expected to result in adverse human health effects for adults or children.

Between 1980 and 2001, a number of different plants, produce, livestock, and game have been sampled for chemical contaminants and radionuclides. A complete list of the types of biota sampled and the contaminants detected are provided in the Environmental Contamination, Exposure Pathways, and Potentially Exposed Populations section of this PHA. PCBs, 16 metals, 21 pesticides, 23 radionuclides, and dioxins and furans were detected in the various biota sampled. Tables 13 through 16 summarize the maximum detected concentrations of contaminants and radionuclides detected in biota. No CVs are available for biota; therefore, all the contaminants detected were evaluated by estimating doses. In reviewing the data, ATSDR selected the food items containing the highest levels of contaminants for estimating exposure doses. These included elk (muscle and bone), fish, goat milk, eggs, honey, produce, and Navajo tea.

For each food item, ATSDR applied conservative assumptions about how much and how often a person would consume the item. For example, ATSDR assumed that people consumed biota containing only the maximum detected concentrations of the contaminants detected and that intake rates represented the 95th percentile for consumption (only 5% of the population would likely eat more of a food item than ATSDR assumed). Using these conservative assumptions, ATSDR estimated doses for the chemical contaminants (PCBs, metals, and pesticides) that, based on a review of health-based standards and the toxicological and epidemiological literature, were below levels of human health concern. Estimated doses for exposure to radionuclides through consumption of locally ground foods were below the ATSDR and DOE standard of 100 mrem/year. Additional information and a description of the evaluation methods are provided in Appendix H.

Health Outcome Data Evaluation

ATSDR found no evidence of contamination from LANL that might be expected to result in ill health to the community. Nevertheless, to address community concerns about cancer, ATSDR evaluated cancer studies from the New Mexico Department of Health (NMDH) and the New Mexico Tumor Registry, University of New Mexico Cancer Center (NMCC). As with many cancer studies of specific areas at specific times, when compared to reference populations some cancers incidents are higher and some are lower. Considering the long term trends in a specific area is most important. Chance alone and limitations of statistical analysis can sometimes report an increase in cancer incidents for one time period that does not remain consistent over many time periods.

This section briefly discusses the cancers that were identified as having elevated incidence rates in *The Los Alamos Cancer Rate Study: Phase 1*. In the early 1990s the *Los Alamos Cancer Rate Study: Phase I* was conducted to look at cancer incidences among populations residing in proximity to LANL. The study looked at data from 1970 to 1990. Incidence rates for brain and nervous system cancer and 22 other major cancers were calculated for Los Alamos County using data from the New Mexico Tumor Registry. The county rates were then compared to rates derived from the New Mexico state reference population and a national reference population. The many different types of cancers that had incidence rates below the comparative state and national rates are not discussed.

Brain Cancer - Area residents have voiced concern about an increase in the number of brain cancer cases. Results from the cancer study showed that "Los Alamos County experienced a modest elevation in brain and nervous system cancer during the mid-to late-1980s" (Athas and Key 1993). The difficulty with interpreting these data is that the number of cases is small and random fluctuation in the county incidence could cause the observed elevated rates: "while the study results indicate a recent elevation in brain and nervous system cancer incidence in Los Alamos County residents, by their descriptive nature they do not indicate a cause. In considering causation it is important to remember that because of the small number of cases (22 brain and nervous system cancers over 21 years, including 10 cases from 1976–1990) it is not possible to rule out chance alone as causing the observed elevated incidence" (Athas and Key 1993). The elevation in Los Alamos County brain cancer incidence was not statistically-significant. This means that when the population and the number of cases is small, an apparent increase in cases during one time period is the result of chance alone. At this time, there are no data linking environmental factors to brain cancer incidence rates in Los Alamos County.

Thyroid Cancer - The results of the *Investigation of Excess Thyroid Cancer Incidence in Los Alamos County* released in 1996, show that the incidence of thyroid cancer in Los Alamos County, when compared to state levels, rose to statistically significant levels during the late-1980s and early-1990s before decreasing in the mid-1990s. Men had higher incidence rates than did women. Thyroid cancer has many risk factors, including genetic susceptibility, therapeutic irradiation to the head and neck, parental history of thyroid surgery for nodular disease, occupational radiations exposure, and obesity (Athas 1996). The thyroid cancer report did not identify a specific cause of the increased incidence of thyroid cancer. At this time there are no data linking environmental factors to the increase in thyroid cancer that occurred in the late 1980s and early 1990s.

Melanoma (Skin Cancer) - Incidence of melanoma in Los Alamos County and the state reference populations was at least 40% higher than the national reference population for the *Los Alamos Cancer Rate Study: Phase 1*. The statistically significant elevation in Los Alamos County incidence rates suggests that the excess in incidence is real and not a result of random variability (Athas and Key 1993). The higher incidence might be explained by the greater amounts of sunshine which New Mexico receives as compared to other parts of the country. A major risk factor for skin cancer is exposure to solar ultra violet light. Los Alamos County is also located at a high elevation, which increases the amount of ground level ultra violet light. At this time, there are no data linking environmental causes, other than naturally occurring ultra violet light from the sun, to the increased skin cancer rates.

Breast Cancer - An increase in breast cancer rates in Los Alamos County was observed over the *Los Alamos Cancer Rate Study: Phase 1* study period. The demographics of Los Alamos County indicate that women living in Los Alamos County might exhibit risk factors for breast cancer that are not environmentally related. For example, high socioeconomic status, delayed first pregnancy, and never bearing children are factors that have been shown to increase breast cancer rates. Because many women in Los Alamos County tend to be of high socioeconomic status, they have delayed child bearing, or have not had children. Thus the elevated breast cancer rates in Los Alamos County are not entirely unexpected (Athas and Key 1993). At this time, no data link environmental factors in Los Alamos County with the increased breast cancer rates.

Ovarian Cancer - The incidence rates for ovarian cancer in Los Alamos County gradually increased over the *Los Alamos Cancer Rate Study: Phase 1* study period. Some census tracks within Los Alamos County had statistically significant elevations in ovarian cancer rates compared to the state reference population. Increased risk of ovarian cancer, like breast cancer, has been associated never having children or having few pregnancies. The development of ovarian and breast cancer seem to be linked to hormones; but the etiology of the cancer is still not well understood. Delaying pregnancy and the low fertility rates among women in Los Alamos County could account for some of the increase in the ovarian cancer rates (Athas and Key 1993). At this time, however, no data link environmental factors in Los Alamos County with the increased ovarian cancer rates.

Leukemia – The overall incidence of leukemia in Los Alamos County was lower than the state and national reference population during the *Los Alamos Cancer Rate Study: Phase 1* study period. There are many different types of leukemia, and a higher percentage of Los Alamos County leukemia cases were diagnosed as Chronic Lymphocytic Leukemia (CLL) than in the reference population. According to the *Los Alamos Cancer Rate Study: Phase 1,* "CLL is the only major subtype of leukemia which has not been associated with exposure to ionizing radiation." At this time, no data link environmental factors in Los Alamos County with leukemia.

Non-Hodgkin's Lymphoma – The incidence of non-Hodgkin's lymphoma was higher in Los Alamos County during the *Los Alamos Cancer Rate Study: Phase 1* study period than the state and national reference populations but the elevated incidence was not large. At this time, no data link environmental factors in Los Alamos County with non-Hodgkin's lymphoma.

Overall, cancer rates in the Los Alamos area are similar to cancer rates found in other communities. In some time periods, some cancers will occur more frequently and others less

frequently than seen in reference populations. Often, the elevated rates are not statistically significant and may be the result of random chance. The studies conducted by the New Mexico Department of Health and the New Mexico Tumor Registry have not linked elevated rates of certain cancers in Los Alamos County with environmental contamination. However, as the recommendations in the *Los Alamos Cancer Rate Study: Phase 1* study state, continued surveillance of cancer incidence in Los Alamos County and neighboring counties will help assure that any statistically significant increases in cancer rates are quickly recognized and investigated.

Community Health Concerns

In 1994, under an ATSDR grant, Boston University (BU) conducted a survey to identify the public health concerns of the community surrounding LANL. Initially, surveys were mailed to 61 citizens and organizations on a CDC contact list. Follow-up telephone interviews were conducted. Later, community concerns were collected more informally. BU identified distinct communities within the areas surrounding LANL. Each of these populations expressed unique concerns about LANL operations. ATSDR's responses to concerns about how LANL operations could impact public health are summarized below.

Citizens expressed concern about elevated cancer rates and possible links to exposures to LANL, specifically exposures to pesticides and radioiodine released from LANL. Specific cancers of concern included: brain (cluster in Western Area), gastrointestinal (cluster in Mora River Valley), pituitary, bone, childhood (including lymphoma), leukemia, tongue, prostate, thyroid, uterine, and clusters in Los Alamos High School graduates and Pueblos.

ATSDR evaluated cancer studies produced by New Mexico Department of Health and the New Mexico Tumor Registry, University of New Mexico Cancer Center and presents its evaluation in the *Health Outcome Data* section of this PHA. The data on cancer rates in the Los Alamos area are similar to cancer rates in communities beyond the influence of LANL. For any given time period some types of cancers will occur more frequently while others will occur less frequently than in reference populations. This is the situation identified when evaluating cancer data for Los Alamos communities. Studies of cancer have not linked cancers in Los Alamos County with any environmental contamination.

In addition, ATSDR conducted an evaluation of potential exposures and identified no levels of contamination that could potentially lead to an increase in cancer cases in Los Alamos. As part of this evaluation, ATSDR reviewed environmental monitoring data from 1980 to 2001, estimated doses using conservative assumptions about how often, how long, and the levels at which exposures might occur, and reviewed the relevant toxicological and epidemiological literature.

A concern regarding possible non-cancer health impacts from exposure to contaminants released from LANL was identified. Specific health concerns listed by citizens included thyroid disease (hypothyroidism, goiter, thyroiditis, benign nodules, non-malignant thyroid disease clusters), allergies, genetic effects/reproductive and birth outcomes (congenital anomalies, still births, infertility), asthma at Pueblos (previously unheard of disease in children), and rheumatism.

In the *Public Health Implications* section, ATSDR evaluated the likelihood, if any, that site related contaminants are associated with adverse non-cancer health effects. ATSDR considered for the period 1980 to 2001 potential exposures to contaminants detected in groundwater, surface soil, surface water and sediment, air, and biota. The primary route of exposure to contaminants for each of these media was ingestion (intentional or accidental), except air, for which inhalation is the greatest concern. ATSDR reviewed the monitoring data, derived estimated exposure doses using conservative assumptions about how often, how long, and the levels at which exposures might occur, and reviewed the relevant toxicological and epidemiological literature to draw

conclusions. Using conservative assumptions allowed ATSDR to overestimate potential exposures and ensure protection of the public. Based on these evaluations, ATSDR found no situation in which exposure to contaminants in environmental media would result in adverse health effects for members of the public. Based on sodium levels in the drinking water supply, ATSDR concluded that people suffering from severe hypertension, and following low-sodium diets (500 mg/day) should speak with their doctors to properly monitor their sodium intake.

Members of tribal nations questioned if releases from LANL would impact their health based on exposures through unique tribal practices, such as use of surface water from streams for ceremonies and irrigation, as well as, impacts to sacred areas.

In evaluating potential cancer and non-cancer effects from exposure to contaminants in site media, ATSDR selected exposure parameters that considered possible Native American uses of the land. As described in the *Public Health Implications* section, intake rates were selected represent the highest intake levels for the general population, and, where available, intake levels for Native American populations. Most of the contaminants found during monitoring volatilize or penetrate the skin to only a minimal degree. As such, ingestion was the primary pathway of concern for potential exposures. To evaluate exposures ATSDR estimated exposure doses using conservative assumptions, such as exposure to only the maximum detected contaminant concentrations. Reviews of the estimated exposure doses, the environmental monitoring data, and the toxicological and epidemiological literature led ATSDR to conclude that exposures to contaminants (both chemical and radionuclide) would not be expected to result in adverse health effects, even at the highest exposure levels.

Historically, children played in the canyons surrounding LANL. Residents noted that children would walk through Pueblo Canyon and play in Acid Canyon. They asked if this past exposure would result in adverse health effects.

Potential contact with surface water and sediment during recreational use of the canyons surrounding LANL, including Pueblo Canyon and Acid Canyon, was considered a potential exposure pathway and evaluated by ATSDR. ATSDR estimated exposure doses for adults and for children hiking, biking, hunting, or conducting other recreational activities in the canyons. Using conservative exposure assumptions (e.g., daily contact with surface water, when present, and sediment; contact with only the maximum detected contaminant concentrations), ATSDR concluded that no adverse health effects would result from recreational use of the canyons. Additional information about this evaluation and conclusions are contained in the *Public Health Implications* section.

Persons living in the communities surrounding LANL use area biota as a food source (e.g., fish, elk, deer, and honey). They also collect firewood and use area biota for ceremonial purposes (e.g., migratory birds). Ongoing exposures from these uses were identified as a concern.

The *Public Health Implications* section provides a detailed evaluation of the potential public health impacts from possible exposures to contaminants in biota. ATSDR found no situation where the consumption of locally grown or harvested foods would result in adverse human health effects. ATSDR estimated doses from consuming biota, assuming that persons only

consumed biota containing the maximum detected concentration of each chemical contaminant or radionuclide and that people consumed more of each food than most of the U.S. population. ATSDR then assessed the resulting doses against health-based dose standards and the scientific literature. ATDSR concluded that no adverse human health effects were expected from consumption of locally grown or harvested foods.

Citizens noted that the drinking water supply was threatened by groundwater contamination and requested information regarding steps being taken to protect the drinking water supply.

Community water suppliers, including LANL, must comply with SDWA and New Mexico Drinking Water Regulations (NMDWR). Under the SDWA and NMDWR, water suppliers ensure that the drinking water supply meets the criteria established by the national MCLs. MCLs are health and technology-based standards developed to protect the health of a person drinking 2 liters of water per day from a single supply over the course of a lifetime. As such, regular monitoring of the water supply is required. Since the sampling program began, no violations of the SDWA have been reported for the Los Alamos water supply systems (LANL 2000).

In addition to monitoring the water supply itself, LANL also collects groundwater samples from monitoring wells located within laboratory boundaries and around the laboratory perimeter. The monitoring program focuses on protecting the regional aquifer supplying drinking water for the community. LANL follows the *Groundwater Protection Management Program Plan*, as discussed in the *Environmental Contamination, Exposure Pathways, and Potentially Exposed Populations* section, to track the movement of groundwater contaminants and ensure protection of the drinking water supply (LANL 2000).

Two accidental releases occurring after 1980 were mentioned, including a spill of hundreds of gallons of highly radioactive liquid waste on the south side of Los Alamos Canyon and west of Diamond Bridge in 1980 or 1981, as well as a July 1985 release of radioiodine from the LAMPF. People asked about the subsequent remediation and possible long-term impacts of these releases.

To address this concern, ATSDR reviewed the Environmental Surveillance Reports (ESs) to identify unplanned/accidental releases occurring from 1980 to 1986. The following incidents were reported.

- 1980: Two unplanned releases were reported (LANL 1981).
  - A 950 liter release of primary coolant water occurred in TA-2 on December 12, 1979. The highest contaminant concentration in sediment was 695 pCi/g of sodium-24 (15 hour half-life), and in surface water was 389 x 10^{-6} mCi/mL of tritium (12 year half life).
  - A tritium leak (approximately 75% tritiated water vapor and 25% tritium gas) to the atmosphere occurred in TA-35. Surveys of the affected areas found that no threat was posed from the contamination. The estimated dose to residents living near the release was <0.001 mrem, assuming exposure to the maximum detected tritiated water vapor concentration.
- 1981: No unplanned releases were reported (LANL 1982).

- 1982: Three unplanned releases were reported (LANL 1983).
  - On March 19, 1982, an industrial waste line leak was discovered at TA-48 (the Radiochemistry Technical Area). Radionuclide levels, except gross beta, were found to be normal. The contaminated area extended 15 meters down the slope of Mortandad Canyon. Removal of the contaminated soil successfully restored background levels of radioactivity to the area.
  - On March 24, 1982, approximately 10 Ci of tritium (measured as tritiated water vapor) was released in the Van de Graaff Facility in TA-3. Most (80%) of the tritium was released indoors, and the remainder was released through a 10-meter vent. The maximum on-site dose to the whole body was estimated as 0.4 mrem, and off-site dose was 0.003 mrem. The dose calculated from the highest measured air concentration was 0.0044 mrem. All other doses calculated from measured tritium concentrations were lower than 0.0044 mrem.
  - On October 26, 1982, 1,100 liters of secondary cooling water from the nuclear research reactor at Omega site TA-2 was released. The majority of contaminants in the cooling water had short half-lives (less than 1 hour). Some tritium (12 year half life) was also released. A total of 25 samples from surface water, shallow alluvial groundwater, and sediment were analyzed for gross alpha, gross beta, gamma, and tritium. No radioactivity could be attributed to the release.
- 1983: Three unplanned releases were reported (LANL 1984).
  - Atmospheric tritium was released at TA-33 on May 12, 1983 (approximately 1,300 Ci, measured as tritiated water vapor). The maximum whole body dose by inhalation was calculated as 0.02 mrem and by ingestion was 0.2 mrem.
  - On August 25, 1983, tritium as water vapor (104 Ci) was released at TA-33. The nearest downwind population were the residents of Pajarito Acres. The maximum whole body dose to these people was less than 1 mrem.
  - An old gas cylinder ruptured on December 1, 1983. The gas and liquid content contained fluorides, most likely in the form of hydrofluoric acid. Although worst-case airborne hydrofluoric acid concentrations near the release were calculated to be as much as 10 times Threshold Limit Value-Short Term Exposure Limit of 5 mg/m^3, the maximum hydrofluoric acid concentrations downwind locations were calculated to be below this level.
- 1984: Five unplanned releases were reported (LANL 1985).
  - On January 4 and 5, 1984, approximately 790 Ci of tritium was released through a stack at TA-41. Air samples were analyzed, and airborne tritium concentrations were found to be consistent with normal fluctuations. The maximum possible whole body dose to the public was found to be 0.1 mrem.
  - On September 19, 1984, plutonium-238 was released from a drum inside TA-54. On-site air samples detected a small increase in plutonium-238; however, the concentrations were less than 0.1% of the DOE's Concentration Guide for Plutonium-238 for Controlled Areas. No plutonium-238 was detected off-site.

- On November 19, 1984, approximately 575 Ci of gaseous tritium (as tritiated hydrogen gas) was released at the DP site at TA-21. Atmospheric moisture samples analyzed for tritium found concentrations were less than 0.03% of the DOE's Concentration Guide for tritium in controlled areas. The estimated whole body dose to a hypothetical maximally exposed individual was less than 1 mrem.
- From November 21 through November 24, 1984, gaseous tritium was released from a container originally housed at TA-33 (approximately 2,000 Ci released), and later moved to TA-35 (approximately 100 Ci released). The dose to a hypothetical maximally exposed individual was calculated to be less than 1 mrem.
- On December 13, 1984, a fluoride release occurred at TA-55. The estimated hydrogen fluoride concentrations were found to be below the Short Term Exposure Limit (adopted by the American Conference of Governmental Industrial Hygienists) for hydrogen fluoride.

- 1985: No unplanned releases were reported (LANL 1986).
- 1986: Four unplanned releases were reported (LANL 1987).
  - On July 22, 1986, approximately 17,000 Ci of tritium, in the form of elemental hydrogen gas, was released at TA-33. Air sampling found no increase in tritiated water and the dose calculated for a maximally exposed individual was less than 0.01 mrem to the lung (the target organ).
  - On October 30 and 31, 1986, approximately 633 Ci of tritium, conservatively assumed to be tritiated water, was released at TA-33. The estimated maximum individual whole body dose was calculated to be 0.05 mrem. Air samples analyzed for tritium found concentrations were less than 0.5% of the DOE's concentration guide for off-site areas.
  - On November 14, 1986, 11.5 Ci of elemental tritium were released at TA-33. The maximum lung dose was calculated to be less than 0.01 mrem. Air samples analyzed for atmospheric tritiated water were less than 0.5% of the DOE's concentration guide for off-site areas.
  - On December 8, 1986, approximately 600 grams of hydrochloric acid were released at TA-3. Maximum air concentrations were estimated to be 0.06 ppm. The maximum exposure was considerably less than the occupational exposure limit of 5 ppm.

In reviewing the information for each of these unplanned releases, ATSDR identified no levels of contamination that would be expected to result in adverse human health effects, either short-term or long-term. The DOE standard for exposure for members of the public to radiation is 100 mrem/yr. This value is well below the level at which no adverse health effects are expected. Additional information about the potential for public health hazards from releases at LANL is provided in the *Public Health Implications* section.

Several citizens mentioned concerns about releases from specific areas of LANL, including, Area G (TA-54), the Omega Reactor (TA-2), the CMR Building (TA-3-29), the Kappa Site (TA-36), and the LAMPF (TA-53).

Environmental monitoring data (1980 to 2001) from areas TA-2 (the Omega Reactor), TA-3 (the CMR Building), TA-53 (LAMPF), and TA-54 (Area G) were specifically evaluated as part of this PHA.

TA-2 is the site of the Omega West Reactor, an 8-megawatt nuclear research reactor. In 1993 the reactor was placed in a safe shutdown condition, all fuel was removed, and the process of transfer into the decontamination and decommissioning program has begun (LANL 1986, 1987; DOE 999).

The South Mesa Site (TA-3) is the main technical area of the laboratory, and includes the CMR Building. The CMR building was designed as a chemistry and metallurgy research facility. It also has facilities for the remote handling of highly radioactive materials performing special nuclear material analytical chemistry and materials science (DOE 1999).

TA-53 includes the Los Alamos Meson Physics Facility (LAMPF), a linear particle accelerator used to conduct research (LANL 1986; DOE 1999).

Area G is located within TA-54, a technical area used as a disposal area for solid radioactive and toxic wastes. Most (90 to 95%) of the solid radioactive waste LANL produces is buried at TA-54. Area G is the primary radioactive solid waste disposal and storage facility (LANL 1986; 1987).

ATSDR identified these areas as the most likely sources of contaminants that could potentially produce public health hazards. As such, environmental data from each area was reviewed in detail in the *Public Health Implications* section. Based on detailed review of possible exposures to contaminants from these areas, ATSDR concluded that exposure to environmental media at LANL is not expected to result in adverse health effects.

The Kappa Site (TA-36) houses four active firing sites that support explosives testing for the DOE nuclear weapons programs. Non-nuclear ordnance testing for the Department of Defense (DOD) also occurs at the site. TA-36 is adjacent and southwest of TA-54 (LANL 1990b). The most likely releases from this site are air emissions. Perimeter air sampling, which was assessed as part of this PHA, would capture off-site migration of air emission. Evaluation of potential air exposures found no contaminants at levels of public health concern.

Reportedly, several past disposal sites were located in areas now beyond existing LANL boundaries and adjacent to or within communities because of development encroachment, some of these areas cannot be fully characterized because contents are unknown. Areas identified as past disposal sites include: the corner of Trinity and Diamond adjacent to the Aquatic Center; Los Alamos Inn received (TA-1 wastes); Sleepy Hollow; Ridge Park; Western Area.

Each of the specified areas of concern (with the exception of Sleepy Hollow) is within the Los Alamos Town Site. Prior to 1965, TA-1 facilities were within the area currently occupied by residents and businesses. When LANL was established in 1942 TA-1 buildings housed the main theoretical, experimental, and production work. Beginning in the 1950s these activities were moved to TA-3. TA-1 became inactive in 1965 and facility decontamination and demolition began in 1966. TA-1 was released for commercial and residential development in the late 1960s.

Consequently, residential areas were built atop areas previously used by the laboratory (LANL 1997b).

Some citizens mentioned tritium and PCBs as specific concerns.

ATSDR has incorporated tritium into evaluations conducted for exposures to groundwater, surface soil, surface water and sediment, air, and biota. In no case was tritium found at levels of health concern based on plausible exposure scenarios.

PCBs are a group of man-made chemicals that have become environmentally ubiquitous. They are either oily liquids or solids, colorless to light yellow. Because they remain stable when heated and are good insulators, they are primary used as coolants and lubricants in electrical equipment such as capacitors and transformers. PCBs persist and bioaccumulate in the environment and in organisms, and can cause adverse health effects; consequently, in the U.S. PCB manufacturing stopped in 1977 (ATSDR 2000). At LANL, spills and releases from transformers, capacitors, generators, dielectric fluids, contaminated solvents and oils are the source of PCBs in the environment. Sources other than LANL may also contribute to PCBs found in the environment.

PCBs are regulated at LANL under TSCA, which addresses materials with PCB concentrations greater than 50 ppm and provides disposal requirements for materials with PCB concentrations greater than 500 ppm. LANL waste items with PCB concentrations exceeding 500 ppm are transported offsite to EPA-permitted disposal and treatment facilities. Waste with PCB concentrations ranging from 50 to 499 ppm are stored, incinerated, or buried at TA-54. In the early 1980s LANL upgraded its PCB inventory control program to improve LANL's surveillance of PCB materials. In 1999 LANL set a goal of having the laboratory PCB-free. LANL continues to retrofill (i.e., replacing the PCB oil with a non-PCB oil) or replace PCB-contaminated transformers. Remedial activities to clean up any PCB releases are also conducted as needed, with oversight by environmental regulatory agencies.

Sampling for PCBs occurred in 1985, 1987, 1988, 1989, 1990, 1992, and 1994 through 2000. Groundwater sampling detected Aroclor-1260 (to 0.77 ppb) in three samples (1990, 1997, 2000). Surface water and sediment sampling for each of these years found no PCBs. Biota sampling in 1995, 1996, 1999, and 2000 found PCBs to 19,000 ppm in small mammals (mice and shrews) (1995, 1996); Aroclor-1254 to 0.66 ppm and Aroclor-1260 (specific concentration not provided) in fish muscle and bone (1999); and total PCBs in fish muscle and bone to 0.028 ppm (2000). Reportedly, the concentrations in fish are the result of background atmospheric sources rather than the result of laboratory operations (LANL 2000; Gonzales and Frequez 2003).

ATSDR concluded that PCB contamination at LANL is minimal and does not pose a threat to human health. PCBs were either not detected or only detected sporadically at low concentrations in groundwater, surface water, sediment, and biota. As part of its evaluation of consumption of locally grown and harvested foods ATSDR evaluated exposures to PCBs in fish. The conservative assumptions applied, the resulting estimated doses, and the review of the relevant toxicological and epidemiological literature led ATSDR to conclude that ingestion of PCBs in locally grown and harvested foods was not expected to result in adverse human health effects.

Conclusions

Conclusions regarding potential past, current, and future exposure situations in the communities near LANL are based on a thorough evaluation of monitoring data gathered from 1980 through 2000, on observations made during site visits, and on a review of toxicological and epidemiological literature regarding possible adverse human health effects. Conclusions about exposures are described below. The public health hazard conclusion categories are described in the glossary in Appendix F of this PHA.

- *The public is not ingesting contaminants in the community and in the LANL water supplies at levels of concern to the general population.* The deep, regional aquifer provides the majority of the public drinking water supply for the community surrounding LANL as well as LANL itself. A number of contaminants have been found in the regional aquifer; however, sampling of the water supplies has found only fluoride, sodium, perchlorate, 10 metals, and gross alpha at maximum concentrations greater than ATSDR CVs for drinking water. An evaluation of potential health effects associated with daily consumption of drinking water containing the maximum detected concentrations of these chemicals found no doses that ATSDR would expect to result in adverse human health effects, however, persons following a low-sodium diet should be aware of the elevated levels of sodium found during monitoring and should consult with their doctors to monitor properly their sodium intake. In addition, the community and LANL water suppliers comply with the SDWA, which involves regular monitoring, limits the concentrations of contaminants in a water supply, and requires action to mitigate contamination to prevent adverse health effects. *As such, ATSDR categorizes this pathway (drinking water) as posing no apparent public health hazard for past (post-1980), current, or potential future exposures.*

- *No adverse human health effects are expected from accidental ingestion of contaminated on-site surface soil.* On-site monitoring from 1980 to 2001 identified only arsenic, cesium-137, plutonium-238, and strontium-90 at concentrations above CVs. Assuming that the maximum detected concentrations found within restricted areas of LANL could also be present in residential yards, ATSDR estimated exposure doses that were below health-based screening levels and doses reported in the scientific literature to cause health effects. *ATSDR therefore categorizes this pathway (surface soil) as posing no apparent public health hazards for past (post-1980), current, or potential future exposures.*

- *Exposure to contaminants in surface water and sediment during recreational use of the canyons surrounding LANL is possible, but is not expected to result in adverse human health effects.* Historically, the canyons surrounding LANL were used for waste and wastewater disposal. These same canyons are now used for recreational activities such as hunting, hiking, and biking. Monitoring from 1980 to 2001 identified contaminants above CVs in surface water (bis(2-ethylhexyl)phthalate, methylene chloride, 15 inorganics, gross alpha, and uranium) and sediment (arsenic, iron, manganese and the radionuclides americium-241, cesium-137, plutonium 239/240, and strontium-90). ATSDR estimated potential exposure doses using conservative assumptions about how often, how long, and how much exposure to contaminants could occur. This exposure evaluation, a review of site data, and the observations of site conditions led ATSDR to conclude that during

recreation, potential contact with surface water—when present—and sediment is not expected to result in adverse health effects. *ATSDR categorizes this pathway (surface water and sediment) as posing no public health hazards for past (post-1980), current, or potential future exposures.*

- *As a result of LANL operations contaminants are released to the air and can migrate to the communities surrounding LANL.* To monitor such releases LANL has established a network of on-site, perimeter, and regional air monitoring stations. None of the samples collected from these stations between 1980 and 2001 reported contaminant concentrations above their health-based CVs. *Inhalation of contaminants in air, therefore, has been categorized as posing no apparent public health hazards for past (post-1980), current, or future exposures.*

- *Adverse health effects are not expected from consumption and use of locally harvested or grown foods.* Monitoring between 1980 and 2001 included sampling a number of different plants, produce, livestock, and game. This sampling found PCBs, 16 metals, 21 pesticides, and 23 radionuclides in the various biota sampled. Because no CVs are available for biota, ATSDR estimated exposure doses using conservative assumptions regarding daily consumption or use of local foods. Because ATSDR assumed that a person was exposed to the maximum detected concentration of each contaminant in each food, estimated doses exceeded actual doses. Estimated doses were below levels expected to result in adverse health effects. *As such, no adverse health effects were expected; ATSDR categorizes this pathway (biota) as posing no apparent public health hazards for past (post-1980), current, or potential future exposures.*

- *For exposures before 1980, ATSR has made no determination regarding potential health effects. ATSDR has not yet examined data on contaminants from LANL from before 1980.* CDC's NCEH is working on the LAHDRA. The LAHDRA aims to review historical documents pertaining to LANL operations and releases (e.g., chemicals and radionuclides) beginning with LANL's inception in 1943. LAHDRA will summarize data regarding environmental releases and prioritized these releases by their potential to result in off-site health effects. At the completion of the LAHDRA, ATSDR will determine what actions are needed to evaluate exposures before 1980. *Because the data are not yet available for examination, ATSDR, at this time, characterizes the health effects from exposures before 1980 as indeterminate.*

Recommendations

- LANL is currently conducting monitoring, evaluating detected contaminant concentrations, and implementing programs to minimize releases of contaminated material during site operations. ATSDR recommends that these tasks continue to ensure continued protection of public health.

- Persons with severe hypertension who are following low-sodium diets (500 mg/day) should be aware that elevated sodium levels have been found in the community and LANL water supplies. They should consult with their doctors to ensure proper monitoring of their sodium intake.

- When the CDC's NCEH Los Alamos Historical Document Retrieval and Assessment Project is completed, ATSDR should determine what actions to take to evaluate pre 1980 exposures and determine follow up activities as appropriate.

Public Health Action Plan

The Public Health Action Plan (PHAP) for LANL contains a description of actions taken and, after the completion of this PHA, those to be taken in the vicinity of the facility by ATSDR, DOE, LANL, and EPA. The purpose of the PHAP is to ensure that the PHA not only identifies public health hazards, but also provides a plan of action designated to mitigate and prevent adverse human health effects resulting from exposure to contaminants in the environment. The following public health actions are completed, are in implementation, or are planned:

Completed Actions

- In 1948, a waste management program was established at LANL as part of the Los Alamos area Office of the Atomic Energy Commission. By the 1980s radioactive and chemical laboratory waste was routed to waste treatment facilities rather than directly released into the environment. Radioactivity was removed via physiochemical processes; treated effluent was released to the canyons. The resulting sludge was treated as solid waste, of which 90 to 95% was buried at TA-54. The remaining 5 to 10% is stored retrievably as transuranic waste.

- In 1979 LANL completed an environmental impact statement evaluating cumulative environmental impacts of LANL's past, present, and future activities. A second laboratory-wide environmental impact statement completed in 1996 addresses operations in the 43 square miles of LANL.

- Beginning in the early 1980s, on-site PCBs were regulated by TSCA. Any materials with concentrations ranging from 50 ppm to 499 ppm are either incinerated in an EPA-approved facility or buried at TA-54. Materials with PCB concentrations exceeding 500 ppm are disposed of off site. By 1995, all high concentration (>500 ppm PCB) transformers were replaced with non-PCB containing transformers.

- In the late 1980s, LANL began to inventory, test for leaks, and remove underground storage tanks (USTs). Releases during UST removals were investigated and remediated as necessary. By December 1998, LANL had removed all but two of the identified USTs. The two remaining USTs, located in TA-15 and TA-16, meet all federal and state regulations and are inspected regularly to ensure continued compliance.

- In 1989, the DOE Office of Environmental Restoration and Waste Management (EM) was created to ensure that past, present, and future DOE operations "do not threaten human or environmental health and safety." EM currently implements LANL's Environmental Restoration (ER) Project. The ER Project determines the nature and extent of contamination at LANL and appropriate remediation activities. The ER Project carries out many of the Resource Conservation and Recovery Act (RCRA) and CERCLA/Superfund Amendments and Reauthorization Act (SARA)-related remedial actions at LANL over the years the ER Project has accomplished the following:

  - Conducted site assessments, site remediation, and the decommissioning of surplus LANL facilities. Remedial activities have included the clean-up of many sites,

including surface disposal areas, septic systems, storage areas, firing sites, and areas of contaminated soil.

- Identified 2,100 potential release sites (SWMUs and areas of concern). Environmental restoration has been conducted or will be conducted at SWMUs, as needed, to reduce possible environmental damage or human exposure to contaminants. The ER Project has already conducted various corrective actions and closures of SWMUs, including remedial actions at the TA-16 material disposal Area P landfill, TA-21, TA-35, TA-40, TA-50 and TA-54.

- From 1994 to 1996, ATSDR conducted environmental sampling of groundwater, soil, surface water, sediment, vegetation, fish, and produce as part of the assessment of public health hazards at LANL.

- In 1995 ATSDR released a health consultation addressing concerns about tritium contamination in drinking water wells.

- In August 1996 ATSDR released a health consultation entitled "Air Monitoring for Radionuclides in San Ildefonso Reservation, New Mexico."

- In 2001, ATSDR released the health consultation addressing concerns about potential releases during the Cerro Grande Fire ("Potential Public Health Impacts of The Cerro Grande Fire, Los Alamos National Laboratory, Los Alamos, Los Alamos County, New Mexico").

- In 1999 LANL's Environmental Stewardship Office (ESO) published *The Los Alamos National Laboratory 1999 Environmental Stewardship Roadmap*. The document describes LANL's current operations and improvements necessary to reach the six LANL goals of excellence, one of which is zero environmental incidents. The prevention of environmental incidents is accomplished through operational improvements to eliminate waste, pollutant releases, and natural resources waste or damage.

- By the end of 2000 only 880 discrete potential release sites of the 2,100 originally designated remained. Of these, NMED administers 541, and DOE administers 339. Many of the initial 2,100 have been designated no further action (NFA) because they meet certain criteria (i.e., the site does not exist, was never used for hazardous waste, there is no suspected hazardous release, it is regulated under another statute, or the site has been remediated and available data indicate the risks from site contaminants are acceptable for present and future land use). The ER Project continually reevaluates previously submitted proposals for NFA to determine whether additional work is necessary to support NFA status and for ecological and other relevant and appropriate concerns.

Ongoing Actions

- LANL operations and waste disposal are carefully planned and monitored. LANL strives to comply with all federal and state environmental and health laws and directives regarding environmental management and monitoring. These laws include the Clean

Water Act (CWA), Clean Air Act (CAA), Safe Drinking Water Act (SWDA), RCRA and HSWA, CERCLA, TSCA, NEPA, EPCRA, FIFRA; the Endangered Species Act; the Cultural Resource Compliance Acts; and NMAC (LANL 1999). EPA, DOE, and NMED administer these laws. LANL operates under a RCRA and HSWA permit. RCRA and HSWA regulate the generation and disposal of hazardous waste and require the cleanup of contamination from prior operations.

- In addition to restoration activities, LANL conducts monitoring to track and assess ongoing releases. The LANL Environmental, Safety, and Health Division is responsible for the extensive monitoring program. Under the 2000 monitoring program, LANL conducted more than 250,000 analyses for radioactive and non-radioactive contaminants on more than 12,000 samples of groundwater, soil, surface water, sediment, air, and biota (LANL 2000). For over 20 years LANL has published results of the monitoring efforts in environmental surveillance reports that provide a detailed overview of the environment and LANL.

- LANL has a waste minimization and pollution prevention program as required under RCRA. Source reduction and recycling activities as part of this program continue to decrease waste produced and stored at LANL (LANL 1998).

- CDC's National Center for Environmental Health (NCEH) is working on the Los Alamos Historical Document Retrieval and Assessment Project (LAHDRA). The University of California (UC), the U.S. Department of Energy (DOE), the New Mexico state agencies, and numerous pueblos in the region are also involved in this project. LAHDRA plans to review—from LANL's inception in 1943 onward—historical documents pertaining to operations and releases (e.g., of chemicals and radionuclides). LAHDRA will summarize data regarding environmental releases and prioritize them by their potential for off-site health effects. CDC will then determine the necessity for further investigations, such as screening-level evaluations or detailed dose reconstructions.

Planned Actions

- LANL has planned decommissioning and decontamination activities for the UST in TA-2 in 2006.

- LANL will continue its environmental surveillance program to monitor contaminant migration.

- LANL's ER Project will complete corrective actions at potential release sites to ensure that these areas pose no human or ecological risk. The ER Project has re-organized its approach by watershed, with each watershed containing multiple PRSs which, if necessary, will be evaluated together and remediated. The watershed approach was chosen because it protects water and sensitive resource areas by evaluating the cumulative effect of many PRSs impacting an area. Work will begin with the Town Site and head southward, watershed by watershed, until all eight watersheds are addressed (estimated completion by 2015).

Authors, Technical Advisors

Authors

Michael Brooks, CHP
Senior Health Physicist
Federal Facilities Assessment Branch
Division of Health Assessment and Consultation
ATSDR

Tarah Somers
Environmental Health Scientist
Federal Facilities Assessment Branch
Division of Health Assessment and Consultation
ATSDR

Reviewers

Rita Ford
Supervisory Environmental Engineer
Federal Facilities Assessment Branch
Division of Health Assessment and Consultation
ATSDR

Sandra G. Isaacs
Chief
Federal Facilities Assessment Branch
Division of Health Assessment and Consultation
ATSDR

References

Athas and Key. 1993. Los Alamos cancer rate study: phase 1 final report. Division of Epidemiology, Evaluation, and Planning—New Mexico Department of Health and New Mexico Tumor Registry—University of New Mexico Cancer Center.

Athas, William F. 1996. Investigation of excess thyroid cancer incidence in Los Alamos County. Division of Epidemiology, Evaluation, and Planning—New Mexico Department of Health. April 1996.

[ATSDR]Agency for Toxic Substances and Disease Registry. 1995. Health consultation on Tritium contamination in area groundwater wells, Los Alamos, New Mexico. Atlanta: US Department of Health and Human Services.

[ATSDR]Agency for Toxic Substances and Disease Registry. 1996. Health consultation, air monitoring for radionuclides, San Ildefonso Reservation, New Mexico. Atlanta: US Department of Health and Human Services.

[ATSDR]Agency for Toxic Substances and Disease Registry. 2000. Toxicological profile for polychlorinated biphenyls. Atlanta: US Department of Health and Human Services.

[ATSDR]Agency for Toxic Substances and Disease Registry. 2003. Los Alamos National Laboratory 5- and 10-mile radii from site boundary, demographics. Atlanta: US Department of Health and Human Services.

[ATSDR]Agency for Toxic Substances and Disease Registry. (No date). Environmental sampling of the San Ildefonso Pueblo and areas in the vicinity of the Los Alamos National Laboratory. Atlanta: US Department of Health and Human Services.

[DOE] US Department of Energy. 1999. Site-wide environmental impact statement for continued operation of the Los Alamos National Laboratory, volume I-main report. Albuquerque, NM: Publication No.: DOE/EIS – 0238

Emelity LA. 1991. Waste management at Los Alamos: protecting our environment. Los Alamos, NM: Call No. LALP-90-30.

Gonzales G and Fresquez P. 2003. Polychlorinated biphenyls (PCBs) in catfish and carp collected from the Rio Grande upstream and downstream of Los Alamos National Laboratory. Available at: http://eweb.lanl.gov/030403.htm#No_One. Last accessed July 16, 2003.

Groundwater.com. 2003. Groundwater.com directory of groundwater resources. Available at: http://www.groundwater.com/what_is_groundwater.html. Downloaded February 27, 2003.

[LADPU] Los Alamos Department of Public Utilities. 2001. Year 2001 drinking water quality report. Available at: http://www.visit.losalamos.com.

[LAHDRA] Los Alamos historical document retrieval and assessment project. 2000. Summary of historical operations at Los Alamos National Laboratory and associated off-site releases of radionuclides and other toxic materials, version 1C (draft report).

[LAHDRA]. Los Alamos historical document retrieval and assessment project. 2003. Los Alamos historical document retrieval and assessment project home. Available at: http://www.shonka.com/ReConstructionZone/default.htm. Last accessed July 16, 2003.

[LANL] Los Alamos National Laboratory. 1981. Environmental surveillance at Los Alamos during 1980. LA-8810-ENV.

[LANL]. Los Alamos National Laboratory 1982. Environmental surveillance at Los Alamos during 1981. LA-9349-ENV.

LANL Los Alamos National Laboratory. 1983. Environmental surveillance at Los Alamos During 1982. LA-9762-ENV. Issued April 1983.

[LANL] Los Alamos National Laboratory. 1984. Environmental surveillance at Los Alamos During 1983. LA-10100-ENV. Issued April 1984.

[LANL] Los Alamos National Laboratory. 1985. Environmental surveillance at Los Alamos During 1984. LA-10421-ENV. Issued April 1985.

[LANL] Los Alamos National Laboratory. 1986. Environmental surveillance at Los Alamos During 1985. LA-10721-ENV. Issued April 1986.

[LANL] Los Alamos National Laboratory. 1987. Environmental surveillance at Los Alamos During 1986. LA-10992-ENV. Issued April 1987.

[LANL] Los Alamos National Laboratory. 1988. Environmental surveillance at Los Alamos During 1987. LA-11306-ENV. Issued May 1988.

[LANL] Los Alamos National Laboratory. 1989. Environmental surveillance at Los Alamos During 1988. LA-11628-ENV. Issued June 1989.

[LANL] Los Alamos National Laboratory. 1990a. Environmental surveillance at Los Alamos During 1989. LA-12000-ENV. Issued December 1990.

[LANL] Los Alamos National Laboratory. 1990b. Solid waste management units report, Los Alamos National Laboratory, Revised November 1990. Los Alamos, NM. Publication Number LAUR 90-3400.

[LANL] Los Alamos National Laboratory. 1992. Environmental surveillance at Los Alamos During 1990. LA-12271-ENV. Issued March 1992.

[LANL] Los Alamos National Laboratory. 1994. Environmental surveillance at Los Alamos During 1992. LA-12764-ENV.

[LANL] Los Alamos National Laboratory. 1995. Environmental surveillance at Los Alamos during 1995. LA-13210-ENV.

[LANL] Los Alamos National Laboratory. 1996a. Environmental surveillance at Los Alamos during 1994. LA-13047-ENV.

[LANL] Los Alamos National Laboratory. 1996b. Environmental surveillance at Los Alamos during 1996. LA-13343-ENV.

[LANL] Los Alamos National Laboratory. 1997a. Environmental surveillance at Los Alamos during 1997. LA-13487-ENV.

[LANL] Los Alamos National Laboratory. 1997b. Overview of Los Alamos National Laboratory – 1997. LA-UR-97-4765.

[LANL] Los Alamos National Laboratory. 1998. Environmental surveillance at Los Alamos during 1998. LA-13633-ENV. This report was issued in September 1999. Referenced LANL 1999 for note about strontium-90 being biased high.

LANL 1999a

LANL 1999b

[LANL] Los Alamos National Laboratory. 2000. Environmental surveillance at Los Alamos during 1999. LA-13775-ENV.

[LANL] Los Alamos National Laboratory. 2001. Environmental surveillance at Los Alamos During 2000. LA-13861-ENV.

[LANL] Los Alamos National Laboratory. 2003. Los Alamos National Laboratory, organization, background. Available at: http://www.lanl.gov/organization/. Last accessed July 16, 2003.

[LANL] Los Alamos National Laboratory. (No date). Visitor's guide, Los Alamos National Laboratory.

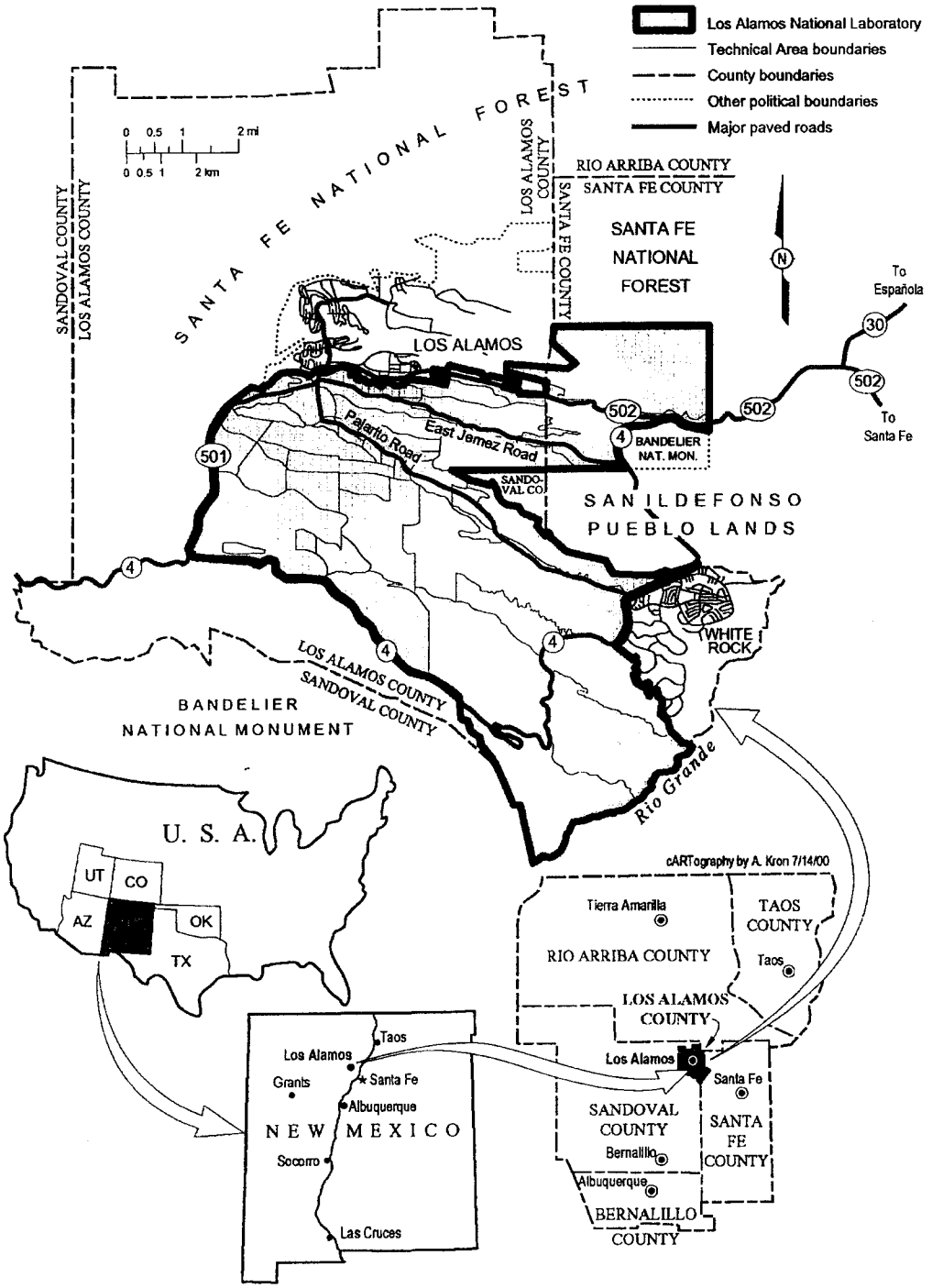
Silver K. 1996. Community concerns at Los Alamos National Laboratory (draft). Boston University School of Public Health.

[SSSA] Soil Science Society of America. 2003. Soil Science Society of America Web site. Available at: http://www.soils.org/. Last accessed July 16, 2003.

Appendices

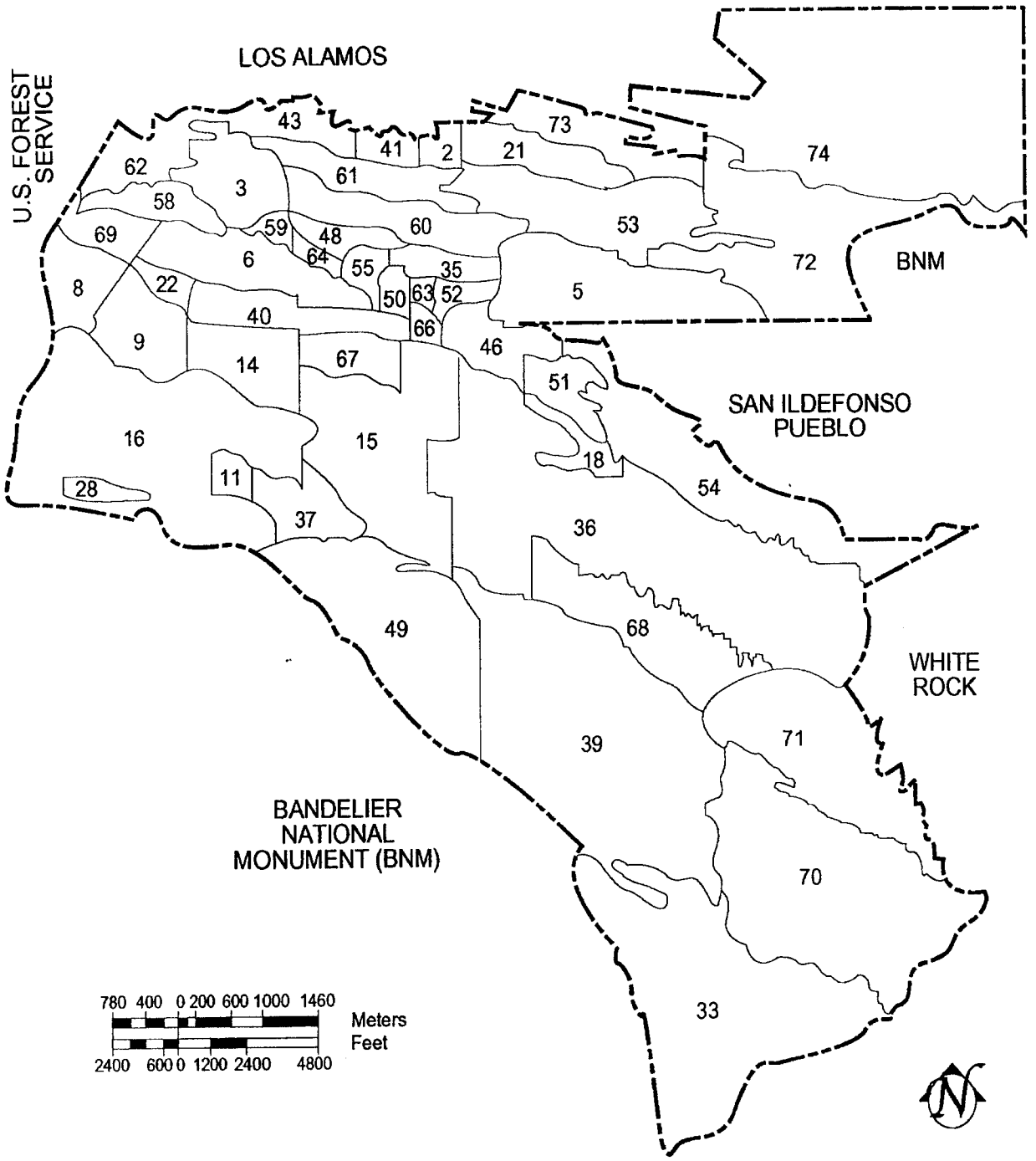
Appendix A: Figures

Figure 1: Los Alamos National Laboratory Area Map



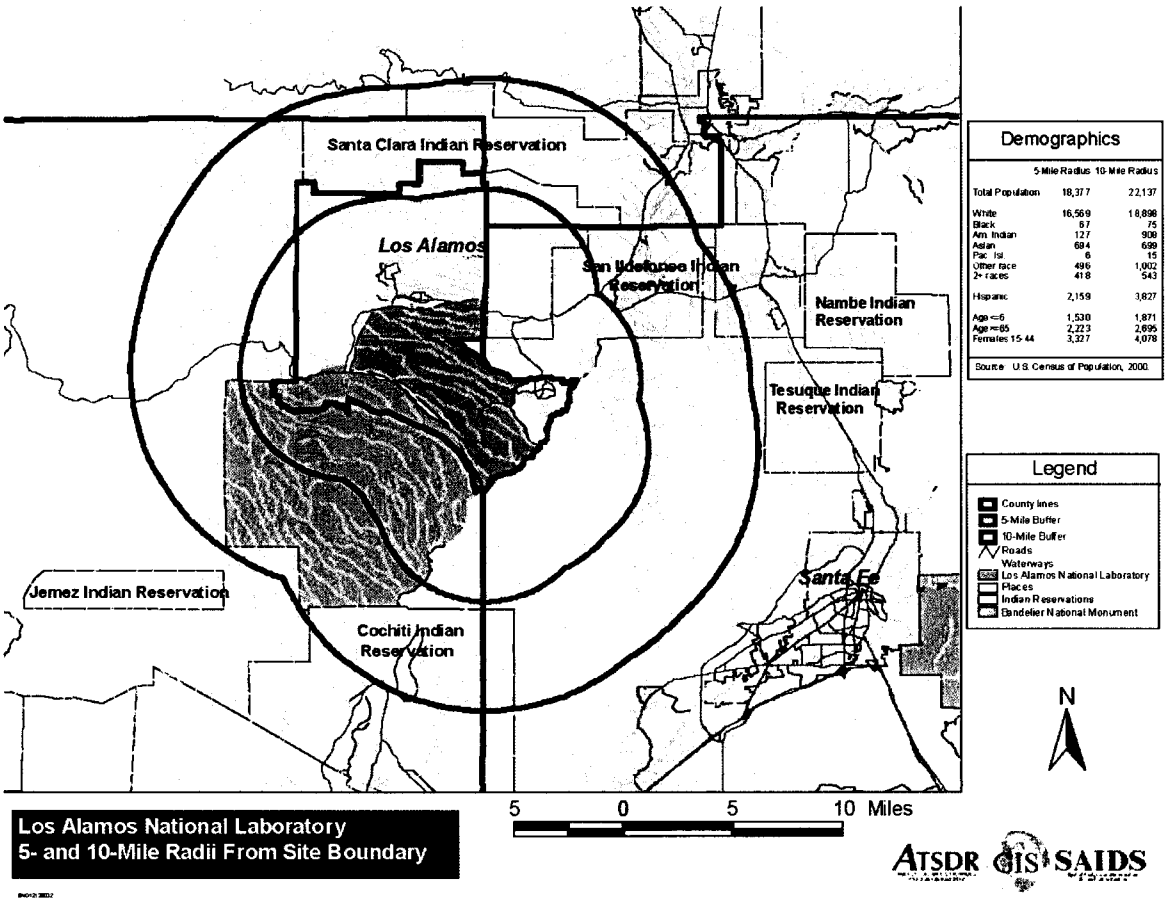
Source: LANL 2002

Figure 2: Los Alamos National Laboratory Technical Areas



Source: LANL 2002

Figure 3: Los Alamos National Laboratory 5- and 10-Mile Radii from Site Boundary



Source: ATSDR 2003

Figure 4: ATSDR Exposure Evaluation Process

REMEMBER: For a public health threat to exist, the following three conditions must all be met:

- Contaminants must exist in the environment
- People must come into contact with areas that have potential contamination
- The amount of contamination must be sufficient to affect people's health

Are the Environmental Media Contaminated?

ATSDR considers:

Soil
Ground water
Surface water and sediment
Air
Food sources

Are People Exposed To Areas With Potentially Contaminated Media?

For exposure to occur, contaminants must be in locations where people can contact them.

People may contact contaminants by any of the following three exposure routes:

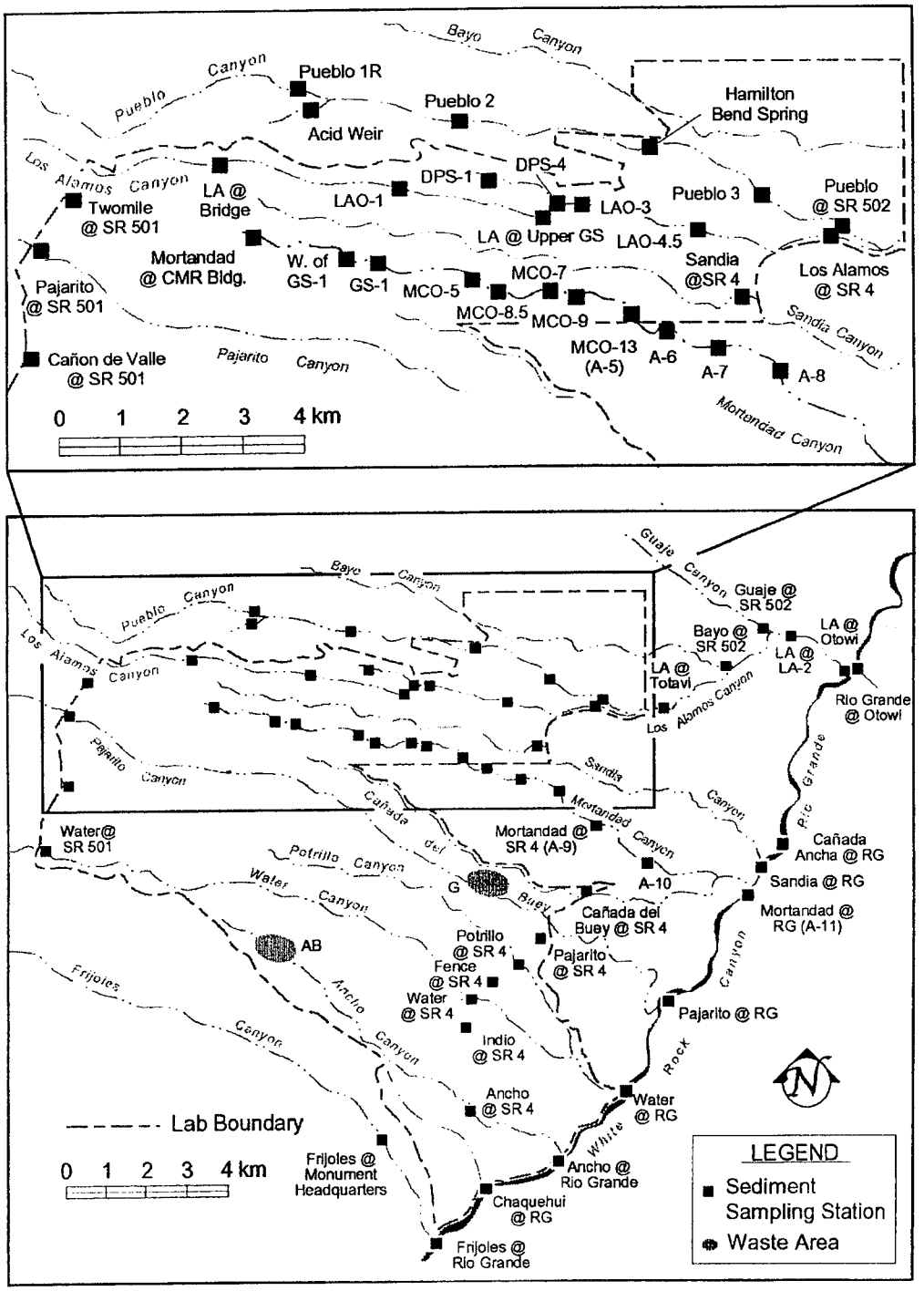
Inhalation
Ingestion
Dermal absorption

For Each Completed Exposure Pathway, Will the Contamination Affect Public Health?

ATSDR will evaluate existing data on contaminant concentration and exposure duration and frequency.

ATSDR will also consider individual characteristics (such as age, gender, and lifestyle) of the exposed population that may influence the public health effects of contamination.

Figure 5: Los Alamos National Laboratory Surface Water Bodies and Sediment Sampling Locations



Source: LANL 2002

Appendix B: Tables

Table 1. Exposure Situation and Hazard Summary Table

Exposure Situation	Time Frame	Hazard	Actions Taken/Planned	Recommendations	Comments
DRINKING WATER FROM THE MUNICIPAL AND TRIBAL WATER SUPPLY WELLS					
Drinking water from the municipal water supply wells and tribal water supply wells. Contaminants: Gross alpha; water quality parameters (e.g. chloride and sodium), and metals (e.g. arsenic, boron, and vanadium).	past current future	no no not likely	Groundwater beneath LANL has been monitored for various contaminants starting as early as 1949. The Groundwater Protection Management Program Plan (GWPMPP) was established in 1994. Today an extensive network of on site, perimeter, and regional wells in three groundwater zones are monitored semi-annually to ensure that site-related contaminants are not reaching the water supply.	Los Alamos National Laboratory (LANL) should continue their extensive monitoring of drinking water at the wellheads and within the distribution system to ensure that contaminants from the upper groundwater zones do not reach the water supply, and that the water supply remains protective of human health. Persons with severe hypertension who are following low-sodium diets (500 mg/day) should consult with their doctors to ensure proper monitoring of their sodium intake in light of the elevated sodium levels found in the community and LANL water supplies.	*No adverse health effects are expected from consumption of water from community and LANL water supplies.* A review of the drinking water supply data from 1980 though 2001 detected chloride, fluoride, sodium, perchlorate, 11 metals, and gross alpha at maximum concentrations greater than the Agency for Toxic Substances and Disease Registry (ATSDR) health-based comparison values (CVs), however, conservatively derived dose estimates were below levels at which health effects are expected.

Table 1. Exposure Situation and Hazard Summary Table (continued)

Exposure Situation	Time Frame	Hazard	Actions Taken/Planned	Recommendations	Comments
INGESTING (UNINTENTIONALLY) DUST FROM CONTAMINATED SURFACE SOIL					
Incidental (accidental) ingestion of windblown dust generated from on-site surface soil. Contaminants: Arsenic, cesium-137, plutonium-238, stronium-90.	past current future	no no not likely	Soil at on-site locations has been monitored for radionuclides since 1980. Inorganic contaminants were added in the early 1990s. LANL's Environmental Restoration (ER) Project has identified 2,100 potential release sites and conducted numerous investigations and remedial actions at areas with contaminated soil to reduce possible human exposure to contaminants.	In addition to the annual monitoring as part of the environmental surveillance program, LANL should continue to identify, evaluate, and perform remedial actions at potential release sites to ensure the continued protection of public health.	*Accidental ingestion of surface soil is not expected to result in adverse health effects.* Four contaminants were measured above their CVs in on-site surface soil; the highest detected levels were found within restricted areas. Conservative exposure dose estimates were below levels at which adverse health effects are expected.

Table 1. Exposure Situation and Hazard Summary Table (continued)

Exposure Situation	Time Frame	Hazard	Actions Taken/Planned	Recommendations	Comments
BREATHING CONTAMINANTS IN THE AIR					
Breathing contaminants released to the air from LANL activities. Contaminants: radionuclides (gross alpha, gross beta, americium-241, tritium [as tritiated water], iodine-131, plutonium-238, plutonium-239/240, total uranium, uranium-234, uranium-235, and uranium-238), beryllium, and criteria pollutants (six common air pollutants regulated by EPA).	past current future	no no not likely	LANL monitors stack emissions and ambient air at reference, perimeter, and onsite locations for radionuclides, beryllium, and/or criteria pollutants.	LANL should continue their environmental surveillance and monitoring program. In addition, LANL should also continue to follow programs in place to reduce wastes.	*No adverse human health effects are expected from contaminants released to the air surrounding LANL.* Contaminant concentrations detected during monitoring from 1980 to 2001 period were below the ATSDR CVs. Throughout the sampling history no contaminants have reached levels that could be harmful to human health.
CONSUMING LOCALLY GROWN OR HARVESTED FOODS					
Eating food grown or harvested locally (e.g., cattle, deer, elk, fish, eggs, milk, honey, produce, and wild plants). Contaminants: polychlorinated biphenyls (PCBs), 16 metals, 21 pesticides, and 23 radionuclides.	past current future	no no not likely	LANL has sampled a variety of different plants, produce, livestock, and game (e.g. produce, fish, and deer meat) at on-site, perimeter, and regional locations since 1980.	LANL should continue to monitor biota surrounding the laboratory to ensure that biota remains free from contaminant concentrations that could be harmful to human health.	*Consumption of locally grown food poses no apparent health hazard.* Monitoring between 1980 and 2001 revealed a number of contaminants in the various biota sampled. Conservative assumptions regarding daily consumption or use of local foods resulted in estimated doses below levels expected to result in adverse health effects.

Notes:

ATSDR	Agency for Toxic Substances and Disease Registry
GWPMPP	Groundwater Protection Management Program Plan
PCBs	Polychlorinated biphenyls
CV	Comparison value
LANL	Los Alamos National Laboratory

Table 2: Summary of Groundwater Monitoring by Groundwater Zone

Zone	Sampling	Location(s)
Alluvium	Shallow observation wells are used to sample the perched groundwater in the alluvial deposits of Pueblo, Los Alamos, Mortandad, and Pajarito Canyons, as well as Cañada del Buey. Monitoring is intended to determine the impact of current and past releases on groundwater quality. Because groundwater quantity in the alluvial deposits is dependent upon effluent and precipitation volume, any of the monitoring wells could be dry in a given year.	Pueblo, Los Alamos Pajarito, and Mortandad Canyons, and Cañada del Buey
Intermediate Perched	Two test wells (1A and 2A), located in Pueblo Canyon, were drilled 134 and 226 feet (ft) below ground surface (bgs) in 1949 and 1950, and are sampled along with one spring from the intermediate perched groundwater zone. In addition, perched water occurring in volcanic rocks near the Jemez mountains to the west of the Los Alamos National Laboratory (LANL) is sampled from a gallery.	Pueblo, Los Alamos, and Sandia Canyons, Western Pajarito Plateau near Jemez Mountains, under Technical Area 16 (TA-16) in the southeast corner of LANL
Regional	LANL samples the regional aquifer from eight test wells (six onsite and two off site). The test wells were drilled by the United States Geological Survey (USGS) from 1949 to 1960 and were positioned to detect migrating contaminants from waste discharge areas before they reached water supply wells. The wells reach the top few hundred feet of the regional aquifer. Because these wells are not lined with cement, surface infiltration along the boreholes is possible. Springs near the Rio Grande are also sampled because they represent immediate discharge from the regional aquifer. Annual sampling of half of the springs located in White Rock Canyon began in 1995 while larger springs and those on San Ildefonso Pueblo lands have been sampled annually since 1987 under the Memorandum of Understanding (MOU) between the Bureau of Indian Affairs and the U.S. Department of Energy (DOE).	600 to 1200 ft bgs
Drinking water wells	Under the Safe Drinking Water Act (SDWA), LANL is required to conduct annual sampling of drinking water from the groundwater source and the distribution system. The number of wells sampled varies from year to year depending upon the wells used for distribution that year. Current water supply wells are located in three separate well fields: Guaje, Pajarito, and Ottowi well fields. The Los Alamos well field was sampled prior to its retirement in 1991. Three wells in this well field continue to be sampled by the San Ildefonso Pueblo. In 2000, Los Alamos County sampled four Guaje wells, five Pajarito wells, and two Otowi wells. LANL sampled all of these wells with the exception of one well in the Pajarito well field.	Guaje, Los Alamos, Otowi, and Pajarito well fields

Source: DOE 1999; LANL 2001

Notes:

bgs below ground surface
DOE U.S. Department of Energy
ft feet
LANL Los Alamos National Laboratory
MOU Memorandum of Understanding
SDWA Safe Drinking Water Act
TA Technical Area
USGS United States Geological Survey

Table 3: Contaminants Detected Above Comparison Values in Alluvial and Perched Groundwater Monitoring Wells

Contaminant	Units	Maximum Detected Concentration	Location of Maximum Detection	Year of Maximum Detection	CV	CV Source
Radionuclides						
Cesium-137	pCi/L	3000 (±470)	Mortandad	1989	1000	10CFR20-Water Effluent
Plutonium-238	pCi/L	123 (±3.2)	Mortandad	1982	20	10CFR20-Water Effluent
Plutonium-239/240	pCi/L	1493 (±30)	Mortandad	1982	20	10CFR20-Water Effluent (Pu-239)
Total Uranium	ppb	123 (±16)	Mortandad	1984	30	MCL
Gross-alpha	pCi/L	6700 (±2600)	Mortandad	1982	15	MCL
Water Quality Parameters						
Chloride	ppm	294	Mortandad	1989	250	EPA Secondary Drinking Water Standard
Fluoride	ppm	7.7	Mortandad	1987	0.5	EMEG-cc
Nitrate (NO3)	ppm	37.8	Mortandad	1981	10	MCL
Perchlorate (ClO4)	ppm	0.4	Mortandad	2000	0.004	EPA interim guidance
Sodium	ppm	812	Mortandad	1981	20	EPA Drinking Water Advisory
Inorganics						
Aluminum	ppm	240	Los Alamos	1998	20	EMEG-ic
Arsenic	ppm	0.083	Los Alamos	1993	0.00002	CREG
Barium	ppm	3.132	Del Buey	1998	0.7	RMEG-c
Beryllium	ppm	0.03	Los Alamos	1995	0.02	EMEG-cc
Boron	ppm	0.48	Los Alamos	1990	0.1	EMEG-ic
Cadmium	ppm	0.33	Los Alamos	1993	0.002	EMEG-cc
Chromium	ppm	7.7	Acid Pueblo	1995	0.03	RMEG-c (hexavalent chromium)
Copper	ppm	3.88	Los Alamos	1980	0.3	EMEG-ic
Iron	ppm	190	Del Buey	1993	11	RBC-n
Lead	ppm	0.592	Acid Pueblo	1980	0.015	EPA action level
Manganese	ppm	14	Los Alamos	1994	0.5	RMEG-c
Molybdenum	ppm	1.72	Los Alamos	2000	0.04	LTHA
Nickel	ppm	0.202	Los Alamos	1999	0.1	LTHA

Table 3: Contaminants Detected Above Comparison Values in Alluvial and Perched Groundwater Monitoring Wells

Contaminant	Units	Maximum Detected Concentration	Location of Maximum Detection	Year of Maximum Detection	CV	CV Source
Silver	ppm	0.17	Mortandad	1995	0.05	RMEG-c
Thallium	ppm	0.006	Del Buey	1992	0.0026	RBC-n
Vanadium	ppm	0.350	Los Alamos	1993	0.03	EMEG-ic
Zinc	ppm	26	Acid Pueblo	1980	3	EMEG-c

Source: LANL 1981 through 2002

Notes:

-c represents CV for a child
-cc represents a chronic CV for a child
CREG Cancer Risk Evaluation Guide
CV Comparison value
EMEG Environmental Media Evaluation Guide
-ic represents intermediate CV for a child
EPA U.S. Environmental Protection Agency
LTHA Lifetime Health Advisory for Drinking Water
MCL Maximum Contaminant Level
-n represents CV for non-carcinogenic effects
ppm parts per million
RMEG Reference Dose Media Evaluation Guide

Table 4: Contaminants Detected Above Comparison Values in Regional Aquifer Groundwater Monitoring (Test) Wells

Contaminant	Units	Maximum Detected Concentration	Location of Maximum Detection	Year of Maximum Detection	CV	CV Source
Water Quality Parameters						
Fluoride	ppm	0.88	Test Well 8	2000	0.5	EMEG-cc
Sodium	ppm	135.4	Test Well 2	1996	20	EPA drinking water advisory
Inorganics						
Arsenic	ppm	0.012	Test Well 2	1996	0.00002	CREG
Cadmium	ppm	0.014	DT-5A	1995	0.002	EMEG-c
Lead	ppm	9	DT-5A	1993	0.015	EPA action level
Molybdenum	ppm	0.72	Test Well 8	1996	0.04	LTHA

Source: LANL 1981 through 2002

Notes:

-c represents CV for child
-cc represents a chronic CV for a child
CREG Cancer Risk Evaluation Guide
CV Comparison value
DT Deep test well
EMEG Environmental Media Evaluation Guide
EPA U.S. Environmental Protection Agency
LTHA Lifetime Health Advisory for Drinking Water
ppm parts per million
RMEG Reference Dose Media Evaluation Guide

Table 5: Contaminants Detected Above Comparison Values in Drinking Water Wells

Contaminant	Units	Maximum Detected Concentration	Location of Maximum Detection	Year of Maximum Detection	CV	CV Source
Radionuclides						
Gross-alpha	pCi/L	30 (±7)	Los Alamos	1991	15	MCL
Water Quality Parameters						
Fluoride	ppm	3.3	Los Alamos	1986	0.5	EMEG-cc
Perchlorate	ppm	0.005	Otowi	2000	0.004	EPA interim guidance
Sodium	ppm	221	Guaje	1982	20	EPA Drinking Water Advisory
Inorganics						
Arsenic	ppm	0.274*	Los Alamos	1981	0.00002	CREG
Boron	ppm	10	Pajarito	1990	0.1	EMEG-ic
Cadmium	ppm	0.017	Guaje	1998	0.002	EMEG-cc
Chromium	ppm	0.039	Los Alamos	1981	0.03	RMEG-c (hexavalent chromium)
Copper	ppm	0.313	Pajarito	1997	0.3	EMEG-ic
Iron	ppm	29.3	Los Alamos	1995	11	RBC-n
Lead	ppm	0.095	Guaje	1991	0.015	EPA action level
Silver	ppm	0.058	Pajarito	1995	0.05	RMEG-c
Thallium	ppm	0.019	Pajarito	1993	0.0026	RBC-n
Vanadium	ppm	0.260	Guaje	1993	0.03	EMEG-ic

Source: LANL 1981 through 2002

Notes:

-c represents CV for a child
-cc represents chronic CV for a child
CREG Cancer Risk Evaluation Guide
CV Comparison value
EMEG Environmental Media Evaluation Guide
-ic represents intermediate CV for a child
EPA U.S. Environmental Protection Agency
LTHA Lifetime Health Advisory for Drinking Water
MCL Maximum Contaminant Level
n- represents CV for non-carcinogenic effects
ppm parts per million
RMEG Reference Dose Media Evaluation Guide

* 0.274 ppm arsenic was detected in LA-6 (stand-by well); well with next highest arsenic concentration (0.11 ppm) was Gauge (G-2) in 1984. All other hits < 0.06 ppm.

Table 6: Contaminants Detected Above Comparison Values in Surface Soil

Contaminant	Location	Maximum Detected Concentration	Year of Maximum Detection	CV	CV Source
Radionuclides (pCi/g)					
Cesium-137	TA-53	3.5 ± 0.40	1980	2.97	NCRP
Plutonium-238	TA-54	16.683 ± NA	1994	8.65	NCRP
Strontium-90	TA-21	4.4 ± 1.6	1981	0.216	NCRP
	TA-50	1.55 ± 0.79	1998	0.216	NCRP
	TA-51	0.88 ± 0.52	1998	0.216	NCRP
	TA-53	1.3 ± 0.61	1998	0.216	NCRP
	TA-54	0.93 ± 0.57	1998	0.216	NCRP
Inorganics (ppm)					
Arsenic	TA-21	6.0	1994	0.5	CREG
	TA-50	3.0	1995	0.5	CREG
	TA-51	3.2	1996	0.5	CREG
	TA-53	3.2	1999	0.5	CREG
	TA-54	3.7	2000	0.5	CREG

Source: LANL 1981 through 2002

Notes:

CREG Cancer Risk Evaluation Guide
NCRP National Council on Radiation Protection and Measurements, Publication 129
pCi/g picocurie(s)/gram
ppm parts per million

Table 7: Contaminants Detected Above Comparison Values in Surface Water and Sediment: Acid Pueblo Canyon

Contaminant	Units	Maximum Detected Concentration	Location	Year of Maximum Detection	CV	CV Source
Surface Water						
Radionuclides						
Gross-alpha	pCi/L	69 (±32)	Pueblo 3	1980	15	MCL
Water Quality Parameters						
Ammonia	ppm	13	Pueblo 1	1980	3	EMEG-ic
Chloride	ppm	300	Acid Weir	1984	250	EPA Drinking Water Standard
Fluoride	ppm	1.3	Pueblo 3	1988	0.6	RMEG-c
Nitrate (NO3)	ppm	76	Pueblo 1	1982	20	RMEG-c
Sodium	ppm	156	Pueblo 1	1990	20	EPA Drinking Water Advisory
Inorganics						
Antimony	ppm	0.009	Pueblo 1	1998	0.004	RMEG-c
Arsenic	ppm	0.019	Pueblo 1	1986	0.00002	CREG
Boron	ppm	4.2	Pueblo 1	1993	0.1	EMEG-ic
Cadmium	ppm	1.0	Pueblo 1	1993	0.002	EMEG-cc
Chromium	ppm	5.0	Pueblo 1	1993	0.03	RMEG-c (hexavalent chromium)
Lead	ppm	0.034	Pueblo 1	1980	0.015	EPA action level
Manganese	ppm	5.4	Pueblo 1	1993	0.5	RMEG-c
Vanadium	ppm	0.0339	Pueblo 3	1990	0.03	EMEG-ic
Organics						
Bis(2-ethylhexyl) phthalate	ppm	0.0054	Pueblo 1	1999	0.003	CREG
Methylene chloride	ppm	0.015	Acid Weir	2000	0.005	CREG
Sediment						
Radionuclides						
Cesium-137	pCi/g	21.54 (±1.63)	Pueblo 3	1998	2.97	NCRP No. 129 (spl)
Plutonium-239/240	pCi/g	18.5 (±1.40)	Acid Weir	1982	7.84	NCRP No. 129 (spl)
Strontium-90	pCi/g	5 (±0.4)	Pueblo at State Route	1994	0.216	NCRP No. 129 (spl)
Inorganics						
Arsenic	ppm	7.5	Pueblo at State Route 502	1999	0.5	CREG
Iron	ppm	25,000	Pueblo at State Route	1994	23,000	RBC-n
Manganese	ppm	18,563	Pueblo at State Route 502	1999	3,000	RMEG-c

Source: LANL 1981 through 2002

Notes:

± Uncertainty
-c represents CV for a child
CREG Cancer Risk Evaluation Guide
CV Comparison Value
EMEG Environmental Media Evaluation Guide
EPA U.S. Environmental Protection Agency
-i represents standard for intermediate exposures
MCL Maximum Contaminant Level
NCRP National Council on Radiation Protection and Measurements, Publication No. 129
pCi/g picocurie(s)/gram
pCi/L picocurie(s)/liter
ppm parts per million
RBC-n Risk Based Concentration, non-cancer effects
RMEG Reference Dose Media Evaluation Guide
spl sparse pasture land

Table 8: Contaminants Detected Above Comparison Values in Surface Water and Sediment: Los Alamos Canyon

Contaminant	Units	Maximum Detected Concentration	Location of Maximum	Year of Maximum Detection	CV	CV Source
Surface Water						
Radionuclides						
Total Uranium	ppb	576 (±115)	DPS-1	1984	30	MCL
Gross-alpha	pCi/L	520 (±220)	DPS-1	1980	15	MCL
Water Quality Parameters						
Fluoride	ppm	56	DPS-1	1984	0.6	RMEG-c
Nitrate (NO3)	ppm	636	DPS-1	1984	20	RMEG-c
Sodium	ppm	1057	DPS-1	1984	20	EPA Drinking Water Advisory
Inorganics						
Arsenic	ppm	0.017	DPS-4	1988	0.00002	CREG
Boron	ppm	0.2	DPS-4	1982	0.1	EMEG-ic
Cadmium	ppm	0.010	DPS-4	1982	0.002	EMEG-cc
Chromium	ppm	0.22	DPS-4	1980	0.03	RMEG-c (hexavalent chromium)
Lead	ppm	0.09	DPS-4	1980	0.015	MCL action level
Manganese	ppm	0.872	DPS-1	1997	0.5	RMEG-c
Molybdenum	ppm	0.041	Los Alamos	1997	0.04	LTHA
Sediment						
Radionuclides						
Americium-241	pCi/g	28 (±4.2)	DPS-1	1985	8.92	NCRP No. 129 (spl)
Cesium-137	pCi/g	28 (±8.4)	Los Alamos of LAO 4.5	1984	2.97	NCRP No. 129 (spl)
Plutonium-239/240	pCi/g	8.11 (±0.355)	DPS-1	1985	7.84	NCRP No. 129 (spl)
Strontium-90	pCi/g	14 (±0.80)	DPS-1	1983	0.216	NCRP No. 129 (spl)
Inorganics						
Arsenic	ppm	65	DPS-4	1994	0.5	CREG
Organics						
Benz(a) anthracene	ppm	1.26	Upper GS	2001	0.87	RBC-c
Benzo(a) pyrene	ppm	0.938	Upper GS	2001	0.1	CREG

Source: LANL 1981 through 2002

Notes:

± Uncertainty
-c represents standard for child
CREG Cancer Risk Evaluation Guide
CV Comparison Value
EMEG Environmental Media Evaluation Guide
EPA U.S. Environmental Protection Agency
-i represents standard for intermediate exposures
MCL Maximum Contaminant Level
NCRP National Council on Radiation Protection and Measurements, Publication No. 129
pCi/g picocurie(s)/gram
pCi/L picocurie(s)/liter
ppm parts per million
RBC-n Risk Based Concentration, non-cancer effects
RMEG Reference Dose Media Evaluation Guide
spl sparse pasture land

Table 9: Contaminants Detected Above Comparison Values in Surface Water and Sediment: Mortandad Canyon (San Ildefonso Pueblo and White Rock)

Contaminant	Units	Maximum Detected Concentration	Location of Maximum	Year of Maximum Detection	CV	CV Source
San Ildefonso Pueblo						
Surface Water						
Water Quality Parameters						
Fluoride	ppm	1.1	Mortandad at Rio Grande	1996	0.6	RMEG-c
Sodium	ppm	92.7	Mortandad at Rio Grande	2000	20	EPA Drinking Water Advisory
Inorganics						
Arsenic	ppm	0.005	Mortandad at Rio Grande	1995	0.00002	CREG
Boron	ppm	0.572	Mortandad at Rio Grande	2000	0.1	EMEG-ic
Sediment						
Radionuclides						
Strontium-90	pCi/g	1.21 (±0.24)	Mortandad A-6	1998*	0.216	NCRP No. 129 (spl)
Inorganics						
Arsenic	ppm	2.4	Mortandad at Transect	1994	0.5	CREG
White Rock						
Sediment						
Inorganics						
Arsenic	ppm	2.4	Cañada del Buey 2	1999	0.5	CREG

Source: LANL 1981 through 2001

Notes:

±	Uncertainty
-c	represents standard for child
CREG	Cancer Risk Evaluation Guide
CV	Comparison Value
EMEG	Environmental Media Evaluation Guide
EPA	U.S. Environmental Protection Agency
-i	represents standard for intermediate exposures
NCRP	National Council on Radiation Protection and Measurements, Publication No. 129
pCi/g	picocurie(s)/gram
ppm	parts per million
RMEG	Reference Dose Media Evaluation Guide
spl	sparse pasture land

* The 1998 strontium-90 measurements resulted from a high analytical bias in the laboratory technique (LANL 1999).

Table 10: Contaminants Detected Above Comparison Values in Surface Water and Sediment: Cañada del Buey

Contaminant	Units	Maximum Detected Concentration	Location of Maximum	Year of Maximum Detection	CV	CV Source
Surface Water						
Water Quality Parameters						
Fluoride	ppm	9.3	Cañada del Buey	1987	0.6	RMEG-c
Sodium	ppm	33	Cañada del Buey	1990	20	EPA Drinking Water Advisory
Inorganics						
Aluminum	ppm	35	Cañada del Buey	1995	20	EMEG-ic
Arsenic	ppm	0.0058	Cañada del Buey	1992	0.00002	CREG
Iron	ppm	18	Cañada del Buey	1995	11	RBC-n
Molybdenum	ppm	0.5	Cañada del Buey	1995	0.04	LTHA
Vanadium	ppm	0.037	Cañada del Buey	1995	0.03	EMEG-ic
Sediment						
Radionuclides						
Strontium-90	pCi/g	1.29 (±0.51)	Cañada del Buey at SR4	1998*	0.216	NCRP No. 129 (spl)
Inorganics						
Arsenic	ppm	0.7	Cañada del Buey at SR4	1994	0.5	CREG

Source: LANL 1981 through 2001

Notes:

± Uncertainty
-c represents standard for child
CREG Cancer Risk Evaluation Guide
CV Comparison Value
EMEG Environmental Media Evaluation Guide
EPA U.S. Environmental Protection Agency
-i represents standard for intermediate exposures
LTHA Lifetime Health Advisory for Drinking Water
NCRP National Council on Radiation Protection and Measurements, Publication No. 129
pCi/g picocurie(s)/gram
ppm parts per million
RMEG Reference Dose Media Evaluation Guide
spl sparse pasture land

Frequency above CV = the number of times detected above the CV / the number of times detected

* The 1998 strontium-90 measurements resulted from a high analytical bias in the laboratory technique (LANL 1999).

Table 11: Summary of Biota Monitoring

Biota type	Years sampled
Produce (fruits, vegetables)	1980-2001
Fish	1980-2001
Honey	1980-2000
Deer, elk	1984, 1995-2001
Goat milk	1998, 1999
Milk	1994-1997
Eggs	1995-1999
Steer,	1996-1999
Navajo tea (Cota)	1996-1999
Herbal tea	2000
Pinon shoot tips	1997-1999
Pinon pine nuts	1999
Small mammals	1998 (squirrels), 1999 (raccoons)
Mushrooms	1998
Wild spinach, alfalfa forage, understory and overstory plants, prickly pears	1999, 2001 (prickly pear, understory and overstory)

Source: LANL 1981 through 2002

Table 12: Maximum Detected Contaminant Concentrations in Honey

Contaminant	Maximum Detected Concentration	Units	Year	Location
Radionuclides				
Actinium 228	34.9 (±15.8)	pCi/L	1996	White Rock/Pajarito Acres
Americum-241	0.12 (±0.060)	pCi/L	1995	White Rock/Pajarito Acres
Beryllium 7	1100 (±980)	pCi/L	1987	Mortandad Canyon
Bismuth 214	-2.6 (±1.52)	pCi/L	1996	White Rock/Pajarito Acres
Cesium 134	127	pCi/L	1985	Northern Los Alamos
Cesium-137	120 (±79)	pCi/L	1987	Mortandad Canyon
Cobalt 57	217 (±70)	pCi/L	1986	Pajarito Acres
Cobalt 58	10.2 (±30.6)	pCi/L	1996	Los Alamos
Cobalt 60	12.3 (±5.2)	pCi/L	1996	Los Alamos
Lead 212	5.66 (±2.84)	pCi/L	1996	Los Alamos
Lead 214	2 (±6.0)	pCi/L	1996	Los Alamos
Manganese 54	100 (±92)	pCi/L	1998	Pajarito Acres
Plutonium-238	0.025 (±0.024)	pCi/L	1995	White Rock/Pajarito Acres
Plutonium-239	0.107 (±0.102)	pCi/L	1994	Los Alamos
Potassium 40	960 (±228.0)	pCi/L	1996	Los Alamos
Rubidium 83	146 (±146)	pCi/L	1986	Mortandad Canyon
Sodium 22	59.52	pCi/L	1982	Mortandad Canyon
Strontium-90	20.3 (±18.60)	pCi/L	1994	Los Alamos
Thallium 208	5.14 (±2.64)	pCi/L	1996	White Rock/Pajarito Acres
Tritium	27.4	pCi/mL	1980	Mortandad Canyon
Uranium-234	0.25 (±0.09)	pCi/L	2000	White Rock
Uranium-235	0 (±0.03)	pCi/L	2000	White Rock
Uranium-238	0.25 (±0.03)	pCi/L	2000	White Rock
Inorganics				
Arsenic	0.1	ppm	1989	Los Alamos
Boron	7	ppm	1988	Pajarito Acres
Cadmium	0.012	ppm	1981	Barranca Mesa
Chromium	0.12	ppm	1988	Pajarito Acres
Fluoride	0.6	ppm	1989	State Road 4
Lead	0.5	ppm	1989	Los Alamos
Mercury	3	ppb	1988	Pajarito Acres
Uranium	0.0092	ppm	1983	Los Alamos

Source: LANL 1981 through 2002

Notes:

± Uncertainty

ppm parts per million

pCi/L picocurie(s)/liter

Table 13: Maximum Detected Contaminant Concentrations in Alfalfa Forage, Produce, Navajo Tea, Prickly Pear, Wild Spinach, Overstory, and Understory

Contaminant	Alfalfa Forage				Produce			
	Max. Conc.	Units	Yr	Location	Max. Conc.	Units	Yr	Location
Radionuclides								
Americum-241	0.0025 (±0.0010)	pCi/g ash	1999	San Ildefonso	587.5 (±225)	10^{-5}pCi/g dry wt.	1996	Los Alamos
Cesium-137	0.26 (±0.20)	pCi/g ash	1999	Los Alamos	3900 (±2000)	10^{-3}pCi/g dry wt.	1982	Los Alamos
Plutonium-238	0.0024 (±0.0026)	pCi/g ash	1999	San Ildefonso	403.5 (±44.54)	10^{-5}pCi/g dry wt.	1999	White Rock/Pajarito Acres
Plutonium-239/240	0.0036 (±0.0031)	pCi/g ash	1999	San Ildefonso	600	10^{-5}pCi/g dry wt.	1980	Pajarito Acres
Strontium-90	3.58 (±0.51)	pCi/g ash	1999	San Ildefonso	525 (±100)	10^{-3}pCi/g dry wt.	1996	Los Alamos
Tritium (H^3)	0.1 (±0.61)	pCi/mL	1999	Los Alamos	17 (±2.0)	pCi/mL	1986	Los Alamos/White Rock
Uranium-234					25.3 (±3.63)	10^{-3}pCi/g dry wt.	2001	White Rock/Pajarito Acres
Uranium-235					37.5 (±15)	10^{-4}pCi/g dry wt.	2001	White Rock/Pajarito Acres
Uranium-238					17.3 (±2.88)	10^{-3}pCi/g dry wt.	2001	White Rock/Pajarito Acres
Total Uranium	1.47 (±0.15)	ppb ash	1999	San Ildefonso	150 (±27)	ppb dry wt.	1983	White Rock/Pajarito Acres
Inorganics								
Antimony					0.6	µg/dry g	1995	White Rock/Pajarito Acres
Arsenic	ND				0.4	µg/dry g	1996	San Ildefonso
Barium	83	ppm dry	1999	Los Alamos	86	µg/dry g	2001	White Rock/Pajarito Acres
Beryllium	ND				ND			
Cadmium	ND				0.8	µg/dry g	2000	San Ildefonso
Chromium					4.2	µg/dry g	2000	White Rock/Pajarito Acres
Copper	7.1	ppm dry	1999	Los Alamos				
Lead	1.3	ppm dry	1999	White Rock/ Pajarito Acres	48	µg/dry g	1996	White Rock/Pajarito Acres
Mercury	ND				0.1	µg/dry g	1996 1997	San Ildefonso Los Alamos
Nickel	ND				91	µg/dry g	2000	Los Alamos
Selenium	0.5	ppm dry	1999	Los Alamos	2	µg/dry g	2000	White Rock/Pajarito Acres
Silver	ND				0.58	µg/dry g	1996	Los Alamos
Zinc					54	µg/dry g	2001	White Rock/Pajarito Acres

Table 13: Maximum Detected Contaminant Concentrations in Alfalfa Forage, Produce, Navajo Tea, Prickly Pear, Wild Spinach, Overstory, and Understory (continued)

Contaminant	Navajo Tea				Prickly Pear				Wild Spinach			
	Max. Conc.	Units	Yr	Location	Max. Conc.	Units	Yr	Location	Max. Conc.	Units	Yr	Location
Radionuclides												
Americum-241	0.15 (±0.100)	pCi/L	1996	Los Alamos	37.1 (±13.3)	10^{-5} pCi/g dry	2001	Los Alamos	58.5 (±18.6)	10^{-5} pCi/g dry	1999	Los Alamos
Cesium-137	17.8 (±26.7)	pCi/L	1997	White Rock/ Pajarito Acres	36.1 (±24.2)	10^{-3} pCi/g dry	2001	Los Alamos	34.6 (±20.0)	10^{-3} pCi/g dry	1999	White Rock/ Pajarito Acres
Plutonium-238	0.048 (±0.017)	pCi/L	1997	San Ildefonso	1.9 (±11.9)	10^{-5} pCi/g dry	2001	San Ildefonso	-20.0 (±75.8)	10^{-5} pCi/g dry	1999	White Rock/ Pajarito Acres
Plutonium-239/240	0.037 (±0.016)	pCi/L	1997	San Ildefonso	14.3 (±8.1)	10^{-5} pCi/g dry	2001	San Ildefonso	263.3 (±75.8)	10^{-5} pCi/g dry	1999	White Rock/ Pajarito Acres
Strontium-90	2.49 (±5.85)	pCi/L	1997	San Ildefonso	1064.0 (±91.2)	10^{-3} pCi/g dry	1999	San Ildefonso	188.9 (±51.9)	10^{-3} pCi/g dry	1999	Los Alamos
Tritium	0.14 (±0.15)	pCi/mL	1997	White Rock/ Pajarito Acres	1.0 (±0.18)	pCi/mL	2001	Los Alamos	-0.04 (±0.60)	pCi/mL	1999	White Rock/ Pajarito Acres
Uranium-234					2.95 (±0.48)	10^{-3} pCi/g dry	2001	Los Alamos				
Uranium-235					2.38 (±1.47)	10^{-4} pCi/g dry	2001	San Ildefonso				
Uranium-238					3.14 (±0.48)	10^{-4} pCi/g dry	2001	San Ildefonso				
Total Uranium	4.95 (±0.50)	ppm	1998	White Rock/ Pajarito Acres	32.3 (±2.72)	ppb dry	1999	San Ildefonso	25.3 (±2.7)	ppb dry	1999	San Ildefonso

Table 13: Maximum Detected Contaminant Concentrations in Alfalfa Forage, Produce, Navajo Tea, Prickly Pear, Wild Spinach, Overstory, and Understory (continued)

Contaminant	Navajo Tea				Prickly Pear				Wild Spinach			
	Max. Conc.	Units	Yr	Location	Max. Conc.	Units	Yr	Location	Max. Conc.	Units	Yr	Location
Inorganics												
Antimony					0.40	ppm dry	1999	San Ildefonso	ND			
Arsenic					ND				ND			
Barium					140	ppm dry	2001	Los Alamos	54	ppm dry	1999	San Ildefonso
Beryllium					ND				ND			
Cadmium					0.45	ppm dry	2001	Los Alamos	ND			
Chromium												
Copper					2	ppm dry	1999	Los Alamos	5.8	ppm dry	1999	White Rock/ Pajarito Acres
Lead					58.4	ppm dry	1999	White Rock/ Pajarito Acres	27.5	ppm dry	1999	Los Alamos
Mercury					ND				ND			
Nickel					41.0	ppm dry	1999	White Rock/ Pajarito Acres	35	ppm dry	1999	Los Alamos
Selenium					1.3	ppm dry	2001	Los Alamos	ND			
Silver					ND				ND			
Thallium					ND				ND			
Zinc					27	ppm dry	2001	Los Alamos				

Table 13: Maximum Detected Contaminant Concentrations in Alfalfa Forage, Produce, Navajo Tea, Prickly Pear, Wild Spinach, Overstory, and Understory (continued)

Contaminant	Overstory				Understory			
	Max. Conc.	Units	Yr	Location	Max. Conc.	Units	Yr	Location
Radionuclides								
Americum-241	0.0378 (±0.0158)	pCi/g ash	1999	ONS	0.0257 (±0.0086)	pCi/g ash	1999	Sportsman's Club
Cesium-137	1.24 (±1.86)	pCi/g ash	1999	Sportsman's Club	0.45 (± 0.68)	pCi/g ash	1999	GT-Site
Plutonium-238	0.018 (±0.0039)	pCi/g ash	1999	West Airport	0.0178 (±0.0094)	pCi/g ash	1999	Sportsman's Club
Plutonium-239/240	0.0224 (±0.003)	pCi/g ash	1999	San Ildefonso	0.0988 (±0.0087)	pCi/g ash	1999	Otowi
Strontium-90	4.59 (±0.58)	pCi/g ash	1999	Otowi	15.39 (±4.680)	pCi/g ash	1999	North Mesa
Tritium	0.96 (±0.71)	pCi/mL	1999	Near TA-49	0.55 (±0.680)	pCi/mL	1999	San Ildefonso
Uranium-234								
Uranium-235								
Uranium-238								
Total Uranium	0.56 (±0.06)	ppm dry	1999	San Ildefonso	0.7 (±0.07)	ppm dry	1999	White Rock

Source: LANL 1981 through 2001

Table 14: Maximum Detected Contaminant Concentrations in Eggs, Milk, Goat's Milk, Mushrooms, Piñon Shoot Tips, Small Mammals, Deer, Elk, and Steer/Cattle

Contaminant	Eggs				Milk				Goat's Milk			
	Max. Conc.	Units	Yr.	Loc.	Max. Conc.	Units	Yr.	Loc.	Max. Conc.	Units	Yr.	Loc.
Radionuclides												
Americum-241	0.02 (±0.026)	pCi/L	1996	Los Alamos					0.054 (±0.017)	pCi/L	1999	White Rock/ Pajarito Acres
Cesium-137	38 (±114.0)	pCi/L	1996	Los Alamos	19.8 (±29.7)	pCi/L	1997	Pojoaque Valley	20 (±30.0)	pCi/L	1997	Los Alamos
Iodine-131					0.0145 (±0.0024)	pCi/mL	1997	Pojoaque Valley	0.019 (±0.0285)	pCi/mL	1997	Los Alamos
Plutonium-238	0.0662 (±0.0119)	pCi/L	1999	White Rock/ Pajarito Acres	0.003 (±0.060)	pCi/L	1994	Pojoaque Valley	0.0071 (±0.0083)	pCi/L	1999	White Rock/ Pajarito Acres
Plutonium-239/240	0.0322 (±0.0100)	pCi/L	1999	White Rock/ Pajarito Acres	0.005 (±0.002)	pCi/L	1997	Pojoaque Valley	0.083 (±0.010)	pCi/L	1997	Los Alamos
Strontium-90	15.11 (±1.86)	pCi/L	1998	Los Alamos	4.7 (±8.200)	pCi/L	1995	Pojoaque Valley	3.56 (±6.09)	pCi/L	1998	White Rock/ Pajarito Acres
Tritium	0.41 (±0.64)	pCi/mL	1999	Los Alamos	0.18 (±0.36)	pCi/mL	1997	Pojoaque Valley	0.31 (±0.63)	pCi/mL	1999	Los Alamos
Uranium-234									0.14 (±0.0149)	pCi/L	1999	White Rock/ Pajarito Acres
Uranium-235									0.0057 (±0.0006)	pCi/L	1999	White Rock/ Pajarito Acres
Uranium-238									0.1227 (±0.0133)	pCi/L	1999	White Rock/ Pajarito Acres
Total Uranium	1.12 (±0.11)	µg/L		White Rock/ Pajarito Acres	1.56 (±0.32)	µg/L	1996	Pojoaque Valley	0.56 (±0.06)	µg/L	1998	Los Alamos

Table 14: Maximum Detected Contaminant Concentrations in Eggs, Milk, Goat's Milk, Mushrooms, Piñon Shoot Tips, Small Mammals, Deer, Elk, and Steer/Cattle (continued)

Contaminant	Mushrooms				Piñon Shoot Tips			
	Max. Conc.	Units	Yr.	Loc.	Max. Conc.	Units	Yr.	Loc.
Radionuclides								
Americum-241	223.4 (±75.6)	10^{-5}pCi/g dry	1998	White Rock/Pajarito Acres	128 (±72.0)	10^{-5}pCi/g dry	1998	San Ildefonso
Cesium-137	95.8 (±143.6)	10^{-3}pCi/g dry	1998	White Rock/Pajarito Acres	42.6 (±13.4)	10^{-3}pCi/g dry	1999	White Rock/Pajarito Acres
Iodine-131								
Plutonium-238	23.5 (±35.3)	10^{-5}pCi/g dry	1998	San Ildefonso	54.4 (±24.8)	10^{-5}pCi/g dry	1998	San Ildefonso
Plutonium-239/240	1234.0 (±141.1)	10^{-5}pCi/g dry	1998	White Rock/Pajarito Acres	67.2 (±25.6)	10^{-5}pCi/g dry	1998	San Ildefonso
Strontium-90	270.5 (±95.8)	10^{-3}pCi/g dry	1998	White Rock/Pajarito Acres	380 (±48.0)	10^{-3}pCi/g dry	1999	Los Alamos
Tritium	-0.13 (±0.65)	pCi/mL	1998	San Ildefonso	0.7 (±0.70)	pCi/mL	1997	Los Alamos
Uranium-234								
Uranium-235								
Uranium-238								
Total Uranium	121.8 (±12.6)	ppb dry	1998	San Ildefonso	177.6 (±17.6)	ppb dry	1997	San Ildefonso

Table 14: Maximum Detected Contaminant Concentrations in Eggs, Milk, Goat's Milk, Mushrooms, Piñon Shoot Tips, Small Mammals, Deer, Elk, and Steer/Cattle (continued)

Contaminant	Small Mammals - muscle				Small Mammals - bone			
	Max. Conc.	Units	Yr.	Loc.	Max. Conc.	Units	Yr.	Loc.
Radionuclides								
Americum-241	0.000884 (±0.000292)	pCi/g ash	1998	Rendija Canyon	0.002958 (±0.00136)	pCi/g ash	1998	Los Alamos
Cesium-137	0.23 (±0.18)	pCi/g ash	2000	Los Alamos	0.1632 (±.2448)	pCi/g ash	1998	Los Alamos
Iodine-131								
Plutonium-238	0 (±0.0007)	pCi/g ash	2000	Los Alamos	0.001632 (±.000442)	pCi/g ash	1998	Rendija Canyon
Plutonium-239/240	0.0002 (±0.006)	pCi/g ash	2000	Los Alamos	0.0015 (±0.0008)	pCi/g ash	2000	Los Alamos
Strontium-90	-0.0492 (±0.048)	pCi/g ash	1998	Los Alamos	1.03 (±1.11)	pCi/g ash	2000	Los Alamos
Tritium	-0.13 (±0.63)	pCi/mL	1998	Los Alamos	-0.17 (±0.63)	pCi/mL	1998	Los Alamos
Uranium-234								
Uranium-235								
Uranium-238								
Total Uranium	0.03 (±0.01)	ppm ash	2000	Los Alamos	0.02 (±0.01)	ppm ash	2000	Los Alamos

Table 14: Maximum Detected Contaminant Concentrations in Eggs, Milk, Goat's Milk, Mushrooms, Piñon Shoot Tips, Small Mammals, Deer, Elk, and Steer/Cattle (continued)

Contaminant	Deer - muscle				Deer - leg bone			
	Max.Conc.	Units	Yr.	Loc.	Max. Conc.	Units	Yr.	Loc.
Radionuclides								
Americum-241	22.1 (±19.8)	10^{-5}pCi/g dry	1997/98	Los Alamos	254.4 (±84.8)	10^{-5}pCi/g dry	1995/96	State Road 501
Cesium-137	459 (±90.0)	10^{-3}pCi/g dry	1995/96	State Road 501	88 (±132.0)	10^{-3}pCi/g dry	1996/97	State Road 502
Iodine-131								
Plutonium-238	47.7 (±10.8)	10^{-5}pCi/g dry	1997/98	Los Alamos	928.4 (±347.6)	10^{-5}pCi/g dry	1999	West of Q-Site
Plutonium-239/240	35.6 (±9.9)	10^{-5}pCi/g dry	1997/98	Los Alamos	61.6 (±61.6)	10^{-5}pCi/g dry	1996/97	DP Road
Strontium-90	307.8 (±115.7)	10^{-3}pCi/g dry	1997/98	DP Road	8824 (±946)	10^{-3}pCi/g dry	1995/96	Pajarito Road
Tritium	0.81 (±0.81)	pCi/mL	1997/98	DP Road	1 (±0.60)	pCi/mL	1995/96	State Road 502
Uranium-234								
Uranium-235								
Uranium-238								
Total Uranium	1.8 (±0.45)	ppb dry	2000	TA-49	8.8 (±4.40)	ppb dry	1996/97	State Road 502

Table 14: Maximum Detected Contaminant Concentrations in Eggs, Milk, Goat's Milk, Mushrooms, Piñon Shoot Tips, Small Mammals, Deer, Elk, and Steer/Cattle (continued)

Contaminant	Elk – muscle				Elk-leg bone			
	Max. Conc.	Units	Yr.	Loc.	Max. Conc.	Units	Yr.	Loc.
Radionuclides								
Americum-241	51 (±13.2)	10^{-5}pCi/g dry	1997/98	East Jemez Road	95.4 (±116.6)	10^{-5}pCi/g dry	1995/96	San Ildefonso
Cesium-137	92.4 (±138.6)	10^{-3}pCi/g dry	1997/98	Firing Site 306	270 (±405.0)	10^{-3}pCi/g dry	1996/97	Pajarito Road
Iodine-131								
Plutonium-238	20.7 (±10.1)	10^{-5}pCi/g dry	1997/98	Ski Hill Road	904.8 (±475.6)	10^{-5}pCi/g dry	1998/99	State Road 4
Plutonium-239/240	25.2 (±33.60)	10^{-5}pCi/g dry	1994/95	Pajarito Road	150.8 (±116.0)	10^{-5}pCi/g dry	1997/98	Ski Hill Road
Strontium-90	141.7 (±109.6)	10^{-3}pCi/g dry	1997/98	Firing Site 306	3964 (±636)	10^{-3}pCi/g dry	1995/96	San Ildefonso
Tritium	11.1 (±2.0)	pCi/mL	1994/95	S-Site Road	12.5 (±2.2)	pCi/mL	1994/95	S-Site Road
Uranium-234								
Uranium-235								
Uranium-238								
Total Uranium	44.4 (±4.40)	ppb dry	1997/98	EF Firing Site	186.9 (±170.00)	ppb dry	1994/95	State Road 4

Table 14: Maximum Detected Contaminant Concentrations in Eggs, Milk, Goat's Milk, Mushrooms, Piñon Pine Nuts, Piñon Shoot Tips, Tea, Small Mammals, Cattle, Deer, Elk, and Steer (continued)

Contaminant	Steer & Cattle – muscle				Steer & Cattle – leg bone			
	Max. Conc.	Units	Yr.	Loc.	Max. Conc.	Units	Yr.	Loc.
Radionuclides								
Americum-241	31.1 (±12.6)	10^{-5}pCi/g dry	1998	Cochiti	495 (±190.0)	10^{-5}pCi/g dry	1998	Cochiti
Cesium-137	42.6 (±6.7)	10^{-3}pCi/g dry	1999	San Ildefonso	30 (±90.0)	10^{-3}pCi/g dry	1996	San Ildefonso
Iodine-131								
Plutonium-238	14.8 (±4.1)	10^{-5}pCi/g dry	1999	San Ildefonso	75 (±60)	10^{-5}pCi/g dry	1999	San Ildefonso
Plutonium-239/240	13 (±4.4)	10^{-5}pCi/g dry	1999	S San Ildefonso	235 (±70)	10^{-5}pCi/g dry	1999	San Ildefonso
Strontium-90	57.7 (±13.3)	10^{-3}pCi/g dry	1999	San Ildefonso	3125 (±295)	10^{-3}pCi/g dry	1999	San Ildefonso
Tritium	0.11 (±0.14)	pCi/mL	1997	San Ildefonso	-0.07 (±0.63)	pCi/mL	1999	San Ildefonso
Uranium-234								
Uranium-235								
Uranium-238								
Total Uranium	1.48 (±0.37)	ppb dry	1997	San Ildefonso	35 (±5.00)	ppb dry	1997	San Ildefonso

Source: LANL 1981 through 2002

Table 15: Maximum Detected Concentrations in Fish

Contaminant	Units	Maximum Detected Concentration	Year	Location
Game Fish				
Radionuclides (Muscle and Bone)				
Americium 241	pCi/g dry	0.0045738 (±0.0010406)	1998	Cochiti Reservoir
Cesium 137	pCi/g dry	1.50	1980	Abiquiu Reservoir
Plutonium 238	pCi/g dry	0.0014 (±0.00042)	1984	Upstream Reservoirs
Plutonium 239/240	pCi/g dry	0.0145	1980	Cochiti Reservoir
Strontium 90	pCi/g dry	0.5 (±0.025)	1987	Abiquiu Reservoir
Tritium	pCi/mL	1.63 (±0.77)	1998	Cochiti Reservoir
Uranium 234	pCi/g dry	0.00545 (±0.00133)	2001	Cochiti Reservoir
Uranium 235	pCi/g dry	0.00254 (±0.00127)	2001	Abiquiu Reservoir
Uranium 238	pCi/g dry	0.00411 (±0.00157)	2001	Cochiti Reservoir
Radionuclides (Gut)				
Cesium 137	pCi/g dry	3.7 (±3.8)	1984	Upstream Reservoirs
Plutonium 238	pCi/g dry	0.0018 (±0.0014)	1982	Cochiti Reservoir
Plutonium 239/240	pCi/g dry	0.0225	1980	Cochiti Reservoir
Strontium 90	pCi/g dry	0.31	1985	Downstream Reservoir
Inorganics (Muscle and Bone)				
Barium	ppm wet weight	1.7	2001	Cochiti Reservoir
Mercury	ppm wet weight	0.76	2001	Cochiti Reservoir
Selenium	ppm wet weight	0.78	2001	Cochiti Reservoir
Silver	ppm wet weight	2.6	2001	Cochiti Reservoir
Uranium	ppb, dry	42	1981	El Vado and Heron Reservoirs
Uranium (gut)	ppb, dry	1210 (±120)	1982	Off-site
Non-Game Fish				
Radionuclides (Muscle and Bone)				
Americium 241	pCi/g dry	0.0009405 (±0.000247)	1998	Cochiti Reservoir
Cesium 137	pCi/g dry	1.0	1980	Cochiti Reservoir
Plutonium 238	pCi/g dry	0.001767 (±0.000342)	2000	Cochiti Reservoir
Plutonium 239/240	pCi/g dry	0.0032	1985	Upstream Reservoirs
Strontium 90	pCi/g dry	0.24 (±0.026)	1987	Cochiti Reservoir
Tritium	pCi/mL	1.54 (±0.77)	1998	Cochiti Reservoir
Uranium 234	pCi/g dry	0.01948 (±0.00252)	2001	Cochiti Reservoir
Uranium 235	pCi/g dry	0.00276 (±0.00105)	2001	Abiquiu Reservoir
Uranium 238	pCi/g dry	0.00998 (±0.00171)	2001	Cochiti Reservoir
Radionuclides (Gut)				
Strontium 90	pCi/g dry	0.36 (±0.02)	1983	Cochiti Reservoir
Cesium 137	pCi/g dry	3.7	1980	Abiquiu Reservoir
Plutonium 238	pCi/g dry	0.0064 (±0.0038)	1983	Cochiti Reservoir
Plutonium 239/240	pCi/g dry	0.012 (±0.0066)	1984	Cochiti Reservoir

Table 15: Maximum Detected Concentrations in Fish

Contaminant	Units	Maximum Detected Concentration	Year	Location
Inorganics (Muscle and Bone)				
Antimony	ppm wet weight	1.25 (±0.00)	1996*	Cochiti Reservoir
Arsenic	ppm wet weight	0.90	2000	Abiquiu Reservoir
Barium	ppm wet weight	4.90	2001	Abiquiu Reservoir
Beryllium	ppm wet weight	0.348 (±0.12)	1996*	Cochiti Reservoir
Cadmium	ppm wet weight	1.60	2000	Abiquiu Reservoir
Chromium	ppm wet weight	9.624 (±14.82)	1996*	Cochiti Reservoir
Copper	ppm wet weight	1.978 (±4.17)	1996*	Cochiti Reservoir
Cyanide	ppm wet weight	2.80	2000	Abiquiu Reservoir
Lead	ppm wet weight	4.0	2000	Cochiti Reservoir
Mercury	ppm wet weight	0.51	2000	Cochiti Reservoir
Nickel	ppm wet weight	3.7	2000	Cochiti Reservoir
Selenium	ppm wet weight	2.0	2000	Abiquiu and Cochiti Reservoirs
Silver	ppm wet weight	0.468 (±0.17)	1996*	Cochiti Reservoir
Thallium	ppm wet weight	8.13 (±2.85)	1996*	Cochiti Reservoir
Uranium	ppb dry, ppb	290	1981	Cochiti Reservoir
Uranium (gut)	ppb dry, ppb	1,350 (±140)	1983	Cochiti Reservoir
Zinc	ppm wet weight	8.92 (±11.19)	1996*	Cochiti Reservoir
PCBs (Muscle and Bone)				
#77	pg/g fresh wt.	212	2001	Cochiti Reservoir
#81	pg/g fresh wt.	9.73	2000	Cochiti Reservoir
#105	pg/g fresh wt.	5,650	2001	Cochiti Reservoir
#114	pg/g fresh wt.	418	2001	Cochiti Reservoir
#118	pg/g fresh wt.	15,700	2001	Cochiti Reservoir
#123	pg/g fresh wt.	311	2000	Cochiti Reservoir
#126	pg/g fresh wt.	21.8	2001	Cochiti Reservoir
#156	pg/g fresh wt.	2,820	2001	Cochiti Reservoir
#167	pg/g fresh wt.	968	2001	Cochiti Reservoir
#169	pg/g fresh wt.	24.3	2000	Cochiti Reservoir
#170	pg/g fresh wt.	3,140	2000	Cochiti Reservoir
#180	pg/g fresh wt.	9,690	2000	Cochiti Reservoir
#189	pg/g fresh wt.	85.2	2000	Cochiti Reservoir
total concentration	ppm fresh wt.	0.0316	2001	Cochiti Reservoir
Dioxins (Muscle and Bone)				
2,3,7,8-TCDD	ppm wet weight	1.53×10^{-7}	2001	Cochiti Reservoir
1,2,3,7,8-PeCDD	ppm wet weight	3.19×10^{-7}	2001	Cochiti Reservoir
1,2,3,4,7,8-HxCDD	ppm wet weight	1.31×10^{-7}	2001	Cochiti Reservoir
1,2,3,6,7,8-HxCDD	ppm wet weight	3.12×10^{-7}	2001	Abiquiu Reservoir
1,2,3,7,8,9-HxCDD	ppm wet weight	1.45×10^{-7}	2001	Cochiti Reservoir
1,2,3,4,6,7,8-HpCDD	ppm wet weight	9.8×10^{-7}	2001	Abiquiu Reservoir
OCDD	ppm wet weight	6.37×10^{-6}	2001	Abiquiu Reservoir
2,3,7,8-TCDF	ppm wet weight	3.77×10^{-7}	2001	Cochiti Reservoir
1,2,3,7,8-PeCDF	ppm wet weight	1.03×10^{-7}	2001	Cochiti Reservoir

Table 15: Maximum Detected Concentrations in Fish

Contaminant	Units	Maximum Detected Concentration	Year	Location
2,3,4,7,8-PeCDF	ppm wet weight	2.13×10^{-7}	2001	Cochiti Reservoir
1,2,3,4,6,7,8-HpCDF	ppm wet weight	1.03×10^{-7}	2001	Cochiti Reservoir
OCDF	ppm wet weight	1.97×10^{-7}	2001	Cochiti Reservoir
Total Tetra-CDD	ppm wet weight	1.78×10^{-7}	2001	Cochiti Reservoir
Total Penta-CDD	ppm wet weight	3.19×10^{-7}	2001	Cochiti Reservoir
Total Hexa-CDD	ppm wet weight	6.62×10^{-7}	2001	Cochiti Reservoir
Total Hepta-CDD	ppm wet weight	1.2×10^{-6}	2001	Abiquiu Reservoir
Total Tetra-CDF	ppm wet weight	5.3×10^{-7}	2001	Off-site
Total Penta-CDF	ppm wet weight	3.74×10^{-7}	2001	Off-site
Total Hexa-CDF	ppm wet weight	1.41×10^{-7}	2001	Off-site
Total Dioxins/Furans	ppm wet weight	9.73×10^{-12}	2001	Abiquiu Reservoir
Organochlorine Pesticides (Muscle and Bone)				
Aldrin	ppb fresh wt.	0.151	2000	Cochiti Reservoir
cis-Chlordane	ppb fresh wt.	9.25	2000	Cochiti Reservoir
trans-Chlordane	ppb fresh wt.	6.94	2000	Cochiti Reservoir
DDT	ppb fresh wt.	6.76	2001	Cochiti Reservoir
DDD	ppb fresh wt.	14.29	2000	Cochiti Reservoir
DDE	ppb fresh wt.	142.15	2000	Cochiti Reservoir
Dieldrin	ppb fresh wt.	0.404	2000	Cochiti Reservoir
Alpha-Endosulphan(I)	ppb fresh wt.	0.214	2001	Cochiti Reservoir
Beta-Endosulphan (II)	ppb fresh wt.	0.076	2001	Cochiti Reservoir
Endosulphan Sulphate	ppb fresh wt.	1	2000	Cochiti Reservoir
Endrin	ppb fresh wt.	0.04	2000	Abiquiu Reservoir
Heptachlor Epoxide	ppb fresh wt.	0.3	2000	Abiquiu Reservoir
Hexachlorobenzene	ppb fresh wt.	2.2	2000	Cochiti Reservoir
alpha HCH	ppb fresh wt.	0.278	2000	Abiquiu Reservoir
beta HCH	ppb fresh wt.	0.125	2001	Cochiti Reservoir
delta HCH	ppb fresh wt.	0.005	2001	Cochiti Reservoir
gamma HCH	ppb fresh wt.	0.337	2000	Cochiti Reservoir
Heptachlor	ppb fresh wt.	1.05	2000	Cochiti Reservoir
Methoxychlor	ppb fresh wt.	0.14	2000	Abiquiu Reservoir
Mirex	ppb fresh wt.	0.499	2000	Cochiti Reservoir
cis-Nonachlor	ppb fresh wt.	4.56	2000	Cochiti Reservoir
trans-Nonachlor	ppb fresh wt.	13.4	2000	Cochiti Reservoir
Oxychlordane	ppb fresh wt.	1.03	2000	Abiquiu Reservoir

Source: LANL 1981 through 2002

Notes:

± Uncertainty
mg/g milligrams(s)/gram
ppm parts per million
ppb parts per billion
pCi/g picocurie(s)/gram
pCi/mL picocurie per milliliter
pg/g picograms/gram
TEF toxicity equivalence quotient

*1995 and 1996 inorganics data are means, not maximums.

Appendix C: Evaluation of Technical Areas (TAs) of Concern at Los Alamos National Laboratory (LANL)

Site Name/Description	Operational History	Monitoring and Remediation Efforts	Public Health Concern
Technical Area (TA) 2 (Omega West Reactor)			
TA-2 is a 4-acre area located along the northern Los Alamos National Laboratory (LANL) boundary and within the Los Alamos Canyon. Eight buildings, including the Omega West Reactor, are included in TA-2.	The Omega West Reactor, which operated from 1956 through 1992, produced radioisotopes used in research laboratories at LANL. For the most part, three underground storage tanks (USTs) were used to hold liquid radioactive wastes produced when the reactor was active. Occasionally, liquid wastes from the reactor were discharged to Los Alamos Canyon. Other buildings in TA-2 mainly served as offices and/or supported research activities at the reactor. Currently, the TA-2 facilities are unused and unoccupied, with the exception of the offices.	During operation, the three USTs were filled with liquid radioactive wastes from the Omega West Reactor. When full, the USTs were emptied and wastes were transported to TA-50 for treatment, if necessary, and disposal. In 1992, the U.S. Department of Energy (DOE) identified a leak in the underground cooling lines of the Omega West Reactor. The leaking section of the cooling line was removed and the remaining lines were sealed to prevent future leaks. In 1993, the Omega West Reactor was placed in a safe shutdown condition. All fuel was removed from the reactor and shipped to the Chemical and Metallurgy Research (CMR) Building in TA-3. The reactor is now slated for decontamination and decommissioning. LANL conducts annual environmental monitoring throughout the installation. At TA-2, monitoring has included air and groundwater (from the regional aquifer) sampling. A review of the monitoring results from 1980 through 2001 found no contaminants in air above health-based comparison values (CVs) and only four metals (arsenic, boron, cadmium, and lead) in the regional aquifer at maximum concentrations above their CVs.	No public health hazards are posed by past releases at TA-2. Access to the site by the public is restricted. Contaminants released to the air or groundwater may have migrated beyond LANL boundaries. Evaluations of off-site air and groundwater monitoring data found no contaminants at levels of health concern. Because the Omega West Reactor has been shut down and is scheduled for demolition, no current or future public health hazards exist.

Site Name/Description	Operational History	Monitoring and Remediation Efforts	Public Health Concern
TA-3 (South Mesa Site: CMR Building and Main Laboratories)			
TA-3 is located on the South Mesa in the northwestern corner of LANL. Los Alamos Canyon is to the north and Two Mile Canyon is to the south. The heads of the Sandia and Mortandad Canyons are found on the east side of TA-3.	TA-3 is the main entry point to LANL and is considered the main technical area. The area supports approximately half of the installation's floor space and employees, including administration facilities, public-access buildings (e.g., the installation library), support operations, and numerous research laboratories. Many of these laboratories use radioactive materials in their research, but only in small quantities. The main facilities at TA-3 include the CMR Building, the Sigma Complex, the Machine Shops, and the Materials Science Laboratory. The CMR Building was constructed in 1952 for conducting actinide chemistry and metallurgy research. The Sigma Complex, built between 1953 and the early 1960s, contains facilities used to study the properties of metals, metal alloys, and ceramics; to fabricate metal and ceramic items; to examine material properties; and to store thorium used in LANL research. The Machine Shops, built in 1953 and 1957, contain equipment used for fabricating specialty components from a variety of materials. The Materials Science Laboratory houses facilities and laboratories used to accommodate researchers and scientists.	Between 1953 and 1963, wastes produced in TA-3 were sent to a wastewater treatment facility and discharged to Acid Canyon to the north. Approximately 30% of the wastewater from TA-3 was discharged untreated because treatment was unnecessary based on monitoring data. Currently, wastes produced at the CMR Building are treated to meet criteria for on-site or off-site disposal. Liquid radioactive wastes produced throughout TA-3 are transported through an underground drainage system to TA-50. Some waste from the CMR Building, however, is seasonally discharged to Mortandad Canyon within TA-3 through a National Pollution Discharge Elimination System (NPDES) permitted outfall. Gaseous wastes are vented through air stacks. Stacks are regularly monitored as required by state and federal regulations. As part of LANL's annual environmental monitoring, TA-3 has been monitored for releases to the air. A review of the monitoring results from 1980 through 2001 found no contaminants above CVs in air.	No public health hazards are posed by releases at TA-3. Public access to research, laboratory, and storage facilities that may contain hazardous materials is restricted. Contaminants released to the air, groundwater, or Acid Canyon may have migrated beyond LANL boundaries. Evaluations of off-site air, groundwater, and canyon monitoring data found no contaminants at levels of health concern. LANL currently uses, stores, and disposes radioactive and hazardous materials according to state and federal regulations to ensure continued protection of public health.

Site Name/Description	Operational History	Monitoring and Remediation Efforts	Public Health Concern
TA-21 (DP-Site)			
TA-21 is located near the northern LANL boundary along State Road 52 and 0.6 miles from the nearest residential neighborhood. Although access to TA-21 is unrestricted, access to the facilities within TA-21 is strictly controlled.	TA-21 is divided into two sections: DP West and DP East. DP West supported a former radioactive materials processing facility, which is no longer used and is now undergoing decontamination and decommissioning. DP East facilities are used for energy, environmental, and weapons defense research and include the Tritium Systems Test Assembly (TSTA) and the Tritium Science and Fabrication Facility (TSFF). TSTA became operational in 1982 and was used for tests related to large-scale fusion reactors. In addition to testing areas, the facility contains additional laboratories, a storage area, and offices. The TSFF, built in 1964 for chemistry processing and retrofitted in 1974, is used as a tritium research and development center. From 1974 through 1993, the TSFF was used to synthesize tritium salt for the underground nuclear testing program. Currently, the TSFF is used for many of the same activities as the TSTA.	From 1945 to 1952, wastes produced at TA-21 were discharged untreated to Los Alamos Canyon. Since 1952, waste has been processed in a wastewater treatment plant prior to discharge to the canyon. Gaseous wastes are vented through air stacks. DOE has several redundant systems in place to prevent releases to the environment. DOE is planning to eventually close facilities in TA-21 and move operations to TA-16. Annual monitoring for contaminants in air and soil is conducted at TA-21. A review of the monitoring results from 1980 through 2001 found no contaminants above CVs in air and only strontium-90 and arsenic above CVs in surface soil.	No public health hazards are posed by releases at TA-21. Public access to research, laboratory, and storage facilities that may contain hazardous materials is strictly restricted. Contaminants released to the air, groundwater, and Los Alamos Canyon may have migrated beyond LANL boundaries. Evaluations of off-site air, groundwater, and canyon monitoring data found no contaminants at levels of health concern. LANL currently uses, stores, and disposes radioactive and hazardous materials according to state and federal regulations to ensure continued protection of public health.

Site Name/Description	Operational History	Monitoring and Remediation Efforts	Public Health Concern
TA-50 (Waste Management Site)			
TA-50 occupies approximately 62 acres of a mesa in the central portion of LANL. TA-50 is bounded by Mortandad Canyon to the north, Ten Site Canyon to the east, and Two Mile Canyon and a branch of the Pajarito Canyon to the south.	TA-50 supports waste management facilities, which began operating in 1963 and are used to treat and dispose of industrial liquid and radioactive liquid wastes generated at other technical areas. Three main facilities are used for waste management: the Radioactive Liquid Waste Treatment Facility (RLWTF); the Radioactive Materials Research, Operations, and Demonstration (RAMROD) Facility; and the Waste Characterization Reduction, and Repackaging (WCRR) Facility. The primary functions of these facilities are waste characterization, packaging, and labeling to identify proper disposal options; waste transport, receipt, and acceptance; radioactive liquid waste storage, pre-treatment, and treatment; equipment decontamination; solid waste size reduction; and solid waste processing. TA-50 was also historically used for solid waste disposal. Between 1948 and 1974, an estimated 3.68 million cubic feet of chemical, radioactive, and mixed wastes were buried in pits and shafts at a 12-acre area within TA-50.	Annually, approximately 5 million gallons of treated effluent are released from the RLWTF at TA-50 to Mortandad Canyon. Sludge from the treatment process is drummed and shipped to TA-54 for disposal. Gaseous wastes are vented through stacks. Review of data from annual monitoring of surface soil between 1980 and 2001 found only strontium-90 and arsenic above their CVs at TA-50.	No public health hazards are posed by releases at TA-50. Access to the waste management facilities by the public is restricted. Contaminants released to the air, groundwater, or Mortandad Canyon may have migrated beyond LANL boundaries. Evaluations of off-site air, groundwater, and canyon monitoring data found no contaminants at levels of health concern. LANL currently follows state and federal regulations to ensure continued protection of public health.

Site Name/Description	Operational History	Monitoring and Remediation Efforts	Public Health Concern
TA-51 (Environmental Research Site)			
TA-51 is located on the Mesita del Buey along the eastern LANL boundary near the San Ildefonso Pueblo Lands and approximately 300 feet from Pajarito Road. The Canyon Cañada del Buey is located to the north and Pajarito Canyon is to the south.	TA-51 contains 17 structures, most of which are temporary trailers. This technical area is currently being used for research and experimental studies examining the long-term impact of radioactive waste on the environment and assessing various types of waste storage and covering options.	As part of LANL's Environmental Surveillance program, annual monitoring of environmental media is conducted throughout LANL. At TA-51, this monitoring includes collecting surface soil samples. A review of the surface soil data collected from 1980 through 2001 found only strontium-90 and arsenic above their CVs.	No public health hazards are posed by releases at TA-51. Access to the area by the public is restricted. Contaminants released to the air or groundwater may have migrated beyond LANL boundaries. Evaluations of off-site air, groundwater, and canyon monitoring data found no contaminants at levels of health concern. LANL currently follows state and federal regulations to ensure continued protection of public health.

Site Name/Description	Operational History	Monitoring and Remediation Efforts	Public Health Concern
TA-53 (Los Alamos Meson Physics Facility [LAMPF])			
TA-53, located in the northeastern corner of LANL, occupies 750 acres of a mesa bounded on the north by Los Alamos Canyon and on the south by Sandia Canyon. This is an isolated portion of LANL.	TA-53 houses LAMPF, which was formally known as the Los Alamos Neutron Science Center (LANSCE). LAMPF includes a proton accelerator, research facilities, and support operations—approximately 400 buildings in all. Approximately 700 people work at LAMPF, but this number increases when the accelerator is active and scientists from around the world are visiting. The 800-million electron volt proton accelerator, built in 1970, produces subatomic particles used in research laboratories at LANL. The accelerator has also been used to produce medical radioisotopes.	Before a sanitary wastewater treatment plant was constructed at LANL, sanitary wastes were discharged to two unlined lagoons, which were later found to contain traces of radioactive and hazardous wastes and were remediated under the Resource Conservation and Recovery Act (RCRA). Currently, air emissions from LAMPF accounts for 90% of all radioactive air emissions from LANL. Six NPDES permitted outfalls (three to Los Alamos Canyon and three to Sandia Canyon) discharge cooling tower blowdown. Liquid radioactive wastes are allowed to decay in four USTs and then discharged to lined lagoons. Annual monitoring at TA-53 under the Environmental Surveillance program includes collecting samples of air, groundwater from the regional aquifer, and surface soil. No contaminants were found above CVs in air between 1980 and 2001. Contaminants found above CVs in the regional aquifer during this period included chloride, hydrogen carbonate, sodium, antimony, arsenic, lead, and molybdenum. Surface soil samples contained cesium-137, strontium-90, and arsenic above their CVs.	No public health hazards are posed by releases at TA-53. Access to facilities, and surface soil, by the public is restricted. Contaminants released to the air or groundwater may have migrated beyond LANL boundaries. Evaluations of off-site air and groundwater monitoring data found no contaminants at levels of health concern. LANL currently operates TA-54 facilities following state and federal regulations to ensure continued protection of public health.

Site Name/Description	Operational History	Monitoring and Remediation Efforts	Public Health Concern
TA-54 (Waste Disposal Site)			
TA-54 occupies approximately 945 acres on the Mesita del Buey located along the eastern LANL boundary. This mesa is bounded by the Canyon Cañada del Buey to the north and the Pajarito Canyon to the south. The northern border of TA-54 forms the 3-mile boundary between LANL and the Ildefonso Pueblo Lands to the north. The southeastern TA-54 boundary borders the White Rock Community to the south. Almost 70 archeological sites have been identified in TA-54, which has been divided into TA-54 West and TA-54 East.	TA-54 West supports the environment, safety, and health offices; research and development buildings; and a potable water supply pumping station and chlorination facility. The Radioactive Assay and Nondestructive Test (RANT) Facility in TA-54 West is used to characterize unopened containerized waste. TA-54 East is the primary waste disposal area for radioactive, hazardous, or mixed wastes produced throughout LANL. Most of the waste is solid waste, but some liquid and gaseous waste is also handled here. Storage, disposal, and some treatment of these wastes are conducted at four waste handling and disposal areas: G, H, J, and L.	DOE determined that waste disposal practices have permanently affected the environment at TA-54. In Area G, DOE is conducting a project to retrieve approximately 17,000 buried containers of transuranic wastes to prevent future releases from these containers to the environment. Area H has been designated for remediation under RCRA. Air, surface soil, surface water, and sediment sampling are part of the annual monitoring conducted at TA-54. Review of the monitoring data from 1980 through 2001 found no contaminants above CVs in air. Surface soil contained plutonium-238, strontium-90, and arsenic above their CVs. Gross alpha, antimony, arsenic, barium, beryllium, boron, cadmium, chromium, iron, lead, manganese, nickel, and vanadium were detected above CVs in surface water and strontium-90, arsenic, and cadmium were above CVs in sediment.	No public health hazards are posed by releases at TA-54. Public access to research and disposal facilities is restricted. Contaminants released to the air, groundwater, or canyons may have migrated beyond LANL boundaries. Evaluations of off-site air, groundwater, and canyon monitoring data found no contaminants at levels of health concern. LANL is currently conducting remediation as necessary and follows state and federal regulations to ensure continued protection of public health.

Site Name/Description	Operational History	Monitoring and Remediation Efforts	Public Health Concern
Mortandad Canyon			
Mortandad Canyon begins in the central portion of LANL at TA-3. It flows southeasterly though LANL and San Ildefonso Pueblo Lands before converging with the Canyon Cañada del Buey east of LANL. The canyons eventually discharge to the Rio Grande.	Mortandad Canyon receives discharges from outfalls serving TA-3 and TA-50. From TA-3, one NPDES permitted outfall from the CMR Building seasonally discharges to the canyon. Effluent flows from this outfall at a rate of approximately 1 gallon per minute. DOE is scheduled to divert liquid wastes from the CMR Building to TA-50 as part of the LANL waste stream reduction plans. The RLWTF in TA-50 annually discharges approximately 5 million gallons of treated liquid wastes to the canyon. Wastes from TA-50 are treated to remove radioactive materials before discharge. Currently and in the past, the canyon may have be used by the public for recreational purposes, such as hiking or hunting	DOE began hyrogeologic studies of Mortandad Canyon in the 1960s. The regional aquifer underlying Mortandad Canyon is approximately 950 feet below a perched aquifer at the surface. Sampling of surface water and shallow groundwater in the perched aquifer has found low, but measurable amounts of radioactivity. Since these studies began, no surface water has flowed in this canyon beyond LANL boundaries. Within Mortandad Canyon, LANL collects non-potable groundwater from the alluvium, surface water, and sediment samples as part of the annual monitoring program. Review of the data collected between 1980 and 2001 found a number of contaminants above CVs in the groundwater, including cesium-137, plutonium-238, plutonium-239/240, uranium, gross alpha, chloride, fluoride, nitrate, perchlorate, sodium, aluminum, antimony, arsenic, barium, boron, cadmium, chromium, copper, iron, lead, manganese, molybdenum, and silver. Surface water contained cesium-137, plutonium-238, plutonium-239/240, gross alpha, chloride, fluoride, nitrate, perchlorate, sodium, antimony, arsenic, boron, lead, and molybdenum at maximum concentrations above CVs. Americium-241, cesium-137, plutonium-238, plutonium-239/240, strontium-90, and arsenic were found above CVs in sediment.	No public health hazards are expected from public use of Mortandad Canyon for recreational activities. Surface water flow and sediment transport has not extended beyond LANL boundaries since investigations began in the 1960s. ATSDR assessed exposures should members of the public enter LANL boundaries during recreational use of the canyon. Evaluations of groundwater, surface water, and sediment data found no contaminants at concentrations likely to cause adverse health effects.

Site Name/Description	Operational History	Monitoring and Remediation Efforts	Public Health Concern
Los Alamos Canyon			
Los Alamos Canyon flows along the northern LANL boundary through numerous technical areas. Pueblo Canyon converges with Los Alamos Canyon at the eastern LANL boundary. Los Alamos Canyon continues northeasterly through the San Ildefonso Pueblo Lands before converging with the Guaje Canyon. Guaje Canyon flows easterly and discharges to the Rio Grande. The Los Alamos Reservoir is located upstream of LANL and captures snow melt and rain water runoff from the mountains to the west. Water intermittently flows from the reservoir into the canyon .	From 1945 through 1952, untreated wastewater produced at TA-21 facilities was discharged from outfalls into pits located near the edge of Los Alamos Canyon. Wastewater treatment plants were built in 1952 and 1967 to treat TA-21 wastes. Treated wastewater was discharged either to the pits along the edge of Los Alamos Canyon or directly into the canyon. Other LANL facilities have also used Los Alamos Canyon for effluent discharge. In TA-53, three NPDES permitted outfalls discharged cooling tower blowdown water from LAMPF. In TA-43, the Health Research Laboratory discharges cooling water from lasers to the canyon through a single outfall. This outfall, however, is under consideration for closure. Facilities at TA-41 and the TA-2 Omega West Reactor have also occasionally released sanitary effluents and cooling water to Los Alamos Canyon. Currently and in the past, the canyon may have be used by the public for recreational purposes, such as hiking or hunting.	Surface water in Los Alamos Canyon is captured in the alluvium at the canyon floor with the highest water levels recorded in the spring. Sampling of surface water and shallow groundwater in Los Alamos Canyon has found low, but measurable levels of radioactivity. Under the annual monitoring program, LANL collects samples of non-potable groundwater from the alluvium, surface water, and sediment. Data collected from 1980 to 2001 were reviewed and the maximum detected concentrations compared to CVs. In groundwater, gross alpha, chloride, fluoride, nitrate, sodium, aluminum, arsenic, barium, beryllium, boron, cadmium, chromium, copper, iron, lead, manganese, molybdenum, nickel, and vanadium exceeded their CVs. Uranium, gross alpha, chloride, fluoride, nitrate, sodium, arsenic, boron, cadmium, chromium, lead, manganese, and molybdenum were found above CVs in surface water, whereas sediment contained americium-241, cesium-137, plutonium-239/240, strontium-90, and arsenic above CVs.	No public health hazards are expected from public use of Los Alamos Canyon for recreational activities. ATSDR assessed exposures to members of the public during recreational use of the canyon. Evaluations of groundwater, surface water, and sediment data found no contaminants at concentrations likely to cause adverse health effects.

Site Name/Description	Operational History	Monitoring and Remediation Efforts	Public Health Concern
Acid Canyon			
Acid Canyon is a small canyon located within the Los Alamos townsite and north of the northwestern LANL site boundary. Acid Canyon converges with the Pueblo Canyon north of LANL. Pueblo Canyon passes through the eastern portion of LANL and converges with the Los Alamos Canyon, which eventually discharges into the Rio Grande west of LANL. The Los Alamos townsite operates two county sanitary sewer treatment plants that discharge into Pueblo Canyon. One plant is located upstream and the other plant is downstream of Acid Canyon.	In late 1943 or early 1944 until 1951, LANL discharging untreated radioactive liquid wastes into Acid Canyon. Specific information about the types of chemicals and radioactive materials in the wastewater is unknown. Research at that time, however, included use of strontium, cesium, uranium, plutonium, americium, and tritium isotopes. Beginning in 1951, radioactive and chemical wastes were processed through a treatment plant before discharge to the canyon. Treatment included a flocculation-sedimentation-filtration process. In 1953, DOE began discharging radioactive wastewater produced in laboratories at TA-3 into Acid Canyon. About 30% of the TA-3 wastewater was discharged untreated, based on monitoring that indicated that treatment was unnecessary. DOE also transported wastewater from TA-43 and TA-48 to Acid Canyon for treatment and disposal. Acid Canyon is currently used for recreation, such as picnicking, trail riding, hiking, firearms practice, wood cutting, and pinon nut gathering. Future use of Acid Canyon is expected to be recreational with the potential for some residential and light commercial development.	The treatment plant at Acid Canyon operated from 1951 to 1964. Decontamination and decommissioning began in October 1966. Solid wastes from the facility and contaminated cliff face materials, rock, and sediment were removed. By July 1967, DOE considered the treatment plant site and Acid Canyon free of contamination. At that time, the treatment plant site and Acid Canyon were included in a land transfer to Los Alamos County. DOE maintains an easement to access sampling locations and wells. Seasonally, surface water and groundwater is captured in the alluvium in Acid Canyon. Sampling of surface water and groundwater has found low, but measurable levels of radioactivity. LANL has collected samples from the non-potable alluvium and intermediate groundwater groundwater zones, surface water, and sediment in Acid Canyon. A review of the data from 1980 to 2001 identified chloride, fluoride, nitrate, sodium, antimony, arsenic, boron, cadmium, chromium, iron, lead, manganese, molybdenum, and vanadium at concentrations above CVs in the non-potable groundwater samples. Surface water contained gross alpha, ammonia, chloride, fluoride, nitrate, sodium, antimony, arsenic, boron, cadmium, chromium, lead, lithium, manganese, and methylene chloride above CVs. Sediment contained cesium-137, plutonium-239/240, strontium-90, arsenic, iron, and manganese above CVs.	No public health hazards are expected from public use of Acid Canyon. DOE ceased discharging to the canyon in 1964 and completed remediation of the canyon and wastewater treatment plant in 1967. Evaluations of groundwater, surface water, and sediment data from ongoing monitoring found no contaminants at concentrations likely to cause adverse health effects.

Site Name/Description	Operational History	Monitoring and Remediation Efforts	Public Health Concern
Canyon Cañada del Buey			
Canyon Cañada del Buey is located along LANL's eastern boundary with San Ildefonso Pueblo Lands to the north and TA-54 to the south. Canyon Cañada del Buey passes through the White Rock Community to the south and converges with Mortandad Canyon immediately west of the Rio Grande.	Available information does not indicate if LANL discharged liquid waste to Canyon Cañada del Buey. Currently and in the past, the canyon may have be used by the public for recreational purposes, such as hiking or hunting.	Canyon Cañada del Buey is included in LANL's annual monitoring program. Media sampled include the non-potable groundwater from the alluvium, surface water, and sediment. Review of the data collected between 1980 and 2001 identified gross alpha, chloride, sodium, sulfate, aluminum, arsenic, barium, cadmium, chromium, iron, lead, manganese, thallium, and vanadium above CVs in the non-potable groundwater. Chloride, fluoride, sodium, aluminum, antimony, arsenic, iron, molybdenum, and vanadium were found above CVs in surface water. Sediment contained only strontium-90 and arsenic above their CVs.	No public health hazards are expected from public use of Canyon Cañada del Buey for recreational activities. ATSDR assessed exposures to members of the public during recreational use of the canyon. Evaluations of groundwater, surface water, and sediment data found no contaminants at concentrations likely to cause adverse health effects.

References

LANL. 1981. *Formerly Utilized MED/AEC Sites Remedial Action Program, Radiological Survey of the Site of a Former Radioactive Liquid Waste Treatment Plant (TA-45) and the Effluent Receiving Areas of Acid, Pueblo, and Los Alamos Canyons, Los Alamos, New Mexico.* Los Alamos, NM: Environmental Surveillance Group (H-8), Health Division of LANL prepared for DOE. May 1981. Publication No.: LA-8890-ENV.

LANL. 1990. *Solid Waste Management Units Report, Los Alamos National Laboratory, Revised November 1990.* Los Alamos, NM. Publication No.: LAUR 90-3400.

LANL. 1990. *Environmental Surveillance at Los Alamos During 1989.* Los Alamos, NM: Environmental Protection Group. December 1990. Publication No.: LA-12000-ENV.

LANL. 1997. *Description of Technical Areas and Facilities at Los Alamos National Laboratory.* Los Alamos, NM: Site-Wide Environmental Impact Statement Project Office, Environment, Safety, and Health Division. Publication No.: LA-UR-97-4275.

DOE. 1999. *Site-Wide Environmental Impact Statement for Continued Operation of the Los Alamos National Laboratory, Volume I-Main Report.* Albuquerque, NM. Publication No.: DOE/EIS-0238.

Notes:

CMR	Chemical and Metallurgy Research
CV	comparison value
DOE	U.S. Department of Energy
LANL	Los Alamos National Laboratory
NPDES	National Pollution Discharge Elimination System
RAMROD	Radioactive Materials Research, Operations, and Demonstration
RANT	Radioactive Assay and Nondestructive Test
RCRA	Resource, Conservation and Recovery Act
RLWTF	Radioactive Liquid Waste Treatment Facility
TA	Technical Area
TSFF	Tritium Science and Fabrication Facility
TSTA	Tritium Systems Test Assembly
UST	underground storage tank
WCRR	Waste Characterization, Reduction, and Repackaging

Appendix D: Detailed Site Descriptions of Technical Areas and Canyons Evaluated by ATSDR

Technical Area 2 (TA-2) (Omega West Reactor)

TA-2 is a 4-acre technical area located along the northern Los Alamos National Laboratory (LANL) boundary and within the Los Alamos Canyon. Eight buildings, including the Omega West Reactor, are included in TA-2. The Omega West Reactor, which operated from 1956 through 1992, produced radioisotopes used in research laboratories at LANL. The nuclear reactor was classified as a category 2 hazard when it was active. Occasionally, discharge from the reactor was released to Los Alamos Canyon. The other buildings in TA-2 were mainly used as offices and supported research activities at the reactor.

In 1992, the U.S. Department of Energy (DOE) identified a leak in the underground cooling lines of the reactor. The leaking section of the cooling line was removed and the remaining lines were sealed to prevent future leaks. Three underground storage tanks (USTs) were used to hold liquid radioactive wastes produced while the reactor was active. Once full, the wastes were removed from the USTs and transported to TA-50 for treatment, if necessary, and disposal.

In 1993, the Omega West Reactor was placed in a safe shutdown condition and all fuel was removed from the reactor and shipped to the CMR Building in TA-3 for storage until a long-term storage option can be identified. The reactor was reclassified as a non-nuclear, low-level radiological facility after the fuel was removed. The reactor is now slated for decontamination and decommissioning. Currently, the TA-2 facilities are unused and unoccupied, with the exception of the offices.

TA-3 (South Mesa Site)

TA-3 is located on the South Mesa in the northwestern corner of LANL. Los Alamos Canyon is to the north and Two Mile Canyon is to the south. The heads of the Sandia and Mortandad Canyons are found on the east side of TA-3. TA-3 is the main entry point to LANL and is considered the main technical area. The area supports approximately half of the installation's floor space and employees, including administration facilities, public-access buildings (e.g., the installation library), support operations, and numerous research laboratories. Many of these laboratories use radioactive materials in their research, but only in small quantities. Between 1953 and 1963, wastes produced in TA-3 were sent to the wastewater treatment facility in TA-45 and discharged to Acid Canyon. Approximately 30 percent of the wastewater was discharged untreated. The main facilities at TA-3 include the Chemical and Metallurgy Research (CMR) Building, the Sigma Complex, the Machine Shops, and the Materials Science Laboratory.

The CMR Building, a category 2 hazard facility, was constructed in 1952 for conducting actinide chemistry and metallurgy research. Actinide chemistry is the study of elements with atomic numbers from actinium-89 to lawrencium-103. An addition was built in 1960 and DOE has been updating the CMR Building facilities since its construction to comply with applicable regulatory and safety standards. The CMR Building has several wings and each wing is designated for a specific use. There are wings designated as hot cells for research with radioactive materials and other areas designated as storage vaults for special nuclear materials (SNM). SNM are a group of elements defined in the Atomic Energy Act of 1954 and include plutonium, uranium-233, and

uranium-235; any other materials identified by the Nuclear Regulatory Commission; or any material enriched by these elements. The CMR Building is the only facility at LANL equipped for research with SNM. The main processes and research conducted at the CMR Building include:

- Analytical chemistry research which involves studying, evaluating, and analyzing radioactive materials to support activities at LANL and other DOE facilities;
- Processing, handling, and storage of uranium and other high radiation materials;
- Destructive and nondestructive analysis and metallographic analysis to measure the properties of radioactive materials;
- Nonproliferation training for international inspection teams working under the Atomic Energy Agency;
- Actinide research and processing, which involves researching the characteristics of highly radioactive materials, separating medical isotopes, and processing neutron sources; and
- Fabrication and metallography to produce targets, weapon components, and research parts from a variety of materials, but mostly with metallic uranium.

Currently, wastes produced at the CMR Building are pretreated and then treated in the building to meet criteria for either on-site or off-site disposal. Liquid radioactive wastes are transported through an underground drainage system to TA-50. Some waste, however, is discharged to Mortandad Canyon through a National Pollution Discharge Elimination System (NPDES) permitted outfall. Discharge to the canyon only occurs seasonally at a rate of approximately 1 gallon per minute.

The Sigma Complex is composed of the Sigma Building, Beryllium Technology Facility, Press Building, and Thorium Storage Building. The Sigma Building and Thorium Storage Building are category 3 hazard facilities. The Beryllium Technology Facility is classified as a non-nuclear, low-level chemical facility and the Press Building is classified as a non-nuclear, low-level radiation facility. These facilities were built between 1953 and the early 1960s, with additions added in the 1980s. The Sigma Building and the Beryllium Technology Facility are used for studying the properties of metals, metal alloys, and ceramics and fabricating metal and ceramic items. Depleted and enriched uranium, ceramics, stainless steel, lithium, and beryllium are commonly used. The Press Building houses a 5,000 ton hydraulic press used in studying material properties and the Thorium Storage Building stores thorium in an oxide form for use in LANL research. Gaseous wastes are vented through air stacks and liquid wastes are transported through underground drains to TA-50 for disposal.

The Machine Shops include the Beryllium Shop, built in 1953, and the Uranium Shop, built in 1957. These shops are considered non-nuclear, low-level radiation and low-level chemical hazard facilities. Both facilities contain milling machines, vertical and horizontal lathes, surface grinders, internal and external grinders and saws, laser cutters, welding equipment, and measuring devices which are used for fabricating specialty components from a variety of

materials and then inspecting these components. Some radioactive wastes are produced from using depleted uranium at the Uranium Shop.

The Materials Science Laboratory houses 27 laboratories, 15 support rooms, 60 offices, 21 research areas, and several conference rooms. These facilities are used to accommodate researchers and scientists, including those visiting from academic institutions and private industries. The laboratories are considered non-nuclear, low-level chemical facilities. Researchers use limited amounts of hazardous chemicals and radioactive materials, such as solid sodium, zirconium, and depleted uranium. The laboratories can support four types of experiments: (1) materials processing which includes wet chemistry, thermomechanical processing, materials handling, microwave processing, heavy equipment materials processing, single crystal growth synthesis, amorphous alloys, tape casting, inorganic synthesis, and powder processing; (2) materials behavior in extreme environments, such as high temperatures and heavy loads; (3) materials development, which explores the uses of new materials; and (4) materials characterization to study the properties of materials using spectroscopy, imaging, electron microscopes, optical spectroscopy, and x-rays.

In addition to these main facilities, DOE has also classified several other facilities in TA-3 as nuclear or non-nuclear hazard categories. The Sealed Source Storage Building, which stores encapsulated radioactive materials and SNM for research, is another category 2 hazard facility within TA-3. The Calibration Building and Health Physics Instrument Calibration Facility are classified as category 3 hazards because they house small amounts of radioactive materials used to calibrate instruments. The former High Pressure Tritium Facility used for tritium handling is also a category 3 hazard facility; this facility is currently in safe shutdown. Non-nuclear facilities include the Liquid and Compressed Gas Facility—a moderate-level chemical facility; the Ion Beam Building and High-Voltage-Test Facility—low-level radiation facilities; the Weapons Test Support Facility—a low-level energy source facility; and warehouses and a water treatment facility—low-level chemical facilities.

TA-21 (DP-Site)

TA-21 is located near the northern LANL boundary along State Road 52 and 0.6 miles from the nearest residential neighborhood. Although access to TA-21 is unrestricted, access to the facilities within TA-21 is strictly controlled. This technical area can be divided into two sections: DP West and DP East. DP West supported a former radioactive materials processing facility, which is no longer used and is now undergoing decontamination and decommissioning. DP East facilities are used for energy, environmental, and weapons defense research and include the Tritium Systems Test Assembly (TSTA) and the Tritium Science and Fabrication Facility (TSFF). Tritium is a radioactive isotope of hydrogen. From 1945 to 1952, wastes produced at TA-21 were discharged untreated to Los Alamos Canyon. Since 1952, waste has been processed in a wastewater treatment plant prior to discharge to the canyon. DOE is planning to eventually close facilities in TA-21 and move operations to TA-16.

In 1977, DOE began planning construction of the TSTA, which would be used as a facility for tests related to large-scale fusion reactors. DOE modified an existing building and began using the facility for testing and research in 1982. The TSTA, a category 2 hazard facility, contains a main testing area, two additional laboratories, a storage area, and offices for support activities and controls. Some of the storage space is used to store tritium-contaminated materials. Research

with tritium began in 1984 in a large mechanism that simulates the proposed fuel cycle for a fusion facility. These experiments require between 180 and 200 grams of tritium. In addition to research, DOE uses the TSTA for a variety of other activities. Cryogenic separation and diffusion and membrane purification are methods used to separate the components of a gaseous mixture. Gas analysis and calorimetry measure the amount and compositions of gaseous mixtures or the amount of tritium in a container, respectively. DOE also stores tritium as a gas, metal hydride, or tritium oxide at the TSTA. Gaseous wastes are vented through a single stack. DOE has several redundant systems in place to prevent tritium releases to the environment.

The TSFF is a category 2 hazard facility used as a tritium research and development center. The TSFF building was constructed in 1964 as a chemistry process building and was modified in 1974 for tritium operations related to nuclear weapons development and testing. From 1974 through 1993, the TSFF was used to synthesize tritium salt for the underground nuclear testing program. Currently, the TSFF is used for many of the same activities as the TSTA, including diffusion and membrane purification; metallurgical and material research; gas analysis; calorimetry; and tritium storage as a gas, metal hydride, or tritium oxide. The TSFF is also used for thin film loading—a process of chemically bonding a radioactive gas to a metallic surface. These activities require approximately 366 grams of tritium, mostly in a gaseous form. Gaseous wastes are vented through two stacks.

One facility, Building 146, is a category 3 hazard facility. Building 146 is a former exhaust filter building that was decommissioned and decontaminated and is currently under review for re-classification as a non-nuclear facility. Two buildings that used to house the Enriched Uranium Processing Facility are classified as non-nuclear, moderate-level chemical facilities. Operations at these buildings have ceased and the facilities are undergoing decommissioning and decontamination. Six other buildings at TA-21, including laboratories, a paint shop, a filter building, the Calcium Building, and a waste disposal plant are classified as non-nuclear, low-level radiation and/or low-level chemical facilities.

TA-50 (Waste Management Site)

TA-50 occupies approximately 62 acres of a mesa in the central portion of LANL. TA-50 is bounded by Mortandad Canyon to the north, Ten Site Canyon to the east, and Two Mile Canyon and a branch of the Pajarito Canyon to the south. TA-50 supports waste management facilities, which began operating in 1963 and are used to treat and dispose of industrial liquid and radioactive liquid wastes generated at other technical areas.

Three main facilities are used for waste management: the Radioactive Liquid Waste Treatment Facility (RLWTF); the Radioactive Materials Research, Operations, and Demonstration (RAMROD) Facility; and the Waste Characterization Reduction, and Repackaging (WCRR) Facility. The primary functions of these facilities are waste characterization, packaging, and labeling to identify proper disposal options; waste transport, receipt, and acceptance; radioactive liquid waste storage, pre-treatment, and treatment; equipment decontamination; solid waste size reduction; and solid waste processing.

The RLWTF is a category 2 hazard facility consisting of 33 structures used for treating radioactive liquid wastes; decontaminating equipment; and characterizing transuranic wastes. Transuranic wastes are wastes that are contaminated with alpha-emitting radionuclides with

atomic numbers above 92 and half-lives greater than 20 years at concentrations greater than 100 nanocuries/gram. Radioactive liquid wastes are transported to the RLWTF through an underground drainage system or in transport trucks. Liquid wastes are stored in seven concrete USTs, which have capacities ranging from 2,600 to 75,000 gallons. Liquid waste from the plutonium facility at TA-55 and acidic or caustic wastes are pre-treated before being combined and processed with wastes from other LANL facilities. Pre-treatment includes adjusting the pH, flocculating, settling, and filtering the liquid. Treatment to remove radioactive materials is done with ultrafiltration and reverse osmosis. Equipment decontamination consists of blasting or washing equipment with a solution to remove radioactive materials. After use, this solution is considered a radioactive liquid waste and is combined with radioactive liquid wastes from other technical areas for treatment. About 5 million gallons of treated effluent are released from the RLWTF to Mortandad Canyon annually. Sludge from the treatment process is drummed and shipped to TA-54 for disposal. Gaseous wastes are vented through stacks.

The RAMROD, formerly know as the Controlled Air Incinerator, was used to burn polychlorinated biphenyl (PCB)-containing and combustible hazardous wastes. This facility, classified as a category 2 hazard facility, is now used to characterize transuranic wastes.

The WCRR, a category 2 hazard facility, is used for waste size reduction. Large items contaminated with radioactive materials are cut into smaller pieces using a plasma torch. The smaller pieces are easier handle for disposal. Exterior areas of the WCRR are used to store containerized wastes.

TA-50 was also historically used for solid waste disposal. Between 1948 and 1974, an estimated 3.68 million cubic feet of chemical, radioactive, and mixed wastes were buried in pits and shafts at a 12-acre area within TA-50.

TA-51 (Environmental Research Site)

TA-51 is located on the Mesita del Buey along the eastern LANL boundary near the San Ildefonso Pueblo Lands and approximately 300 feet from Pajarito Road. The Canyon Cañada del Buey is located to the north and Pajarito Canyon is to the south. There are 17 structures within TA-51, but most of these are temporary trailers. TA-51 is being used for research and experimental studies examining the long-term impact of radioactive waste on the environment and assessing various types of waste storage and covering options.

TA-53 (Los Alamos Neutron Science Center)/(Los Alamos Meson Physics Facility)

TA-53, located in the northeastern corner of LANL, occupies 750 acres of a mesa bounded on the north by Los Alamos Canyon and on the south by Sandia Canyon. TA-53 houses the Los Alamos Meson Physics Facility (LAMPF), which includes a proton accelerator, research facilities, and support operations—approximately 400 buildings in all. The largest of these buildings is more than 0.5 mile long. There is one category 3 hazard facility (Isotope Production Facility), one non-nuclear, low-level energy source facility (Low-Level Energy Demonstration Accelerator), and 22 non-nuclear, low-level radiation facilities. Approximately 700 people work at LAMPF, but this number increases when the accelerator is active and scientists from around the world are visiting.

The 800-million electron volt proton accelerator was built in 1970 and is one of the highest powered and largest research accelerators in the world. It produces subatomic particles used in research laboratories at LANL. The particle beams are used to conduct basic and applied research associated with condensed matter science, materials science, nuclear physics, particle physics, nuclear chemistry, atomic physics, and defense-related sciences. The accelerator has also been used to produce medical radioisotopes.

Air emissions from the LAMPF accounts for 90 percent of all radioactive air emissions from LANL. There are six NPDES permitted outfalls that discharge cooling tower blowdown. Three of the outfalls discharge to Los Alamos Canyon and the other three discharge to Sandia Canyon. Liquid radioactive wastes are allowed to decay in four USTs and then discharged into lined lagoons. Before the sanitary wastewater treatment plant at LANL was constructed, sanitary wastes were discharged to two unlined lagoons, which were later found to contain traces of radioactive and hazardous wastes and were remediated under the Resource Conservation and Recovery Act (RCRA). To minimize the impacts from waste releases at TA-53, the LAMPF was sited in an isolated portion of LANL and access to the site is restricted.

TA-54 (Waste Disposal Site)

TA-54 occupies approximately 945 acres on the Mesita del Buey located along the eastern LANL boundary. This mesa is bounded by the Canyon Cañada del Buey to the north and the Pajarito Canyon to the south. The northern border of TA-54 forms the 3-mile boundary between LANL and the Ildefonso Pueblo Lands to the north. The southeastern TA-54 boundary borders the White Rock Community to the south. Almost 70 archeological sites have been identified in TA-54.

TA-54 West supports the environment, safety, and health offices; research and development buildings; and a potable water supply pumping station and chlorination facility. The Radioactive Assay and Nondestructive Test (RANT) Facility, a category 2 hazard facility, in TA-54 West is used to characterize unopened containerized waste. TA-54 East is the primary waste disposal area for radioactive, hazardous, or mixed wastes produced throughout LANL. Most of the waste is solid waste, but some liquid and gaseous waste is also handled here. Storage, disposal, and some treatment of these wastes are conducted at four waste handling and disposal areas: G, H, J, and L. DOE has determined that waste disposal has had permanent environmental impacts at TA-54.

Area G, considered a category 2 hazard facility, is principally used for disposal of solid low-level wastes and storage of transuranic wastes. Area G is also approved for PCB waste disposal. Disposal began in Area G in 1957 and continues today. Wastes have been disposed in 35 cells, 260 shafts, and 4 trenches. Five of these cells are currently active. These disposal areas encompass 37 of the 80 acres within Area G. In the past, volume reduction through compaction and other nondestructive means was conducted before disposal. DOE is currently conducting a project to retrieve approximately 17,000 buried containers of transuranic wastes to prevent future releases from these containers to the environment.

Area H occupies 0.3 acres and was used from May 1960 through August 1986 for disposal of radioactive waste. Wastes were disposed in nine shafts, each with a capacity of approximately 1,700 cubic feet. This area has been designated for remediation under RCRA.

Area J occupies 2.65 acres and has been used since 1961 for disposal of classified industrial solid wastes, such as personnel papers and classified documents. Wastes were disposed in six cells and four shafts. Three of the cells and two of the shafts are closed, the others are still open. Until October 1993, Area J also accepted materials that were previously classified as hazardous, but no longer fit the criteria for a hazardous waste. Oil-contaminated soil was disposed of in land-farms at Area J until 1992 and asbestos containing-materials used to be stored here.

Area L is a 2.65-acre paved and fenced area that was used for chemical waste disposal from the 1950s through 1986. Low-level chemical wastes were disposed in 1 pit, 3 surface impoundments, and 34 shafts. Now the area is used for receipt, storage, and shipment of Toxic Substances Control Act (TSCA), RCRA, and mixed wastes. These wastes includes gaseous, liquid, and solid hazardous wastes; PCB-containing wastes; liquid low-level radioactive mixed waste; and irradiated lead. Area L houses several storage buildings, each with a dedicated use, including the Liquid-Low-Level-Mixed-Waste-Storage Building, the Gas Cylinder Canopy, the PCB Building, the Liquid Chemical Storage Canopy, the Lab Pack Storage Units, and the Sampling Shipment and Treatment Canopies.

Acid and Pueblo Canyon

Acid Canyon is a small canyon located within the Los Alamos townsite and north of the northwestern LANL site boundary. Acid Canyon converges with the Pueblo Canyon north of LANL. Pueblo Canyon passes through the eastern portion of LANL and converges with the Los Alamos Canyon, which eventually discharges into the Rio Grande west of LANL. The Los Alamos townsite operates two county sanitary sewer treatment plants that discharge into the Pueblo Canyon. One plant is located upstream and the other plant is downstream of Acid Canyon.

In late 1943 or early 1944, the U.S. Army Manhattan Engineer District (MED) began discharging untreated radioactive liquid wastes into Acid Canyon. MED operated at LANL until 1947, when responsibility for LANL transferred to the U.S. Atomic Energy Commission (AEC). Discharge of untreated waste continued until 1951. Specific information about the types of chemicals and radioactive materials in the wastewater is unknown. Research at that time, however, included use of strontium, cesium, uranium, plutonium, americium, and tritium isotopes.

In 1951, wastewater was processed through a treatment plant built at the end of the canyon before being discharged to the canyon. The plant treated radioactive and chemical wastes by a flocculation-sedimentation-filtration process. Effluent from the plant was sampled at discharge. In 1953, DOE began discharging radioactive wastewater from laboratories at TA-3 into Acid Canyon. Only very low levels of radioactive materials were present in TA-3 wastewater. DOE, therefore, monitored this waste stream to determine if treatment was necessary to comply with the discharge criteria. As a result, about 30 percent of the TA-3 wastewater was discharged to Acid Canyon untreated. By 1953, DOE was also transporting wastewater produced in the Health Research Laboratory in TA-43 and a radiochemistry building in TA-48 to Acid Canyon for treatment and disposal.

The treatment plant at Acid Canyon continued to receive wastewater from TA-1, TA-3, TA-43, and TA-48 until July 1963. At that time, DOE redirected wastewater from TA-3 and TA-48 to a

central waste treatment plant in TA-50. TA-43 wastewater was redirected to the sanitary sewer system. From July 1963 through June 1964, Acid Canyon received wastewater only from TA-1. Discharges to Acid Canyon ceased in 1964.

DOE began decontaminating and decommissioning the treatment plant in October 1966. Solid wastes from the facility were buried at LANL in solid waste burial areas. Contaminated cliff face materials, rock, and sediment were removed from the canyon itself. By July 1967, the treatment plant site and Acid Canyon were considered free of contamination and permitted for unrestricted access. At that time, the treatment plant site and Acid Canyon were included in a land transfer from AEC to Los Alamos County. DOE, however, maintains an easement to access sampling locations and wells.

Acid Canyon is currently used for recreation, such as picnicking, trail riding, hiking, firearms practice, wood cutting, and pinon nut gathering. The canyon also includes habitat for endangered species, such as peregrine falcons. Future use of Acid Canyon is expected to be recreational with the potential for some residential and light commercial development. Seasonally, surface water and groundwater is captured in the alluvium in Acid Canyon. Sampling of surface water and ground water has found low, but measurable levels of radioactivity.

Los Alamos Canyon

Los Alamos Canyon flows along the northern LANL boundary through numerous technical areas. Pueblo Canyon converges with Los Alamos Canyon at the eastern LANL boundary. Los Alamos Canyon continues northeasterly through the San Ildefonso Pueblo Lands before converging with the Guaje Canyon. Guaje Canyon flows easterly and discharges to the Rio Grande. The Los Alamos Reservoir is located upstream of LANL and captures snow melt and rain water runoff from the mountains to the west. Water intermittently flows from the reservoir into the canyon .

From 1945 through 1952, untreated wastewater produced at TA-21 facilities was discharged from outfalls into pits located near the edge of Los Alamos Canyon. A wastewater treatment plant was built and began treating wastes from TA-21 in 1952. This plant was replaced with a newer treatment facility in 1967, which is still operating currently. Treated wastewater was discharged either to the pits along the edge of Los Alamos Canyon or directly into the canyon. Various radioactive materials and hazardous chemicals may have been released to the canyon in the wastewater.

Other LANL facilities have also used Los Alamos Canyon for effluent discharge. Three NPDES permitted outfalls discharge cooling tower blowdown water from the LAMPF at TA-53 into the canyon. The Health Research Laboratory in TA-43 discharges cooling water from lasers to Los Alamos Canyon through a single outfall. DOE is considering closing the TA-43 outfall and discharging cooling water to the sanitary sewer system. Facilities at TA-41 and the TA-2 Omega West Reactor have also occasionally released sanitary effluents and cooling water to Los Alamos Canyon.

Intermittent flow from the reservoir and effluent released from LANL are captured in the alluvium at the canyon floor. The highest water levels are recorded in the spring. Sampling of

surface water and shallow groundwater in Los Alamos Canyon has found low, but measurable levels of radioactivity.

Mortandad Canyon

Mortandad Canyon begins in the central portion of LANL at TA-3. It flows southeasterly though LANL and San Ildefonso Pueblo Lands before converging with the Canyon Cañada del Buey east of LANL and discharging to the Rio Grande.

Mortandad Canyon receives discharges from outfalls serving TA-3 and TA-50. One NPDES permitted outfall from the CMR Building in TA-3 seasonally discharges to Mortandad Canyon. Effluent flows from this outfall at a rate of approximately 1 gallon per minute. DOE is currently scheduled to divert liquid wastes from the CMR Building to TA-50 as part of the LANL waste stream reduction plans. The RLWTF in TA-50 also discharges wastes to Mortandad Canyon. Approximately 5 million gallons of treated liquid wastes is discharged to Mortandad Canyon annually. Wastes from TA-50 are treated to remove radioactive materials before discharge.

DOE began hydrogeologic studies of Mortandad Canyon in the 1960s. The regional aquifer underlying Mortandad Canyon was found approximately 950 feet below a perched groundwater zone at the surface. Sampling of surface water and shallow groundwater in the perched zone has found low but measurable amounts of radioactivity. Since these studies began, no surface water has flowed in this canyon beyond LANL boundaries.

Canyon Cañada del Buey

Canyon Cañada del Buey is located along LANL's eastern boundary with San Ildefonso Pueblo Lands to the north and TA-54 to the south. Canyon Cañada del Buey passes through the White Rock Community to the south and converges with Mortandad Canyon immediately west of the Rio Grande.

Terminology

Non-Nuclear Facility Hazard Categories

Low-level Radiation. The facility uses or stores radioactive materials, but does not meet the criteria for a nuclear category 3 hazard. Releases would present minor impacts to on-site areas and negligible impacts to off-site areas.

Low-level Chemical. The facility stores, processes, or handles nonradioactive materials, such as chemicals or biohazards. Releases would present minor impacts to on-site areas and negligible impacts to off-site areas. LANL criteria for a chemical facility are based on DOE Order 6430.1A, DOE's Subcommittee on Consequence Assessment and Protective Actions, and the American Industrial Hygiene Association's emergency response planning guide.

Moderate-level Chemical. The facility stores, processes, or handles nonradioactive materials, such as chemicals or biohazards. Releases would present considerable impacts to on-site areas and minor impacts to off-site areas. LANL criteria for a chemical facility are based on DOE Order 6430.1A, DOE's Subcommittee on Consequence Assessment and Protective Actions, and the American Industrial Hygiene Association's emergency response planning guide.

Low-level Energy Source. The facility processes, handles, or stores more than 2.2 pounds (1 kilogram) of a high-explosive material; contains a laser that could cause harm beyond distances described for American National Standards Institute Class IV lasers, or; contains electrical, motion, gravity-mass, pressure, chemical, heat/fire, cold, or radiant energy sources. Releases would present minor impacts to on-site areas and negligible impacts to off-site areas.

References

LANL. 1981. Formerly utilized MED/AEC sites remedial action program, radiological survey of the site of a former radioactive liquid waste treatment plant (TA-45) and the effluent receiving areas of Acid, Pueblo, and Los Alamos Canyons, Los Alamos, New Mexico. Los Alamos, NM: Environmental Surveillance Group (H-8), Health Division of LANL prepared for DOE. May 1981. Publication No.: LA-8890-ENV.

LANL. 1990. Solid Waste Management Units report, Los Alamos National Laboratory, Revised November 1990. Los Alamos, NM. Publication No.: LAUR 90-3400.

LANL. 1990. Environmental surveillance at Los Alamos During 1989. Los Alamos, NM: Environmental Protection Group. December 1990. Publication No.: LA-12000-ENV.

LANL. 1997. Description of technical areas and facilities at Los Alamos National Laboratory. Los Alamos, NM: Site-Wide Environmental Impact Statement Project Office, Environment, Safety, and Health Division. Publication No.: LA-UR-97-4275.

DOE. 1999. Site-wide environmental impact statement for continued operation of the Los Alamos National Laboratory, Volume I-Main Report. Albuquerque, NM. Publication No.: DOE/EIS-0238.

Notes:

CMR	Chemical and Metallurgy Research
DOE	U.S. Department of Energy
LAMPF	Los Alamos Meson Physics Facility
LANL	Los Alamos National Laboratory
MED	Manhattan Engineer District
NPDES	National Pollutant Discharge Elimination System
PCB	polychlorinated biphenyl
RAMROD	Radioactive Materials Research, Operations, and Demonstration
RANT	Radioactive Assay and Nondestructive Test
RCRA	Resource Conservation and Recovery Act
RLWTF	Radioactive Liquid Waste Treatment Facility
SNM	special nuclear materials
TA	Technical Area
TSCA	Toxic Substances Control Act
TSFF	Tritium Science and Fabrication Facility
TSTA	Tritium Systems Test Assembly
UST	underground storage tank
WCRR	Waste Characterization Reduction, and Repackaging

Appendix E: Regional Hydrogeology

None of the three groundwater zones underlying the Los Alamos region have been fully characterized even though investigations have been ongoing for almost half a century. Los Alamos National Laboratory (LANL) is currently implementing their Hydrogeologic Workplan. This plan proposes the addition of new wells to further study the full nature of the groundwater in the region. While many of these wells have already been drilled, the workplan is not expected to be complete until 2005 (LANL 2001). This appendix summarized what is currently understood regarding the groundwater.

Hydrogeology

LANL was built on the Pajarito Plateau which ranges from 8 to 16 miles (mi) wide and 30 to 40 mi long. The plateau is located between the Jemez Mountains and the Rio Grande and is divided by a number of east-west running canyons which ultimately empty into the Rio Grande. The plateau is made up primarily of Bandelier Tuff, a rock type formed by the cooling of ash and lava from volcanic eruptions that occurred 1.2 to 1.6 million years ago. This layer of volcanic rock is thickest (more than 1,000 feet [ft]) near the volcanic source to the west of the plateau and thins out to 260 ft thick toward the Rio Grande in the east. The Bandelier Tuff layer is underlain by a layer of sediments washed down from the Jemez mountains and a layer of basalts (another type of volcanic rock) which sit atop a sedimentary group greater than 3,300 ft in thickness.

The Rio Grande is adjacent to the site and flows along the Rio Grande Rift. The rift began forming about 29 million years ago and consists of four north-south tending, low-lying basins created when forces pulled apart a zone of weakness in the earth's crust. Over time the basins were filled with sediment that had been eroded from the surrounding mountains and lava from accompanying volcanic activity, creating the rock layers we see today. The rift runs from central Colorado to northern Mexico and is slowly widening, causing minor but frequent seismic movements. Near LANL, the rift is about 35 mi wide (DOE 1999).

There are three groundwater zones beneath LANL: a shallow groundwater zone found in alluvial sediments in the canyons, intermediate perched groundwater, an unsaturated zone, and the regional aquifer.

Alluvium

The canyons in the area are lined with river or alluvial sediments that were deposited by stream flow and range from 1 to 100 ft thick. The alluvium is more permeable than the underlying volcanic rocks and, as a result, shallow bodies of perched groundwater found in these sediments flow through the canyons. The amount of groundwater present in the alluvial sediments depends upon effluent release, storm water runoff, precipitation, evapo-transpiration, and seepage into the volcanic rocks beneath. Perennially saturated alluvium has only been found in Mortandad, Los Alamos, Pueblo, and Pajarito Canyons and in Cañada del Buey (DOE 1999). This water has been characterized using shallow observation wells located in areas most likely to be impacted by outfall from LANL.

Intermediate Perched Groundwater Zone

Perched groundwater is found at a deeper levels in the basalts and conglomerates ranging from 90 to 450 ft deep beneath Pueblo, Los Alamos, and Sandia Canyon. This layer interacts with the

overlying alluvial groundwater and discharges at Basalt Spring in Los Alamos Canyon. Perched groundwater has also been found in the Jemez mountains and on the western portion of the Pajarito Plateau (DOE 1999). In 1998, one other perched water body was confirmed about 750 ft below the surface of the mesa top at TA-16 in the southwestern portion of the laboratory. Continued work is being conducted to further characterize this perched groundwater zone (LANL 2001).

Vadose Zone

The vadose zone is a layer of lower impermeability tuff and volcanic sediments located between the intermediate perched groundwater above and the regional aquifer below. The vadose zone has been studied by United States Geological Survey (USGS) since 1949 when they first began to investigate the possibility of water trickling from the overlying intermediate perched groundwater, through this layer, to recharge the underlying regional aquifer. The moisture content of this 350 to 620 feet thick layer has been determined to be less than 10 percent thereby making it difficult for water above to recharge the regional aquifer.

Regional Aquifer

The top of the regional aquifer is between 600 and 1,200 ft below the ground surface (bgs) and is separated from other groundwater by the low moisture vadose zone. As a result, minimal recharge is expected from above, however the primary source of recharge has not been identified. The recharge for the aquifer is thought to be either the Sangre de Cristo Mountains to the east or from the north via the Rio Grande Rift (DOE 1999). Groundwater in the regional aquifer east of the Rio Grande generally flows westward toward the river while groundwater in the west flows to the southeast also toward the river. The water converges near the river and flows southwest. The regional aquifer discharges into the White Rock Canyon of the Rio Grande at an estimated rate of 1,400 to 1,800 gallons (5.3 to 6.8 million cubic meters) per year (LANL 1998). The Hydrogeologic Workplan proposes the addition of new wells in order to further understand the movement of water in the regional aquifer. While deeper groundwater has not been characterized, shallow water in the regional aquifer cannot cross the Rio Grande. (DOE 1999). The 27 springs discharging into White Rock canyon from the regional aquifer add an estimated 45 to 52 gallons per second of water into the river (DOE 1999).

References

US Department of Energy (DOE). 1999. Site-wide environmental impact statement for continued operation of the Los Alamos National Laboratory, Volume I-Main Report. Albuquerque, NM. Publication No.: DOE/EIS – 0238

LANL. 2001. Environmental surveillance at Los Alamos During 2000. LA-13861-ENV. Issued October 2001.

Notes:

bgs	below ground surface
ft	feet
LANL	Los Alamos National Laboratory
mi	mile
USGS	United States Geological Survey

Appendix F: ATSDR Glossary of Environmental Health Terms

The Agency for Toxic Substances and Disease Registry (ATSDR) is a federal public health agency with headquarters in Atlanta, Georgia, and 10 regional offices in the United States. ATSDR's mission is to serve the public by using the best science, taking responsive public health actions, and providing trusted health information to prevent harmful exposures and diseases related to toxic substances. ATSDR is not a regulatory agency, unlike the U.S. Environmental Protection Agency (EPA), which is the federal agency that develops and enforces environmental laws to protect the environment and human health.
This glossary defines words used by ATSDR in communications with the public. It is not a complete dictionary of environmental health terms. If you have questions or comments, call ATSDR's toll-free telephone number, 1-888-42-ATSDR (1-888-422-8737).

Absorption
The process of taking in. For a person or animal, absorption is the process of a substance getting into the body through the eyes, skin, stomach, intestines, or lungs.

Acute
Occurring over a short time [compare with **chronic**].

Acute exposure
Contact with a substance that occurs once or for only a short time (up to 14 days) [compare with **intermediate duration exposure** and **chronic exposure**].

Adverse health effect
A change in body function or cell structure that might lead to disease or health problems.

Ambient
Surrounding (for example, *ambient* air).

Analyte
A substance measured in the laboratory. A chemical for which a sample (such as water, air, or blood) is tested in a laboratory. For example, if the analyte is mercury, the laboratory test will determine the amount of mercury in the sample.

Analytic epidemiologic study
A study that evaluates the association between exposure to hazardous substances and disease by testing scientific hypotheses.

Background level
An average or expected amount of a substance or radioactive material in a specific environment, or typical amounts of substances that occur naturally in an environment.

Biota
Plants and animals in an environment. Some of these plants and animals might be sources of food, clothing, or medicines for people.

Cancer
Any one of a group of diseases that occurs when cells in the body become abnormal and grow or multiply out of control.

Cancer risk
A theoretical risk of for getting cancer if exposed to a substance every day for 70 years (a lifetime exposure). The true risk might be lower.

Carcinogen
A substance that causes cancer.

CERCLA [see **Comprehensive Environmental Response, Compensation, and Liability Act of 1980**]

Chronic
Occurring over a long time (more than 1 year) [compare with **acute**].

Chronic exposure
Contact with a substance that occurs over a long time (more than 1 year) [compare with **acute exposure** and **intermediate duration exposure**].

Comparison value (CV)
Calculated concentration of a substance in air, water, food, or soil that is unlikely to cause harmful (adverse) health effects in exposed people. The CV is used as a screening level during the public health assessment process. Substances found in amounts greater than their CVs might be selected for further evaluation in the public health assessment process.

Completed exposure pathway [see **exposure pathway**].

Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA)
CERCLA, also known as **Superfund**, is the federal law that concerns the removal or cleanup of hazardous substances in the environment and at hazardous waste sites. ATSDR, which was created by CERCLA, is responsible for assessing health issues and supporting public health activities related to hazardous waste sites or other environmental releases of hazardous substances.

Concentration
The amount of a substance present in a certain amount of soil, water, air, food, blood, hair, urine, breath, or any other media.

Contaminant
A substance that is either present in an environment where it does not belong or is present at levels that might cause harmful (adverse) health effects.

Dermal
Referring to the skin. For example, dermal absorption means passing through the skin.

Dermal contact
Contact with (touching) the skin [see **route of exposure**].

Detection limit
The lowest concentration of a chemical that can reliably be distinguished from a zero concentration.

Disease registry
A system of ongoing registration of all cases of a particular disease or health condition in a defined population.

DOD
United States Department of Defense.

DOE
United States Department of Energy.

Dose (for chemicals that are not radioactive)
The amount of a substance to which a person is exposed over some time period. Dose is a measurement of exposure. Dose is often expressed as milligram (amount) per kilogram (a measure of body weight) per day (a measure of time) when people eat or drink contaminated water, food, or soil. In general, the greater the dose, the greater the likelihood of an effect. An "exposure dose" is how much of a substance is encountered in the environment. An "absorbed dose" is the amount of a substance that actually got into the body through the eyes, skin, stomach, intestines, or lungs.

Dose (for radioactive chemicals)
The radiation dose is the amount of energy from radiation that is actually absorbed by the body. This is not the same as measurements of the amount of radiation in the environment.

Dose-response relationship
The relationship between the amount of exposure [**dose**] to a substance and the resulting changes in body function or health (response).

Environmental media
Soil, water, air, **biota** (plants and animals), or any other parts of the environment that can contain contaminants.

Environmental media and transport mechanism
Environmental media include water, air, soil, and **biota** (plants and animals). Transport mechanisms move contaminants from the source to points where human exposure can occur. The **environmental media and transport mechanism** is the second part of an **exposure pathway**.

EPA
United States Environmental Protection Agency.

Epidemiology
The study of the distribution and determinants of disease or health status in a population; the study of the occurrence and causes of health effects in humans.

Exposure
Contact with a substance by swallowing, breathing, or touching the skin or eyes. Exposure may be short-term [**acute exposure**], of intermediate duration, or long-term [**chronic exposure**].

Exposure assessment
The process of finding out how people come into contact with a hazardous substance, how often and for how long they are in contact with the substance, and how much of the substance they are in contact with.

Exposure pathway
The route a substance takes from its source (where it began) to its end point (where it ends), and how people can come into contact with (or get exposed to) it. An exposure pathway has five parts: a **source of contamination** (such as an abandoned business); an **environmental media and transport mechanism** (such as movement through groundwater); a **point of exposure** (such as a private well); a **route of exposure** (eating, drinking, breathing, or touching), and a **receptor population** (people potentially or actually exposed). When all five parts are present, the exposure pathway is termed a **completed exposure pathway**.

Groundwater
Water beneath the earth's surface in the spaces between soil particles and between rock surfaces [compare with **surface water**].

Half-life ($t_{½}$)
The time it takes for half the original amount of a substance to disappear. In the environment, the half-life is the time it takes for half the original amount of a substance to disappear when it is changed to another chemical by bacteria, fungi, sunlight, or other chemical processes. In the human body, the half-life is the time it takes for half the original amount of the substance to disappear, either by being changed to another substance or by leaving the body. In the case of radioactive material, the half life is the amount of time necessary for one half the initial number of radioactive atoms to change or transform into another atom (that is normally not radioactive). After two half lives, 25% of the original number of radioactive atoms remain.

Hazard
A source of potential harm from past, current, or future exposures.

Hazardous waste
Potentially harmful substances that have been released or discarded into the environment.

Health consultation
A review of available information or collection of new data to respond to a specific health question or request for information about a potential environmental hazard. Health consultations are focused on a specific exposure issue. Health consultations are therefore more limited than a

public health assessment, which reviews the exposure potential of each pathway and chemical [compare with **public health assessment**].

Health education
Programs designed with a community to help it know about health risks and how to reduce these risks.

Indeterminate public health hazard
The category used in ATSDR's public health assessment documents when a professional judgment about the level of health hazard cannot be made because information critical to such a decision is lacking.

Incidence
The number of new cases of disease in a defined population over a specific time period [contrast with **prevalence**].

Ingestion
The act of swallowing something through eating, drinking, or mouthing objects. A hazardous substance can enter the body this way [see **route of exposure**].

Inhalation
The act of breathing. A hazardous substance can enter the body this way [see **route of exposure**].

Intermediate duration exposure
Contact with a substance that occurs for more than 14 days and less than a year [compare with **acute exposure** and **chronic exposure**].

Lowest-observed-adverse-effect level (LOAEL)
The lowest tested dose of a substance that has been reported to cause harmful (adverse) health effects in people or animals.

mg/kg
Milligram per kilogram.

mg/m^3
Milligram per cubic meter; a measure of the concentration of a chemical in a known volume (a cubic meter) of air, soil, or water.

Migration
Moving from one location to another.

Minimal risk level (MRL)
An ATSDR estimate of daily human exposure to a hazardous substance at or below which that substance is unlikely to pose a measurable risk of harmful (adverse), non-cancerous effects. MRLs are calculated for a route of exposure (inhalation or oral) over a specified time period

(acute, intermediate, or chronic). MRLs should not be used as predictors of harmful (adverse) health effects [see **reference dose**].

National Priorities List for Uncontrolled Hazardous Waste Sites (National Priorities List or NPL)
EPA's list of the most serious uncontrolled or abandoned hazardous waste sites in the United States. The NPL is updated on a regular basis.

No apparent public health hazard
A category used in ATSDR's public health assessments for sites where human exposure to contaminated media might be occurring, might have occurred in the past, or might occur in the future, but where the exposure is not expected to cause any harmful health effects.

No-observed-adverse-effect level (NOAEL)
The highest tested dose of a substance that has been reported to have no harmful (adverse) health effects on people or animals.

No public health hazard
A category used in ATSDR's public health assessment documents for sites where people have never and will never come into contact with harmful amounts of site-related substances.
NPL [see **National Priorities List for Uncontrolled Hazardous Waste Sites]**

Point of exposure
The place where someone can come into contact with a substance present in the environment [see **exposure pathway**].

Population
A group or number of people living within a specified area or sharing similar characteristics (such as occupation or age).

Potentially responsible party (PRP)
A company, government, or person legally responsible for cleaning up the pollution at a hazardous waste site under Superfund. There may be more than one PRP for a particular site.

ppb
Parts per billion.

ppm
Parts per million.

Prevention
Actions that reduce exposure or other risks, keep people from getting sick, or keep disease from getting worse.

Public health action
A list of steps to protect public health.

Public health advisory
A statement made by ATSDR to EPA or a state regulatory agency that a release of hazardous substances poses an immediate threat to human health. The advisory includes recommended measures to reduce exposure and reduce the threat to human health.

Public health assessment (PHA)
An ATSDR document that examines hazardous substances, health outcomes, and community concerns at a hazardous waste site to determine whether people could be harmed from coming into contact with those substances. The PHA also lists actions that need to be taken to protect public health [compare with **health consultation**].

Public health hazard
A category used in ATSDR's public health assessments for sites that pose a public health hazard because of long-term exposures (greater than 1 year) to sufficiently high levels of hazardous substances or **radionuclides** that could result in harmful health effects.

Public health hazard categories
Public health hazard categories are statements about whether people could be harmed by conditions present at the site in the past, present, or future. One or more hazard categories might be appropriate for each site. The five public health hazard categories are **no public health hazard, no apparent public health hazard, indeterminate public health hazard, public health hazard**, and **urgent public health hazard**.

Radioisotope
An unstable or radioactive isotope (form) of an element that can change into another element by giving off radiation.

Radionuclide
Any radioactive isotope (form) of any element.

RCRA [See **Resource Conservation and Recovery Act (1976, 1984)**]

Receptor population
People who could come into contact with hazardous substances [see **exposure pathway**].

Reference dose (RfD)
An EPA estimate, with uncertainty or safety factors built in, of the daily lifetime dose of a substance that is unlikely to cause harm in humans.

Registry
A systematic collection of information on persons exposed to a specific substance or having specific diseases [see **exposure registry** and **disease registry**].

Resource Conservation and Recovery Act (1976, 1984) (RCRA)
This Act regulates management and disposal of hazardous wastes currently generated, treated, stored, disposed of, or distributed.

RfD
See **reference dose**.

Risk
The probability that something will cause injury or harm.

Risk communication
The exchange of information to increase understanding of health risks.

Route of exposure
The way people come into contact with a hazardous substance. Three routes of exposure are breathing [**inhalation**], eating or drinking [**ingestion**], or contact with the skin [**dermal contact**].

Safety factor [see **uncertainty factor**]

SARA [see **Superfund Amendments and Reauthorization Act**]

Sample
A portion or piece of a whole. A selected subset of a population or subset of whatever is being studied. For example, in a study of people the sample is a number of people chosen from a larger population [see **population**]. An environmental sample (for example, a small amount of soil or water) might be collected to measure contamination in the environment at a specific location.

Solvent
A liquid capable of dissolving or dispersing another substance (for example, acetone or mineral spirits).

Source of contamination
The place where a hazardous substance comes from, such as a landfill, waste pond, incinerator, storage tank, or drum. A source of contamination is the first part of an **exposure pathway**.

Special populations
People who might be more sensitive or susceptible to exposure to hazardous substances because of factors such as age, occupation, sex, or behaviors (for example, cigarette smoking). Children, pregnant women, and older people are often considered special populations.

Statistics
A branch of mathematics that deals with collecting, reviewing, summarizing, and interpreting data or information. Statistics are used to determine whether differences between study groups are meaningful.

Substance
A chemical.

Superfund Amendments and Reauthorization Act (SARA)
In 1986, SARA amended CERCLA and expanded the health-related responsibilities of ATSDR. CERCLA and SARA direct ATSDR to look into the health effects from substance exposures at

hazardous waste sites and to perform activities including health education, health studies, surveillance, health consultations, and toxicological profiles.

Surface water
Water on the surface of the earth, such as in lakes, rivers, streams, ponds, and springs [compare with **groundwater**].

Survey
A systematic collection of information or data. A survey can be conducted to collect information from a group of people or from the environment. Surveys of a group of people can be conducted by telephone, by mail, or in person. Some surveys are done by interviewing a group of people [see **prevalence survey**].

Toxicological profile
An ATSDR document that examines, summarizes, and interprets information about a hazardous substance to determine harmful levels of exposure and associated health effects. A toxicological profile also identifies significant gaps in knowledge on the substance and describes areas where further research is needed.

Toxicology
The study of the harmful effects of substances on humans or animals.

Tumor
An abnormal mass of tissue that results from excessive cell division that is uncontrolled and progressive. Tumors perform no useful body function. Tumors can be either benign (not cancer) or malignant (cancer).

Uncertainty factor
Mathematical adjustments for reasons of safety when knowledge is incomplete. For example, factors used in the calculation of doses that are not harmful (adverse) to people. These factors are applied to the lowest-observed-adverse-effect-level (LOAEL) or the no-observed-adverse-effect-level (NOAEL) to derive a minimal risk level (MRL). Uncertainty factors are used to account for variations in people's sensitivity, for differences between animals and humans, and for differences between a LOAEL and a NOAEL. Scientists use uncertainty factors when they have some, but not all, the information from animal or human studies to decide whether an exposure will cause harm to people [also sometimes called a **safety factor**].

Urgent public health hazard
A category used in ATSDR's public health assessments for sites where short-term exposures (less than 1 year) to hazardous substances or conditions could result in harmful health effects that require rapid intervention.

Volatile organic compounds (VOCs)
Organic compounds that evaporate readily into the air. VOCs include substances such as benzene, toluene, methylene chloride, and methyl chloroform.

Other glossaries and dictionaries:

Environmental Protection Agency. Available at:
http://www.epa.gov/OCEPAterms/. Last accessed July 22, 2003.

National Center for Environmental Health (CDC) Available at:
http://www.cdc.gov/nceh/dls/report/glossary.htm. Last accessed July 22, 2003.

National Library of Medicine. Available at:
http://www.nlm.nih.gov/medlineplus/mplusdictionary.html. Last accessed July 22, 2003.

Appendix G: Comparison Values

Agency for Toxic Substances and Disease Registry (ATSDR) health assessors use comparison values (CVs) as screening tools to evaluate environmental data relevant to each exposure pathway. CVs represent media-specific contaminant concentrations that are much lower than exposure concentrations observed to cause adverse health effects. In that way, CVs are protective of public health in essentially all exposure situations. If the concentrations in the exposure medium are less than the CV, the exposures are not of health concern and no further analysis of the pathway is required. Although concentrations below the CV are not expected to lead to any observable health effects, it should not be inferred that a concentration greater than the CV will necessarily lead to adverse effects. Depending on site-specific environmental exposure factors (for example, duration of exposure) and activities of people that result in exposure (time spent in area of contamination), exposure to levels above the CV may or may not lead to a health effect. Therefore, ATSDR's CVs are not used to predict the occurrence of adverse health effects. Rather, they are used by ATSDR to select contaminants for further evaluation to determine the possibility of adverse health effects.

CVs used in this PHA include:

Cancer Risk Evaluation Guide (CREG)

Estimated contaminant concentrations that would be expected to cause no more than one excess cancer in a million (10^{-6}) persons exposed over a 70-year life span. ATSDR's CREGs are calculated from the U.S. Environmental Protection Agency's (EPA) cancer slope factors (CSFs).

Environmental Media Evaluation Guide (EMEG)

EMEGs are based on ATSDR minimal risk levels (MRLs) and consider body weight and ingestion rates. An EMEG is an estimate of daily human exposure to a chemical (in milligrams chemical/kilograms body weight/day [mg/kg/day]) that is likely to be without non-carcinogenic health effects over a specified duration of exposure, including acute, intermediate, and chronic exposures.

Reference Dose Media Evaluation Guides (RMEG)

ATSDR derives RMEGs from EPA's oral reference doses (RfDs). The RMEG represents the concentration in water or soil at which daily human exposure is unlikely to result in adverse non-carcinogenic effects.

EPA Maximum Contaminant Level (MCL)

MCLs are enforceable drinking water standard established by the EPA. They are the maximum permissible level of a contaminant in water that is delivered to a free-flowing outlet. MCLs are considered protective of human health over a lifetime (70 years) for individuals consuming 2 liters of water per day.

Lifetime Health Advisory for Drinking Water (LTHA)

The LTHA is a lifetime exposure level developed by EPA specifically for drinking water. The LTHA is the level at which adverse, non-carcinogenic health effects would not be expected to occur.

EPA Region III Risk-Based Concentration (RBC)

EPA Region III combines RfDs and CSF with "standard" exposure scenarios (e.g. ingestion of 2 liters of water per day, over a 70-year life span) to calculate RBCs, which are chemical concentrations corresponding to fixed levels of risk (i.e., a hazard quotient of 1, or lifetime cancer risk of 10^{-6}, whichever occurs at a lower concentration) in water, air, fish tissue, and soil.

CVs are derived from available health guidelines, such as ATSDR's MRLs and EPA's RfDs, and EPA's CSFs. These guidelines are based on the no-observed-adverse-effect levels (NOAEL), lowest-observed-adverse-effect-levels (LOAELs), or the cancer effect levels (CELs) reported for a contaminant in the toxicologic literature. A description of these terms is provided:

Minimal Risk Levels (MRL)

MRLs are estimates of daily human exposure to a chemical (i.e., doses expressed in mg/kg/day) that are unlikely to be associated with any appreciable risk of deleterious non-cancer effects over a specified duration of exposure. MRLs are calculated using data from human and animal studies and are reported for acute (≤14 days), intermediate (15–364 days), and chronic (≥365 days) exposures.

Reference Dose (RfD)

The RfD is an estimate, with safety factors built in, of the daily, life-time exposure of human populations to a possible hazard that is not likely to cause harm to the person.

Cancer Slope Factor (CSF)

Usually derived from dose-response models and expressed in mg/kg/day, CSFs describe the inherent potency of carcinogens and estimate an upper limit on the likelihood that lifetime exposure to a particular chemical could lead to excess cancer deaths.

Lowest-Observed-Adverse-Effect Level (LOAEL)

The LOAEL is the lowest dose of a chemical that was found to produce an adverse effect following human exposure or when it was administered to animals in a toxicity study.

No-Observed-Adverse-Effect Level (NOAEL)

The NOAEL is the highest dose of a chemical in a study, or group of studies, that did not cause harmful health effects in people or animals.

Cancer Effect Level (CEL)

The CEL is the lowest dose of a chemical in a study, or group of studies, that was found to produce increased incidences of cancer (or tumors).

For radioactive contaminants, ATSDR uses information on radiation exposure and its effects, as related to environmental levels. This information comes from federal agencies, including EPA, the U.S. Department of Energy (DOE), and the Nuclear Regulatory Commission (NRC). ATSDR also uses other publicly available data sources and recommendations on radiation dose limits. The National Council on Radiation Protection and Measurements (NCRP), the International Commission on Radiological Protection (ICRP), and the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) develop these sources.

The CVs used for radioactive contaminants in this PHA are:

National Council on Radiation Protection and Measurements, Publication No. 129 (NCRP No. 129)

The National Council on Radiation Protection and Measurements has recommended screening limits for contaminated surface soil based on the contaminant's contribution to a maximum annual effective dose to an individual of less than 25 millirem/year from a single set of sources (one site). The maximum effective yearly dose was recommended in NCRP Report No. 116 (1993).

Code of Federal Regulations Title 10, Part 20 (10CFR20)

The Nuclear Regulatory Commission (NRC) has established standards as part of Title 10, Chapter 1, of the *Code of Federal Regulations (CFR)* that all facilities receiving a permit from NRC must follow. Part 20 of these regulations (10CFR20) establishes limits for the protection against radiation. The limits for effluent outlined in Appendix B of Part 20 are equivalent to the radionuclide concentrations that would produce a total effective dose equivalent of 50 millirem/year if continuously inhaled or ingested for a year.

Notes:

ATSDR	Agency for Toxic Substances and Disease Registry
CEL	Cancer effects level
CREG	ATSDR Cancer Risk Evaluation Guide
CSF	Cancer Slope Factor
CV	Comparison value
EMEG	ATSDR Environmental Media Evaluation Guide
EPA	U.S. Environmental Protection Agency
LOAEL	Lowest-observable-adverse-effects level
LTHA	EPA Lifetime Health Advisory for Drinking Water
MCL	EPA Maximum Contaminant Level
MRL	ATSDR Minimal Risk Level
NOAEL	No-observable-adverse-effects level
NRC	Nuclear Regulatory Commission
RBC	Risk-based Concentration
RfD	EPA Reference Dose
RMEG	ATSDR Reference Dose Media Evaluation Guide
10CFR20	Code of Federal Regulations Title 10, Part 20 (10CFR20)
mg/kg/day	milligrams chemical/kilograms body weight/day
NCRP No. 129	National Council on Radiation Protection and Measurements, Publication No. 129

Appendix H: Estimates of Human Exposure Doses and Determination of Health Effects

Deriving Exposures Doses H–2
Estimating Exposure Doses from Ingesting Groundwater as Drinking Water H–3
Non-cancer Effects H–3
Cancer Effects H–11
Radiation Effects H–12
Estimated Exposure Doses for Incidental Ingestion of Surface Soil H–12
Non-cancer and Cancer Effects H–13
Radiation Effects H–13
Estimated Exposure Doses for Incidental Ingestion of Surface Water and Sediment H–14
Non-cancer Effects H–14
Cancer Effects H–18
Radiation Effects H–20
Estimated Exposure Doses for Consumption of Locally Grown Food H–21
Non-cancer Effects H–21
Cancer Effects H–28
Radiation Effects H–30
Multiple Pathway Exposures H–30
Non-cancer and Cancer Effects H–31
Radiation Effects H–32
References H–33

Deriving Exposures Doses

After identifying contaminants in site media above comparison values (CVs) and identifying potential pathways of exposure, the Agency for Toxic Substances and Disease Registry (ATSDR) further evaluates exposures to these contaminants considering information about exposures and scientific information from the toxicological and epidemiological literature. If necessary, ATSDR estimates exposure doses, which are estimates of how much of a contaminant a person is exposed to on a daily basis. Variables considered when estimating exposure doses include the contaminant concentration, the exposure amount (how much), the exposure frequency (how often), and the exposure duration (how long). The following equation is used to estimate exposures. The parameters applied to this equation (Table H-1) vary for each exposure pathway.

$$\textit{Estimated exposure dose} = \frac{C \times IR \times EF \times ED}{BW \times AT}$$

where:

C Maximum concentration in the media of concern (e.g., groundwater or surface soil)
IR Intake rate (how much of a media is ingested or contacted)
EF Exposure frequency or number of exposure events per year (how often exposure occurs)
ED Exposure duration or the duration over which exposure occurs (how long exposure occurs)
BW Body weight
AT Averaging time or the period over which cumulative exposures are averaged

The estimated exposure doses can be used to evaluate potential non-cancer and cancer effects associated with contaminants detected in site media. When evaluating *non-cancer* effects, ATSDR compares the estimated exposure dose to standard toxicity values, including ATSDR's minimal risk levels (MRLs) and the U.S. Environmental Protection Agency's (EPA) reference doses (RfDs), to evaluate whether adverse effects may occur. The chronic MRLs and RfDs are estimates of daily human exposure to a substance that is likely to be without appreciable risk of adverse non-cancer effects over a specified duration. The chronic MRLs and RfDs are conservative values, based on the levels of exposure reported in the literature that represent no-observed-adverse-effects levels (NOAELs) or lowest-observed-adverse-effects levels (LOAELs) for the most sensitive outcome for a given route of exposure (e.g., ingestion). Uncertainty (safety) factors are applied to NOAELs or LOAELs to account for variation in the human population and uncertainty involved in extrapolating human health effects from animal studies. ATSDR also reviews the toxicological literature and epidemiology studies to further evaluate the potential for adverse effects.

ATSDR also evaluates the likelihood that site-related contaminants could cause *cancer* in people who would not otherwise develop it. As an initial screen, ATSDR calculates a theoretical increase of cancer cases in a population over a lifetime of exposure using EPA's cancer slope factors (CSFs), which represent the relative potency of carcinogens. This is accomplished by multiplying the calculated exposure dose by a chemical-specific CSF. CSFs are developed using data from studies of animals or humans exposed to doses. Because they are derived using

mathematical models that apply a number of uncertainties and conservative assumptions, estimates generated by using CSFs tend to be overestimated. Although no risk of cancer is considered acceptable, achieving a zero cancer risk is impossible. Consequently, ATSDR often uses a range of 10^{-4} to 10^{-6} estimated lifetime cancer risk (1 new case in 10,000 to 1,000,000 exposed persons), based on conservative assumptions about exposure, to determine the likelihood of excess cancer resulting from this exposure.

ATSDR also compares an estimated lifetime exposure dose to available cancer effects levels (CELs), which are doses that produce significant increases in the incidence of cancer or tumors, and reviews genotoxicity studies to further understand the extent to which a chemical might be associated with cancer outcomes. This process enables ATSDR to weigh the available evidence in light of uncertainties and offer perspective on the plausibility of harmful health outcomes under site-specific conditions.

Estimating Exposure Doses from Ingesting Groundwater as Drinking Water

Regular monitoring conducted from1980 through 2001 detected fluoride, sodium, perchlorate, 10 metals, and gross alpha at maximum concentrations greater than ATSDR CVs for drinking water. The primary exposure pathway of concern is through ingestion of groundwater from the community and Los Alamos National Laboratory (LANL) water supplies. Skin contact and inhalation are also potential pathways of concern for gross alpha. These pathways, however, are typically responsible for only a small portion of the overall exposure. Fluoride, sodium, perchlorate, and metals are not readily absorbed through the skin or volatilized to indoor air. As such, exposure via skin contact and inhalation are expected to be minimal and not of health concern. ATSDR's evaluation focused on exposures via ingestion of contaminated drinking water.

In estimating to what extent people might be exposed to contaminants, ATSDR used protective assumptions about how long people were exposed to contaminants and how much contaminated water they ingested each day. Although this Public Health Assessment (PHA) focuses on environmental data from 1980 to 2001, exposures may have begun before 1980. As such, ATSDR made conservative assumptions about how long and how often exposures occurred, as well as how much of a contaminant was ingested. For drinking water supplies, these assumptions included assuming that people would drink water containing the maximum detected contaminant concentration found in a single supply well. Prior to distribution, however, water from multiple wells is blended, which results in a lower exposure concentration than assumed by ATSDR. ATSDR estimated doses for adults/lifetime residents and children. The exposure parameters are listed in Table H-1. Using conservative assumptions creates a protective estimate of exposure and allows ATSDR to safely evaluate the likelihood, if any, that contaminants in the community and LANL water supply could cause harm to its users. Table H-2 summarizes the estimated exposure doses from ingesting contaminants in the community and LANL water supplies.

Non-cancer Effects

As an initial screen, ATSDR compared the estimated doses to the MRL or RfD for each contaminant. Doses estimated for adults/lifetime residents and children exceeded the MRL, RfD, or other health value for fluoride, perchlorate, arsenic, boron, cadmium, iron, thallium, and vanadium. The estimated dose for a child exposed to cadmium, chromium, copper, and silver also exceeded the MRL or RfD. No MRLs or RfDs are available for sodium or lead. ATSDR

then reviewed the scientific literature for contaminants exceeding their MRL or RfD to further evaluate the potential for non-cancer health effects associated with ingestion of drinking water from community and LANL supplies. Much of the toxicological and health effects information reviewed by ATSDR came from experimental animal studies or from epidemiological investigations of persons exposed in the workplace (human data). Less information is available that directly examines the relationship between exposure via drinking water and human health effects.

Fluoride

Fluoride is a naturally occurring element found in water as part of fluoride compounds. Sodium fluoride has been intentionally added to drinking water supplies, toothpastes, and mouth rinses because of its ability to strengthen teeth and prevent cavities. The practice of fluoridating drinking water is a major factor in the widespread decline in tooth decay. Drinking water supplies and dental products are typically supplemented with fluoride to a concentration of approximately 1 ppm. Fluoride in drinking water typically ranges from 0.02 to 1.5 ppm, but can exceed 1.5 ppm in parts of the southwest United States (ATSDR 2001a).

Although a little fluoride is beneficial, too much fluoride can affect human health. Much of the fluoride taken into the body is excreted in urine, but some will remain stored in the bones and teeth. To capitalize on the beneficial properties of fluoride, women with osteoporosis were given 0.56 mg/kg/day of fluoride for treatment. At this dose level, an increase in bone fractures was observed. Some children (under the age of 6 years) exposed to 4 ppm of fluoride in their drinking water supplies developed brown spots or pitting on their permanent teeth. This is typically considered a cosmetic effect, but may also cause the teeth to be more fragile and develop a greater number of cavities (ATSDR 2001a).

ATSDR derived the MRL of 0.06 mg/kg/day based on the study of women with osteoporosis given 0.56 mg/kg/day of fluoride (ATSDR 2001a). EPA derived an RfD for fluoride (0.06 mg/kg/day) based on extensive epidemiological studies in children that found that concentrations in water of 1 ppm fluoride maximized the benefit for decreased tooth decay and 2 ppm resulting in minor spotting of teeth (EPA 2003a).

At the maximum detected fluoride concentration (3.3 ppm), ATSDR estimated doses of 0.1 mg/kg/day for adults/lifetime residents and 0.3 mg/kg/day for children. These doses are below levels shown to weaken bones in humans. The maximum detected concentration, however, is above levels (2 ppm) shown to cause the cosmetic effect of spotting teeth in children with chronic exposure. Concentrations of fluoride above 2 ppm were only detected in the Los Alamos well field and monitoring indicates that fluoride concentrations fluctuated from an annual maximum of 0.3 ppm to 3.3 ppm. As such, chronic exposures to levels above 2 ppm were not likely. Based on this information, ATSDR concluded that fluoride is not expected to result in adverse health effects to users of the community and LANL water supplies.

Sodium

Sodium is another naturally occurring element. Sodium is a component of table salt (sodium chloride). Most of the sodium in a person's diet comes from the food they eat; drinking water, however, is another source. For people with high blood pressure (hypertension), excessive sodium intake can aggravate their condition. Hypertension can lead to heart attack, stroke, or

organ damage. People with risk of heart attack from hypertension may follow a low-sodium diet, which restricts sodium intake to 500 mg/day, under supervision of their doctor (University of Kansas 2002). EPA developed a draft drinking water advisory of 20 ppm sodium in water to protect this population (EPA 2002b).

At LANL, the maximum detected concentration (221 ppm) exceeded the 20 ppm draft drinking water advisory. For people not suffering from hypertension, the American Heart Association recommends a daily sodium intake of no more than 2,400 mg/day (University of Kansas 2002). Drinking 2.35 liters of water containing the maximum detected sodium concentration would contribute approximately 520 mg of sodium to the diet, or less than 25% of this recommended daily intake. Monitoring data indicate that sodium concentrations in the community and LANL water supplies ranged from 3.4 ppm to the maximum of 221 ppm. As such, chronic exposure to the highest level of sodium is not expected.

ATSDR concluded that sodium found in the community and LANL water supplies would not be expected to affect human health. People following a low-sodium diet (500 mg/day), however, should speak with their doctor and carefully monitor their sodium intake.

Perchlorate

As a component of rocket fuels and propellants, perchlorate has been released to the environment as a man-made material. Perchlorate is also naturally occurring at low-levels. Monitoring for perchlorate in the Ottowi well field in 2000 detected perchlorate at maximum concentration of 0.005 ppm.

Assuming ingestion of the maximum detected concentration, ATSDR estimated an exposure dose of 0.0002 mg/kg/day for adults/lifetime residents and 0.0005 mg/kg/day for children. Perchlorate has been the subject of intense scrutiny by EPA and the scientific community because of health concerns. Perchlorate affects the thyroid by inhibiting iodine uptake and was historically used as a treatment for people suffering from Graves' disease. Toxicity data from treatment studies are considered insufficient for deriving an RfD because exposures were often chronic and patients were not representative of the general public. As such, the draft RfD (0.00003 mg/kg/day) is based on a study in pregnant rats and a number of studies conducted to extrapolate human toxicity information from rodent toxicity data. This study was considered relevant for human health, but very conservative because of differences in the thyroid structure and hormone half-lives in humans and rats. A human equivalent exposure of 0.01 mg/kg/day for hormonal effects was identified as a LOAEL. An uncertainty factor of 300 was applied to further account for differences in toxicity between species (human and rat). This LOAEL is 20 times greater than the estimated dose for children and 60 times greater than the estimated doses for adults/lifetime residents (EPA 2002a).

Because the environmental data indicate that perchlorate was found in only a fraction of the monitoring samples and the toxicological data indicate that uncertainties applied to the RfD are very conservative, ATSDR concluded that exposure to perchlorate in the community and LANL water supplies is not expected to adversely affect human health.

Arsenic

Arsenic, a ubiquitous mineral in water and soil, was detected at a maximum concentration of 0.11 ppm in community and LANL water supplies. Arsenic is present in the environment as organic arsenic or inorganic arsenic. Organic forms of arsenic are typically less toxic than inorganic forms. The liver will convert some of the inorganic arsenic to the less toxic organic form. Both forms are excreted from the body in urine within several days of exposure (ATSDR 2000a). To conduct a conservative evaluation, ATSDR assumed that all the detected arsenic was the inorganic, and more toxic, form.

Inorganic arsenic has been used as a poison for centuries. Death will occur at exposures above 60 ppm in food or water. Illness (stomach irritation, nausea, vomiting, and diarrhea) can occur when exposed to 3 to 30 ppm in food or water, which is greater than the maximum concentration detected at LANL. The ATDR MRL of 0.0003 mg/kg/day is based on an epidemiology study of people exposed to arsenic in their drinking water. The MRL is based on a NOAEL of 0.0008 mg/kg/day. The next highest dose tested (0.014 mg/kg/day) was identified as the study LOAEL (hyperpigmentation and keratosis of the skin were observed) (ATSDR 2000a).

The estimated doses at LANL exceeded the NOAEL, but were below the LOAEL (0.004 mg/kg/day for adults/lifetime residents and 0.011 mg/kg/day for children). The estimated doses were calculated assuming chronic exposure to the maximum detected arsenic concentration (0.11 ppm). Monitoring data, however, report that the next highest detected concentration was 0.052 ppm. As such actual doses would be lower than the estimated doses. In addition, community water supplies are required by law to meet the maximum contaminant levels (MCLs) for chemicals in their water supply. For arsenic, the MCL has currently been reduced from 0.05 ppm to 0.01 ppm.

Based on this information, ATSDR concluded that no adverse human health effects were expected from ingestion of arsenic in the community or LANL water supplies.

Boron

Boron was found in community and LANL water supplies at a maximum concentration of 10 ppm. Boron is a naturally occurring substance that can be found in the air, water, or soil. Usually boron occurs in combination with other substances in nature to form borates (ATSDR 1992c).

About half of the boron ingested will leave the body in urine within 24 hours. ATSDR reports that ingestion of large amounts of boron (approximately 4,100 ppm) in a short period can affect health (ATSDR 1992c). At LANL, a person would need to drink approximately 410 liters (or 100 gallons) of water containing the maximum detected boron concentration (10 ppm) in a short period to reach this exposure level.

ATSDR estimated doses of 0.3 mg/kg/day for adults/lifetime residents and 1 mg/kg/day for children consuming boron in the community and LANL water supplies. Studies of dogs, rats, and mice exposed to boron in their food or water serve as the basis for the boron RfD. EPA identified no studies in humans to support the RfD. The estimated doses for LANL are below the NOAEL (8.8 mg/kg/day) observed in a 2-year study of dogs eating boron in their food. The NOAEL was the highest dose tested in the 2-year dog study and served as the basis for the RfD. A 2-year study in rats exposed to boron in their food identified a NOAEL of 17.5 mg/kg/day and a

LOAEL of 58.5 mg/kg/day. Testicular effects, such as severe testicular atrophy and spermatogenic arrest, were observed at the LOAEL (EPA 2003a).

After review and evaluation of the scientific literature and estimated doses, ATSDR concluded that consumption of boron in community and LANL water supplies was not expected to result in adverse human health effects. The estimated doses were below levels reported in the literature to result in adverse health effects and the estimated doses were derived based on conservative assumptions designed to overestimate actual doses.

Cadmium

As an element in the environment, cadmium is typically found in cadmium compounds. Cadmium ingested in the body is excreted through the feces for the most part. Small amounts may be ingested and stored in the liver and kidney for many years during detoxification (ATSDR 1999a). At LANL, the maximum detected cadmium concentration in community and LANL water supplies was 0.017 ppm. The second highest detected level was 0.007 ppm.

Using conservative assumptions, ATSDR estimated a dose of 0.002 mg/kg/day for children ingesting the maximum cadmium levels in their drinking water. Doses for adults and lifetime residents (0.0006 mg/kg/day) were at the MRL (0.0002 mg/kg/day). The MRL is based on an epidemiology study of people living in a cadmium-contaminated area. An increased incidence of proteinuria was identified in residents with a lifetime intake of 2,000 mg of cadmium from dietary sources (NOAEL of 0.0021 mg/kg/day) (ATSDR 1999a). Estimated doses at LANL are at the NOAEL for children and below the NOAEL for adults, and lifetime residents.

Because exposure to 0.017 ppm cadmium was not continuous, all estimated doses were at or below the NOAEL, and ATSDR assumed that people drank exclusively from a well containing the maximum detected cadmium concentrations, ATSDR concluded that exposure to cadmium in the community and LANL water supplies was not expected to result in adverse health effects.

Chromium

Chromium is a naturally occurring element found in rocks, animals, plants, soil, and volcanic gases. Chromium occurs in the environment in several forms: primarily as trivalent (III) chromium or hexavalent (VI) chromium. Trivalent chromium is less toxic than hexavalent chromium. Most chromium in the environment (e.g., soil, water) and the body is trivalent chromium, the less toxic form of the chemical (ATSDR 2000b). Monitoring results for LANL report only total chromium, and do not report the speciation between trivalent and hexavalent chromium. To conduct a conservative evaluation, ATSDR assumed that all the chromium detected in the water supplies was the more toxic hexavalent chromium.

Chromium was detected to a maximum concentration of 0.039 ppm, which exceeds the CV for children (0.03 ppm), but not the CV for adults (0.18 ppm). Assuming daily exposure to the maximum detected concentration, the estimated doses for ingestion of chromium in drinking water were 0.004 mg/kg/day for children and 0.001 mg/kg/day for adults/lifetime residents. The estimated dose for children slightly exceeded the RfD of 0.003 mg/kg/day. The RfD is based on animal studies in which no observed adverse health effects were reported in rats administered chromium at 2.5 mg/kg/day in drinking water (EPA 2003a). This dose is more than 600 times higher than the estimated doses for children exposed to the maximum chromium concentration.

Relatively few human studies have been identified that address the oral toxicity of hexavalent chromium. One drinking water study suggests that gastrointestinal effects may be associated with hexavalent chromium concentrations of 20 ppm in drinking water, but the study fails to detail exact exposure concentrations, possible confounding factors, or what effects might be seen at lower levels (EPA 2003a).

Based on available information, ATSDR concluded that ingestion of chromium at detected levels in community and LANL water supplies was not expected to result in adverse human health effects.

Copper

Copper is a commonly found metal in the environment. Most people are familiar with its use to make pennies and copper plumbing pipes. Naturally occurring copper and copper pipes are sources of copper in drinking water. Once ingested, copper will leave the body in urine and feces in several days (ATSDR 2002b).

A small amount of copper is necessary and considered an essential nutrient. The recommended daily allowance is 0.013 mg/kg/day. The estimated dose for adults and lifetime residents exposed to the maximum concentration of copper in drinking water (0.313 ppm) is 0.01 mg/kg/day, and for children the dose is 0.03 mg/kg/day. ATSDR established an intermediate MRL (0.02 mg/kg/day) based on acute effects (nausea, vomiting, and diarrhea) from copper exposure. The MRL is based on a NOAEL of 0.05, which is higher than the estimated doses for adults/lifetime residents and children (ATSDR 2002b). EPA has also established an MCL (1.3 ppm) and secondary MCL (1 ppm) for copper. The MCL is based on corrosion of copper pipes and potential gastrointestinal distress from copper. The secondary MCL is based on taste and odor thresholds (EPA 2003b). The maximum detected copper concentration at LANL was below this level.

ATSDR concluded that exposure to copper in the community and LANL water supplies would not be expected to result in adverse human health effects. Doses for adults, lifetime residents, and children are below the NOAEL and the maximum detected concentration is below the primary and secondary MCLs.

Iron

Iron is an important mineral, assisting in the maintenance of basic life functions, and found naturally in the environment. Iron combines with protein and copper to make hemoglobin, which transports oxygen in the blood from the lungs to other parts of the body, including the heart. It also aids in the formation of myoglobin, which supplies oxygen to muscle tissues. Without sufficient iron, the body cannot produce enough hemoglobin or myoglobin to sustain life. Iron deficiency anemia is a condition occurring when the body does not receive enough iron (ANR 2001).

The oral health guideline for iron is based on dietary intake data collected as part of CDC's Second National Health and Nutrition Examination Survey in which no adverse health effects were associated with average iron intakes of 0.15 to 0.27 mg/kg/day. These levels were determined to be sufficient for protection against iron deficiency, but also low enough to not cause harmful health effects. No uncertainty factors or modifying factors were applied to derive

the provisional RfD of 0.3 mg/kg/day (EPA 2001). Doses for adults/lifetime residents, and children consuming water containing the maximum detected iron concentration (29.3 ppm) were 1 mg/kg/day and 3 mg/kg/day, respectively.

Although these conservatively derived doses exceed the NOAEL, iron is not generally considered to cause harmful health effects except when swallowed in extremely large doses, such as in the case of accidental drug ingestion. Acute iron poisoning has been reported in children less than 6 years of age who have accidentally overdosed on iron-containing supplements for adults. According to the FDA, doses greater than 200 mg per event could poison or kill a child (FDA 1997). To reach this exposure level, a child would need to consume almost 7 liters (1.75 gallons) of water containing the maximum iron concentration in a single exposure event. Further, the body uses a homeostatic mechanism to keep iron burdens at a constant level despite variations in the diet (Eisenstein and Blemings 1998). As such, no adverse human health effects are expected from exposure to iron in the community and LANL water supplies.

Lead

Lead, which is found in the environment naturally, is a concern for children. Within a few weeks, 99% of the amount of lead absorbed by adults will exit in urine and feces, whereas only about 68% of the lead taken into children will leave their bodies. Once in the body, lead will travel to soft tissues, such as the liver, kidneys, lungs, brain, spleen, muscles, and heart. After several weeks of continual exposure, most of the lead moves from the soft tissue into bones and teeth. In adults, about 94% of the total amount of lead in their bodies can be found in bones. In children, about 73% of lead in their bodies is stored in their bones (ATSDR 1999c).

Chronically consuming the maximum detected lead concentrations (0.095 ppm) in the water supply would result in doses of 0.003 mg/kg/day for adults and lifetime residents and 0.009 mg/kg/day for children. These doses are much lower than the NOAELs of 0.57 to 27 mg/kg/day for lead. The Centers for Disease Control and Prevention (CDC) also uses a blood lead level of 10 micrograms/deciliter (µg/dL) as a level of concern to assess possible adverse effects in children. A number of studies have been conducted to correlate drinking water lead concentrations and blood lead levels. These studies have reported an increase of 0.04 to 0.25 µg/dL in blood lead per 0.001 ppm of lead in water consumed by children. Based on these studies, a child drinking water containing 0.095 ppm of lead might experience and increase in blood lead levels of 3.68 to 23 µg/dL. At the higher level, chronic exposure to lead in water would exceed 10 µg/dL and be of concern. However, the other elevated lead levels were 0.041, 0.02, and below. Chronic exposure at these levels would result in doses below the NOAEL and below blood lead levels of concern (1.6 to 10 µg/dL and 0.8 to 5 µg/dL, respectively) (ATSDR 1999c).

In addition, community water supplies are required by law to meet the MCL for lead (0.015 ppm exceeded in less than 10 percent of samples) in their water supply (EPA 2003b). Based on this information, ATSDR concluded that no adverse human health effects were expected from contact with lead in the community or LANL water supplies.

Silver

As a metal, silver is a valued metal used in jewelry, silverware, electronic equipment, and many more items. As a compound, silver is used in photography and other processes. Silver is found in

the environment naturally, and typically as a compound in groundwater. Most of the silver ingested is excreted from the body in feces within a week. A small amount of silver will be retained in the body (ATSDR 1990).

Ingestion of the maximum silver concentration (0.058 ppm) in the community and LANL water supplies resulted in a dose of 0.002 mg/kg/day in adults and lifetime residents and 0.006 mg/kg/day in children. The EPA RfD for silver (0.005) was slightly exceeded when estimating a dose for children. The RfD is based on a human study of argyria, a condition that permanently leaves the skin tainted bluish-gray but causes no other effects. Before antibiotics, silver was used as a treatment for syphilis. Studies of individuals treated with silver found noticeable argyria after ingestion of 1 gram of silver; in others, no effects were seen until a total dose of 20 grams was ingested (EPA 2003a). At a concentration of 0.058 ppm, a total dose of 1 gram of silver would be reached after consuming 2.35 liters of water every day for approximately 20 years. Because concentrations of silver were lower than the maximum of 0.058 ppm during sampling from 1980 to 2001, an individual is unlikely to drink exclusively from the community or LANL water supplies, and argyria is a cosmetic effect (not an adverse health effect), ATSDR concluded that consumption of community and LANL water supplies was not expected to result in adverse health effects.

Thallium

Thallium is a naturally occurring metal found in the environment in a pure form, mixed with other metals, or combined with other substances to form salts. When ingested via drinking water, thallium is believed to be absorbed rapidly and distributed to various parts of the body. About half of the ingested dose will leave the body in urine or feces within 3 days. The systems or organs shown to be affected by high or poisonous doses include the cardiac, nervous, liver, and kidney (ATSDR 1992d).

Much of what we know about thallium is from human poisoning cases reports and a relatively sparse animal data set that describe effects associated with various thallium compounds (e.g., thallic oxide, thallium sulfate, or thallium chloride). Only limited amounts of data are available regarding dose-response relationships. EPA Region III reports an RfD of 0.00007 mg/kg/day. A review of the literature identified the lowest reported LOAEL (changes to the testis) to be 0.7 mg/kg/day, based on a 30 to 60 day study in which rats were exposed to thallium sulfate via gavage (i.e., administered directly into their guts). A NOAEL of 0.2 mg/kg/day was reported in a study of rats exposed to thallium sulfate via gavage for 90 days (ATSDR 1992d). The estimated doses associated with continuous exposure to the highest detected thallium concentration (0.019 ppm) found in the community and LANL water supply were 0.0006 mg/kg/day and 0.002 mg/kg/day for an adult/lifetime resident and child, respectively. These doses are approximately 330 and 100 times, respectively, lower than the lowest NOAEL identified during a literature review. As such, no adverse human health effects are expected from exposure to thallium in community and LANL water supplies.

Vanadium

Vanadium is naturally found in rocks and soil and can leach to groundwater. Vanadium could also be released during industrial processes, such as making steel or processing ore. If ingested, small amounts of vanadium can enter the bloodstream, although most is expelled in feces (ATSDR 1992e).

The maximum detected vanadium concentration found in community and LANL water supplies (0.26 ppm) was above the CVs for adults and children. Doses for people exposed to this concentration chronically were 0.009 mg/kg/day for adults and lifetime residents and 0.03 mg/kg/day for children. ATSDR derived an intermediate MRL (0.003 mg/kg/day) based on a 3-month drinking water study in rats. Histological changes in kidneys, lungs, and spleen that became progressively more severe with increased doses were identified and a NOAEL was established at a dose of 0.3 mg/kg/day (ATSDR 1992e). Doses estimated for adults/lifetime residents and children were 35 and 12 times, respectively, lower than the NOAEL.

Because actual exposure to vanadium would be at levels less than the maximum detected concentration and conservatively estimated doses were below the NOAEL, ATSDR concluded that no adverse human health effects were expected from consumption of water from the community and LANL water supplies.

Cancer Effects

Not all contaminants in the environment have the potential to cause cancer. Arsenic is the only contaminant detected in the community or LANL water supplies that has been classified by EPA as a possible carcinogen via oral exposure. (Chromium is considered a carcinogen, but only through inhalation. Insufficient data are available to assess chromium's carcinogenicity from oral exposures, such as through consumption of drinking water.)

Assuming daily exposure to the maximum detected arsenic concentration (0.11 ppm), ATSDR estimated doses for cancer effects of 0.002 mg/kg/day for and adult and 0.004 mg/kg/day for a lifetime resident. These doses correspond with a theoretical excess lifetime cancer risk of 3×10^{-3} for an adult (3 new cases in 1,000 exposed people) and 5×10^{-3} for a lifetime resident (5 new cases in 1,000 exposed people). Based on these findings, ATSDR conducted further review of the toxicology literature to assess potential public health affects.

A Taiwanese study, which has sparked much debate, serves as the basis for the EPA CSF (used to estimate the theoretical cancer risk once a dose has been established). In this study, the lowest exposure levels associated with the onset of cancer (skin) were observed in people drinking water containing 0.170 to 0.800 ppm arsenic for 45 years. Although the study demonstrated an association between arsenic in drinking water and skin cancer, the study failed to account for a number of complicating factors, including exposure to other non-water sources of arsenic, genetic susceptibility to arsenic, and poor nutritional status of the exposed population. Furthermore, arsenic exposure may have been underestimated in the study, possibly leading to an overestimation of the actual risk. These weakness and uncertainties may limit the study's usefulness in evaluating cancer risk for people drinking water containing arsenic at LANL. In addition, several epidemiological studies conducted in the United States found no increase in skin cancer incidences in populations chronically exposed to 0.1 to 0.2 ppm of arsenic in drinking water. Study limitations (e.g., small study population), however, restrict the usefulness of these results in deriving a CSF (ATSDR 2000a; EPA 2003a).

ATSDR also compared the estimated doses to available CELs, which are doses that produce significant increases in the incidence of cancer or tumors, and reviewed genotoxicity studies to further understand the extent to which a chemical might be associated with cancer outcomes. CELs ranging from 0.0011 mg/kg/day for lung cancer to 3.67 mg/kg/day for bladder cancer were

identified, with most CELs near or above 0.02 mg/kg/day for skin and bladder cancers (ATSDR 2000a).

In addition to the toxicological data, ATSDR also reviewed the monitoring data. Estimated exposure doses assumed exposure to the maximum detected concentration of 0.11 ppm. The next highest detected concentration was 0.052 ppm. As such actual doses would be lower than the estimated doses. In addition, community water supplies are required by law to meet MCLs for chemicals in their water supply. For arsenic, the MCL has currently been reduced from 0.05 ppm to 0.01 ppm. Considering this information, ATSDR does not expect people who contact detected levels of arsenic via drinking water to be at an increased risk of developing cancer.

Radiation Effects

Radiation is unlike chemical contaminants, which are measured by mass and cause adverse health effects by interfering with normal cell chemistry. Radiation is a measure of the decay, or breakdown, of natural (e.g., uranium) or man-made (e.g., strontium) radionuclides, which are unstable elements that lose energy by releasing protons, electrons, and neutrons in the process of transforming into other, stable elements or are elements that simply lose energy without transforming. Radiation, therefore, is measured as the amount of transformations occurring or energy lost. The protons, electrons, and/or neutrons and energy released during decay can cause cell damage or death when colliding with living tissue. In some cases, a damaged cell survives, mutates, and becomes a cancer-causing cell. As such, exposure to radiation is a human health concern because of its potential to result in an increased risk of cancer (EPA 2000; ATSDR 1999b).

Drinking water was monitored for a number of radionuclides between 1980 and 2001. Only gross alpha was detected above its CV. Gross alpha is a measure of alpha particles released from a number of different radionuclides, both naturally occurring and man-made. Alpha particles are composed of two protons and two neutrons; they are the largest decay product from radionuclides. Because of their size, alpha particles are unable to penetrate skin easily—their movement can be stopped by a sheet of paper or the outer layer of skin. Ingestion of alpha particles is, therefore, the greatest concern for causing damage. Once inside the body, alpha particles cause damage as they pull electrons from other molecules and deposit their energy. Alpha particles are transformed into harmless helium atoms and expelled in a person's breath (EPA 2000; ATSDR 1999b).

EPA has established an MCL of 15 picocuries/liter (pCi/L) of gross alpha in drinking water. EPA derived this MCL by using risk assessment methodologies to identify the gross alpha concentration the would correspond with a theoretical increased cancer risk of 10^{-4} to 10^{-6}, assuming continuous lifetime exposure and consumption of 2 L of water each day (EPA 2000). At LANL, the highest detected level of gross alpha in the community or LANL water supplies was 30 pCi/L. However, for most monitoring years, the gross alpha concentrations were below the MCL of 15 pCi/L; only exceeding this level in the Los Alamos well field in 1985 (21 pCi/L), 1989 (18 pCi/L), and 1991 (30 pCi/L) and in the Pajarito well field in 1982 (20 pCi/L). Because continuous exposures are not occurring, ATSDR concluded that intermittent exposures to elevated levels of gross alpha are not expected to increase cancer risk.

Estimated Exposure Doses for Incidental Ingestion of Surface Soil

Arsenic and the radionuclides cesium-137, plutonium-238, and strontium-90 were detected in surface soil at levels above ATSDR CVs. The maximum concentrations detected between 1980 and 2000 were found in surface soil collected within restricted areas of LANL. Members of the public, therefore, would not have access or contact with these areas of contamination. To be conservative, however, ATSDR assumed that surface soil containing contaminants could migrate as windblown dust to offsite residential areas. Incidental ingestion of arsenic and radionuclides in surface soil in residential yards was identified as the primary route of exposure. Arsenic is an inorganic and does not readily volatilize to the air or penetrate skin, therefore, ingestion is the primary pathway of concern. Skin contact and inhalation are also potential pathways of concern for radionuclides. These pathways, however, are typically responsible for only a small portion of the overall exposure.

As with exposures doses derived for ingestion of drinking water, ATSDR applied conservative assumptions about how often and how long exposures occurred. ATSDR also very conservatively assumed that the maximum detected concentrations onsite could be found in residential yards offsite. Exposure parameters used to estimate doses for incidental ingestion of surface soil are listed in Table H-1. Using conservative exposure assumptions creates a protective estimate of exposure and allows ATSDR to safely evaluate the likelihood, if any, that contaminants in off-site surface soil could cause harm to its users. Table H-3 summarizes estimated exposure doses from accidentally ingesting surface soil.

Non-cancer and Cancer Effects

Arsenic (6 ppm) was the only non-radionuclide contaminant detected above its CV in surface soil. Estimated doses for an adult and lifetime resident (0.000004 mg/kg/day) and child (0.00007 mg/kg/day) were below the MRL (0.0003 mg/kg/day). Arsenic has been classified as a human carcinogen through oral exposure. Estimated cancer doses for an adult (0.000002 mg/kg/day) and a lifetime resident (0.000004 mg/kg/day) correspond with theoretical excess cancer risk values below 10^{-4}. For an adult, this level was 3×10^{-6} (or 3 cases of cancer in a population of 1,000,000 exposed people). For a lifetime resident, the theoretical excess cancer risk was 1×10^{-5} (or 1 new case of cancer in a population of 100,000 exposed people).

As such, ATSDR concluded that incidental ingestion of soil containing 6 ppm of arsenic was not expected to result in adverse human health effects. Additional chemical and toxicological information about arsenic is provided in this appendix under the assessment of exposures to arsenic in groundwater.

Radiation Effects

In surface soil, monitoring between 1980 and 2001 found the radionuclides cesium-137, plutonium-238, and strontium-90 above their CVs. To assess possible human health concerns, ATSDR estimated radiation doses for adults and children living in the Los Alamos community. Exposure doses for radiation are calculated much the same way doses for chemical contaminants are calculated. Variables, such as the measure (concentration) of radiation, intake rate, exposure frequency, exposure duration, and body weight, are considered for both estimates. To calculate radiation doses, however, radionuclide concentrations are also multiplied by a dose conversion factor (DCF). The DCF is specific for each radionuclide and relates the radionuclide concentrations to internal or external doses (LANL 2000; EPA 1989).

The U.S. Department of Energy (DOE) has established 100 millirem/year (mrem/yr) (in addition to the background dose of approximately 360 mrem/yr at LANL) as the level below which no adverse health effects are expected from exposure to radionuclides. This screening value is based on studies that have found health effects occurring only at doses above 10,000 mrem (LANL 2000).

Conservatively assuming that an individual was exposed daily to the maximum detected radionuclide concentrations found between 1980 and 2001, ATSDR calculated an exposure dose of 3 mrem/yr for an adult and 4 mrem/yr for a child. ATSDR also assumed the maximum detected radionuclide concentrations found within restricted areas of LANL could represent concentrations that might be found in residential yards. Because the maximum detected concentrations overestimate concentrations likely found in areas of exposure for the general public (e.g., residential yards) and estimated doses were well below the DOE screening value of 100 mrem/yr, ATSDR concluded that contact with radionuclides in surface soil were not expected to result in adverse health effects for adults and children living in the Los Alamos community.

Estimated Exposure Doses for Incidental Ingestion of Surface Water and Sediment

Bis(2-ethylhexyl)phthalate, methylene chloride, 15 inorganics, and the radionuclides gross alpha and uranium were detected in surface waters at maximum concentrations exceeding their ATSDR CVs. Benz(a)anthracene, benzo(a)pyrene, arsenic, iron, manganese and the radionuclides americium-241, cesium-137, plutonium 239/240, and strontium-90 were detected in sediment at maximum concentrations above ATSDR CVs. Surface water and sediment samples were collected from canyons that historically received waste water discharge or storm water runoff from LANL operations. Members of the public have used some portion of these canyons for recreation, such as hiking, biking, and hunting. Inorganics do not readily volatilize to the air or penetrate skin. As such, incidental ingestion of surface water or sediment during recreational activities is the primary exposure pathway. Skin contact and inhalation are also potential pathways of concern for the organics and radionuclides. These pathways, however, are typically responsible for only a small portion of the overall exposure.

Consistent with the drinking water and surface soil pathways, ATSDR applied conservative assumptions about how often and how long exposures occurred to estimate to what extent people might be exposed to contaminants. ATSDR assumed that exposures would have begun before 1980, even though this PHA focuses on environmental data collected from 1980 to 2001. Exposure parameters used to estimate doses for incidental ingestion of surface water and sediment are listed in Table H-1. Using conservative exposure assumptions creates a protective estimate of exposure and allows ATSDR to safely evaluate the likelihood, if any, that contaminants in off-site surface soil could cause harm to its users. Tables H-4 and H-5 summarize the estimated doses for exposure to contaminants found in surface water and sediment.

Non-cancer Effects

As an initial screen, ATSDR compared the estimated doses to the MRL or RfD for each contaminant, except benzo(a)anthracene and benzo(a)pyrene in sediment. These two contaminants are part of a group of chemicals referred to as polycyclic aromatic hydrocarbons (PAHs). PAHs are considered a greater concern for cancer, versus non-cancer, health effects and

very little data are available regarding non-cancer health effects. As such, the PAHs are considered under cancer effects only. Estimated doses for adults/lifetime residents and children accidentally ingesting surface water were below associated MRLs and RfDs for bis(2-ethylhexyl)phthalate, methylene and 10 inorganics. Lead and sodium have no MRL or RfD. Cadmium, chromium, chloride, fluoride, and nitrate doses exceeded their MRL or RfD and are evaluated in more detail. For sediment, estimated doses for incidental ingestion by adults/lifetime residents and children exceeded their MRL or RfD for arsenic, iron, and manganese. ATSDR conducted further evaluation of these chemicals.

Lead and Sodium

No MRL or RfD has been derived for either lead or sodium. A number of studies have been conducted to correlate drinking water lead concentrations and blood lead levels. These studies have reported an increase of 0.04 to 0.25 µg/dL in blood lead per 0.001 ppm of lead in water consumed by children. A child ingesting 0.05 L of surface water containing 0.13 ppm of lead may have and increased blood lead level of 0.26 to 1.6 µg/dL. This level is well below the CDC level of concern (10 µg/dL) (ATSDR 1999c). Sodium consumption is a concern for people on a restricted diet because of hypertension. Consuming 0.01 L as an adult of 0.05 L as a child would add approximately 10 mg and 52 mg of sodium, respectively, to the diet. In extreme cases of hypertension, a restricted diet of 500 mg of sodium is followed (University of Kansas 2002). Incidental consumption of surface water containing the maximum detected sodium concentration is well below this dietary limit.

Based on this information, lead and sodium are not expected to result in adverse health effects for recreational users. Additional information for each of these chemicals is provided in this appendix under the evaluation of exposures to community and LANL water supplies.

Cadmium

Using conservative assumptions, only the dose for children ingesting the maximum cadmium levels in surface water (0.003 mg/kg/day) exceeded the MRL (0.0002 mg/kg/day). The MRL is based on an epidemiology study of people living in a cadmium-contaminated area. An increased incidence of proteinuria was identified in residents with a lifetime intake of 2,000 mg of cadmium from dietary sources (NOAEL of 0.0021 mg/kg/day) (ATSDR 1999a). This dose slightly exceeds the NOAEL from this study. The maximum detected cadmium concentration (1 ppm), on which the dose was based, was more than 30 times higher than the next highest detected concentration (0.03 ppm).

Because exposure to 1 ppm cadmium was not continuous, the next highest detected concentration was 30 times lower (0.03 ppm), and the estimated dose for children only slightly exceed the NOAEL using conservative assumptions, ATSDR concluded that exposure to cadmium in surface water during recreational use was not expected to result in adverse health effects.

Chromium

Chromium was detected to a maximum concentration of 5 ppm, which exceeds the CV for children (0.03 ppm) and adults (0.18 ppm). Assuming daily exposure to the maximum detected concentration, the estimated doses for ingestion of chromium in drinking water were 0.02

mg/kg/day for children and 0.007 mg/kg/day for adults/lifetime residents. The estimated dose for children exceeded the RfD of 0.003 mg/kg/day. The RfD is based on animal studies in which no observed adverse health effects were reported in rats administered chromium at 2.5 mg/kg/day in drinking water (EPA 2003a). This dose is 125 times higher than the estimated doses for children exposed to the maximum chromium concentration.

Relatively few human studies have been identified that address the oral toxicity of hexavalent chromium. One drinking water study suggests that gastrointestinal effects may be associated with hexavalent chromium concentrations of 20 ppm in drinking water, but the study fails to detail exact exposure concentrations, possible confounding factors, or what effects might be seen at lower levels (EPA 2003a).

Based on available information, ATSDR concluded that ingestion of chromium at detected levels in surface water was not expected to result in adverse human health effects.

Chloride

Estimated doses for adults/lifetime residents and children accidentally ingesting surface water containing the maximum detected chloride concentrations were 0.05 mg/kg/day and 1 mg/kg/day, respectively. The RfD of 0.1 mg/kg/day was derived from a 2-year study in rats and mice given chloride in their drinking water. The NOAEL from this study was 14.4 mg/kg/day in rats and 14.2 mg/kg/day in mice. Some effects were seen at the highest dose tested in mice (24.2 mg/kg/day), including decreased water consumption and decreased weight gain. Survival rates, however, were unaffected (EPA 2003a).

The dose for an adult/lifetime resident was below the RfD. The dose for a child was above the RfD, but 14 times lower than doses found to cause no adverse effects in laboratory studies. Because ATSDR estimated doses using conservative assumptions intended to overestimate actual doses and the conservatively derived doses are below levels at which health effects have been observed in laboratory studies, ATSDR concluded that accidental ingestion of chloride in surface water is not expected to result in adverse human health effects.

Fluoride

The estimated doses for adults and lifetime residents (0.008 mg/kg/day) exposed to fluoride in surface water during recreational use were below the RfD (0.06 mg/kg/day). The estimated dose for children (0.2 mg/kg/day), however, was elevated. Cosmetic effects in children's teeth have been reported when chronic exposure to 2 ppm or greater fluoride in drinking water occurs, however, a concentration of 1 ppm in drinking water is recommended as beneficial for teeth. A concentration of 2 ppm in drinking water corresponds to daily consumption of 2 mg fluoride when drinking 1 liter of water. At the maximum detected concentration (56 ppm), a child accidentally ingesting 0.05 liter of surface water would consume approximately 2.8 mg of fluoride. Chronic exposure to this level of fluoride could result in spotting on teeth. However, chronic exposure is unlikely as the next highest concentrations of fluoride detected were 18.5 ppm and 13 ppm, which correspond with daily intakes of 0.9 mg and 0.7 mg, respectively, of fluoride. These levels fall below the concentration at which beneficial effects of fluoride are seen (1 milligram fluoride from ingesting 1 liter per day containing 1 ppm fluoride).

As such, incidental ingestion of fluoride in surface water is not expected to result in adverse health affects. More information regarding fluoride is provided in this appendix under the assessment of exposures to fluoride in the community and LANL water supplies.

Nitrate

Nitrate is a naturally occurring compound, part of the nitrogen cycle, and is the primary source of nitrogen for plants. Agricultural and residential use of nitrogen-based fertilizers, nitrogenous wastes from livestock and poultry production, and urban sewage treatment systems are sources of nitrate in soil and water. Nitrate-containing compounds are water soluble, which means that they can be carried in water. Thus, nitrate can enter drinking water supplies through surface water runoff, home sewage systems, agricultural fields, and groundwater recharge.

Nitrate was detected in surface water to a maximum concentration of 636 ppm. ATSDR estimated exposure doses from incidental ingestion this concentration of nitrate in surface water for an adult/lifetime resident (0.09 mg/kg/day) and child (2 mg/kg/day). The estimated exposure dose for an adult/lifetime resident was below the RfD of 1.6 mg/kg/day, but the child dose slightly exceeded this level. The RfD is based on a NOAEL of 1.6 mg/kg/day from studies in cases of infant (children less than 1 year old) methemoglobinemia associated with exposure to nitrate-contaminated water (EPA 2003a). Methemoglobinemia occurs when nitrate interferes with the oxygen carrying capacity of the blood. The lack of oxygen causes shortness of breath and blueness of the skin. Although the condition can be serious, it is easily reversed with treatment. In a study of children age 1 to 8 years, doses of 2.2 to 11 mg/kg/day resulted in no adverse health effects (EPA 2003a). These doses are consistent with the estimated dose for children age 1 to 6 years who may be using the canyons at LANL for recreation.

As such, ATSDR believes that adults and children would not have experienced adverse health effects from exposure through incidental ingestion of surface water, even if they consumed the maximum detected concentration.

Arsenic

The ATDR MRL of 0.0003 mg/kg/day is based on an epidemiology study of people exposed to arsenic in their drinking water. The MRL is based on a NOAEL of 0.0008 mg/kg/day. The next highest dose test (0.014 mg/kg/day) was identified as the study LOAEL (hyperpigmentation and keratosis of the skin were observed) (ATSDR 2000a).

The estimated doses for incidental ingestion of sediment during recreation were below the MRL for adults and lifetime residents (0.00004 mg/kg/day), but above the MRL for children (0.0008 mg/kg/day). The conservatively estimated dose for children is the same as the NOAEL established for drinking water containing arsenic. Investigations of the bioavailability of arsenic have found that inorganic arsenic in soil is absorbed to a lesser extent than arsenic found in water. Studies report soil bioavailability ranging from 8 to 25%, versus reported levels of 70 to 95% bioavailability in water (ATSDR 2000a). As such, assuming arsenic in soil is absorbed to the same degree as arsenic in water when estimating doses results in an overestimate of potential health effects.

Based on these data, ATSDR concluded that incidental ingestion of sediment containing arsenic would not be expected to result in adverse human health affects. Additional information

regarding arsenic is provided in this appendix under the discussion of arsenic in the community and LANL water supplies.

Iron

Only one sediment sample contained iron above its CV of 23,000 ppm. The doses for adults/lifetime residents (0.02 mg/kg/day) exposed to this concentration of iron were below the provisional RfD (0.3 mg/kg/day). The estimated dose for a child (0.3 mg/kg/day) was equal to the provisional RfD. Based on the environmental sampling data and conservatively estimated doses, ATSDR expects no adverse human health effects to result from exposure to iron in sediment. Additional information regarding iron is provided in this appendix under the discussion of iron in the community and LANL water supplies.

Manganese

Manganese is a naturally occurring substance typically found in compounds with oxygen, sulfur, and chloride. Uses of manganese include steel manufacturing and battery, fertilizer, pesticide, and ceramic production. Manganese is also considered and essential nutrient for good health, and as such, is sometimes found in vitamins. The body normally controls manganese concentrations; most is excreted in feces with only about 3 to 5% absorbed (ATSDR 2000d).

The estimated dose for an adult/lifetime resident accidentally ingesting manganese in sediment was 0.01 mg/kg/day; below the RfD of 0.05 mg/kg/day. For children, the estimated dose was 0.2 mg/kg/day. EPA derived the RfD for manganese from investigations of manganese levels needed for good health. Based on these studies, EPA concluded that 10 mg/day was an appropriate upper limit of the amount of manganese an individual should consume (EPA 2003a). Typically, people will consume 3 to 5 mg of manganese in their diet each day (ATSDR 2000d). Accidental ingestion of sediment containing 18,563 ppm of manganese would add approximately 0.9 mg and 3.5 mg manganese to the diets of adults and children. Neither of these increases would result in a total dose of greater than 10 mg/day when considering dietary sources.

In addition, the next highest detected manganese concentration was 646 ppm, which is below the CVs of 40,000 ppm and 3,000 ppm for adults and children, respectively. As such, no adverse human health effects are expected from incidental ingestion of sediment during recreation.

Cancer Effects

EPA has classified arsenic as human carcinogens via oral exposure and benz(a)abthracene, benzo(a)pyrene, bis(2-ethylhexyl)phthalate, and methylene chloride as a probable human carcinogen. These are the only carcinogens detected in surface water or sediment. (Chromium was also found in surface water and is considered a carcinogen, but only through inhalation. Insufficient data are available to assess chromium's carcinogenicity from oral exposures, such as through accidental ingestion of surface water.) ATSDR estimated theoretical cancer risk from ingesting surface water and sediment containing the maximum detected concentration of arsenic in surface water (0.019 ppm) and sediment (65 ppm), benz(a)anthracene (1.26 ppm) and benzo(a)pyrene (0.938 ppm) in sediment, bis(2-ethylhexyl)phthalate (0.0054 ppm) in surface water, and methylene chloride (0.015 ppm) in surface water. For each of these contaminants, conservatively derived doses for incidental ingestion of surface water and sediment during recreation correspond with estimated theoretical excess cancer risks below 10^{-4}.

Arsenic

For arsenic in surface water, the dose of 0.0000005 mg/kg/day for an adult corresponds with a theoretical excess cancer risk of 8×10^{-7} (or 8 cases of cancer in a population of 10,000,000 exposed people) and the dose of 0.000001 mg/kg/day for a lifetime resident corresponds with theoretical excess cancer risk of 2×10^{-6} (or 2 cases of cancer in a population of 1,000,000 exposed people). For arsenic in sediment, the estimated doses were 0.00002 mg/kg/day for an adult (3×10^{-5}; 3 cases of cancer in a population of 100,000 exposed people) and 0.00005 mg/kg/day for a lifetime resident (5×10^{-5}; 5 cases of cancer in a population of 100,000 exposed people). Additional chemical and toxicological information about arsenic is provided in this appendix under the assessment of exposures to arsenic in groundwater. Because the theoretical excess cancer risks were below 10^{-4}, ATSDR concluded that incidental ingestion of surface water and sediment containing arsenic would not place recreational users of the canyons at an increased risk of developing cancer.

Benz(a)anthracene and Benzo(a)pyrene

Benz(a)anthracene and benzo(a)pyrene are two PAHs, a group of 100s of chemicals that form when organic substances, such as coal, wood, garbage, or tobacco, burn. They are also found in oil, tar, and creosote. When found in the environment, PAHs typically occur in complex mixtures. At LANL, incidental ingestion of sediment containing benz(a)anthracene and benzo(a)pyrene is the primary route of exposure. Once in the body, these PAHs may be stored in the kidneys, liver, or fat. Residence time in the body, however, is short; most PAHs are expelled in urine and feces within a few days of exposure (ATSDR 1995).

Benzo(a)pyrene is considered the most toxic of the PAHs, therefore, the potential for other PAHs to cause cancer is based on data regarding benzo(a)pyrene. EPA derived a CSF based on a study of mice ingesting benzo(a)pyrene, which resulted in increases in forestomach and squamous cell papillomas and carcinomas. For recreational use of the canyons surrounding LANL, the estimated doses from incidental ingestion of benzo(a)pyrene were 0.0000003 mg/kg/day for an adult (2×10^{-6}; 2 cases of cancer in a population of 1,000,000 exposed people) and 0.0000007 mg/kg/day for a lifetime resident (5×10^{-6}; 5 cases of cancer in a population of 1,000,000 exposed people). The estimated doses from incidental ingestion of benz(a)anthacene, considered 10 times less toxic than benzo(a)pyrene, were 0.0000004 mg/kg/day for an adult (4×10^{-7}; 4 cases of cancer in a population of 10,000,000 exposed people) and 0.0000009 mg/kg/day for a lifetime resident (6×10^{-7}; 6 cases of cancer in a population of 10,000,000 exposed people). Because the theoretical excess cancer risks were below 10^{-4} for both PAHs, ATSDR concluded that incidental ingestion of sediment containing these contaminants would not place recreational users of the canyons at an increased risk of developing cancer.

Bis(2-ethylhexyl)phthalate

Bis(2-ethylhexyl)phthalate is a man-made chemical often added to plastics for flexibility. Leaching from plastics releases bis(2-ethylhexyl)phthalate to the environment. Once in water, this contaminant dissolves slowly and biodegrades slowly when oxygen is present. Incidental ingestion of surface water containing bis(2-ethylhexyl)phthalate is a source of exposure at LANL. Once ingested, the body rapidly metabolizes bis(2-ethylhexyl)phthalate and metabolites are typically excreted in urine and feces within 24 hours (ATSDR 2002a).

EPA derived the CSF based on studies of mice ingesting bis(2-ethylhexyl)phthalate, which resulted in increases in liver tumors. The estimated doses from incidental ingestion of bis(2-ethylhexyl)phthalate during recreational use of canyons surrounding LANL were 0.0000002 mg/kg/day for an adult (2×10^{-9}; 2 cases of cancer in a population of 1,000,000,000 exposed people) and 0.0000003 mg/kg/day for a lifetime resident (4×10^{-9}; 4 cases of cancer in a population of 1,000,000,000 exposed people).). Because the theoretical excess cancer risks were below 10^{-4}, ATSDR concluded that incidental ingestion of sediment containing these contaminants would not place recreational users of the canyons at an increased risk of developing cancer.

Methylene Chloride

Methylene chloride is a man-made industrial solvent commonly used as a paint stripper. Methylene chloride is found in the environment only as a result of accidental releases. Much of the methylene chloride ingested enters the bloodstream. The body expels methylene chloride and its breakdown product primarily in exhaled breaths (about half is discharged in exhaled breaths within 40 minutes). A small amount is excreted in urine (ATSDR 2000f).

No information is available regarding methylene chloride's ability to cause cancer in humans. EPA derived the CSF based on studies of mice ingesting and inhaling methylene chloride, which resulted in increases in liver tumors. For recreational use of the canyons surrounding LANL, the estimated doses from incidental ingestion of methylene chloride were 0.0000004 mg/kg/day for an adult (3×10^{-9}; 3 cases of cancer in a population of 1,000,000,000 exposed people) and 0.0000009 mg/kg/day for a lifetime resident (7×10^{-9}; 7 cases of cancer in a population of 1,000,000,000 exposed people). Because the theoretical excess cancer risks were below 10^{-4}, ATSDR concluded that incidental ingestion of surface water containing methylene chloride would not place recreational users of the canyons at an increased risk of developing cancer.

Radiation Effects

As described under the evaluation of radiation effects from contact with radionuclides in surface soil, ATSDR estimated doses for adults and children exposed to radionuclides detected in surface water and sediment. In surface water, the maximum detected concentrations of total uranium and gross alpha exceeded CVs and, in sediment americium-241, cesium-137, plutonium 239/240, and strontium-90 exceeded their CVs.

Gross alpha (to 69 pCi/L) exceeded the EPA MCL for drinking water (15 pCi/L). EPA derived this MCL by using risk assessment methodologies to identify the gross alpha concentration the would correspond with a theoretical increased cancer risk of 10^{-4} to 10^{-6}, assuming continuous lifetime exposure and consumption of 2 L of water each day (EPA 2000). Incidental ingestion of surface water is expected to be 0.05 L/day for a child and 0.01 L/day for an adult during wading, much lower than the amount of water consumed as drinking water. In addition, surface water is absent from the canyons for large portions of the year. As such, no increase in cancer risk is expected from occasional exposure to elevated gross alpha concentrations.

ATSDR estimated exposure doses conservatively assuming that adults and children would contact radionuclides at their maximum detected concentrations in surface water and sediment. Sediment contact was assumed to occur daily. Surface water flow is intermittent, so contact was assumed to occur for 153 days/year (a conservative estimate of how often surface water flow

occurs in the canyons). For an adult, the estimated exposure doses were 0.1 mrem/yr for surface water contact and 0.8 mrem/yr for sediment contact. ATSDR estimated that a child would receive doses of 1 mrem/yr from surface water and 4 mrem/yr from sediment. These estimated doses are below the DOE standard of 100 mrem/yr (above background), therefore ATSDR concluded that contact with radionuclides in surface water and sediment would not result in adverse health effects for adults or children living in the Los Alamos community.

Estimated Exposure Doses for Consumption of Locally Grown Food

People surrounding LANL, including the Native American populations, have expressed concern about contaminants from LANL entering the food chain and affecting the fruit, vegetables, game, and medicinal plants that they consume and use. Between 1980 and 2001, a number of different plants, produce, livestock, and game have been sampled. Polychlorinated biphenyls (PCBs), 16 metals, 21 pesticides, and 23 radionuclides were detected in the various biota sampled. Metals and some radionuclides are naturally occurring in the environment (i.e., they are present from the natural breakdown of rock and soil and are not the result of specific releases from LANL). Regardless of the source, however, ATSDR evaluated potential public health impacts from consumption of all contaminants found in biota. No CVs are available for food items, therefore all the contaminants detected were evaluated by estimating doses. In reviewing the data, ATSDR selected the food items that contained the highest levels of contaminants for estimating exposure doses. These included elk (muscle and bone), fish (non-game), goat milk, eggs, honey, produce, and Navajo tea. Consumption of these food items was the primary pathway of concern.

For each food item, ATSDR applied conservative assumptions about how much and how often a person would consume the item. Exposure parameters used to estimate doses for consumption of locally grown or harvested foods are presented in Table H-1. Using conservative exposure assumptions creates a protective estimate of exposure and allows ATSDR to safely evaluate the likelihood, if any, that contaminants in locally grown or harvested foods could cause harm to users. Table H-6 summarizes the estimated exposure doses for each of the contaminants found in elk (muscle and bone), fish (non-game, muscle and bone), goat milk, eggs, honey, produce, and Navajo tea.

Non-cancer Effects

As an initial screen, ATSDR compared estimated doses to the MRL or RfD for each contaminant. Doses estimated for adults, children, and/or lifetime residents exceeded the MRL, RfD, or other health value for antimony, arsenic, cadmium, chromium, mercury, thallium, and PCBs in non-game fish; and antimony, arsenic, barium, cadmium, chromium, mercury, nickel, selenium, and zinc in produce. Lead was detected in biota, but has no MRL or RfD. ATSDR reviewed the scientific literature for contaminants exceeding their MRL or RfD to further evaluate potential health non-cancer effects associated with exposure to the these contaminants at the maximum detected concentration in biota. Much of the toxicological and health effects information reviewed by ATSDR came from experimental animal studies or from epidemiological investigations of persons exposed in the workplace (human data).

Antimony

Antimony is a metal that occurs naturally at low levels in the earth's crust. It can also be used in industrial applications when mixed with other metals to form alloys or produce antimony oxide.

Some of the uses of the alloys include lead storage batteries, solder, sheet and pipe metal, bearings, castings, ammunition, and pewter (ATSDR 1992a).

Estimated Antimony Doses for Biota	Non-game fish (mg/kg/day)	Produce (mg/kg/day)
Adult (recreational angler)	0.0004	0.002
Lifetime resident (subsistence angler)	0.003	0.002
Child	0.001	0.004

Antimony was detected in non-game fish and produce samples collected from areas beyond LANL boundaries and potentially accessible to the public. Using conservative assumptions, ATSDR estimated doses at or above the chronic EPA RfD of 0.0004 mg/kg/day. The highest estimated dose (0.004 mg/kg/day) was for a child consuming produce containing the maximum detected antimony concentration. The RfD is based on the lowest level at which adverse effects (decreased non-fasting serum glucose) have been reported in laboratory animals (rats) administered chronic oral doses of antimony (0.262 mg/kg/day). ATSDR found that the estimated dose for a child consuming antimony in produce is approximately 65 times lower than the LOAEL on which the RfD was based (EPA 2003a). Human exposure data are limited, however, short-term doses as low as 0.539 mg/kg/day resulted in vomiting in a worker exposed to antimony-tainted lemonade (ATSDR 1992a). This dose is approximately 135 times higher than the highest, conservatively derived dose for people exposed to antimony in fish and produce. Based on this information, ATSDR concluded that exposures to antimony in biota were not expected to result in adverse health effects.

Arsenic

Arsenic can be found in most foods, and ingesting these foods is one way in which people can be exposed (FDA 1993). Most of the arsenic in food, however, is the less toxic organic form of arsenic. In fish, generally only about 1 to 20% of the total arsenic is in the more harmful inorganic form (ATSDR 2000a; Francesconi and Edmonds 1997; NAS 2001; FDA 1993). The U.S. Food and Drug Administration (FDA) proposes that 10% of the total arsenic be estimated as inorganic arsenic rather than specifically analyze for inorganic arsenic (FDA 1993).

Estimated Arsenic Doses for Biota	Non-game fish (mg/kg/day)	Produce (mg/kg/day)
Adult (recreational angler)	0.0003	0.002
Lifetime resident (subsistence angler)	0.002	0.002
Child	0.001	0.003

As a conservative estimate, ATSDR assumed that all of the arsenic detected in biota was the more toxic inorganic form. The highest dose estimated for consumption of non-game fish and produce containing arsenic was 0.003 mg/kg/day for a child consuming the maximum detected arsenic level in produce. This dose exceeds the chronic MRL of 0.0003 mg/kg/day, which is based on a NOAEL of 0.0008 mg/kg/day from a study of people chronically exposed to arsenic in drinking water. Doses estimated assuming that only 1 to 20% of the arsenic was the more toxic inorganic form (0.00004 to 0.0008 mg/kg/day) were at or below the MRL or NOAEL for arsenic. These doses are also below the LOAEL (0.014 mg/kg/day) observed in the drinking water study. The observed health effects at the LOAEL were hyperpigmentation and keratosis of the skin (ATSDR 2000a).

Considering that the highest dose estimated for biota exposures was below the LOAEL for arsenic and this dose was derived using conservative assumptions designed to overestimate the actual dose, ATSDR concluded that exposures to arsenic in biota are not expected to result in

adverse health effects. Additional information regarding arsenic is provided in this appendix under the discussion of arsenic in community and LANL water supplies.

Barium

Barium is a metal that occurs naturally in many different forms. Barium is used for a number of industrial purposes and may be released to the environment from these activities. However, some amount of barium is naturally present in food. Once ingested, barium is poorly absorbed to the bloodstream; most barium ingested is excreted within a few days. The small amount that is retained in the body is stored in the teeth and bones (ATSDR 1992b).

Most of the toxicity data from barium comes from small numbers of people exposed to high levels of barium for short periods. Individuals that consume large amounts of barium have experienced health effects such as difficulties breathing, gastrointestinal impacts, and cardiac affects (ATSDR 1992b). Exposure to the maximum detected barium concentration in produce (86 ppm dry weight) resulted in estimated exposure doses of 0.3 mg/kg/day for an adult or lifetime resident and 0.6 mg/kg/day for a child. These doses exceed EPA's chronic RfD of 0.07 mg/kg/day for barium. The RfD for barium is based on a combination of data from four different studies. A subchronic study of human exposure and a community exposure study identified a NOAEL of 0.21 mg/kg/day. No LOAEL was identified for humans in either of these studies. Two studies of rats identified NOAELs of 45 and 65 mg/kg/day and LOAELs of 75 and 115 mg/kg/day. Increased kidney weights were observed at the LOAEL (EPA 2003a). The estimated doses were above the NOAEL observed in human studies, but were 90 to 325 times below the NOAELs found in the rat studies.

In addition to the toxicological data, ATSDR also reviewed the monitoring data. Estimated exposure doses assumed continuous exposure to the maximum detected concentration of 86 ppm dry weight. The next highest detected concentrations were 62.7 and 36 ppm dry weight. Because people would actually consume lower doses of barium than assumed using the maximum detected concentration, actual doses would be lower than the conservatively estimated doses. As such, no adverse health effects are expected from exposure to barium in produce.

Cadmium

Using conservative assumptions, ATSDR estimated exposure doses for cadmium in fish and produce for adults, lifetime residents, and children that exceeded the cadmium MRL of 0.0002 mg/kg/day. These doses, except for adults exposed to cadmium in non-game fish, also exceeded the NOAEL in humans (0.0021 mg/kg/day) used to derive the MRL. The highest dose estimated for LANL (0.006 mg/kg/day) was to child chronically exposed to the maximum detected cadmium concentration in produce (0.8 ppm dry weight).

Estimated Cadmium Doses in Biota	**Non-game fish** (mg/kg/day)	**Produce** (mg/kg/day)
Adult (recreational angler)	0.0006	0.003
Lifetime resident (subsistence angler)	0.004	0.003
Child	0.002	0.006

ATSDR reviewed the monitoring data and found that the maximum detected cadmium concentrations in non-game fish were 1.6 ppm and 0.233 ppm. Two other monitoring years reported only non-detect levels. For produce, the maximum detected concentrations were 0.8, 0.49, and 0.22 ppm dry weight, with four additional monitoring years reporting only non-

detect levels. Because people would consume lower doses of cadmium than assumed using the maximum detected concentration, actual doses would be lower than the conservatively estimated doses. Considering this information, ATSDR does not expect people who ingest cadmium to experience adverse health effects. Additional information regarding cadmium is provided in the appendix under the discussion of cadmium in the community and LANL water supplies.

Chromium

Conservatively assuming that all of the chromium detected in biota was the more toxic form of chromium (chromium VI), ATSDR estimated doses that exceeded the RfD for Chromium VI (0.003mg/kg/day). The highest dose estimated was for a child (0.03 mg/kg/day) consuming the maximum detected chromium concentration in produce (4.2 ppm dry weight). The RfD was based on animal studies in which no observed adverse health effects were reported in rats administered chromium at 2.5 mg/kg/day in drinking water (EPA 2003a). This dose is more than 80 times higher than the estimated doses for children exposed to the maximum chromium concentration. In addition, ATSDR estimated doses using conservative assumption about how much produce a child eats, and how much of this produce is grown locally. Actual exposures to chromium in biota are expected to be lower. As such, ATSDR concluded that exposure to chromium in biota is not expected to result in adverse health affects. Additional information regarding chromium is provided in this appendix under the discussion of chromium in community and LANL water supplies.

Estimated Chromium Doses in Biota	**Non-game fish** (mg/kg/day)	**Produce** (mg/kg/day)
Adult (recreational angler)	0.003	0.02
Lifetime resident (subsistence angler)	0.02	0.02
Child	0.01	0.03

Lead

Ingesting lead in fish, produce, and honey will cause some lead to enter the body and bloodstream. The amount of lead that enters the body depends on age because more lead enters the blood in children than in adults. Within a few weeks, 99% of the amount of lead absorbed by adults will exit in urine and feces, whereas only about 68% of the lead taken into children will leave their bodies. Once in the body, lead will travel to soft tissues, such as the liver, kidneys, lungs, brain, spleen, muscles, and heart. After several weeks of continual exposure, most of the lead moves from the soft tissue into bones and teeth. In adults, about 94% of the total amount of lead in their bodies can be found in bones. In children, about 73% of lead in their bodies is stored in their bones (ATSDR 1999c).

Health effects from chronic exposure to lead have not been documented in humans. However, no adverse effects were observed in animals chronically exposed to 0.57 to 27 mg/kg/day of lead (ATSDR 1999c). Chronic consumption of lead in biota from LANL would result in lead doses lower than these NOAELs for animals. The highest estimated doses (0.3 mg/kg/day) were for children consuming produce containing the maximum detected lead levels (48 ppm dry weight). No studies relating lead levels in food stuff and blood

Estimated Lead Doses in Biota	**Non-game fish** (mg/kg/day)	**Produce** (mg/kg/day)	**Honey** (mg/kg/day)
Adult (recreational angler)	0.002	0.2	0.0002
Lifetime resident (subsistence angler)	0.009	0.2	0.0002
Child	0.004	0.3	0.0004

lead levels are available to allow for an assessment of blood lead impacts from biota consumption. Lead concentrations in biota from LANL are below levels of health concern for non-cancer effects. Additional information regarding lead is provided in this appendix under the discussion of lead in community and LANL water supplies.

Mercury

Mercury exists naturally in the environment in several different forms; the predominant form in biota is methylmercury. Methylmercury is the most studied organic mercury compound. It is readily absorbed in the gastrointestinal tract (about 95% absorbed) and can easily enter the bloodstream. It moves rapidly to various tissues and the brain, where methylmercury can be turned into inorganic mercury, which can remain in the brain for long periods. Slowly, over months, methylmercury will leave the body, mostly as inorganic mercury in the feces (ATSDR 2000e).

Estimated Mercury Doses in Biota	**Non-game fish** (mg/kg/day)	**Produce** (mg/kg/day)
Adult (recreational angler)	0.0002	0.0004
Lifetime resident (subsistence angler)	0.001	0.0004
Child	0.0005	0.0007

In fish tissue, mercury is present predominantly as methylmercury (about 85%), the more toxic form. Therefore, to be conservative, ATSDR assumed that all the mercury detected in biota was methylmercury. A review of the literature identified a study in which people who were exposed to 0.0013 mg/kg/day of methylmercury in their food did not experience any adverse health effects. The lowest NOAELs identified in chronic animal studies were 0.02 mg/kg/day in cats and rats and 0.1 mg/kg/day in rats (ATSDR 2000e). Assuming daily consumption of fish containing the maximum detected mercury concentration (0.51 ppm wet weight) resulted in a dose of 0.001 mg/kg/day for a subsistence angler at LANL. This dose, and other conservatively derived doses, was below the NOAEL of 0.0013 mg/kg/day. Based on a review of the toxicity data and use of conservative exposure assumptions, ATSDR concluded that consumption of mercury in biota was not expected to result in adverse human health affects.

Nickel

Nickel, a naturally occurring element, is commonly found in compounds in soil and rocks. Biota, food, and water naturally contain some level of nickel. For most of the population, food provides the largest source of their nickel exposure; a person consumes about 0.17 mg of nickel in food every day. Once ingested, small amounts of nickel are absorbed through the stomach and intestines to the bloodstream. Nickel in the bloodstream is expelled in urine and unabsorbed nickel is expelled in the feces (ATSDR 1997).

The most common health effect resulting from nickel exposure is an allergic reaction, which can develop after direct nickel contact with the skin (e.g., jewelry). If not allergic to nickel, a person must consume very large amounts to experience adverse effects. For example, workers consuming 250 ppm of nickel in water suffered from stomachaches, blood effects, and kidney changes. Another case report describes a child that died of heart failure after consuming 5,700 mg of nickel (ATSDR 1997). The maximum concentration of nickel in produce (91 ppm dry weight, or 91 mg/kg dry weight) is well below these levels shown to cause effects in humans. A person would have to consume more than 2 kg (or 4.4 pounds) of dried produce containing the maximum nickel concentration to reach the exposure level of 250 mg nickel.

EPA derived a chronic RfD for nickel (0.02 mg/kg/day) based on a 2-year feeding study in dogs and rats. In this study, NOAELs of 5 mg/kg/day for dogs and 25 mg/kg/day for rats were identified (EPA 2003a). The conservatively estimated doses from consumption of nickel in produce were 0.4 mg/kg/day for adults/lifetime residents and 0.7 mg/kg/day for children. These dose are below the NOAELs for dogs and mice.

ATSDR concluded that consumption of nickel in produce was not expected to result in adverse health effects based on a review of the toxicological literature, evaluation of the environmental data, and application of conservative exposure assumptions.

Selenium

Selenium is an essential nutrient that protects cell membranes, is an antioxidant in Vitamin E, and decreases the risk of cancer and heart disease. The Dietary Reference Intake for maintenance of good health is 0.055 mg/day (ATSDR 2001b). However, consuming too much selenium can lead to harmful health effects.

Absorption studies in humans reported that 80 to 97% of ingested selenium is absorbed in the gastrointestinal tract. Therefore, consuming produce with elevated selenium levels will result in some entering the bloodstream. Once in the body, selenium tends to be found at the highest concentrations in the liver and kidneys. Within 24 hours, most of the selenium will leave the body in urine, feces, and to a lesser extent though sweat (ATSDR 2001b).

The chronic MRL for selenium (0.005 mg/kg/day) is based on two studies in which no adverse health effects were reported in people who were exposed to 0.015 mg/kg/day of selenium in their food over their lifetime. Dermal health effects (selenosis: sloughing of nails and brittle hair) were observed when people were exposed to 0.023 mg/kg/day of selenium (ATSDR 2001b; EPA 1991). At LANL, doses estimated from consumption of produce containing the maximum detected selenium concentration (2 ppm dry weight) were 0.008 mg/kg/day for adults and lifetime residents and 0.01 mg/kg/day for children. The estimated doses are lower than observed NOAELs and assumptions used derive the estimated doses were selected to overestimate the actual risk. As such, no adverse human health effects are expected from consumption of selenium in biota.

Thallium

EPA Region III reports an RfD of 0.00007 mg/kg/day. A review of the literature identified the lowest reported LOAEL (changes to the testis) to be 0.7 mg/kg/day, based on a 30 to 60 day study in which rats were exposed to thallium sulfate via gavage (i.e., administered directly into their guts). A NOAEL of 0.2 mg/kg/day was reported in a study of rats exposed to thallium sulfate via gavage for 90 days (ATSDR 1992d). The highest estimated dose associated with continuous exposure to the highest detected thallium concentration was for a subsistence angler consuming non-game fish (0.02 mg/kg/day). This dose is approximately 10 times lower than the lowest NOAEL. Because the estimated doses were based on conservative assumptions about exposures and doses were below the reported NOAEL, no adverse human health effects are expected from exposure to thallium in fish.

Estimated Thallium Doses in Biota	**Non-game fish** (mg/kg/day)
Adult (recreational angler)	0.003
Lifetime resident (subsistence angler)	0.02
Child	0.009

Additional information regarding thallium is provided in this appendix under the discussion of thallium in community and LANL water supplies.

Zinc

Zinc is an essential nutrient needed by the body for normal growth, bone formation, brain development, behavioral response, reproduction, fetal development, sensory function, immune function, membrane stability, and wound healing. Too little zinc can lead to poor health, reproductive problems, and a lowered resistance to disease (ATSDR 1994).

Zinc absorption in humans (8 to 81%) varies with the amount of zinc ingested and the amount and kind of food eaten. The body uses a homeostatic mechanism to control zinc absorption in the gastrointestinal tract. People with adequate nutritional levels of zinc tend to absorb 20 to 30% of ingested zinc, whereas people with zinc deficiencies absorb more. Zinc is one of the most abundant trace metals in the body. Muscle and bone contain about 90% (60% and 30%, respectively) of the total amount of zinc in the body. Zinc can also be found in the liver, gastrointestinal tract, kidney, skin, lung, brain, heart, pancreas, prostate, retina, and sperm (ATSDR 1994).

Estimated doses for children (0.4 mg/kg/day) consuming produce with the maximum detected zinc concentration (54 ppm dry weight) was slightly above the chronic MRL of 0.3 mg/kg/day. Estimated doses for adults/lifetime residents (0.2 mg/kg/day) were below the MRL. The oral MRL for zinc is based on a study in which hematological health effects (i.e., decreased superoxide dismutase activity, hematocrit, and ferritin) were observed when people were given doses of 0.83 mg/kg/day of zinc in capsule form for 10 weeks and is supported by several other studies that investigated effects from zinc supplementation (ATSDR 1994). This NOAEL is greater than the highest dose estimated for zinc exposure at LANL. Based on this information, and the conservative assumptions used to estimate doses, ATSDR concluded that ingestion of zinc in produce is not expected to result in adverse health effects.

Polychlorinated biphenyls

PCBs are a group of man-made chemicals that have become ubiquitous in our environment. They were widely used as coolants and lubricants in transformers, capacitors, and other electrical equipment, but their manufacture in the U.S. stopped in 1977 because of concerns about their toxicity and persistence in the environment (ATSDR 2000g).

PCBs are known to bioaccumulate in the food chain, specifically in fish. For humans, fish are a major dietary source of PCBs, but other animal meat and dairy products can also contain PCBs. Once ingested, PCBs are converted to other chemicals or stored unchanged in fat and the liver. PCBs can be stored in the body for many years (ATSDR 2000g).

Sampling at LANL identified PCBs in non-game fish tissue to a maximum concentration of 0.0316 ppm. Assuming daily ingested on fish containing this PCB concentration, ATSDR estimated doses of 0.00001 mg/kg/day for a recreational angler, 0.00007 mg/kg/day for a subsistence angler, and 0.00003 mg/kg/day for a child. The doses for a subsistence angler and child exceed the RfD (0.00002 mg/kg/day) for Aroclor-1254 (a component of PCBs) and MRL (0.00002 mg/kg/day) for PCBs.

A number of studies have investigated the affects of PCBs on human health, however, uncertainties and shortcomings in these studies make them insufficient for deriving health-based toxicity values. As such, both EPA and ATSDR derived their toxicity values based on a chronic study of monkeys consuming Aroclor-1254. The LOAEL (immunological effects) identified in this study was 0.005 mg/kg/day, which is 70 times higher than the highest, conservatively derived dose for LANL (ATSDR 2000a; EPA 2003a). Based on this information, environmental data, and conservative assumptions, no adverse health effects are expected from consumption of fish caught in water bodies near LANL.

Cancer Effects

Only some contaminants in the environmental have the potential to cause cancer. In non-game fish, arsenic, PCBs, and 12 pesticides are classified as human or probable human carcinogens by EPA. In produce and honey, arsenic (a human carcinogen) was detected; no other carcinogens were detected in these media. (Chromium was also detected in non-game fish, produce, and honey. Chromium is considered a carcinogen, but only through inhalation. Insufficient data are available to assess chromium's carcinogenicity from oral exposures, such as through consumption of biota.) For each of these contaminants, ATSDR estimated doses for an adult and a lifetime resident. The doses and corresponding theoretical excess cancer risk for each contaminant was below 10^{-4}, except for exposures to arsenic in non-game fish, produce, and honey, and PCBs and DDE in non-game fish. As such, for all contaminants except arsenic, PCBs, and DDE, ATSDR concluded that exposures were not expected to pose an increased risk of cancer. ATSDR conducted further evaluation of exposures to arsenic, PCBs, and DDE.

Arsenic

As a conservative estimate, ATSDR assumed that all of the arsenic detected in biota was the more toxic inorganic form. The highest dose for cancer effects from consumption of fish, produce, and honey containing arsenic was 0.002 mg/kg/day for a subsistence angler consuming the maximum detected arsenic level in non-game fish. This dose corresponds with a theoretical excess lifetime cancer risk of 3×10^{-3} (3 new cases in 1,000 exposed people). Based on these findings, ATSDR conducted further review of the toxicology literature to assess potential public health affects.

Estimated Arsenic Doses and Excess Cancer Risk in Biota	**Non-game fish** (mg/kg/day)	**Produce** (mg/kg/day)	**Honey** (mg/kg/day)
Adult (recreational angler)	0.0002 2×10^{-4}	0.0007 1×10^{-3}	0.00002 3×10^{-5}
Lifetime resident (subsistence angler)	0.002 3×10^{-3}	0.002 2×10^{-3}	0.0004 6×10^{-5}

The EPA CSF (used to estimate the theoretical cancer risk once a dose has been established) is based on a study of people drinking water containing 0.17 to 0.8 ppm arsenic for 45 years. Many weaknesses and uncertainties, which may lead to an overestimation of actual risk, have been identified with this study (ATSDR 2000a; EPA 2003a). ATSDR also compared the estimated doses to available CELs, which are doses that produce significant increases in the incidence of cancer or tumors. CELs ranging from 0.0011 mg/kg/day for lung cancer to 3.67 mg/kg/day for bladder cancer were identified, with most CELs near or above 0.02 mg/kg/day for skin and bladder cancers (ATSDR 2000a).

In addition to the toxicological data, ATSDR also reviewed the monitoring data. Estimated exposure doses assumed continuous exposure to the maximum detected concentration of 0.9 ppm

in fish. The next highest detected concentration was 0.25 ppm. For produce, the maximum detected concentration was 0.4 ppm dry weight, followed by 0.2 ppm dry weight. Most years of available monitoring data, however, reported no arsenic in produce. Monitoring of honey also detected a maximum concentration of 0.1 ppm arsenic, followed by 0.01 ppm arsenic. Because people would actually consume lower doses of arsenic than assumed using the maximum detected concentration, actual doses would be lower than the conservatively estimated doses. Considering this information, ATSDR does not expect people who ingest arsenic in biota to be at an increased risk of cancer.

DDE

DDE is a breakdown product of the infamous pesticide DDT. DDT was widely used to control insects until 1972, when DDT was banned in the U.S. because of its environmental impacts. DDT and its breakdown products (DDD and DDE) are currently found throughout the globe. DDT, DDD, and DDE bioaccumulate in the food chain; reaching higher concentrations in higher-level animals. As such, consumption of meat, fish, poultry, and dairy products are the primary sources for people. Once ingested, DDE is primarily stored in the fatty tissue and slowly excreted in urine (ATSDR 2000c).

Rather than a specific LANL source, DDE is likely present in non-game fish caught near LANL as a result of the widespread use of DDT. Regardless of the source, ATSDR evaluated potential public health impacts from DDE ingestion in non-game fish. DDE was detected in non-game fish at a maximum concentration of 0.142 ppm. The doses for a recreational and subsistence angler consuming fish with this concentration of DDE were 0.00002 mg/kg/day and 0.0003 mg/kg/day, respectively. EPA has classified DDE as a probable human carcinogen. A dose of 0.00002 mg/kg/day corresponds with a theoretical excess cancer risk of 8×10^{-6} (8 new cases in 1,000,000 exposed people). A dose of 0.0003 mg/kg/day for a subsistence angler corresponds with a theoretical excess cancer risk of 1×10^{-4} (4 new cases in 10,000 exposed people).

Further review of the toxicology literature to assess potential public health effects identified a number of studies of the carcinogenicity of DDE in humans, but these studies have been inconclusive. EPA derived the CSF based on two studies in rats and one study in hamsters. Increases liver tumors in rats at doses of 0.9 mg/kg/day and 2.45 mg/kg/day. Increases in thyroid tumors in hamsters were observed at a dose of 4.79 mg/kg/day (EPA 2003a). These doses are at least 3,000 times higher than the conservatively estimated exposure dose for a subsistence angler consuming fish with the maximum detected DDE concentration. As such, no excess cancers from DDE exposures are expected from consumption of fish caught near LANL.

Polychlorinated biphenyls

PCBs have been classified as probable human carcinogens by EPA. ATSDR estimated exposure doses for recreational and subsistence anglers consuming PCBs in fish caught near LANL. The estimated dose for a recreational angler (0.000005 mg/kg/day) corresponds with a theoretical excess cancer risk of 1×10^{-5} (1 new cases of cancer for 100,000 exposed people). For a subsistence angler, the estimated exposure dose of 0.00008 mg/kg/day corresponds with a theoretical excess cancer risk of 2×10^{-4} (2 new case of cancer for 10,000 exposed people).

EPA developed the CSF based on a study of rats exposed to four different PCB congeners and a study of rats exposed to a group of PCBs. Each of these studies showed increased cases of liver

tumors; the lowest doses at which tumors were seen ranged from 0.35 to 1.3 mg/kg/day (EPA 2003a). The lowest of these doses is over 4,000 times greater than the estimated dose for a subsistence angler regularly consuming fish containing the maximum detected PCB concentrations. As such, ATSDR expects no increase in cancer incidences as a result of concentrations of PCBs found in fish near LANL. Additional information regarding PCBs is provided in this appendix under the discussion of non-cancer effects associated with PCBs in biota.

Radiation Effects

During biota monitoring, a total of 23 radionuclides were sampled for and detected in the various biota analyzed. As described under the evaluation of radiation effects from contact with radionuclides in surface soil, estimated exposure doses were calculated for adults and children. ATSDR selected conservative assumptions when estimating dose to ensure consideration of Native American uses of the land and biota surround LANL. Again, ATSDR assumed that people were exposed to the maximum detected concentration of each radionuclide detected in each locally grown or harvested food item (e.g., fish, game, produce).

Based on these conservative assumptions, ATSDR estimated that an adult would receive a dose of 38 mrem/yr and a child would receive a dose of 19 mrem/yr from consumption of locally grown food items found in accessible area in and around LANL. These doses are below the DOE standard of 100 mrem/yr and well below levels where adverse health effects have been reported (10,000 mrem).

Multiple Pathway Exposures

In addition to considering possible adverse health effects from exposure through a single exposure pathway, ATSDR recognizes that members of the community may be exposed to a contaminant found in multiple media at LANL. For example, a person may be exposed to arsenic in drinking water and to arsenic in surface water and sediment during recreational use of the canyons surrounding LANL. As such, ATSDR identified contaminants found above their CVs in multiple media, including:

- Chloride (drinking water, surface water)
- Fluoride (drinking water, surface water, biota)
- Perchlorate (drinking water, surface water)
- Sodium (drinking water, surface water)
- Antimony (surface water, biota)
- Arsenic (drinking water, surface soil, surface water, sediment, biota)
- Barium (surface water, biota)
- Beryllium (surface water, biota)
- Boron (drinking water, surface water, biota)
- Cadmium (drinking water, surface water, sediment, biota)
- Chromium (drinking water, surface water, biota)
- Copper (drinking water, biota)
- Iron (drinking water, surface water, sediment)
- Lead (drinking water, surface water, biota)
- Manganese (surface water, sediment)

- Mercury (drinking water, biota)
- Nickel (surface water, biota)
- Silver (drinking water, biota)
- Thallium (drinking water, biota)
- Vanadium (drinking water, surface water)
- Uranium (surface water, biota).

Six radioactive components were also detected above CVs in drinking water, surface soil, surface water and/or sediment (americium-241, cesium-137, gross alpha, plutonium-238, plutonium 239/240, and strontium-90). A total of 23 radioactive components were found in biota; no CVs are available for radionuclides in biota

As noted previously, exposure to contaminants detected above CVs does not necessarily result in adverse health effects. Rather, additional examination, as presented for the individual pathway evaluations, is warranted.

Non-cancer and Cancer Effects

To evaluate combined doses from contaminants found in multiple exposure pathways, ATSDR summed the contaminant-specific dose estimated for each pathway. Using arsenic as an example, the combined dose is the sum of the arsenic doses calculated individually for drinking water, surface soil, surface water, sediment, and biota. Using this method, ATSDR estimated what could be considered extremely conservative combined doses, which reflect the conservative assumptions used to estimate the individual media doses. More specifically, ATSDR assumed that people were exposed to only the maximum detected concentration of a contaminant; people ingested/inhaled/contacted relatively large amounts of a media; and people were exposed at relatively long durations and frequencies. Reviewing the assumptions used to estimate doses for exposure to contaminants in drinking water illustrates these conservative, and therefore protective, assumptions. More information about the assumptions applied for each exposure pathway is presented in the relevant sections of this appendix. For drinking water, ATSDR assumed that a person would ingest 2.3 liters of groundwater containing the maximum detected contaminant concentration every day for 33 years. The maximum detected concentration represents the worst-case scenario, regardless that monitoring data often report detections at much lower concentrations as well. The ingestion amount—2.3 liters per day—is based on studies finding that 90% of the population drink 2.3 liters of fluids or less every day, including non-drinking water sources such as soda, bottled water, juice, and other beverages (EPA 1997). ATSDR, therefore, has assumed that all fluids consumed in a day are from a single source. The duration of 33 years accounts for the findings that 90% of the population live in a single home for 33 years or less.

For chemicals detected above CVs in LANL media, estimated doses from exposure through use of groundwater as drinking water and consumption of locally grown foods (biota) were higher than doses estimated for exposures to other LANL media. As with the exposures evaluated for individual pathways, ATSDR reviewed estimated doses, available toxicological literature, and environmental data to further assess exposures to contaminants found in multiple pathways. For contaminants detected in LANL media, except arsenic, the estimated doses for combined pathways were below the contaminant's NOAEL or LOAEL. The combined arsenic dose (0.016

mg/kg/day) for a child slightly exceeded the arsenic LOAEL (0.014 mg/kg/day), with the more than half of this dose resulting from exposure to arsenic in drinking water. As described in the discussion of arsenic in drinking water in this appendix, arsenic is not considered a potential health hazard because the maximum detected concentration is double the next highest detection (110 ppb versus 52 ppb), ATSDR assumed all the arsenic detected was present in it's most toxic form, and water supplies must comply with state and federal arsenic standards. In addition to arsenic, the maximum detected concentration of other chemicals was often higher (twice or more times higher) than the next highest detection. Based on estimated doses, a review of the toxicological literature and environmental data, and evaluation of conservative assumptions, ATSDR concluded that combined doses from exposure to contaminants in multiple pathways would not be expected to result in adverse health effects.

Radiation Effects

Radionuclides release radiation through their decay or breakdown. Regardless of the radionuclide, damage to cells occurs when a radionuclide releases protons, electrons, neutrons, or energy. In some cases, a damaged cell survives, mutates, and becomes a cancer-causing cell. As such, exposure to radiation is a human health concern because of its potential to result in an increased risk of cancer. For radionuclides, the individual pathways doses account for the similar mode of action of radionuclides and are presented as a single dose. ATSDR, therefore, summed the doses for each media to estimate the dose from multiple pathway exposures. Similar to estimating non-cancer and cancer effects for chemical contaminants, the individual doses for radionuclides are also estimated using conservative assumptions about how much, how long, and how often exposures occur. ATSDR assumed exposure to the maximum detected concentrations, regardless of source—naturally occurring levels or hazardous releases. These assumptions result in conservative doses that likely overestimate estimate actual doses.

At LANL, the total radiation dose for adults (42 mrem/year) is driven by the doses from consuming locally grown food (biota) (38 mrem/yr). For children, the total radiation dose (27 mrem/year) is also driven by consuming locally grown food (biota) (19 mrem/yr). Regardless, doses are below the DOE standard of 100 mrem/yr, and well below levels where adverse health effects have been reported (10,000 mrem). Because the combined dose is below DOE standards and levels with reported health effects even when using conservative exposure assumptions, ATSDR concluded that exposure to radionuclides in multiple pathways is not expected to result in adverse health effects.

References

Agency for Toxic Substances and Disease Registry (ATSDR). 1990. Toxicological profile for silver. Atlanta: US Department of Health and Human Services.

ATSDR. 1992a. Toxicological Profile for Antimony. Atlanta: US Department of Health and Human Services.

ATSDR. 1992b. Toxicological Profile for Barium and Compounds. Atlanta: US Department of Health and Human Services.

ATSDR. 1992c. Toxicological Profile for Boron. Atlanta: US Department of Health and Human Services.

ATSDR. 1992d. Toxicological Profile for Thallium. Atlanta: US Department of Health and Human Services.

ATSDR. 1992e. Toxicological Profile for Vanadium and Compounds. Atlanta: US Department of Health and Human Services.

ATSDR. 1994. Toxicological Profile for Zinc. Atlanta: US Department of Health and Human Services.

ATSDR. 1995. Toxicological Profile for Polycyclic Aromatic Hydrocarbons. Atlanta: US Department of Health and Human Services.

ATSDR. 1997. Toxicological Profile for Nickel. Atlanta: US Department of Health and Human Services.

ATSDR.1999a. Toxicological Profile for Cadmium. Atlanta: US Department of Health and Human Services.

ATSDR.1999b. Toxicological Profile for Ionizing Radiation. Atlanta: US Department of Health and Human Services.

ATSDR.1999c. Toxicological Profile for Lead. Atlanta: US Department of Health and Human Services.

ATSDR. 2000a. Toxicological Profile for Arsenic (Update). Atlanta: US Department of Health and Human Services.

ATSDR. 2000b. Toxicological Profile for Chromium. Atlanta: US Department of Health and Human Services.

ATSDR. 2000c. Toxicological Profile for DDT, DDD, and DDE. Atlanta: US Department of Health and Human Services.

ATSDR. 2000d. Toxicological Profile for Manganese. Atlanta: US Department of Health and Human Services.

ATSDR. 2000e. Toxicological Profile for Mercury (Update). Atlanta: US Department of Health and Human Services.

ATSDR. 2000f. Toxicological Profile for Methylene Chloride. Atlanta: US Department of Health and Human Services.

ATSDR. 2000g. Toxicological Profile for Polychlorinated Biphenyls. Atlanta: US Department of Health and Human Services.

ATSDR. 2001a. Toxicological Profile for Fluorine, Hydrogen Fluoride, and Fluorides. Atlanta: US Department of Health and Human Services.

ATSDR. 2001b. Toxicological Profile for Selenium. Atlanta: US Department of Health and Human Services.

ATSDR. 2002a. Toxicological Profile for Di(2-ethylhexyl)phthalate. Atlanta: US Department of Health and Human Services.

ATSDR. 2002b. Toxicological Profile for Copper. Atlanta: US Department of Health and Human Services.

Austin Nutritional Research (ANR). 2001. Reference guide for minerals. Available from: http://www.realtime.net/anr/minerals.html. Last accessed May 27, 2003.

Eisenstein RS and Blemings KP. 1998. Iron regulatory proteins, iron responsive elements and iron homeostasis. J Nutr 128: 2295-298.

[EPA 1989] US Environmental Protection Agency. 1989. Risk assessment guidance for Superfund, Volume I, human health evaluation, Part A. Office of Emergency and Remedial Response. Publication EPA/540/1-89/002. December 1989. Available at: http://www.EPA.gov/superfund/programs/risk/ragsa/index.htm. Last accessed July 22, 2003.

[EPA 1991] US Environmental Protection Agency. 1991. Toxicological review of selenium and compounds. Washington, DC.

[EPA 1997] US Environmental Protection Agency.1997. Exposure factors handbook. Available at: http://www.EPA.gov/ncea/exposfac.htm. Last accessed July 22, 2003.

[EPA 2000] US Environmental Protection Agency. 2000. Radionuclides notice of data availability technical support document. Office of Ground Water and Drinking Water in collaboration with Office of Indoor Air and Radiation and United States Geological Survey. March 2000. Available at: http://www.EPA.gov/ogwdw000/rads/tsd.pdf. Last accessed July 22, 2003.

[EPA 2001] US Environmental Protection Agency. 2001. Risk assessment issue paper for: derivation of the provisional RfD for iron (CASRN 7439-89-6) and compounds. National Center for Environmental Assessment. Superfund Technical Support Center.

[EPA 2002a] US Environmental Protection Agency. 2002a. Perchlorate environmental contamination: toxicological review and risk characterization (external review draft). Available at: http://cfpub.EPA.gov/ncea/cfm/recordisplay.cfm?deid=24002. Last accessed July 22, 2003.

[EPA 2002b] US Environmental Protection Agency. 2002b. National recommended water quality criteria: 2002. November 2002. Available at: http://www.EPA.gov/ost/drinking/standards/. Last accessed July 22, 2003.

[EPA 2003a] US Environmental Protection Agency. 2003a. Integrated Risk Information System. Available at: http://www.EPA.gov/iris/. Last accessed July 22, 2003.

[EPA 2003b] US Environmental Protection Agency. 2003b. List of drinking water contaminants and maximum contaminant levels. Office of Groundwater and Drinking Water. Available at: http://www.EPA.gov/safewater/mcl.html#1. Last accessed July 22, 2003.

[FDA 1993] US Food and Drug Administration. 1993. Guidance document for arsenic in shellfish. US Department of Health and Human Services, Public Health Service, Food and Drug Administration, Center for Food Safety and Applied Nutrition. Washington, DC. January 1993. Available at: http://www.foodsafety.gov/~frf/guid-as.html. Last accessed July 22, 2003.

[FDA 1997] US Food and Drug Administration. 1997. Preventing iron poisoning in children. FDA Backgrounder. January 15, 1997. Available from URL: http://vm.cfsan.fda.gov/~dms/. Last accessed July 22, 2003.

Francesconi KA and Edmonds JS. 1997. Arsenic and marine organisms. Adv Inorg Chem 44:147–89.

[LANL 1998] Los Alamos National Laboratory. 1998. Environmental surveillance at Los Alamos During 1998. LA-13633-ENV.

[LANL 2000] Los Alamos National Laboratory. 2000. Environmental srveillance at Los Alamos During 1999. LA-13775-ENV.

[NAS 2001] National Academy of Sciences (NAS). 2001. Dietary reference intakes for vitamin A, vitamin K, arsenic, boron, chromium, copper, iodine, iron, manganese, molybdenum, nickel, silicon, vanadium, and zinc. Washington, DC: National Academy Press. Available at: http://books.nap.edu/books/0309072794/html/index.html. Last accessed July 22, 2003.

University of Kansas. 2002. Water quality: sodium in drinking water. Available at: http://www.oznet.ksu.edu/library/H20QL2/MF1094.PDF. Last accessed July 22, 2003.

[USDA 1996] US Department of Agriculture. 1996. Data tables: food and nutrient intakes by individuals in the United States, by region, 1994–96, Table Set 13. Continuing survey of food intakes by individuals, 1994–96. Food Surveys Research Group. Available at: http://www.barc.usda.gov/bhnrc/foodsurvey/pdf/Region.pdf. Last accessed July 22, 2003.

Notes:

ATSDR	Agency for Toxic Substances and Disease Registry
CEL	cancer effects level
CSF	cancer slope factor
CV	comparison value
DOE	Department of Energy
EPA	United States Environmental Protection Agency
FDA	Food and Drug Administration
LANL	Los Alamos National Laboratory
LOAEL	lowest-observable-adverse-effects level
MCL	EPA maximum contaminant level
MRDL	EPA maximum residual disinfectant levels
mrem/yr	millirem/year
MRL	minimal risk level
NOAEL	no-observable-adverse-effects level
PCB	polychlorinated biphenyls
pCi/g	picocuries/gram
pCi/L	picocuries/liter
PHA	public health assessment
ppm	parts per million
TA	technical area
µg/dL	micrograms/deciliter
mg/kg/day	milligrams chemical/kilograms body weight/day