Core Document for Canyons Investigations

Environmental
Restoration
Project

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A Department of Energy
Environmental Cleanup Program

Los Alamos
NATIONAL LABORATORY

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EXECUTIVE SUMMARY

Purpose

This Resource Conservation and Recovery Act (RCRA) facility investigation (RFI) document establishes the technical approach and methodology for environmental investigations of the major canyon systems at Los Alamos National Laboratory (hereafter "the Laboratory"). Specifically, the purposes of the canyons investigations are to evaluate the present-day human health and ecological risks from Laboratory-derived contaminants within the canyon systems and to assess future impacts from the transport of these contaminants. To achieve these goals, canyons investigations will

- determine the potential for contaminant transport into or within major canyon watersheds;
- evaluate human health risks and ecological impacts associated with the presence of contaminants, as needed;
- refine the conceptual model for contaminant occurrence and transport;
- assess the potential for interconnections between groundwater in alluvium, perched intermediate zones, and the regional aquifer; and
- assess the projected impact that contaminants may have on off-site receptors and the Rio Grande.

This core document presents a technical approach that will be applied to the investigations of the 19 major canyon systems that are, or may have been, affected by Laboratory operations. This document provides information common to all sampling and analysis plans (SAPs) for investigations in the canyon systems including the regulatory and programmatic framework for the investigations, historical background information on area land uses and Laboratory operations, regional environmental setting, conceptual model for contaminant occurrence, transport, and exposure route (hereafter "the conceptual model") in the canyon systems, technical approach, and approach to present-day human health risk assessment and ecological impact assessment. The groundwater investigations outlined in this document were developed in cooperation with other Laboratory investigators who are responsible for groundwater issues. As a result of these consultations, canyons groundwater investigations are an integral part of the Laboratory's Hydrogeologic Workplan, developed for the Groundwater Protection Management Program Plan.

Response to Regulatory Requirements

The Laboratory Environmental Restoration (ER) Project addresses the requirements of Module VIII of the Laboratory's Hazardous Waste Facility Permit (the Hazardous and Solid Waste Amendments [HSWA] Module) (modification dated May 19, 1994), which was issued by the Environmental Protection Agency (EPA) to address corrective actions at the Laboratory. The New Mexico Environment Department (NMED) is the Administrative Authority for the HSWA Module. This document addresses and satisfies a portion of the requirements in Module VIII, Sections I.5 and Q, Tasks I through V, of the HSWA Module.

Because the canyons are identified as transport pathways for contaminants migrating across and off the Laboratory rather than as the sources of contaminants, a distinction is created between the HSWA Module requirements for investigations of the canyon systems and the HSWA Module requirements for investigations of solid waste management units (SWMUs). These canyon pathways cross American Indian, private, and public land and eventually contribute sediments, surface water, and groundwater to the Rio Grande. Because the canyons and the associated transport processes, rather than distinct SWMUs, are identified as the focus, the canyons investigations are different from SWMU-based investigations, in both a regulatory and a scientific perspective.

Therefore, the scope of a task/site work plan for canyons investigations is significantly different from the scope of previous RFI work plans for investigations of SWMUs. Canyons task/site work plans deal with the investigation of affected media within the canyon systems rather than the investigation of SWMUs. The general technical approach presented in this core document and the SAPs for specific investigations are designed to address the broad requirements contained in the HSWA Module Sections I.5 and Q.

Background

Description of Field Unit 4

Field Unit 4, one of the six major field units in the ER Project, includes three operable units (OUs): OU 1098, OU 1129, and OU 1049. OU 1049 comprises 19 canyon systems with approximately 110 miles of canyon and drainage systems located on property controlled by the Laboratory. For purposes of planning and conducting the investigations of these canyon systems, the 19 canyons have been consolidated into 8 groups and prioritized for investigation according to these four criteria:

- potential for risk to human health and the environment (canyons judged to pose the highest potential risk are placed at highest priority for investigation);
- known presence of contamination (canyons known to contain Laboratory-derived contaminants, based on records of prior use and/or monitoring data, are placed at high priority for investigation);
- amount of data available on sources, occurrence, distribution, and severity of contamination; and
- geographic proximity (adjacent canyons are combined for investigation if other criteria are also similar for the canyons).

Future Task/Site Work Plans/SAPs

This core document supports the preparation of the canyon-specific SAPs by providing information that is common to all the plans. The *Task/Site Work Plan for Operable Unit 1049: Los Alamos Canyon and Pueblo Canyon* was developed before this core document and therefore is a stand-alone document that contains all the sections found in an RFI work plan. The remaining seven task/site work plans will be primarily SAPs and will be prepared in the following few years. These canyon- or canyon aggregate-specific SAPs will address the remaining canyon systems of the Pajarito Plateau that are known to have been, or may have been, affected by Laboratory operations (see Table 1-1 in Chapter 1 of this document).

This core document will be used as an umbrella document for the seven remaining SAPs, providing most of the information typically required in stand-alone task/site work plans, information which is common to all the canyon systems. Each of the seven SAPs will have only an introduction, a discussion of the historical background including potential contaminants in and contaminant sources for the specific canyon system(s), a description of the issues concerning the environmental setting of the specific canyon system(s), and the sampling and analysis methods and the quality assurance procedures that will be followed in the investigation. This approach is expected to effectively and efficiently satisfy the permit requirements.

Public Involvement

At the beginning of calendar year 1992, the ER Project established a public involvement effort. The ER Project Office schedules informal and formal meetings with the general public, the neighboring Indian Pueblos, and ER Project advisory groups. The purpose of these meetings is to involve these groups with the ER Project and its goals within the RCRA regulations. Activities undertaken for this core document include formal interactions with the Pueblos of San Ildefonso, Santa Clara, Cochiti, and Jemez, which have formal accords and agreements with the Department of Energy (DOE) and the Laboratory. (These Indian Pueblos are referred to as the “Accord Pueblos” in this core document.) These interactions result in suggested approaches for the SAPs and for risk assessment. In addition, the ER Project has employed Indian Pueblo members to work on the field characterization teams. The intent of these interactions is to allow the American Indian perspective to become an integral part of the preparation and execution of the canyons SAPs.

Conceptual Model and Technical Approach

One of the significant distinctions of the canyons investigations compared with a SWMU-based RFI is the responsibility to investigate the canyons as an integrated natural system. This integration is accomplished through a conceptual model which guides the technical approach to the investigations and is refined by the findings of each successive investigation. The canyons that drain the Pajarito Plateau at the Laboratory are geologically, hydrologically, and ecologically diverse. This diversity and wide geographic extent coupled with the common investigation objectives for all canyons necessitates a flexible and broadly applicable methodology for these studies that is based on well-defined regulatory and technical issues applicable to the canyons.

The characterization study area is bounded on the west by the Laboratory boundary, on the east by the Rio Grande, in the canyon floors laterally from the stream channel to the edge of the modern floodplain deposits, and in the stream channel vertically to the deepest groundwater bodies affected by regulatorially defined limits of contaminant concentrations. The characterization data is used, as needed, to develop risk scenarios based on Laboratory use, recreational land use, traditional use by American Indians, and residential use such as at Totavi, Otowi, and Halladay Houses or potential new communities. Risk scenarios based on impacts to future generations are recognized as possible products of these investigations but are not explicitly dealt with at this time. Qualitative evaluation of long-term changes will be addressed.

The canyon characterization activities are designed to collect data for risk assessment based on present-day contaminant levels, to evaluate the potential impact of contaminant transport into and within the watersheds and, subsequently, to transition to a long-term monitoring program. The conceptual model of contaminant transport and the framework for investigations of human or ecological risk at future times need to be refined before studies of future risk can be undertaken. Transferring ongoing characterization activities to the Laboratory’s long-term monitoring program ensures that later, when more detailed regulatory guidance and conceptual (and numerical) models are available, studies of current and future risk can be performed.

Sampling and Analysis Strategy

Characterization activities in the canyons investigations will include

- detailed mapping and description of the geomorphology of selected canyon reaches;

- drilling and coring of boreholes to elucidate details on the hydrogeologic structure of the Pajarito Plateau;
- sampling and analysis of surface and near-surface sediments on the canyon floors to evaluate surface exposure pathways, historic contaminant transport, and potential sources for migration to groundwater; and
- sampling and analysis of surface and groundwater to assess the transport pathways and potential impacts on the different zones of saturation.

The sampling strategy is designed to gain an understanding of the nature of the contaminants present. This understanding will be gained initially through a biased sample location selection strategy and analyses of a limited number of samples for a broad, comprehensive suite of contaminants. The initial analyses will enable identification of contaminants actually present, and subsequent investigation will limit analyses to the suite of known contaminants.

For example, sediment sampling and analysis is largely restricted to post-1942 canyon deposits in both the active channels and the floodplains. Furthermore, SAPs will focus on identifying areas *most likely* to contain contaminants, determining the geomorphic settings where the greatest contaminant inventories could occur (post-1942 sediments), and assessing the susceptibility of the contaminants to redistribution in sediments and dust. Mesa tops, alluvial and colluvial deposits on canyon walls, and drainages of canyon walls may contain contaminants from individual potential release sites. These sites will be characterized as part of RFIs conducted by other ER Project field units.

Because there is a high probability that Laboratory-derived contamination is predominantly radioactive and that there are associated radioactive components in virtually all waste streams serving as canyon contamination source terms, the initial sampling strategy relies heavily on the use of radiological surveys and geomorphologic mapping to give a broad view of the distribution of contaminants within surface sediments. Discrete sampling points will be identified initially using radiological screening surveys and geomorphologic features.

In all sediment sampling and analyses, the selection criteria for location and analytical protocols will be designed to develop the best possible data set at the most reasonable cost. An iterative technique will be used to select locations for additional sampling and analysis to minimize uncertainty in the spatial distributions of contaminant concentrations. The iterative strategy will allow the investigators to adjust the characterization activities to observed conditions in the field. This approach will ultimately lead to a well-defined and quantitative understanding of the natural systems and processes involved in contaminant occurrence and transport in the canyon systems.

Plans for groundwater investigations also will focus on areas most likely to contain contaminants, such as the near-surface alluvial groundwaters downgradient of known release sites. Results of these groundwater investigations are also used for enhancing current Laboratory groundwater monitoring systems, if necessary. Studies of the deep unsaturated zone and the regional aquifer will provide information about contaminants in intermediate perched zones and the top of the regional aquifer. Proposed boreholes drilled to investigate these deep groundwater systems are initially sited downgradient of potential release sites with large inventories and where Laboratory surveillance data indicate that Laboratory-derived contaminants are present in the deeper groundwater systems. Groundwater investigations will follow an iterative approach in which information obtained from each borehole will be evaluated in the context of the hydrogeological portion of the conceptual model. These ongoing evaluations will be made in collaboration with other investigators implementing the

Hydrogeologic Workplan and may lead to changes in the locations and numbers of future boreholes. Changes in the scope of groundwater investigations will be negotiated annually with regulators.

Schedule and Reporting

Annex I of this document contains a preliminary schedule for conducting the canyons investigations. The schedule is subject to change based on future DOE funding.

The Laboratory, DOE, NMED, EPA, and the stakeholders have not produced a final definition of the types and schedule of reports for the efforts in task/site work plans and SAPs. Because the canyons contain no SWMUs, reporting schedules pertinent to the HSWA Module are not directly applicable.

The HSWA Module contains no specific submittal requirements for the canyons investigations. The HSWA Module Section P (Facility Submission Summary) allows for the schedule of submittal of task/site work plans to be specified in the Installation Work Plan (IWP) for the ER Project, indicating that the dates of submittal may change annually with each IWP update. The Laboratory will continue to submit to NMED information on the canyons investigations in the monthly and quarterly reports. Every effort is directed at creating an efficient schedule and communicative format for reporting the results of canyons investigations. Procedures for reporting results of the canyons investigations are recommended in Chapter 7 of this core document. They include SAPs for each of the canyon and canyon aggregate investigations and a report at the completion of each canyon or canyon aggregate investigation. Each SAP in sequence during the investigations will integrate the experience and findings of prior investigations into a refined conceptual model and modified sampling and analysis techniques.

Consistent with the technical approach, the Laboratory will notify NMED if any results indicate the need for an immediate interim action or remedial action. The action will be initiated following the approach agreed to by the Laboratory, DOE, and the regulators for the ER Project.

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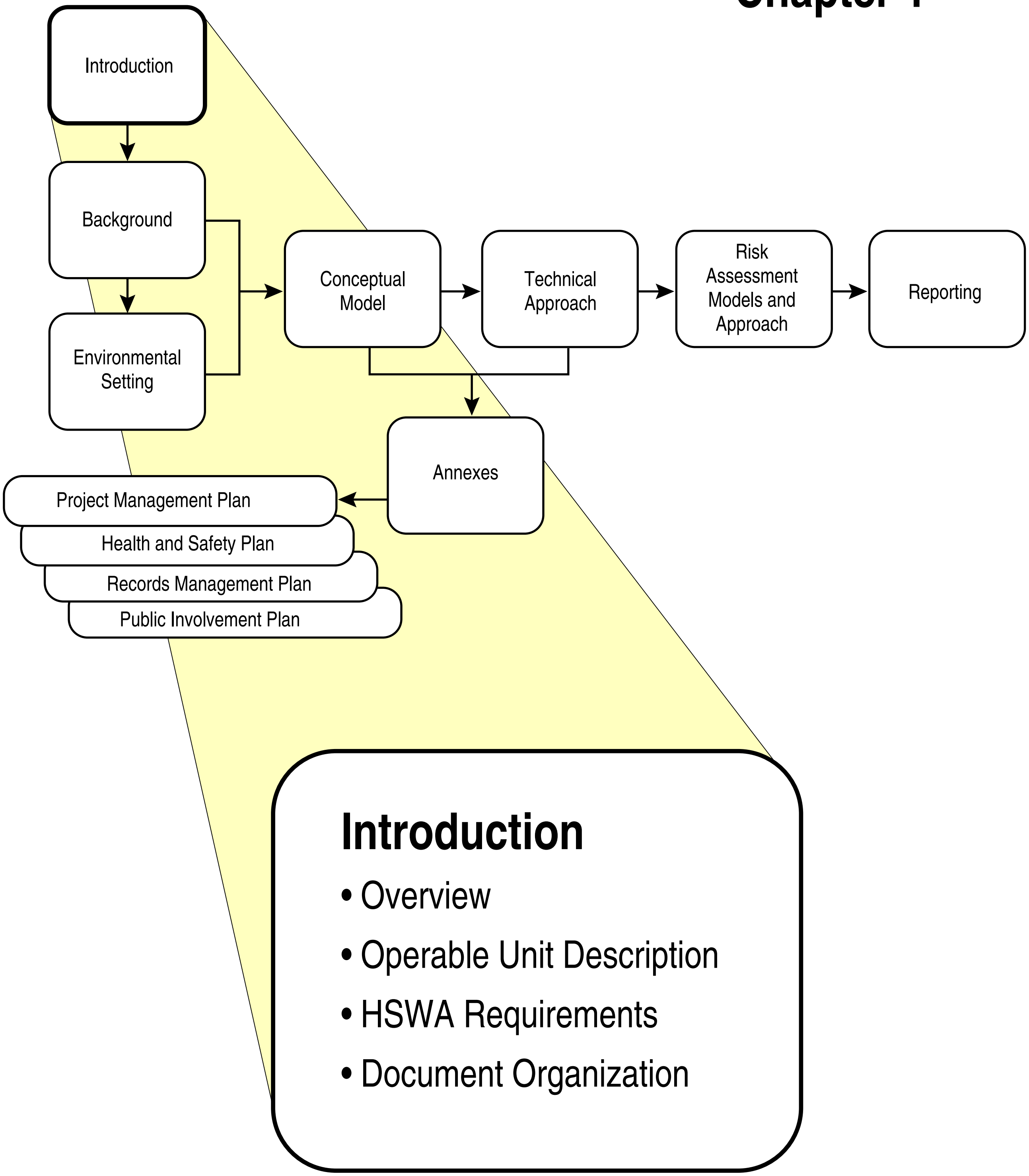
ACRONYMS AND ABBREVIATIONS

ACGIH	American Conference of Governmental Industrial Hygienists
AEC	Atomic Energy Commission
AOC	area of concern
BIA	US Bureau of Indian Affairs
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
CGI	combustible gas indicator
CMS	corrective measures study
COPC	chemical of potential concern
CU	University of Colorado
CWA	Clean Water Act
DAC	derived air concentration (DOE draft order 5480.11)
DOE	Department of Energy
DQO	data quality objective
EM	Environmental Management (Laboratory Program)
EPA	Environmental Protection Agency
ER	Environmental Restoration
ESG	Environmental Surveillance Group
ESH	Environment, Safety, and Health (Laboratory Division)
FIDLER	field instrument for detecting low-energy radiation
FIMAD	Facility for Information Management, Analysis, and Display
FPL	field project leader
FUSRAP	Formerly Utilized Sites Remedial Action Program
GI	gastrointestinal
GPMPP	Groundwater Protection Management Program Plan
HASP	health and safety plan
H&S	health and safety
HSWA	Hazardous and Solid Waste Amendments
ID	inside diameter
IWP	Installation Work Plan
LAMPF	Los Alamos Meson Physics Facility
LEL	lower explosive limit
Ma	million years
MCL	maximum contaminant level
MDA	material disposal area
MOU	memorandum of understanding
MSL	mean sea level
NIOSH	National Institute for Occupational Health
NM	New Mexico
NMED	New Mexico Environment Department
NPDES	National Pollutant Discharge Elimination System

NS	Not surveyed
NWT	Nuclear Weapons Technology
OD	outside diameter
OSHA	Occupational Safety and Heath Administration
OU	operable unit
PCB	polychlorinated biphenyl
PEL	permissible explosive level (OSHA/NIOSH)
PRG	preliminary remediation goal
PRS	potential release site
PVC	polyvinyl chloride
QA	quality assurance
QAPP	Quality Assurance Project Plan
QC	quality control
RAM	real-time aerosol monitor
RCRA	Resource Conservation and Recovery Act
RFI	RCRA facility investigation
RPF	Records-Processing Facility
SAP	sampling and analysis plan
SI	saturation index
SOP	standard operating procedure
SPCC	spill prevention control and countermeasures (Laboratory Program)
STEL	short-term exposure level (OSHA/NIOSH)
STP	sewage treatment plant
SVOC	semivolatile organic compound
SWSC	Sanitary Wastewater Systems Consolidation
SWMU	solid waste management unit
TA	technical area
TDS	total dissolved solids
TLD	thermoluminescent dosimeter
TSD	treatment, storage, and disposal
TWA	time-weighted average
UC	University of California
USDA	United States Department of Agriculture
US	Unites States
USGS	United States Geological Survey
VCA	voluntary corrective action
WMPP	Watershed Management Program Plan
WSC	waste stream identification and characterization (program)

Chapter 1



Introduction

- Overview
- Operable Unit Description
- HSWA Requirements
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1.0 INTRODUCTION

1.1 Purpose

This core document discusses investigations to be conducted in canyon systems as part of the Environmental Restoration (ER) Project Operable Unit (OU) 1049, the canyons OU at Los Alamos National Laboratory (hereafter "the Laboratory"). These canyons investigations will evaluate the effects of past and current Laboratory releases into the major canyon systems of the Pajarito Plateau.

This document describes the scope and general technical approach for investigations in all canyons that were part of historical operations at the Laboratory or that now cross property controlled by the Laboratory. It contains background information that is common to all canyon systems, and is intended to be a companion document to sampling and analysis plans (SAPs) that will be prepared for each canyon or canyon aggregate as described below. This document is consistent with the requirements of Module VIII of the Laboratory's Hazardous Waste Facility Permit (EPA 1990, 1585) (hereafter "the HSWA Module"), meets the requirements of the Environmental Protection Agency (EPA) and the New Mexico Environment Department (NMED) under the Resource Conservation and Recovery Act (RCRA) as amended by the Hazardous and Solid Waste Amendments (HSWA) and is in accordance with related Department of Energy (DOE) orders. This core document, together with canyon- or canyon aggregate-specific SAPs, addresses the requirements of the HSWA Module.

This core document is intended to be the upper-level-tier document for subsequent SAPs for investigations in individual canyons and canyon aggregates. Its purpose and function is to provide text common to all SAPs for the introduction (including regulatory and programmatic frameworks for the investigations), background (historical) information, environmental setting, conceptual model for contaminant occurrence, transport, and exposure route (hereafter "the conceptual model") in the canyons, overall technical approach, and present-day human health and ecological risk assessment.

This introductory chapter explains the structure of the canyons investigations and gives a brief summary of the HSWA Module requirements for these investigations.

1.2 Description of the Canyons Operable Unit

1.2.1 General Setting

Los Alamos County is situated on the Pajarito Plateau, a region 5 to 6 miles wide and 6,200 to 7,700 ft above sea level, between the 10,500-ft-high Jemez Mountains to the west and the 5,500-ft-high Rio Grande Valley and White Rock Canyon to the east (Figure 1-1). The plateau is cut by many deep canyons that run generally west-northwest to east-southeast from the mountains to the Rio Grande. Developments within Los Alamos County include the Los Alamos and White Rock residential areas and the Laboratory technical areas. The Los Alamos townsite and most of the Laboratory technical areas occupy relatively flat mesa tops situated between the canyons. A more in-depth description of the regional geologic and hydrologic setting is found in Chapter 3 of this document and in Chapter 2 of the Laboratory-wide Installation Work Plan (IWP) (LANL 1996, 55574).

Nineteen significant canyon systems drain surface water from the Laboratory sites located on the Pajarito Plateau (Figure 1-2). Most of the reaches of these canyons within the Laboratory boundaries are ephemeral. Runoff flows naturally but briefly in response to spring snowmelt and precipitation events, mostly summer thunderstorms. During these events the runoff drains rapidly from the flanks of the Jemez

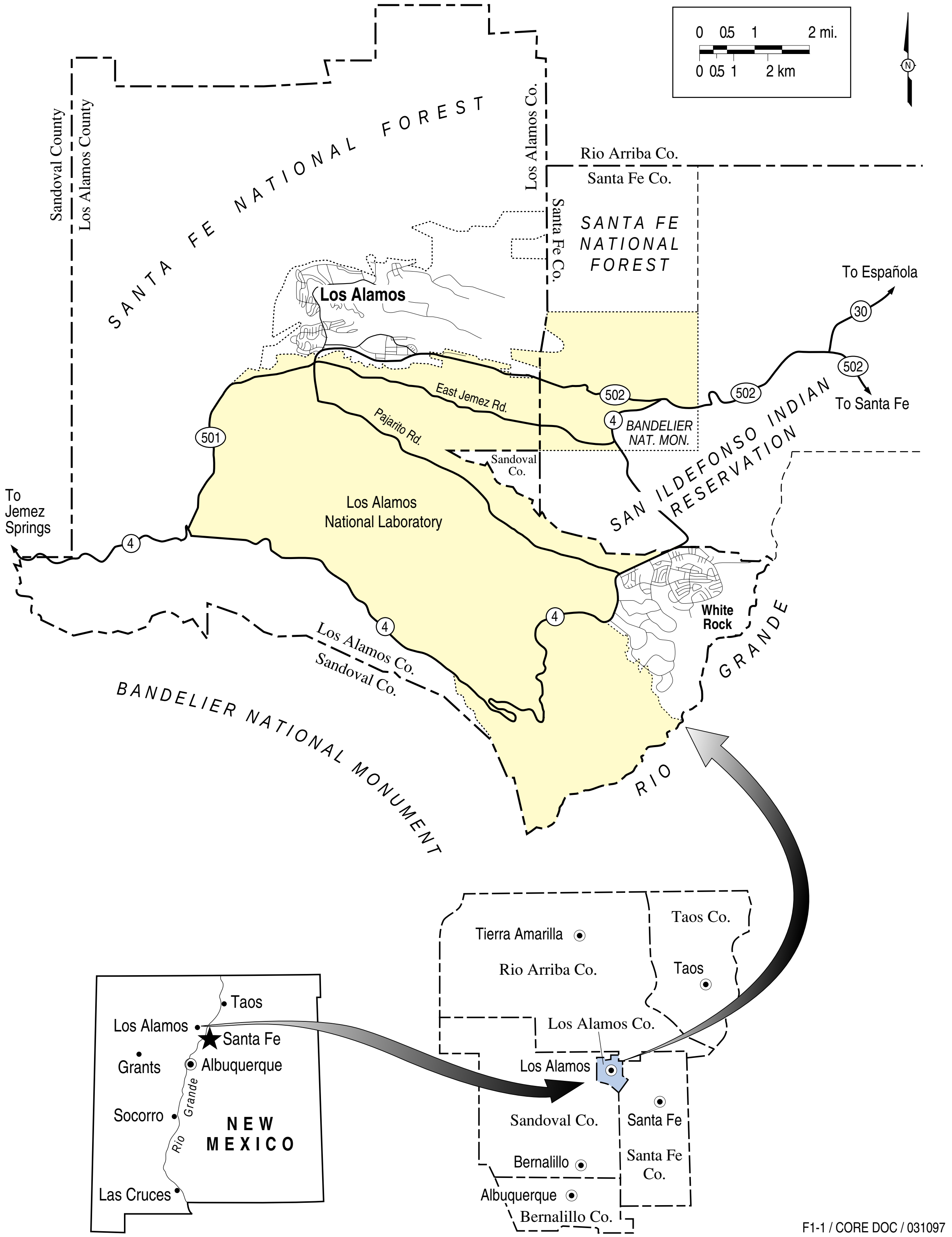

Figure 1-1. Location map of Los Alamos National Laboratory.

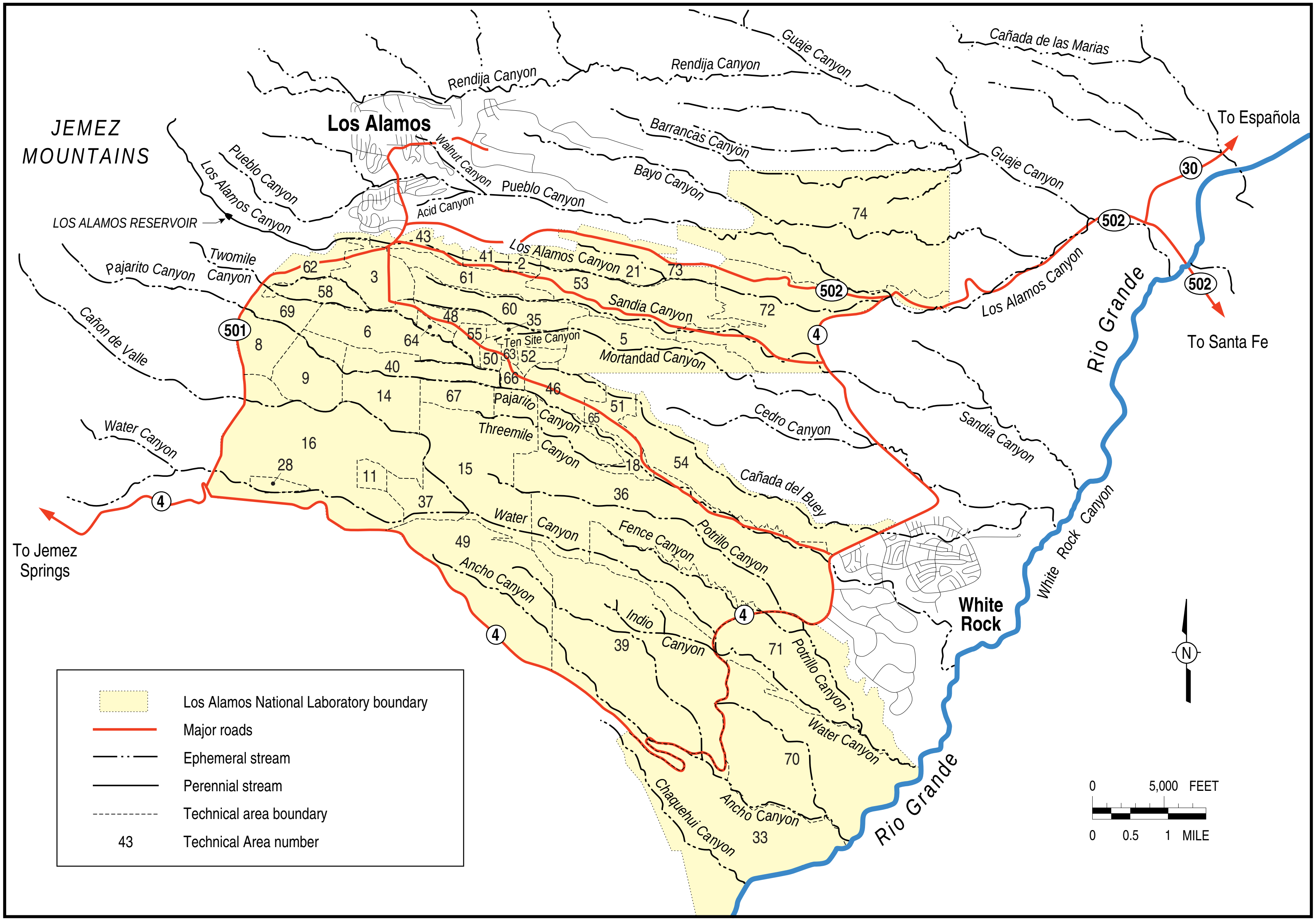

Figure 1-2. Major surface water drainages in the Los Alamos area.

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Mountains and the mesa tops into these deep canyon systems. Essentially all the surface water discharge that leaves the Laboratory property moves through these canyons and occasionally reaches the Rio Grande. From there the water flows downstream to Cochiti Lake.

1.2.2 Task/Site Work Plans/SAPs

Investigations of the 19 canyon systems are consolidated into 8 groups (Table 1-1). The consolidation of canyon systems is based on proximity, similarity of discharges and potential resulting contamination, and economic efficiency, as well as the potential for combined off-site human health and ecological impacts.

With this core document as the upper-level tier document, canyon-specific SAPs will be prepared incorporating the core document by reference, and providing detail specific to the canyon(s) being investigated. Canyon- or canyon aggregate-specific SAPs will contain only a brief introduction, a short discussion of the canyon’s history and environmental setting, a discussion of the potential contaminants in and contaminant sources for the specific canyon(s) under investigation, and a comprehensive SAP.

In accordance with the requirements of the ER “Quality Assurance Project Plan Requirements for Sampling and Analysis Plans” (hereafter “the QAPP”) (LANL 1996, 53450), each of the canyon- or canyon aggregate-specific SAPs will contain a thorough description of the QA/quality control (QC) procedures and the field and laboratory investigation methods to be used in conducting each investigation. Accordingly, this core document does not include a quality assurance project plan or a compendium of field and laboratory investigation methods.

The canyons investigations will be coordinated with several other programs at the Laboratory, and the canyon- or canyon aggregate-specific SAPs will reflect program coordination. These programs include: studies for the Laboratory’s Groundwater Protection Management Program Plan (LANL 1995, 50124); the Nuclear Weapons Technology Program’s Monitoring Well Installation Project coordinated through the Hydrogeologic Workplan (LANL 1996, 55430) for installation and sampling of wells; the Watershed Management Protection Plan, currently being developed, for surface water investigations; the Laboratory’s Environmental Surveillance Program; and a program to develop a Laboratory-wide ecological risk assessment approach. Information derived from these programs is integrated through the ER Project Earth Science Council.

Because of scheduling constraints, the *Task/Site Work Plan for Operable Unit 1049: Los Alamos Canyon and Pueblo Canyon* (LANL 1995, 50290) was developed before this core document; therefore, it is a stand-alone document that contains all the sections found in an RCRA facility investigation (RFI) work plan including the SAP as Chapter 7 of that task/site work plan, the project specific quality assurance project plan as Annex II, and field and laboratory investigation methods as Appendix C.

1.3 Public Participation

The HSWA Module requires public participation in the corrective action process. In addition, through the Community Involvement and Outreach Office, the Laboratory is providing a variety of opportunities for public participation. These opportunities include meetings held as needed to disseminate information, to discuss significant milestones, and to solicit informal public review of RFI work plans, task/site work plans, and future SAPs for canyons investigations. The ER Project staff will also discuss this core document and plans for canyon- or canyon aggregate-specific investigations at meetings of community organizations. Activities include formal interactions with the Pueblos of San Ildefonso, Santa Clara, Cochiti, and Jemez, which have formal accords and agreements with the DOE and the Laboratory. These Indian Pueblos are referred to as the “Accord Pueblos” in this document.

TABLE 1-1

OPERABLE UNIT 1049 CANYONS AND ASSOCIATED OPERABLE UNITS AND TECHNICAL AREAS

Canyon Groups	Associated Technical Areas	Associated Operable Units	Task/Site Work Plan Date[a]
Core Document	N/A[b]	N/A	April 1997
Group 1			
Los Alamos/DP	Former TA[c]: 1 Current TAs: 0, 2, 3, 21, 41, 43, 53, 62, 72, 73, 74	1071, 1078, 1098, 1100, 1106, 1111, 1114, 1136	November 1995
Pueblo/Acid	Former TAs: 1, 45 Current TAs: 0, 72, 73, 74	1071, 1078, 1079, 1100, 1106	
Group 2			
Mortandad and Sediment Traps	Current TAs: 3, 4, 5, 35, 42, 48, 50, 55, 59	1114, 1129, 1147	September 1997
Group 3			
Pajarito	Current TAs: 6, 7, 8, 9, 14, 18, 22, 23, 36, 40, 46, 50, 51, 54, 65, 66, 67, 69	1093, 1111, 1129, 1130, 1140, 1157	September 1998
Twomile	Current TAs: 3, 55, 58, 59, 64	1111, 1114, 1129	
Threemile	Current TAs: 14, 15, 18, 36, 67	1085, 1086, 1093, 1130	
Group 4			
Cañada del Buey	Current TAs: 5, 18, 46, 51, 52, 54	1129, 1140, 1148	September 1999
Sandia	Current TAs: 3, 53, 60, 61, 72	1100, 1114	
Group 5			
Guaje	Current TAs: 74, residences	1071	September 2001
Bayo	Current TAs: 0, 10, 74, residences	1071, 1079	
Barrancas	Current TAs: 74, residences	1071	
Rendija	Current TAs: 0, 74, residences	1071	
Groups 6, 7, and 8			
Water	Current TAs: 11, 16, 28, 36, 37, 49, 68, 71	1082, 1086, 1122, 1130, 1132, 1144	September 2002
Cañon de Valle	Current TAs: 9, 11, 14, 15, 16, 37, 67	1082, 1085, 1086, 1157	
Ancho	Current TAs: 33, 39, 49	1122, 1132, 1144	
Indio	Current TAs: 39, 49, 70	1132, 1144	
Chaquehui	Current TA: 33	1122	
Potrillo	Current TAs: 14, 15, 36, 67	1085, 1086, 1130	
Fence	Current TAs: 36, 68, 70, 71	1122, 1130	

a. Based on budgets

b. N/A = not applicable

c. TA = Technical Area

The Community Involvement and Outreach Office also distributes meeting notices and updates the ER Project mailing list, prepares information sheets summarizing completed and future activities, and provides public access to plans, reports, and other ER Project documents. These materials are available for public review between 8:00 a.m. and 5:00 p.m. on Laboratory business days in the Laboratory Community Reading Room at 1350 Central Avenue, Suite 101 in Los Alamos; at the public libraries in Española, Los Alamos, and Santa Fe; and at the San Ildefonso Pueblo Governor’s Office.

1.4 Regulatory Requirements Governing the Work Plans

In March 1987 DOE established a national ER Program to address environmental cleanup requirements at its Defense Program facilities nationwide. DOE and the University of California (UC), which operates the Laboratory for DOE, are jointly responsible for implementing the DOE ER Program at the Laboratory. The Laboratory’s ER Project is the organization responsible for that implementation, which must satisfy a number of regulatory mandates and meet internal requirements of DOE and the Laboratory.

1.4.1 Resource Conservation and Recovery Act Requirements

The Laboratory’s Hazardous Waste Facility Permit under RCRA sets forth requirements that are implemented by the ER Project. The broad Permit was issued by NMED; its HSWA Module (EPA 1990, 1585), which gives specific requirements affecting the conduct of the ER Project, was issued by EPA because, at the time, NMED did not have authority to implement HSWA requirements. The HSWA Module became effective May 23, 1990, and is modified to reflect changes in the corrective action process at the Laboratory. The most recent Class III permit modification became effective May 19, 1994. Early in 1996, NMED received authority to implement HSWA and is now the administrative authority for the entire Permit.

The HSWA Module requires the Laboratory to prepare an IWP that contains the programmatic elements of an RFI work plan. The IWP (LANL 1996, 55574), which DOE/UC uses to guide and manage the ER Project, meets this requirement. The most recent revision of the IWP was submitted in December 1996. The IWP describes the DOE ER Program and its history at the Laboratory, describes current Laboratory conditions, identifies the Laboratory’s potential release sites (PRSs) and their aggregation into field units, and presents the management and technical approaches for meeting the requirements of the HSWA Module. It should be noted that although the authority of RCRA and HSWA does not include radionuclide contaminants, DOE and the Laboratory have agreed to include them in the ER Project investigations; thus a PRS may be either a solid waste management unit (SWMU) (which is regulated under RCRA) or an area of concern (AOC) (which may contain contaminants not regulated under RCRA). Relevant information presented in the IWP will be cited but not repeated in this document.

The HSWA Module also requires the Laboratory to prepare RFI work plans for specific SWMU-based investigations and task/site work plans for investigations of the affected media of the canyon systems. Generic guidance for preparing RFI work plans is found in the proposed regulations of Subpart S of 40 CFR 264 (EPA 1990, 31277); specific requirements are described in the HSWA Module. EPA has provided specific guidance in Volume I of the interim final RFI guidance (EPA 1989, 8794). The HSWA Module sets out the scope of the RFI work plan, establishes the expected correspondence between the RFI tasks identified in EPA guidance documents (EPA 1989, 8794) and the equivalent ER Program tasks, and specifies the requirements to be fulfilled. These considerations are summarized in Table 1-2, which has been adapted from the HSWA Module, Section Q. Table 1-2 lists the major RFI tasks and subtasks defined by EPA and shows where the required subtasks are, or will be, discussed in the IWP, this core document, and the task/site work plan or SAPs.

TABLE 1-2

LOCATION OF DISCUSSIONS OF HSWA MODULE REQUIREMENTS

HSWA Module Requirements	IWP (1996)	Location in Core Document*
RFI Task I: Description of Current Conditions		
Facility Background	Chapter 2	Chapters 2 and 3
Nature and Extent of Contamination	Appendices A and B	Chapters 2 and 3
RFI Task II: RFI Workplan		
Data Collection Quality Assurance Plan	Chapter 4	Future SAPs
Data Management Plan	Chapter 5	Annex III (Records Management Plan)
Health and Safety Plan	Chapter 6	Annex II
Community Relations Plan	Chapter 7	Annex IV (Public Involvement Plan)
RFI Task III: Facility Investigation		
Environmental Setting		Chapter 3
Source Characterization		Chapters 2, 3, 4, and 5
Contamination Characterization		Chapters 2, 3, 4, and 5
Potential Receptor Identification		Chapter 6
RFI Task IV: Investigative Analysis		
Data Analysis		Chapters 5 and 6
Protection Standards		Chapter 6
RFI Task V: Reports		
Preliminary and Workplan	The IWP with annual update	Task/Site Work Plan and Future SAPs
Progress Draft and Final		Chapter 7 and Annex I

* The *Task/Site Work Plan for Operable Unit 1049: Los Alamos Canyon and Pueblo Canyon* (LANL 1995, 50290) included a SAP as Chapter 7, a project-specific quality assurance project plan as Annex II, and field and laboratory investigation method as Appendix C. Plans for subsequent canyons investigations will consist primarily of a SAP, incorporating this core document by reference for general background information, and providing canyon- or canyon aggregate-specific background information plus QA/QC procedures and field and laboratory investigation methods.

The IWP specifies that the ER Project's approach to the canyons investigations will comply with the HSWA Module and other regulatory obligations. This core document, and the subsequent SAPs, fulfill part of the requirements of the HSWA Module, Section I.5: Task/Site Work Plan, Canyon Systems (EPA 1990, 1585), which defines the requirement for canyons investigations. That section calls for one or more task/site work plans for studies to evaluate the potential impact of contaminants from SWMUs on the 15 (the Laboratory currently recognizes 19) major drainage areas or canyon systems at the Laboratory. It states that

> "The Permittee shall submit one or more Task/Site Workplans for studies to evaluate the 15 major drainage areas or Canyon systems at the facility. These studies must address each system as an integrated unit and evaluate them for potential impacts of contaminants from SWMUs. The plans must address the existence of contamination and the potential for movement or transport to or within Canyon watersheds and interactions with the alluvial aquifers and the main aquifer. The

> studies shall evaluate the potential for offsite exposure through these pathways including the ground water and possible impacts on the Rio Grande."

The requirement to submit one or more task/site work plans for investigations to evaluate the 15 (currently the Laboratory considers 19 canyons) major canyon systems at the facility is addressed in part by this core document, which summarizes the general technical approach and site information that are applicable to all canyon systems. This HSWA Module requirement will be completed for each of the canyon systems by preparation of SAPs, tiered from this core document, that are specific to each canyon or canyon aggregate under investigation. SAPs will be prepared with input from NMED, EPA, DOE, and the Accord Pueblos. The remainder of the text of Section I.5 of the HSWA Module contains both requirements and criteria for the design of investigations. These requirements and the approaches to addressing them are discussed in detail in Section 5.2.1 in Chapter 5 of this core document.

Section Q of the HSWA Module, which describes the scope of work for RFIs at facilities, calls for comprehensive characterization of hydrogeological and geochemical properties relevant to contaminant migration in soils and sediments. The canyons are not facilities in the sense of Section Q. They are natural environments containing contaminated media transported from nearby Laboratory facilities, mostly located on adjacent mesa tops. Therefore, the canyon- or canyon aggregate-specific SAPs developed for investigations in each of the canyon systems are not RFI work plans in the typical sense; rather this core document and the SAPs are the plans for investigations designed to evaluate the role of canyons as collection points and transport pathways for contaminants derived from nearby SWMUs. Nevertheless, the canyons investigations described in this core document and in the SAPs for canyon- or canyon aggregate-specific investigations address the guidelines for conducting RFIs as outlined in Section Q. These guidelines include obtaining the following hydrogeological and geochemical information (adapted from the HSWA Module, Section Q, Table III.A [Environmental Setting]):

- geological and hydrogeological characteristics that affect groundwater flow and quality beneath the facilities;

- topographic features that might influence the groundwater flow system;

- representative, accurate classification and description of near-surface hydrogeological units that may be part of the migration pathways at the facility (that is, the water-bearing zones and any intervening unsaturated units);

- zones of near-surface fracturing or channeling in consolidated or unconsolidated deposits and zones of high or low permeability that might direct and restrict the flow of water and contaminants;

- representative description of water level or fluid pressure monitoring; and

- man-made influences that might affect the hydrogeology of the site.

Moreover, the canyon-specific requirements in Section I.5 of the HSWA Module for investigations to evaluate the potential for off-site exposure necessitates that much of the same information called for in facility-specific RFIs be obtained in canyons investigations as well. Investigations on the environmental setting will be performed as they relate to identified sources, pathways, and areas of release of hazardous constituents and their impact on the canyons. Sample collection targets areas likely to be affected by upstream releases; sample collection is not at random.

Sites to be investigated and evaluated by the ER Project are collectively referred to as potential release sites (PRS). A PRS may be a SWMU or an AOC. A SWMU is defined in the HSWA Module (EPA 1990, 1585) as “any discernible unit at which solid wastes have been placed at any time, irrespective of whether the unit was intended for the management of solid or hazardous waste. Such units include any area at or around a facility at which solid wastes have been routinely and systematically released.” Radioactive materials and some hazardous substances (as defined under the Comprehensive Environmental Response, Compensation, and Liability Act [CERCLA] and listed in 40 CFR 302 [EPA 1990, 0093]) are not included in the RCRA definitions of solid waste, hazardous waste, and hazardous constituents and are not subject to the provisions of the HSWA Module. However, the IWP (LANL 1996, 55574) indicates that the ER Project will address the potential release of radioactive and hazardous substances not regulated by RCRA. Sites that potentially contain hazardous substances but not hazardous wastes or hazardous constituents as defined by RCRA are called AOCs. The different geologic media of the canyons system—sediments, groundwater-bearing zones, and contaminant source material—which lack SWMUs, are considered to be AOCs for purposes of the canyons investigations.

1.4.2 CERCLA, NEPA, and DOE Orders

Sections 1.2.1.3 and 1.2.1.4 of the IWP (LANL 1996, 55574) discuss the integration of the RCRA-based ER Project with applicable requirements of CERCLA and the National Environmental Policy Act. Additionally, the ER Project will comply with other applicable federal acts, state statutes, and DOE orders and policy statements. Chapter 5 of this document discusses further the regulatory basis and requirements for investigation of the canyon systems and the implementation of the general technical approach for addressing those requirements.

DOE orders applicable to the ER Project are identified in Annex I (Program Management Plan) of the 1993 version of the IWP (LANL 1993, 26077) (all annexes to the 1993 IWP are current with the 1996 IWP update but incorporated by reference in the latter; thus, reference is made to the 1993 IWP where the annexes are actually located). Compliance with the requirements of these orders is integral to all Laboratory operations and is ensured through the documented policies, planning, auditing, and work review procedures of the Laboratory.

1.4.3 Assessment of Natural Resource Damage

CERCLA Section 120 extends the liability for natural resource damage to federal facilities, which includes the Laboratory. The first part of a natural resource damage assessment is a preassessment screen as described at 43 CFR 11 (Department of the Interior 1993, 43390). The preassessment screen is used to determine whether a full natural resource damage assessment is appropriate and should be integrated with the CERCLA ecological assessment process for the canyons. The proposed RCRA Subpart S also requires that releases from SWMUs be addressed; specific methods to evaluate natural resource damage are currently being discussed by the ER Project, NMED, and EPA. Information gathered during ecological impact assessment activities in canyons investigations will create a baseline that will be used to assess the damage to natural resources. Any modifications of the general procedure will be described in investigation reports. This procedure is consistent with DOE guidance (DOE 1991, 8641). Natural resource damage assessment is not a direct regulatory requirement under this document. If ecological risk assessments are necessary, as required under RCRA and as performed under the CERCLA process, then the environmental impacts or damages will be evaluated through these existing programs. The need to integrate these requirements with natural resource damage assessments will be determined on a site-specific basis by the lead trustee (DOE).

1.5 Environmental Restoration Project Guidance

The IWP (LANL 1996, 55574) specifies the ER Project's technical and managerial approaches for compliance with the HSWA Module and other regulatory obligations. As illustrated in Table 1-2, the IWP has been prepared and is updated annually in accordance with the requirements of the HSWA Module. The IWP provides overall direction to the ER Project; specific guidance on the preparation of work plans for RFIs conducted under the project; detailed description of the facility (the Laboratory); and programmatic-level plans for data collection QA, data management, health and safety, and public involvement.

Each work plan for PRS-based RFIs deals with the investigation of a specific operable unit and provides (with the guidance of the IWP and in accordance with the requirements of the HSWA Module) detail on that operable unit with respect to environmental setting, source and contaminant characterization, and identification of potential receptors. Each PRS-based RFI work plan also details the technical approach to investigation of the operable unit using the general approach of the IWP for guidance and includes operable unit-specific plans for data collection QA, data management, health and safety, and public involvement.

Each work plan for PRS-based RFIs uses the IWP for both guidance and as a referenceable source of information regarding the history of the Laboratory and its operations. Accordingly, reference to existing text in the IWP that describes programmatic-level issues and general facility history and status is made in this core document, in the subsequent canyon- or canyon aggregate-specific SAPs (which are focused on affected media and AOCs), and in every work plan for PRS-based RFIs.

The QAPP (LANL 1996, 53450) provides guidance on the procedures and methods employed to ensure that environmental data of the desired quality are available for the decision-making process. The QAPP addresses quality objectives for measurement data, as determined by the data quality objectives process, and the sampling and analysis procedures to be implemented to achieve the quality objectives. It discusses the QC requirements for the data collection process, including the need to define acceptance criteria for certain QC procedures and samples. It provides guidance for QA assessments and response actions. The QAPP also presents guidance on personnel training; sample handling and custody; and data management, review, validation, and verification. In addition to requirements for measurement data, the QAPP also provides guidance for using archived and nonmeasurement data. Wherever possible, the appropriate ER Project administrative and quality procedures and standard operating procedures to be used in conducting the investigation are cited in applicable sections of the QAPP. Each of the canyon- or canyon aggregate-specific SAPs will follow the QAPP guidance in specifying detailed QA/QC procedures for the investigation.

1.6 Organization of This Document

This document contains seven chapters, four annexes, and three appendixes, as listed below.

Chapters

Chapter 1, this chapter, gives a brief introduction to the overall regulatory, operational, and environmental setting.

Chapter 2 provides background on the prehistoric and modern land uses within the investigation areas, including a discussion of general contaminant sources, and current environmental surveillance and protection programs.

Chapter 3 describes the environmental setting for the Pajarito Plateau.

Chapter 4 develops the conceptual model in and through the canyon systems and its implications in shaping the overall investigation efforts.

Chapter 5 describes the general technical approach that will be followed in the canyons investigations.

Chapter 6 explains the human health and ecological risk assessment considerations and approach for evaluating the data derived from canyons investigations.

Chapter 7 discusses reporting of findings of the investigations, and refinements to the conceptual model during the course of the investigations.

Annexes

Annex I presents a general project management plan for Field Unit 4 along with an implementation schedule for canyons investigations.

Annex II is the overall health and safety plan for Field Unit 4 field operations.

Annex III is a brief description of the records management plan.

Annex IV describes the general public involvement plan for obtaining and maintaining stakeholder interest and communication in canyons investigation activities.

Appendixes

Appendix A contains the fold-out color maps referenced in the text.

Appendix B contains the detailed plant and animal checklists used for ecological evaluations.

Appendix C lists the individuals who contributed to this document.

A list of acronyms precedes this introductory chapter. Definitions of unfamiliar terms can be found in the IWP (LANL 1993, 26078) and in the Glossary of Geology (Bates and Jackson 1987, 50287).

1.7 Units of Measurement

The units of measurement used in this document are expressed in both English and metric units, depending on which unit is commonly used in the field being discussed. For example, English units are used in text pertaining to engineering, and metric units are often used in discussions of geology, geochemistry, and hydrology. When information is derived from some other published report, the units are consistent with those used in that report. However, both English and metric units are provided for length, area, and volume measurements.

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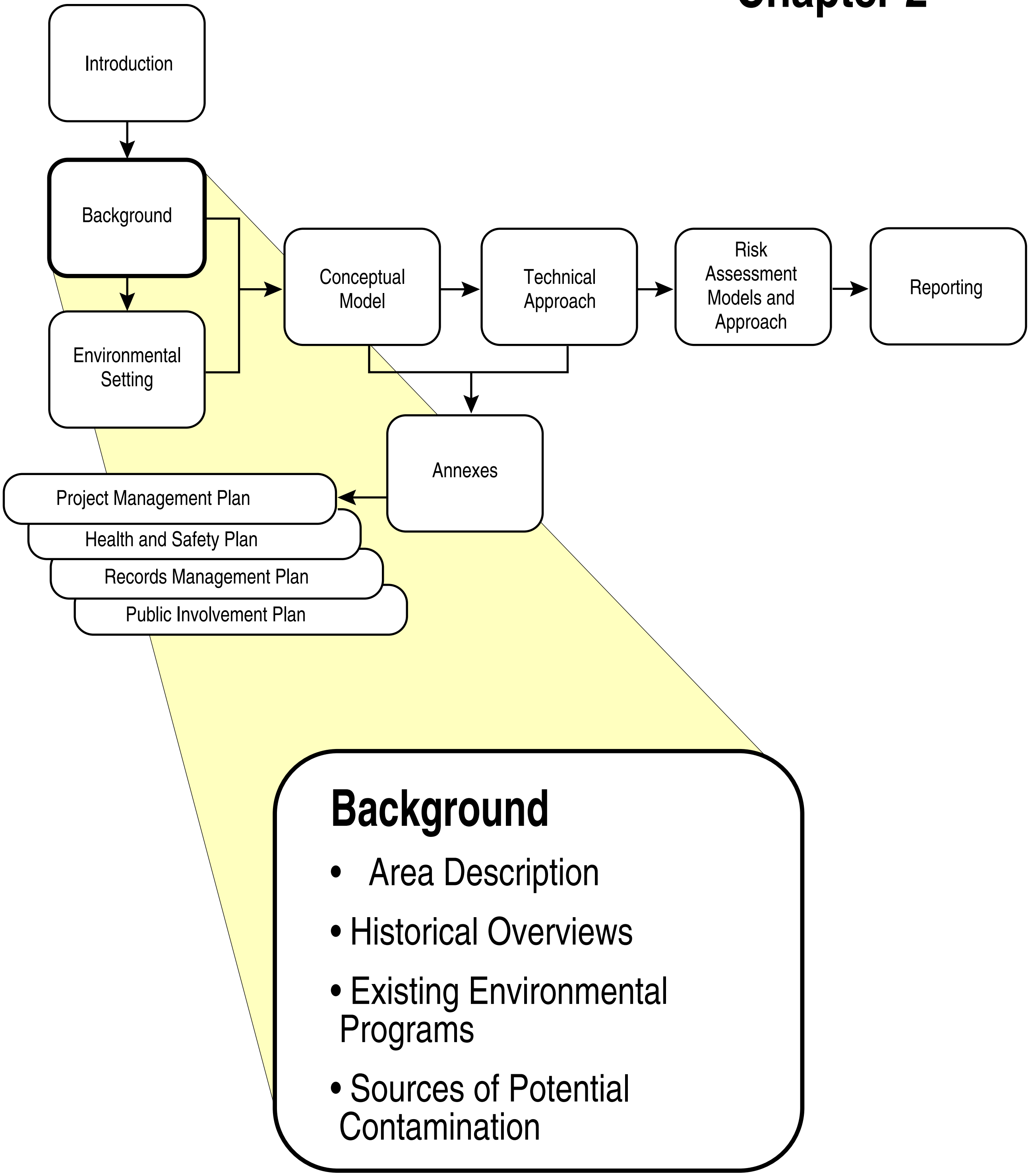
Chapter 2



Background

- Area Description
- Historical Overviews
- Existing Environmental Programs
- Sources of Potential Contamination

2.0 BACKGROUND

This chapter describes the past uses of the canyon systems and adjacent areas, from prehistoric time to the present day. This chapter also discusses the environmental protection program and surface water, sediment and groundwater monitoring programs in operation at the Laboratory, and special studies conducted in support of those programs.

Each of the canyon- or canyon aggregate-specific sampling and analysis plans (SAPs) will include a discussion of canyon-specific information about the known contamination that has been released into the canyons under investigation. This discussion will cover the potential sources of past and current contamination (solid waste management units [SWMUs] and other potential release sites [PRSs] located adjacent to or within the canyons), and what is known of the nature and distribution of contamination in the canyons.

2.1 Description

The Laboratory is located in Los Alamos County in north-central New Mexico. It is situated approximately 100 km (60 mi) north-northeast of Albuquerque and 40 km (25 mi) northwest of Santa Fe (see Figure 1-1, Chapter 1 of this core document). Most of the Laboratory and community developments are confined to mesa tops, although some of the Laboratory technical areas have facilities located in canyon floors. The surrounding land is largely undeveloped with large tracts of land north, west, and south of the Laboratory held by the Santa Fe National Forest, United States (US) Bureau of Land Management, Bandelier National Monument, US General Services Administration, and Los Alamos County. San Ildefonso Pueblo borders the Laboratory to the east (LANL 1996, 55574).

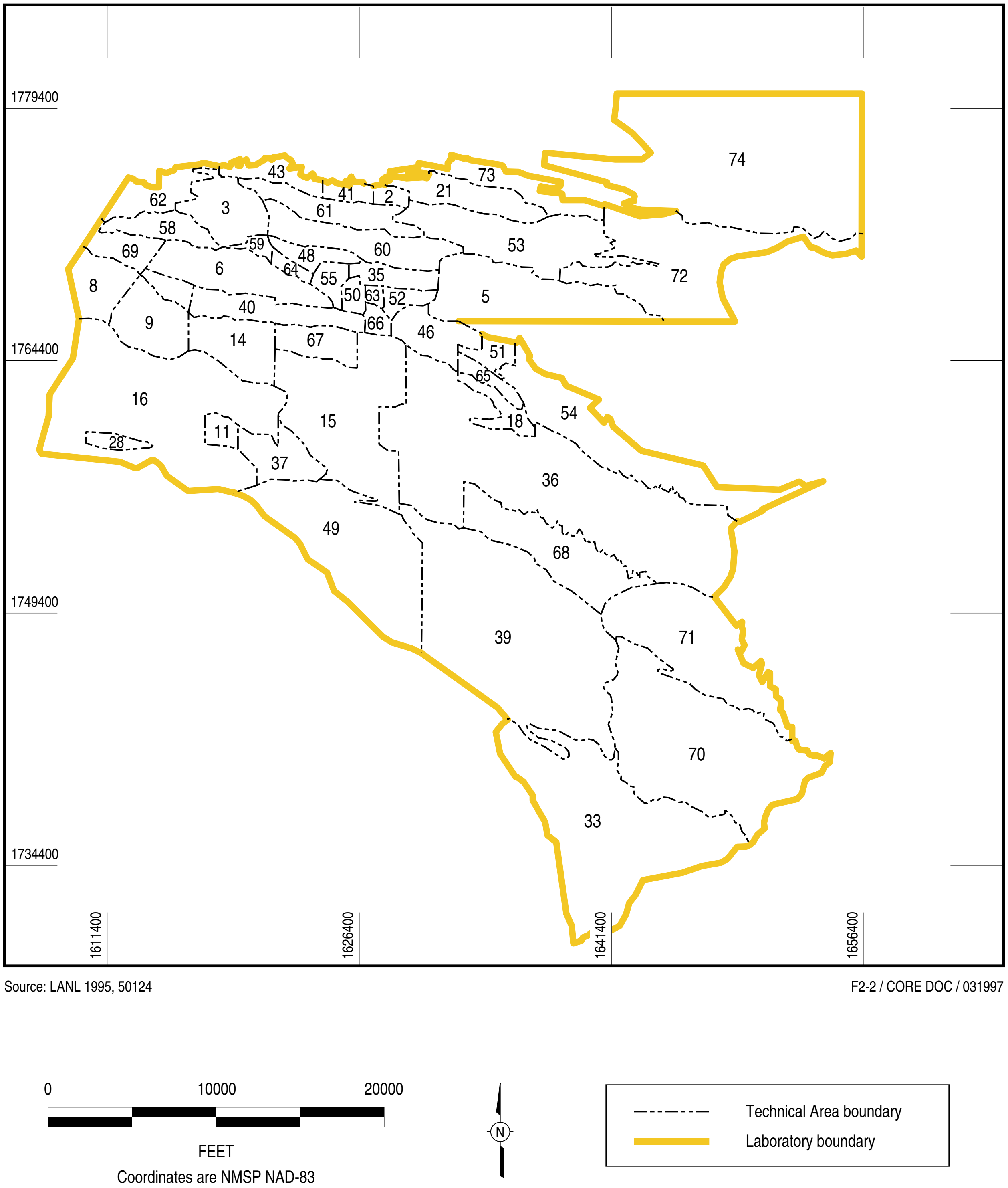
Laboratory land is used for building sites, experimental areas, waste disposal locations, roads, and utility rights-of-way. The facility is divided into technical areas each of which has a specific research function or other use (Figure 2-1). However, the developed sites account for only a small part of the total land area. Most land provides isolation for security and safety purposes and is held in reserve for future use (LANL 1995, 50124).

2.1.1 Overview of the Area

The 111-km^2 (43-mi^2) Laboratory site and Los Alamos and White Rock communities are situated on the Pajarito Plateau, which consists of a series of finger-like mesas separated by deep, west-to-east-oriented canyons cut by ephemeral and intermittent streams. Mesa tops range in elevation from approximately 2,350 m (7,700 ft) on the flanks of the Jemez Mountains to about 1,900 m (6,200 ft) at their eastern termination above the Rio Grande Valley and White Rock Canyon (LANL 1996, 55574).

The mesas in the Laboratory area are made up of the Bandelier Tuff, which consists of ignimbrite and ash-fall and pumice-fall deposits. These tuff deposits are up to at least 250 m (820 ft) thick in the western part of the plateau and thin eastward to about 60 m (200 ft) or less above the Rio Grande (Broxton and Reneau 1996, 55429). The Bandelier Tuff was deposited as a result of a series of major volcanic eruptions in the Jemez Mountains about 1.2 and 1.6 million years ago (Izett and Obradovich 1994, 48817; Spell et al. 1996, 55542).

In the western portion of the Pajarito Plateau, the tuff overlies the Tschicoma Formation, which consists of older volcanic rocks that form the eastern Jemez Mountains. In the central and eastern parts of the plateau, the tuff is underlain by the fanglomerate of the Puye Formation and basaltic rocks of the Cerros del Rio volcanic field. Cerros del Rio basalts interfinger with the Puye Formation.



Source: LANL 1995, 50124

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Figure 2-1. Technical areas at the Los Alamos National Laboratory.

These formations overlie the sediments of the Tesuque and Chamita Formations, which make up the Santa Fe Group. The regional aquifer providing the major water supply to the Laboratory and surrounding communities is in the Puye Formation and the Santa Fe Group. The Santa Fe Group extends eastward across the Rio Grande Valley and is more than 1,000 m (3,300 ft) thick.

The Pajarito Plateau is located in the western part of the Rio Grande rift and is cut by several active faults of the Pajarito fault system. Because the rift is slowly widening, the area experiences frequent but minor seismic disturbances (LANL 1996, 55574). A more complete description of the area is found in Chapter 3, Environmental Setting, of this core document.

2.1.2 Canyon Systems

Major surface drainages are associated with many of the Laboratory technical areas. These surface drainages make up the canyon systems, which are part of Field Unit 4 of the Laboratory's Environmental Restoration (ER) Project. Technical areas that have canyons within their boundaries include Technical Areas (TAs) -2, -5, -15, -16, -18, -33, -36, -37, -39, -41, -43, -46, -49, -53, -54, -58, -62, -68, -70, -71, -72, and -74.

The larger canyon systems originate on US Forest Service land in the Jemez Mountains and extend eastward across the Laboratory. Some smaller canyon systems originate within Laboratory boundaries and extend eastward to the Rio Grande or to confluences with a larger canyon system. The canyon floors are typically relatively flat, filled with alluvium and colluvium eroded from the canyon walls, and vary in width from a few tens of feet to 2,000 ft (610 m). The sides of these canyons are steep and rocky and are partially covered by trees, particularly on the north-facing slopes. Small intermittent streams characterized by extremely variable flow are located on the floors of all canyons. The structure and hydrology of the canyons are discussed in detail in Chapter 3 of this core document.

2.2 History

2.2.1 Prehistoric Use by American Indians

This section summarizes the cultural resources of the central portion of the Pajarito Plateau and the archaeological survey of those portions of the canyon systems that are located on Laboratory property. The sections of the canyon systems that are located on San Ildefonso Pueblo land will be surveyed, with Pueblo permission, during the initial stages of the investigations of a canyon or canyon aggregate.

2.2.1.1 Paleo-Indian Period

The Paleo-Indian Period (10,000 B.C. to 4,000 B.C.) is characterized by small groups of big game hunters who might have followed herds up and down the Rio Grande and made trips to the Pajarito Plateau to procure obsidian and other materials. This period is represented on Laboratory property mainly by scattered surface finds of diagnostic projectile points (dart and/or spear points) made from both local obsidian and exotic (excellent quality, nonlocal) chert.

Paleo-Indian sites in the Southwest are often revealed by severe erosion. Paleo-Indian sites may exist or have existed in the canyons, but it is possible that such sites either have been buried under the sediment that has built up on the canyon floor or have been eroded away. Such sites have not yet been recognized in any of the canyon systems.

2.2.1.2 Archaic Period

The Archaic Period (4000 B.C. to A.D. 600) is characterized by small groups of people who might have used the Pajarito Plateau for lithic (stone) resource procurement, hunting expeditions, and seasonal exploitation of certain wild plants. This period is represented on Laboratory property mainly by scattered finds of lithic tools, chipping debris (waste chips produced during stone tool manufacture), and diagnostic projectile points. Little research has been conducted on this period, but buried habitation or burial sites might be present on Laboratory property.

The Archaic populations that occupied the Pajarito Plateau probably used the canyons for gathering, hunting, and small-scale horticulture (gardening).

2.2.1.3 Prehistoric Indian Pueblo Period

The prehistoric Indian Pueblo Period, which succeeded the Archaic culture, has traditionally been referred to by archeologists as the Anasazi culture. However, consultation with representatives of the present Indian Pueblos has indicated that this term is not currently applied by the American Indian community to the people they consider their ancestors. The representatives expressed a preference for the term “prehistoric Indian Pueblo culture,” and this term is used here in recognition of that preference.

2.2.1.3.1 Developmental Period

The Early Developmental Period (A.D. 600 to A.D. 900) is characterized by settled hunter-gatherers living in semi-subterranean pit houses and making pottery with simple designs. Some possible locations of pit houses and associated artifacts have been identified on Laboratory property, but identification is tenuous.

The Late Developmental Period (A.D. 900 to A.D. 1100) is characterized by small groups of maize horticulturists who still relied to a great extent on gathering wild plants. Structures at these sites are typically small, adobe, and sometimes crude masonry, pueblos. Very few sites from this period have been located on Laboratory property. Most of those recorded are located close to the Rio Grande in the vicinity of Chaquehui Mesa and lower Water Canyon.

2.2.1.3.2 Coalition Period

The Coalition Period (A.D. 1100 to A.D. 1325) is characterized by maize horticulturists. Early sites are rectangular adobe and masonry structures. Later sites are large masonry-enclosed plaza roomblocks with more than 100 rooms. Most of the ruins recorded on Laboratory property date to this period (1,000 have been recorded).

The canyons contain more sites from the Coalition Period than from any other period. These sites include small to large pueblos (habitation sites), field houses (one- to two-room storage structures), rock shelters (using rock overhangs), cavates (small rooms carved into the canyon cliff faces), garden plots, and artifact scatters. Terraced garden plots, which are often located near pueblos, indicate that at least portions of the canyon floors were used for growing crops.

2.2.1.3.3 Classic Period

The Classic Period (A.D. 1325 to A.D. 1600) is characterized by intensive maize horticulturists. Prehistoric Indian Pueblo settlements on the Pajarito Plateau are aggregated into three population clusters with outlying one- to two-room field houses. The central site cluster consists of four temporally overlapping sites: Navawi, Otowi, Tsankawi, and Tshirege. Otowi and Tshirege are located on Laboratory property. These ruins were inhabited by the ancestors of the Tewa speakers now living at San Ildefonso Pueblo.

2.2.2 Historic Use

The American Indians at San Ildefonso Pueblo claim much of the Pajarito Plateau as their ancestral land and, in fact, have an unsettled American Indian Original Land Claim on file with the US government. Much of the Indian Pueblo history is not written but is handed down orally by the elders through traditional stories. Many of the elders speak of sites on the Pajarito Plateau that are called by traditional names, such as Navawi and Tshirege. The ancient people (or “old ones” as they are sometimes called) came from a lake to the north called Sipophe. It is thought that these people migrated from the lake to Chaco Canyon (in northwestern New Mexico), and later to Mesa Verde (in southern Colorado) and into what is now Bandelier National Monument. They used the mesas and the canyons for farming, hunting, gathering food (such as piñon nuts and acorns), and gathering plants for religious and ceremonial purposes (Hewett 1953, 44150). The Keresan-speaking Indian Pueblos (such as Cochiti Pueblo) and the Tewa-speaking Indian Pueblos (such as San Ildefonso Pueblo), as well as other Pueblo Indians probably have ancestral and cultural links to the area.

Today, the Indian Pueblo people use the canyons as their ancestors did, using the nearby mesas for hunting and grazing, making pilgrimages to shrines and sacred sites, and collecting plants from the canyons for dietary, religious, ceremonial, economic, and medicinal use. When the piñon nuts are abundant, the crop is gathered for consumption. Some plants are used to dye wool.

During the westward expansion by pioneers of European origin, much of the Pajarito Plateau was part of the Ramon Vigil land grant from the King of Spain. During the Spanish Colonial and Territorial Periods (A.D. 1600 to A.D. 1900) grazing and seasonal utilization of the plateau by non-Indian groups is highly probable but has not been thoroughly documented. The Homesteading Period (A.D. 1890 to A.D. 1943) was an outgrowth of the earlier undocumented use of the Plateau for cattle grazing, timbering, and farming activities. Hispanic and Anglo-American homestead-era sites are characterized by wooden cabin and corral structures, rock or cement cisterns, and a scattering of debris associated with household, farming, and grazing activities.

From the mid-1840s to the late 1880s, the Pajarito Plateau was used mainly as an access route to the Jemez Mountains where the cattle, mining, and lumber industries were expanding. Cattle were later grazed on the plateau itself beginning in the late 1880s. From 1897 until 1903, the Ramon Vigil land grant was used for timber harvest. During that time, Santa Fe and Española and the newly constructed town of Buckman (on the Rio Grande below the Pajarito Plateau) were connected by railroad. A dirt road connected Buckman to the Pajarito Plateau. In 1906, the Ramon Vigil land grant was bought by the Ramon Land and Lumber Co. At that time, a sawmill, called the Phillips Mill, was built in Pajarito Canyon.

The land grant was bought in 1914 by Ashley Pond and some Detroit executives who hoped to turn the area into a recreational ranch called The Pajarito Club. The venture failed, and subsequently the grant was purchased by Frank Bond and used as a line camp. In 1917, the Brook Ranch, situated on Los Alamos Mesa, was purchased by Ashley Pond who established the Los Alamos Ranch School (Foxx and Tierney 1984, 5950).

In 1942, Dr. J. Robert Oppenheimer and General Leslie R. Groves (commanding officer of the Manhattan Project) decided that the Pajarito Plateau was ideal for the research, design, and assembly facility for the

Manhattan Project. Condemnation proceedings for the Los Alamos Ranch School began in November 1942; in February 1943 it closed (Rothman 1992, 55540).

2.2.3 Los Alamos National Laboratory History and Operational Use

2.2.3.1 Historical Review

The Laboratory was established in 1943 as Project Y of the Manhattan Engineer District—the secret World War II effort to develop the world's first nuclear weapons. A physics professor at Berkeley, J. Robert Oppenheimer, was selected to head the effort. To keep the project developing in an academic atmosphere, the University of California (UC) was asked to manage the Laboratory (LANL 1996, 55574).

In 27 months, Oppenheimer and his colleagues successfully completed their mission, and the war against Japan ended. After the war, Congress chose to sustain the Los Alamos site with continued funding. The Atomic Energy Commission (AEC) received control of the Laboratory from the Army and renewed the operating contract with the UC. During subsequent years, the Laboratory continued to expand, first under the AEC and later under the Energy Research and Development Administration. The Laboratory was designated a national laboratory and has operated under the Department of Energy (DOE) since 1978 (LANL 1996, 55574).

From its origins during World War II, the Laboratory has evolved into a large, multiprogram, multidisciplinary national laboratory. Table 2-1 highlights the major milestones in scientific research that have been accomplished over the years at the Laboratory (LANL 1995, 50124).

TABLE 2-1

MILESTONES IN THE HISTORY OF LOS ALAMOS NATIONAL LABORATORY

1943	The Los Alamos Laboratory, under the direction of J. Robert Oppenheimer, begins operation as Project Y of the Manhattan Project. The Bethe-Feynman formula, a simple method for calculating the yield of a fission bomb, is derived.
1944	The world's third nuclear reactor (a uranium-solution-fueled "Water Boiler" named LOPO) achieves criticality.
1945	The world's first nuclear bombs (Little Boy, a gun-type uranium bomb, and Fat Man, an implosion-type plutonium bomb) prove successful. Norris E. Bradbury is named second director of the Laboratory.
1946	The world's first plutonium-fueled nuclear reactor (Clementine) achieves criticality.
1947	The Monte Carlo technique for particle-transport computations is formulated.
1948	Helium-3 is first liquefied.
1951	First thermonuclear reaction is produced in the George shot of the Greenhouse test series.
1952	The MANIAC computer becomes operational. The first thermonuclear explosion is achieved by the Mike shot of the Ivy test series. The first facility for handling liquid hydrogen on a large scale becomes operational. Plutonium-244, plutonium-246, americium-246, einsteinium-253, and fermium-256 are discovered in the debris of the Mike shot.
1953	The Lady Godiva critical assembly achieves prompt criticality. The S_n, or discrete ordinates, method for solving neutron-transport problems is formulated.
1954	The first thermonuclear bomb containing solid fusion fuel is demonstrated in the Bravo shot of the Castle test series.
1955	The Rover Project to investigate nuclear-reactor-powered rockets is initiated.

TABLE 2-1 (continued)

MILESTONES IN THE HISTORY OF LOS ALAMOS NATIONAL LABORATORY

1957	The particle-in-cell (PIC) method for numerical fluid dynamics is invented.
1958	A helium-3 refrigerator providing temperatures below 0.45 Kelvin is developed.
1959	Plutonium-238 is used as a power source in space.
1960	The KIWI nuclear reactor for the Rover Project is operated at full power.
1961	The Stretch computer is developed in collaboration with IBM.
1963	Satellite-borne sensors to verify adherence to the Limited Test Ban Treaty are developed. PHERMEX, the world's highest-intensity x-ray facility, is constructed.
1964	The world's highest-voltage Van de Graaff accelerator is completed.
1965	The Phoebus I-A Rover reactor is tested at full power.
1967	The side-coupled cavity is developed for the Los Alamos Meson Physics Facility (LAMPF) linear accelerator.
1968	Funding for construction of LAMPF is approved by Congress and President Johnson.
1969	The ultra-high-temperature nuclear reactor (UHTREX) begins operation at 2400°F.
1970	Harold M. Agnew is named third director of the Laboratory.
1971	Naturally occurring plutonium-244 is isolated.
1972	LAMPF accelerates protons to design energy. Isotopes of uranium are separated by selective laser excitation of UF_6.
1974	Insensitive high explosives for use in nuclear weapons are developed. The Laboratory is named a national resource for stable isotopes.
1976	A portion of the Laboratory site is designated a national environmental research park.
1977	Fusion neutrons are detected in a plasma confined by radiation from a carbon-dioxide laser.
1978	The Hot Dry Rock Program is initiated (Fenton Hill).
1979	Donald M. Kerr is named fourth director of the Laboratory. Universality of the approach to chaos in deterministic systems is discovered.
1980	The University of California establishes a branch of the Institute of Geophysics and Planetary Physics. The center for Nonlinear Studies is established.
1981	The Center for Materials Sciences is established.
1982	The Laboratory is designated a national resource for flow cytometry. GenBank, the national database for nucleic-acid sequences, begins operation. A heavy-fermion superconductor is discovered.
1983	Congress approves long-term visits at LAMPF for citizens of the People's Republic of China.
1984	The radio-frequency quadrupole cavity is developed for a neutral-particle accelerator.
1985	A new technique (CORRTEX) is developed to verify yields of underground nuclear explosions.
1986	Siegfried S. Hecker is named fifth director of the Laboratory. The world's first high-temperature hot-dry-rock system is successfully tested.
1987	The first edition of nucleotide-sequence data for HIV samples is published.
1988	The Laboratory is designated as one of three national DOE centers for human genome studies. A new type of chemical bond is discovered in the binding of molecular hydrogen to the central metal atom in certain metal complexes.
1989	A beam of energetic neutral particles is created in space.
1990	Superconducting tapes and thin films are fabricated.
1991	The Laboratory is designated as one of two centers for research on high performance computing.
1993	Cross section for the scattering of electron neutrinos by electrons is determined experimentally.

2.2.3.2 Laboratory Operational Use

A detailed discussion of Laboratory activities conducted within and adjacent to the various canyons within the canyon systems will be presented in the seven canyon- or canyon aggregate-specific SAPs that will be prepared. The *Task/Site Work Plan for Operable Unit 1049: Los Alamos Canyon and Pueblo Canyon*, which was prepared and submitted in November 1995 (LANL 1995, 50290), contained just such a detailed discussion for these two canyons.

2.2.4 Current Recreational Use

The canyon systems comprise land managed by the Laboratory, US Bureau of Land Management, Santa Fe National Forest, Bandelier National Monument, Los Alamos County, and San Ildefonso Pueblo. Portions of the canyon systems formerly managed by the Laboratory have been transferred to Los Alamos County. An extensive system of hiking and riding trails provides recreational access to many of the canyons.

Currently, portions of the canyon systems located within Laboratory boundaries as well as outside Laboratory boundaries are used as popular recreation areas by local residents for activities such as biking, jogging, and bird watching. Other areas of the canyon systems are restricted from current recreational use by institutional controls (signs and fences).

2.3 Environmental Monitoring and Protection Programs

2.3.1 Background

Environmental monitoring for chemical and radiochemical quality of surface water, groundwater, and sediments began with studies by the US Geological Survey (USGS) in 1945 (Purtymun 1964, 0183; Purtymun and Kunkler 1967, 0202; Purtymun 1967, 0188; Purtymun 1975, 11787; Environmental Protection Group 1993, 23249). The Laboratory became increasingly involved in this work after 1949 and in 1970 initiated a formal environmental monitoring program which includes sampling and analysis of these media. This program continues as required by DOE Order 5400.1 (DOE 1988, 0075) under the direction of the Laboratory's Environment, Safety, and Health (ESH) Division. The USGS remained active in surface water and sediment monitoring for the AEC through 1971.

The Environmental Surveillance Group began systematic environmental monitoring in the canyons in 1966. Results of this monitoring are reported in the Laboratory's annual environmental surveillance reports and other special reports (e.g., ESG 1990, 6995; Elder and Knoell 1986, 6670; Montoya 1991, 6997). These reports provide the basis for the following discussion.

The protection of groundwater in the Los Alamos area has been of paramount importance since the end of World War II, when the AEC needed to develop a reliable water supply. Beginning in 1945, the USGS became extensively involved in overseeing and conducting various studies for the development of groundwater supplies. Special studies specifically designed to protect and monitor groundwater quality were initiated as joint efforts between the AEC, the Laboratory, and the USGS as early as 1949 (LANL 1995, 50124).

Groundwater monitoring and protection efforts at the Laboratory have evolved from the early programs initiated by the USGS to present efforts including the ER Project, the Decommissioning Project, and emergency management and response programs. Other protection efforts include Resource

Conservation and Recovery Act (RCRA) closures and compliance with the Laboratory's environmental permits (the National Pollutant Discharge Elimination System [NPDES], and the RCRA Hazardous Waste Facility Permit with the Hazardous and Solid Waste Amendments [HSWA] Module VIII requirements for groundwater monitoring.) (LANL 1995, 50124).

To comply with the NPDES permit, the Laboratory has four primary programs: the Sanitary Wastewater Systems Consolidation (SWSC) Project, the Storm Water Pollution Prevention Plan, the Waste Stream Identification and Characterization (WSC) Program, and the Spill Prevention Control and Countermeasures (SPCC) Program.

The Laboratory also maintains a groundwater monitoring network to detect any effects that Laboratory activities may have on the quality of the regional aquifer. The Laboratory's Groundwater Protection Management Program Plan (GPMPP) addresses environmental monitoring, resource management, aquifer protection, and hydrogeologic investigations (LANL 1995, 50124).

2.3.2 Protection Programs

2.3.2.1 Corrective Actions

The ER Project (established in 1987) implements the DOE's policy to protect natural resources and restore those damaged by contamination from past releases of hazardous substances and radionuclides. The ER Project goals include: (1) ensurance that the environmental impacts of Laboratory activities are thoroughly investigated and that corrective actions are taken; (2) compliance with RCRA, the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), the National Environmental Policy Act, the Atomic Energy Act, and other applicable regulations and orders; and (3) provision of mechanisms through which interested parties can participate in the corrective action review process (LANL 1995, 50124).

2.3.2.2 Decommissioning Project

The Decommissioning Project at the Laboratory was established in 1989 to remove nonoperational, contaminated facilities. The Decommissioning Project responsibilities include assessment and cleanup of facilities and equipment not regulated under CERCLA or RCRA. The Decommissioning Project has been integrated with the ER Project to enhance cleanup efforts. All activities are conducted in accordance with federal and state requirements and DOE orders applicable to nuclear facilities and other facilities that generate radioactive and hazardous materials and wastes (LANL 1995, 50124)

2.3.2.3 RCRA Closures

RCRA mandates a program to regulate hazardous wastes from generation through disposal. The program emphasizes the reduction of hazardous waste volume, mobility, and toxicity and requires treatment of hazardous waste before disposal. Contaminated PRSs may be subject to the corrective action requirements of RCRA. Recently active SWMUs managing hazardous wastes may be subject to the closure provisions of RCRA (LANL 1995, 50124).

All corrective actions conducted by the Laboratory are to comply specifically with the RCRA regulations. Laboratory sites are assessed and, if necessary, remediated by either voluntary corrective actions, corrective measures implementation, or RCRA closure. These activities ensure that releases are identified and either mitigated or eliminated (LANL 1996, 55574). The ER Project may be responsible for the implementation of corrective actions at PRSs and some SWMUs or the closure provisions of RCRA.

2.3.2.4 Emergency Management and Response

The Laboratory maintains an emergency management and response system that, through emergency planning, preparedness, and effective response capabilities, is capable of responding to and mitigating the potential consequences of emergencies (LANL 1995, 50124).

2.3.2.5 Compliance with the NPDES Permit

NPDES was established by the Clean Water Act (CWA) and requires permitting of all point-source effluent discharges into the nation's waters. The primary goal of the CWA is to restore and maintain the chemical, physical, and biological integrity of the nation's waters. Specific criteria for an effluent must be met before that effluent can be discharged into the environment. The Laboratory has two NPDES permits, one for Laboratory facilities and one for operations at the Fenton Hill hot-dry-rock geothermal facility (LANL 1995, 50124).

The Laboratory has established the SWSC Project and taken other actions to reduce the number of NPDES outfalls, correct deficiencies in outfalls, and improve compliance with the provisions of the NPDES permit. As part of the SWSC Project, a new, centralized, sanitary wastewater treatment plant was constructed at TA-46 to replace the TA-3 wastewater treatment plant and 6 smaller treatment facilities that consistently failed to meet NPDES discharge regulations. The new treatment plant will also eliminate the need for approximately 30 septic tank systems and result in a significant savings in operating and maintenance costs (LANL 1995, 50124).

2.3.2.6 Corrective Activities Program

The Corrective Activities Program includes activities designed to bring active or standby facilities into compliance with ambient air, water, and solid waste regulations and agreements. The program is responsible for compliance with CWA and other requirements for effluent discharge, including WSC and SPCC (LANL 1995, 50124).

2.3.3 Groundwater Monitoring

Groundwater protection activities at the Laboratory include installation of an extensive groundwater monitoring system for assessment of water quality (in conjunction with the Laboratory's Hydrogeologic Workplan [LANL 1996, 55430]).

The existing groundwater monitoring network in the Los Alamos area consists of a variety of supply wells, test wells, observation wells, and springs located on-site and outside the Laboratory boundary. Scientists routinely sample and analyze water from wells and springs for radioactive and toxic constituents, for basic water quality parameters, and for evidence of resource depletion. Results are published in the annual environmental surveillance report, for example, *Environmental Surveillance at Los Alamos during 1992* (Environmental Protection Group 1994, 35363) and the annual water supply report, for example, *Water Supply at Los Alamos during 1991* (Purtymun et al. 1994, 41290).

Information on groundwater monitoring and sampling requirements, design criteria, and sampling procedures and equipment can be found in the Groundwater Monitoring Plan, Appendix F of the GPMPP (LANL 1995, 50124), and the Hydrogeologic Workplan (LANL 1996, 55430). Monitoring networks for sampling the three principal groundwater-bearing zones present at the Laboratory—alluvial, intermediate perched zones, and the regional aquifer—are summarized below. A list of the monitoring stations used for environmental surveillance, the general locations, sampling rationale, and programmatic drivers is given in Table 2-2. Locations of monitoring wells are shown in Figure A-4 in Appendix A of this core document.

TABLE 2-2

CURRENT ENVIRONMENTAL SURVEILLANCE GROUNDWATER MONITORING WELLS

Station	Date Installed	East-West[a] Coordinate	North-South[a] Coordinate	Ground Elevation (ft MSL[b])	Casing Depth (ft)	Depth of Screened Interval (ft)	Purpose	Geologic Unit Screened/ Comments
Regional Aquifer Wells								
DT-10	1960	1628988	1754449	7020	1409	1080–1390	Test	Basalt, Puye Formation, Santa Fe Group
DT-5A	1960	1625310	1754789	7144	1821	1172–1392	Test	Basalt, Puye Formation, Santa Fe Group
DT-9	1960	1628994	1751493	6936	1501	1040–1500	Test	Totavi Lentil and Santa Fe Group
G-1	1950	1656191	1783609	5973	2000	282–1980	Supply	Santa Fe Group, Basalt
G-1A	1954	1655241	1784353	6014	1519	272–1513	Supply	Santa Fe Group, Basalt
G-2	1954	1654210	1785123	6056	1970	281–1960	Supply	Santa Fe Group
G-3	1951	1651676	1786218	6139	1792	441–1785	Supply	Santa Fe Group, Basalt/Off line
G-4	1951	1648949	1786452	6229	1930	426–1925	Supply	Santa Fe Group, Basalt
G-5	1951	1646950	1787907	6306	1840	462–1830	Supply	Santa Fe Group, Basalt
G-6	1964	1644824	1786851	6422	1530		Supply	Santa Fe Group
LA-1A	1946	1668082	1776927	5824	870	60–865	Observation	Alluvium, Santa Fe Group/ Plugged 1993
LA-1B	1960	1668248	1776952	5602	1750	326–1690	Observation	Santa Fe Group/No pump
LA-2	1946	1666924	1777219	5651	870	105–865	Supply	Santa Fe Group
LA-5	1948	1659826	1772533	5840	1750	440–1740	Observation	Santa Fe Group/No pump
O-1	1991	1649396	1772232	*6400.9*	2497	1017–2477	Supply	Santa Fe Group, Basalt/Off line
O-4	1991	1637337	1772995	*6639.0*	2596	1115–2596	Supply	Santa Fe Group, Basalt
PM-1	1965	1647734	1768112	*6513.2*	2499	945-2479	Supply	Santa Fe Group, Basalt
PM-2	1965	1636786	1760326	*6712.0*	2300	1001–2280	Supply	Puye Formation, Santa Fe Group, Basalt
PM-3	1966	1642631	1769426	*6610.9*	2552	956–2532	Supply	Santa Fe Group, Basalt
PM-4	1981	1635717	1764674	*6916.1*	2875	1260–2854	Supply	Puye Formation, Santa Fe Group, Basalt
PM-5	1982	1632110	1767790	*7094.0*	3093	1440–3072	Supply	Puye Formation, Basalt, Santa Fe Group
TW-1	1950	1650041	1772077	*6369.9*	642	632–642	Test	Puye Formation
TW-2	1949	1634231	1777268	*6646.4*	834	779–789	Test	Totavi Lentil
TW-3	1949	1637727	1773138	*6626.9*	815	805–815	Test	Totavi Lentil
TW-4	1950	1624048	1777680	*7242.7*	1205	1195–1205	Test	Tschicoma Formation
TW-8	1960	1632574	1769507	*6875.5*	1065	953–1065	Test	Puye Formation

a. Coordinates listed are based on the New Mexico planar coordinate system as used in the maps in Appendix A of this core document. All locations are shown in Figure A-4 of Appendix A. A more complete list of wells in the Los Alamos area is available in Appendix E of the GPMPP (LANL 1995, 50124). Locations of wells are updated continually as new wells are installed and other wells are abandoned and plugged.

b. MSL = mean sea level, the elevations in italics are either surveyed or they are taken from the Digital Elevation Model for the Laboratory; these elevations are considered to be of good quality. The remaining elevations are literature values, and they are of unknown quality.

TABLE 2-2 (continued)

CURRENT ENVIRONMENTAL SURVEILLANCE GROUNDWATER MONITORING WELLS

Station	Date Installed	East-West[a] Coordinate	North-South[a] Coordinate	Ground Elevation (ft MSL[b])	Casing Depth (ft)	Depth of Screened Interval (ft)	Purpose	Geologic Unit Screened/ Comments
Intermediate Perched Zone Wells								
TW-1A	1950	1650057	1772066	*6369.8*	225	215–225	Test	Basalt
TW-2A	1949	1634185	1777288	*6646.4*	132	127–132	Test	Puye Formation
Alluvial Groundwater Observation Wells								
APCO-1	1990	1649210	1773020	6368	19.7	4.7–14.7	Observation	Alluvium, Puye Formation/HSWA Spec Permit
CDBO-4	1985	1645475	1758547	6565	12	8–12	Observation	Alluvium, Bandelier Tuff
CDBO-5	1992	1633583	1765818	6879	17	7–17	Observation	Alluvium
CDBO-6	1992	1636209	1764760	6817	49	34–44	Observation	Band.Tuff/ Water from PM-4 pump start-up
CDBO-7	1992	1637400	1763301	6871	44	29–39	Observation	Band. Tuff/ Water from PM-4 pump start-up
CDBO-8	1992	1639294	1762366	6722	23	13–23	Observation	Alluvium, Bandelier Tuff
FCO-1	1989	1642412	1751182	6509	12.4	2.4-12.4	Observation	Alluvium, Bandelier Tuff/ Dry; HSWA Special Permit
LAO-0.3	1994	1624799	1774512	6968	8.33	5.9–10.9	Observation	Alluvium/TA-2/41 specific
LAO-0.6	1994	1626748	1774333	6910	10.54	8.0–13.0	Observation	Alluvium/TA-2/41 specific
LAO-0.7	1994						Observation	Alluvium/TA-2/41 specific
LAO-0.8	1994	1627700	1774275	6887	7.5	7.5–12.5	Observation	Alluvium/TA-2/41 specific
LAO-0.91	1994	1628654	1774207	6862	9.5	9.5–14.5	Observation	Alluvium/TA-2/41 specific
LAO-1	1966	1629395	1773956	6836	25.4	8–28	Observation	Alluvium, Band.Tuff (?)
LAO-2	1966	1637608	1773096	6593	29	12–32	Observation	Alluvium, Band.Tuff (?)
LAO-3	1966	1638011	1773098	6578	24	16–32	Observation	Bandelier Tuff (?)
LAO-3A	1989	1637981	1773100	6579	15	4.7–14.7	Observation	Alluvium
LAO-4	1966	1640752	1772729	6519	24	14–24	Observation	Bandelier Tuff (?)
LAO-4.5	1969	1643659	1772088	6452	40	10–40	Observation	Alluvium, Puye Formation (/)
LAO-4.5A	1989	1643500	1772052	6460	18.5	8.5–18.5	Observation	Basalt/Dry; HSWA Special Permit
LAO-4.5B	1989	1643512	1772055	6459	34.9	24.9–34.9	Observation	Puye Formation (/) Dry; HSWA Special Permit
LAO-4.5C	1989	1643547	1772077	6458	23.3	13.3–23.3	Observation	Alluvium, Puye Formation (/) Dry; HSWA Special Permit
LAO-6	1966	1646222	1771330	6395	16	6–16	Observation	Basalt/Dry
LAO-6A	1989	1646222	1771344	6396	14.2	4.2–14.2	Observation	Alluvium, Puye Formation (/) HSWA Special Permit
LAO-B	1994	1615149	1775170	7323	14.24	11.8–26.8	Observation	Alluvium/Background

a. Coordinates listed are based on the New Mexico planar coordinate system as used in the maps in Appendix A of this core document. All locations are shown in Figure A-4 of Appendix A. A more complete list of wells in the Los Alamos area is available in Appendix E of the GPMPP (LANL 1995, 50124). Locations of wells are updated continually as new wells are installed and other wells are abandoned and plugged.

b. MSL = mean sea level, the elevations in italics are either surveyed or they are taken from the Digital Elevation Model for the Laboratory; these elevations are considered to be of good quality. The remaining elevations are literature values, and they are of unknown quality.

TABLE 2-2 (continued)

CURRENT ENVIRONMENTAL SURVEILLANCE GROUNDWATER MONITORING WELLS

Station	Date Installed	East-West[a] Coordinate	North-South[a] Coordinate	Ground Elevation (ft MSL[b])	Casing Depth (ft)	Depth of Screened Interval (ft)	Purpose	Comments
LAO-C	1970	1622158	1775250	7050	12.2	3–13	Observation	Alluvium/Baseline well
MCO-3	1967	1627363	1770237	7053	12	2–12	Observation	Alluvium, Bandelier Tuff
MCO-4	1963	1631215	1769786	*6897.5*	19	14–19	Observation	Alluvium, Bandelier Tuff
MCO-4A	1989	1632028	1769700	*6886.6*	19.4	9.4–19.4	Observation	Alluvium, Bandelier Tuff/ HSWA Special Permit
MCO-4B	1990	1632036	1769695	*6886.7*	33.9	8.9–28.9	Observation	Alluvium, Bandelier Tuff/ HSWA Special Permit
MCO-5	1965	1632466	1769537	*6875.7*	46	21–46	Observation	Alluvium, Bandelier Tuff
MCO-6	1974	1633634	1769012	*6849.5*	47	27–47	Observation	Alluvium, Bandelier Tuff/ Replaces original MCO-6
MCO-6A	1989	1633633	1768961	*6849.7*	36	22.7–32.7	Observation	Alluvium, Bandelier Tuff/ HSWA Special Permit
MCO-6B	1990	1633630	1768982	*6850.3*	47.1	22–42	Observation	Alluvium, Bandelier Tuff/ HSWA Special Permit
MCO-7	1960	1634516	1768508	*6827.3*	69	39–69	Observation	Alluvium, Cerro Toledo interval
MCO-7.5	1961	1635463	1768496	*6808.9*	60	35–60	Observation	Alluvium, Bandelier Tuff
MCO-7A	1989	1634501	1768508	*6827.6*	44.8	34.8–44.8	Observation	Alluvium, Bandelier Tuff
MCO-8	1960	1636021	1768529	*6796.7*	84	64–84	Observation	Bandelier Tuff, Cerro Toledo interval/Out of service since 1977
PCO-1	1985	1637919	1759991	6687	12.3	4.3–12.3	Observation	Alluvium, Bandelier Tuff
PCO-2	1985	1641700	1757443	6618	9.5	1.5–9.5	Observation	Alluvium, Bandelier Tuff
PCO-3	1985	1646089	1755489	6547	17.7	5.7–17.7	Observation	Alluvium, Bandelier Tuff
SCO-1	1989	1642298	1769502	6619	19.3	9.3–19.3	Observation	Alluvium/Dry; HSWA Special Permit
SCO-2	1989	1647259	1767864	6501	19.4	9.4–19.4	Observation	Alluvium, Bandelier Tuff/ Dry; HSWA Special Permit
WCO-1	1989	1632759	1755069	6616	34.4	24.4–34.4	Observation	Alluvium (?), Bandelier Tuff/ Dry; HSWA Special Permit
WCO-2	1989	1636870	1753228	6625	23.5	13.5–23.5	Observation	Alluvium, Bandelier Tuff/ Dry; HSWA Special Permit
WCO-3	1989	1640213	1750620	6436	12.4	9–14	Observation	Alluvium, Basalt/Dry

a. Coordinates listed are based on the New Mexico planar coordinate system as used in the maps in Appendix A of this core document. All locations are shown in Figure A-4 of Appendix A. A more complete list of wells in the Los Alamos area is available in Appendix E of the GPMPP (LANL 1995, 50124). Locations of wells are updated continually as new wells are installed and other wells are abandoned and plugged.

b. MSL = mean sea level, the elevations in italics are either surveyed or they are taken from the Digital Elevation Model for the Laboratory; these elevations are considered to be of good quality. The remaining elevations are literature values, and they are of unknown quality.

Source: LANL 1995, 50124

2.3.3.1 Regional Aquifer Monitoring

Measurements of the quality of water in the regional aquifer are made at various locations in and around the Laboratory at least once a year. There are 8 deep test wells and 14 supply wells that belong to DOE. There are also several regional aquifer wells near the Rio Grande that do not belong to DOE. These wells are on San Ildefonso Pueblo land and are sampled under the memoranda of understanding (MOU) between the US Bureau of Indian Affairs (BIA), DOE, and the Laboratory. In addition there are many springs along the Rio Grande that are sampled. Springs are discussed in Section 2.3.3.4.

Deep test wells include TW-1 and TW-2 in Pueblo Canyon; TW-3 in Los Alamos Canyon; TW-4 near Acid Canyon; TW-8 in Mortandad Canyon; and DT-5A, DT-9, and DT-10 on Frijoles Mesa near the southwestern boundary of the Laboratory between Water Canyon and Ancho Canyon. Test wells TW-1, TW-2, TW-3, TW-4, and TW-8 are located in or near canyons that have received or are now receiving industrial effluents. The test wells were constructed between 1949 and 1960 using cable-tool drilling methods. All test wells are equipped with pumps and continuous recording transducers.

DOE supply wells include the Guaje well field, the Pajarito Mesa wells, and the Otowi well O-4. The Guaje wells are G-1, G-1A, G-2, G-4, and G-5 in Guaje Canyon and G-6 in Rendija Canyon. The Pajarito Mesa wells are PM-1 and PM-3 in Sandia Canyon, PM-2 in Pajarito Canyon, PM-4 in Cañada del Buey, and PM-5 between Cañada del Buey and Mortandad Canyon. Otowi well O-4 is in Los Alamos Canyon. These wells are also equipped with dedicated pumps and either continuous recording water-level transducers or airline recorders.

Two supply wells that are not currently being used to monitor the regional aquifer are Guaje well G-3 and Otowi well O-1. Well G-3 was taken off line in 1993 because of a decline in production and sand in the pump. Well O-1 does not have a turbine pump because the borehole was drilled too crookedly to allow for the installation of one.

The depth to water varies between wells that are located on canyon floors and those located on mesa tops. Depth to water also varies with location on the Pajarito Plateau, depending on how close to the mountains or to the eastern edge of the plateau the well is located.

Regional aquifer wells are sampled for standard analysis of 10 radiochemical constituents (^{90}Sr, ^{137}Cs, ^{238}Pu, ^{239,240}Pu, ^{241}Am, total uranium, ^{3}H, and gross-alpha, -beta, and -gamma radiation); metals (Ag, Al, As, B, Ba, Be, Cd, Co, Cr, Cu, Fe, Hg, Mn, Mo, Ni, Pb, Sb, Se, Sn, Sr, Tl, V, and Zn); general inorganic constituents (SiO_2, Ca, Mg, K, Na, CO_3, HCO_3, PO_4, SO_4, NO_3, CN, total dissolved solids, total hardness, total suspended solids, pH, and electrical conductance); and organic compounds (volatiles, semivolatiles, individual herbicides, pesticides, polychlorinated biphenyls [PCBs], and oils or solvents). Regional aquifer supply wells are sampled annually for radiochemical constituents, metals, and general inorganic constituent analyses, and triennially for organic compound analysis. Regional aquifer test wells are sampled annually for radiochemical and major constituent analyses and triennially for trace metal and organic compound analyses.

Regional aquifer wells on San Ildefonso Pueblo land that are sampled under the MOU include LA-1A, LA-1B, LA-2, LA-5. Residential or community wells sampled under the MOU include Otowi House well, Halladay House well, New Community well, Martinez House well, Sanchez House well, and Pajarito Well Pumps 1 and 2. Wells LA-1A and LA-1B are observation wells, whereas the others are supply wells for San Ildefonso Pueblo. No information is currently available on the construction of wells other than the LA-wells; thus they are not listed in Table 2-2. The wells to be sampled and analyzed are determined annually under the terms of the MOU. Wells chosen for sampling will vary from year to year. Other San Ildefonso Pueblo wells that are sometimes sampled for special studies are the Old Community well, Westside Artesian well, Eastside Artesian well, and Don Juan Playhouse well.

annually under the terms of the MOU. Wells chosen for sampling will vary from year to year. Other San Ildefonso Pueblo wells that are sometimes sampled for special studies are the Old Community well, Westside Artesian well, Eastside Artesian well, and Don Juan Playhouse well.

Under the MOU, wells are sampled annually for analysis of eight radiochemical constituents (the 10 standard analyses above except ^{241}Am and ^{90}Sr), metals, and general inorganic constituents and triennially for ^{241}Am, ^{90}Sr, and organic compounds (LANL 1995, 50124).

2.3.3.2 Intermediate Perched Zone Monitoring

Perched groundwater zones of limited extent are known to occur at depths below canyon alluvium and above the regional aquifer in the Guaje Pumice bed at the base of the Bandelier Tuff as well as in the underlying conglomerates and basalts in portions of Pueblo Canyon, Los Alamos Canyon, and Sandia Canyon. Samples are routinely obtained from two test wells screened in two of these zones and one spring which discharges from one of these zones (discussed in Section 2.3.3.4).

Test Well (TW)-1A is located in lower Pueblo Canyon and is completed at a depth of 225 ft (69 m) into basalts. These basalts are known to have been recharged by effluent from the Los Alamos County Sewage Treatment Plant located between Bayo Canyon and Pueblo Canyon.

TW-2A is located in the middle of Pueblo Canyon and is completed to a depth of 132 ft (40.2 m) into fanglomerates of the Puye Formation.

Intermediate perched zone groundwater wells are sampled and analyzed annually for the 10 standard radiochemical constituents, and for general inorganic constituents. They are sampled and analyzed triennially for metals and organic compounds (LANL 1995, 50124).

2.3.3.3 Monitoring of Shallow Groundwater in Canyon Alluvium

Shallow alluvial groundwater zones are known to exist in Pueblo Canyon, Los Alamos Canyon, Mortandad Canyon, and Pajarito Canyon. The shallow alluvial groundwater zones are sampled by means of twenty-three observation wells and one spring (discussed in Section 2.3.3.4). Seventeen wells are sampled annually as part of the environmental surveillance activities. Seven of these wells and six other wells are designated for quarterly sampling in response to an Environmental Protection Agency requirement. Fourteen other shallow alluvial wells are also monitored regularly but are not always sampled because they are completely dry or contain insufficient water for sampling. The number of wells sampled may vary from year to year because of monitoring requirements or because a well is dry.

Shallow alluvial groundwater may exist in portions of Water Canyon, Sandia Canyon, Potrillo Canyon, and Cañon de Valle; however, several boreholes and observation wells installed in the alluvium of these canyons have failed to confirm the presence of alluvial groundwater.

Groundwater in the alluvium of Pueblo Canyon is sampled at one observation well above the confluence with Los Alamos Canyon. Well APCO-1 was completed in 1990 as part of the HSWA Special Permit Condition requirements to evaluate the extent of the shallow alluvial groundwater zone.

Los Alamos Canyon shallow alluvial groundwater is sampled at seven observation wells. Well LAO-C is near the western Laboratory boundary, well LAO-4.5 is near the eastern boundary, and wells LAO-0.7, LAO-1, LAO-2, LAO-3, and LAO-4 are spaced along the axis of the canyon. Well LAO-1 is below the site of the Omega West Reactor. Wells LAO-2, and LAO-3 are located near the confluence with DP Canyon, which received radioactive effluent from TA-21 before 1986.

Mortandad Canyon shallow alluvial groundwater is sampled at five observation wells. Mortandad Canyon receives wastewater and treated effluent through NPDES-permitted outfalls from the Radioactive Liquid Waste Treatment Facility at TA-50 and the SWSC at TA-46. It is the major release area for treated radioactive effluents. Wells MCO-4, MCO-5, MCO-6, MCO-7, and MCO-7.5 are located in the upper part of the canyon and cover about a 2-mi (3.2-km) section corresponding to the known extent of saturation. Well MCO-7.5 is located below the Mortandad Canyon sediment traps.

Pajarito Canyon shallow alluvial groundwater is sampled at three observation wells. Wells PCO-1, PCO-2, and PCO-3 are located in the lower part of the canyon near the waste storage and disposal Areas G and L at TA-54 (LANL 1995, 50124).

In Cañada del Buey, well CDBO-6 is the final well sampled as part of the annual environmental surveillance activities. This well was completed in 1992 to monitor planned effluent releases from the SWSC Project. Effluent from the SWSC Project has never been discharged into Cañada del Buey, although it may be in the future. Currently, effluent from the SWSC Project is generally reused for cooling water and ultimately discharged to Sandia Canyon. The water in CDBO-6 is thought to be from discharge during the start-up of the pump in supply well PM-4 (Purtymun 1995, 45344).

As part of the environmental surveillance activities, shallow alluvial groundwater wells are sampled and analyzed annually for the 10 standard radiochemical constituents, metals and general inorganic constituents. These wells are also sampled and analyzed triennially for organic compounds.

Three wells (MCO-8, PCO-3, and LAO-4.5) are sampled and analyzed under requirements of Module II of the Hazardous Waste Facility Permit. These wells are sampled and analyzed annually for radiochemical constituents, metals, general inorganic constituents, and organic compounds.

Other shallow alluvial groundwater wells that were installed as part of the HSWA Special Permit Condition requirements include LAO-3A, LAO-4.5C, LAO-6A, MCO-4B, MCO-6B, and MCO-7A. These wells and their pairs (LAO-3, LAO-4.5, LAO-6, MCO-4, MCO-6, and MCO-7) as well as APCO-1 in Pueblo Canyon were sampled quarterly during 1995 in response to an EPA requirement (LANL 1993, 21404). These wells are being sampled and analyzed by the Laboratory’s Surveillance Group during the annual investigations in Los Alamos Canyon.

Shallow alluvial wells installed in Los Alamos Canyon specifically to monitor background and effects of discharges from TA-2 and TA-41 include LAO-B, LAO-0.3, LAO-0.6, LAO-0.7, LAO-0.8, and LAO-0.91.

Other shallow alluvial wells at the Laboratory are monitored regularly but are not always sampled because they are completely dry or contain insufficient water for sampling. These include wells LAO-4.5A, LAO-4.5B, MCO-4A, MCO-6A, SCO-1, SCO-2, FCO-1, WCO-1, WCO-2, WCO-3, CDBO-4, CDBO-5, CDBO-7, and CDBO-8. These wells will be sampled if water is ever present in sufficient amounts (LANL 1995, 50124).

2.3.3.4 Springs

There are 30 natural springs in and around the Laboratory that are sampled and analyzed to monitor the quality of water in the regional aquifer, the intermediate perched groundwater zones, and the shallow alluvial groundwater zones. Table 2-3 lists the springs currently sampled in the Laboratory Environmental Surveillance Program (LANL 1995, 50124). Locations are shown on Figure A-4 in Appendix A of this core document.

Regional aquifer springs sampled include 22 springs in White Rock Canyon and 6 springs on San Ildefonso Pueblo land near the confluence of Los Alamos Canyon with the Rio Grande. White Rock Canyon springs are sampled and analyzed annually for 7 radiochemical constituents (^{90}Sr, ^{137}Cs, ^{238}Pu, ^{239,240}Pu, tritium, total uranium, and gross-gamma activity) and general inorganic constituents, and triennially for metals. Selected springs are sampled and analyzed annually for PCBs.

TABLE 2-3

CURRENT SPRINGS SAMPLED IN THE ENVIRONMENTAL SURVEILLANCE PROGRAM

Spring	East-West Coordinate[a]	North-South Coordinate[a]	Elevation (ft MSL[b])	Source (Geologic Unit)
Alluvial				
Water Canyon Gallery	1604144	1762562	8000	Bandelier Tuff
Intermediate				
Basalt Spring	1656544	1770762	6000	Landslide blocks over Puye Formation
Regional Aquifer				
Ancho Spring	1645644	1739962	5700	Totavi Lentil
Doe Spring	1642325	1733598	5600	Cerros del Rio maar deposits
Indian Spring	1665944	1777262	5640	Santa Fe Group (?)
La Mesita Spring	1656544	1770762	5580	Santa Fe Group (?)
Rio Spring 1	1667928	1767857	5615	Unknown
Rio Spring 2	1667312	1766348	5600	Unknown
Rio Spring 2A	1662644	1754862	5495	Landslide blocks over Santa Fe Group
Rio Spring 3	1661487	1753562	5560	Landslide blocks
Rio Spring 3A	1661520	1753298	5560	Landslide blocks
Rio Spring 3AA	1661291	1751050	5560	Landslide blocks
Rio Spring 3B	1661354	1749814	5500	Unknown
Rio Spring 4	1656028	1747887	5570	Landslide blocks
Rio Spring 4A	1656144	1747862	5570	Landslide blocks
Rio Spring 5	1656056	1742541	5770	Unknown
Rio Spring 5A	1655365	1742005	5395	Unknown
Rio Spring 5AA	1651144	1742562	5760	Unknown
Rio Spring 5B	1561044	1738162	5390	Unknown
Rio Spring 6	1648882	1735517	5380	Unknown
Rio Spring 6A	1646562	1734272	5375	Unknown
Rio Spring 7	1645044	1733562	5370	Unknown
Rio Spring 8	1644444	1733462	5370	Unknown
Rio Spring 8A	1643818	1733508	5520	Cerros del Rio maar deposits
Rio Spring 8B	1643244	1733562	5480	Cerros del Rio maar deposits

a. Coordinates listed are based on the New Mexico planar coordinate system as used in the maps in Appendix A of this core document. All locations are shown in Figure A-4 of Appendix A.

b. MSL = mean sea level

TABLE 2-3 (continued)

CURRENT SPRINGS SAMPLED IN THE ENVIRONMENTAL SURVEILLANCE PROGRAM

Spring	East-West Coordinate[a]	North-South Coordinate[a]	Elevation (ft MSL[b])	Geologic Unit Spring Issuing From
Rio Spring 9	1643435	1733317	5485	Cerros del Rio maar deposits
Rio Spring 9A	1642742	1733147	5525	Cerros del Rio maar deposits
Rio Spring 10	1638023	1728162	5360	unknown
Sacred Spring	1670044	1780362	5640	Santa Fe Group
Sandia Spring	1663182	1761490	5700	Totavi Lentil
Other Springs (Occasional Sampling)				
American Spring	1601044	1760062	8280	Tschicoma Fm. /Bandelier Tuff contact
Apache Spring	1599144	1753662	8320	Bandelier Tuff
Armstead Spring	1599744	1762762	8216	Alluvium/Tschicoma contact
Bulldog Spring	1614970	1767245	~7450	Alluvium/Bandelier Tuff contact
Burning Ground Spring	1614275	1764630	~7500	Bandelier Tuff
Charlies Spring	1613350	1767790	~7500	Bandelier Tuff
DP Spring	1636615	1773713	~6900	Alluvium/Bandelier Tuff contact
Frijoles Spring 1	1592344	1759562	8430	Tschicoma Fm.
Guaje Spring 1	1600444	1797762	8850	Bandelier Tuff
Guaje Spring 2	1600444	1796062	8840	Bandelier Tuff
Hamilton Bend Spring	1642844	1776162	~6510	Alluvial Terrace
Homestead Spring	1614275	1768555	~7350	Bandelier Tuff
Los Alamos Spring	1657444	1770962	6000	Landslide Deposit
Otowi Seep	Unknown	Unknown		unknown
PC Spring	1601844	1773262	8660	Alluvium/Bandelier Tuff contact
Quemazon Spring	1603044	1788462	8660	Alluvium/Bandelier Tuff contact
Reservoir Spring	1605944	1778862	8000	Alluvium/Bandelier Tuff contact
Rio Spring 8B	1643244	1733562	5480	Cerros del Rio maar deposits
Rio Spring 9B	1642437	1732938	~6100	Cerros del Rio maar deposits
Skate Spring	1617130	1776080	~7200	unknown
Starmer Spring	1613260	1767830	~7500	Bandelier Tuff
SWSC Line Spring	1613905	1764760	~7450	Bandelier Tuff
TA-18 Spring	1634193	1760782	~6750	Colluvium/Bandelier Tuff contact
Valle Spring 1	1604144	1766462	8260	Alluvium/Bandelier Tuff contact
Valle Spring 2	1604344	1766582	8240	Alluvium/Bandelier Tuff contact

a. Coordinates listed are based on the New Mexico planar coordinate system as used in the maps in Appendix A of this core document. All locations are shown in Figure A-4 of Appendix A.

b. MSL = mean sea level

An intermediate perched groundwater zone in lower Los Alamos Canyon is regularly sampled at Basalt Spring. Although the main source of water for Basalt Spring is believed to be an intermediate perched zone, several lines of evidence developed recently (Yanicak 1996, 54418) suggest that at least some of the water may come from nearby surface water infiltration. As a location specified in Module II of the Hazardous Waste Facility Permit, this spring is sampled and analyzed annually for the 10 radiochemical constituents, metals, general inorganic constituents, and organic compounds (LANL 1995, 50124).

One set of springs, the Water Canyon Gallery, is located near the western boundary of the Laboratory and is used as part of the Laboratory water supply. The gallery collects discharge from a perched groundwater zone issuing from the Bandelier Tuff on the flanks of the Jemez Mountains. Water from the gallery is sampled and analyzed annually for 8 radiochemical constituents (the 10 standard analyses, except ^{90}Sr and ^{241}Am) and general inorganic constituents and triennially for metals and organic compounds.

Many other springs are located in and around the Laboratory. Twelve are located on the eastern flank of the mountains and one on San Ildefonso Pueblo land just east of the Laboratory boundary in Los Alamos Canyon (Los Alamos Spring). Additional springs within the Laboratory boundary include Bulldog Spring, Burning Ground Spring, Charlies Spring, DP Spring, Hamilton Bend Spring (currently dry), Homestead Spring, Otowi Seep, Skate Spring, Starmer Spring, SWSC Line Spring, and TA-18 Spring. Some of these have not yet been surveyed for specific location information and are not shown on Figure A-4 in Appendix A of this core document. Many of these springs are sampled only occasionally for special studies or for determination of background water chemistry but are not included as part of the normal environmental surveillance activities (LANL 1995, 50124).

2.3.4 Special Studies and Programs

In addition to the monitoring network, the Laboratory conducts a number of special studies and programs related to groundwater protection. These programs include hydrogeologic studies, studies of the vadose zone, age-dating studies of the regional aquifer water, surface water studies, and groundwater quality studies at San Ildefonso Pueblo. These programs are described below (LANL 1995, 50124).

2.3.4.1 Hydrogeologic Studies

Since 1992, the ER Project has drilled a number of boreholes to fill gaps in the knowledge of the hydrogeology and the extent of intermediate perched groundwater. Many of the boreholes have been drilled to 300 ft (90 m) or more.

- Borehole LADP-4, drilled to a total depth of 800 ft (244 m) in DP Canyon, encountered no perched groundwater. Core samples were analyzed for hydrologic properties.

- Well LADP-3, the borehole for which was drilled to a depth of 349 ft (106 m) in Los Alamos Canyon, encountered perched groundwater in the Guaje Pumice Bed of the Otowi Member.

- Well LAOI(A)-1.1, the borehole for which was drilled to a depth of 323 ft (98.5 m) in Los Alamos Canyon, encountered perched groundwater in both the Guaje Pumice Bed and the top of the Puye Formation.

- Borehole 21-2523, drilled to a depth of 707 ft (215 m) west of material disposal area (MDA) -V at TA-21, passed through some moist zones, but no saturated zones were encountered.

- At TA-54, six boreholes have been drilled near MDA-L and two deep angle boreholes have been drilled from Cañada del Buey to beneath Mesita del Buey. One of the deep angle boreholes encountered wet zones beneath Mesita del Buey in the Puye Formation.

- Borehole 49-2-700-1 at TA-49 was drilled to a depth of 700 ft (213 m). No perched groundwater was encountered.
- A 300-ft (91-m) borehole drilled to the top of the basalt at TA-33 encountered wet zones in basalt cinder deposits, but no perched groundwater was found.

2.3.4.2 Vadose Zone Studies

The occurrence and movement of water under unsaturated conditions (vadose zone) has been studied at numerous locations within the Laboratory starting with special USGS studies in the 1950s. Knowledge of vadose zone processes is relevant to understanding the potential for downward movement of water that could constitute recharge to intermediate perched zones and the regional aquifer, and provide a mechanism for downward migration of contaminants.

In general, studies of the vadose zone on mesa tops show that moisture content in the tuff beneath the mesa tops at depths greater than a few meters (the zone affected by seasonal moisture and evapotranspiration) is less than 10% by volume; thus, significant vertical migration on the mesa tops is unlikely.

In 1985, vadose zone characterization studies were completed for TA-54 waste disposal sites Areas G and L (Pajarito Canyon and Cañada del Buey). The results indicate that aqueous transport of contaminants through the tuff is not a viable mechanism for contaminant migration at either area.

Field investigations of the vadose zone under mesa tops are currently underway at six material disposal areas. These include MDA-T and MDA-V at TA-21, MDA-AB at TA-49, MDA-G and MDA-L at TA-54, and the Airport Landfill at TA-73.

At TA-54, angle and vertical boreholes have been drilled from the mesa top to obtain detailed hydrologic and stratigraphic information. Boreholes to depths of 300 ft (91 m) have been instrumented to measure downhole concentrations and pressures of contaminant vapors and the significance of vapor transport of contaminants. This information has been used for the initial design of a pilot vapor extraction system for MDA-L. Preliminary analyses of hydraulic gradients in the vadose zone at TA-54 suggest that the general direction of water movement within the exposed finger mesa may be upward, with significant implications for long-term waste disposal (Rogers and Gallaher 1995, 48845). This hypothesis is being tested by ongoing investigations supported by the MDA-G performance assessment, which is discussed below. Movement of water below the adjacent canyon floor elevation is downward.

A separate performance assessment is ongoing at MDA-G. Geological, hydrological, and geochemical data have been assembled into a basic data report from which a conceptual hydrogeologic model for the site was formulated. Computer simulations forecast long-term performance of the disposal area over thousands of years. The analysis will include an initial evaluation of the role of fractures on contaminant migration within the mesa.

The potential for downward migration of water in canyons that contain shallow alluvial groundwater is presumed to be greater than in canyons that do not contain groundwater because the water provides both a vertical head and a source. Several studies have been conducted in the canyons for RCRA compliance requirements to further define the occurrence of shallow alluvial groundwater and the potential for movement of water or contaminants.

A 1989 study in Sandia Canyon, Potrillo Canyon, Fence Canyon, and Water Canyon revealed no saturated conditions in the alluvium. In 1987, observation wells were installed in Cañon de Valle adjacent to an inactive waste disposal area (MDA-P). Monitoring of the wells revealed no saturation or evidence of leachate or seepage from the landfill to the alluvium. However, high concentrations of barium were found in the tuff underlying the area.

In 1992, a study in Cañada del Buey was initiated to monitor conditions in and beneath the alluvium resulting from planned discharges from the new SWSC treatment plant at TA-46. Those discharges have not yet occurred but may at a future date. Five observation wells and two neutron moisture logging holes were installed within the upper and middle reaches of the drainage. Results of the study, under predischarge conditions, indicate that there is limited shallow alluvial groundwater in Cañada del Buey. Along the drainage system, saturation was found within only a 0.8-km (0.5-mi) segment. The apparent source of saturation is purge water from the nearby municipal water supply well PM-4. The alluvium is dry upstream of the point of purge water entry. If effluents are eventually released into the drainage system, infiltration along the stream bottom will create a narrow ribbon of saturation within the alluvium and weathered tuff overlying the unweathered Bandelier Tuff (Environmental Protection Group 1994, 35363).

2.3.4.3 Age-of-Water and Recharge Source Studies

To better understand the nature of recharge to the regional aquifer, researchers have performed age-dating measurements on selected water samples. This cooperative effort, involving several Laboratory divisions and staff from another DOE installation, uses geochemical techniques based on measurements of both radioactive and stable isotopes to help identify specific sources and estimate the age of water in the regional aquifer. Preliminary interpretation of the data indicates that the water ranges in age from more than 1,000 years to more than 30,000 years.

Another series of tests on regional aquifer waters was initiated to sample for ultra-low levels of tritium, ^{36}Cl, ^{14}C, and plutonium and uranium isotopes. These tests can help indicate whether recent recharge has occurred (LANL 1995, 50124).

2.3.4.4 Studies of Surface Water Discharge

The Laboratory is conducting ongoing studies of expected flood size in the Los Alamos region (McLin 1992, 12014). These studies involve use of computer-based models developed by the US Army Corps of Engineers, Hydrologic Engineering Center to project the effects of severe thunderstorms on all the watersheds in the Los Alamos area. The modeling effort predicts the effects of storm runoff on flood elevations within canyons and on different Laboratory facilities and structures. Precipitation totals and floodplain elevations have been projected for 2-, 5-, 10-, 25-, 50-, and 100-year storm events.

Stream gauges have been installed recently in many of the major drainages at the Laboratory's upstream and downstream boundaries. The locations of stream gauges are shown in Figure A-4 in Appendix A of this core document. Other drainages are also equipped with stream gauges on a site-specific basis. Although only limited data have been obtained from these gauges to date, they will contribute data to help understand the watersheds and refine the above-mentioned flood models (LANL 1995, 50124).

2.3.4.5 Environmental Studies at San Ildefonso Pueblo

The Laboratory conducts an ongoing environmental studies program at the San Ildefonso Pueblo. As previously mentioned, the Laboratory and DOE have entered into an MOU with the Pueblo and the BIA to conduct environmental sampling on Pueblo land. Part of the sampling program includes monitoring water quality in wells located on Pueblo land, and ensuring that the water is safe for consumption and has not been adversely impacted by Laboratory operations (LANL 1995, 50124).

2.3.5 Sediment Monitoring

Environmental data on soils and sediments have been collected at the Laboratory and published since 1945. Until 1949, these data were gathered almost exclusively in Los Alamos Canyon and Pueblo Canyon. The USGS monitored the effects of releases of radioactive effluents and conducted geohydrological studies in the Laboratory area for the AEC from 1949 through 1971.

Previous studies indicate that most radionuclides (excluding ^{90}Sr) and other contaminants (such as Ba^{2+}) are transported on suspended and bedload sediments transported during storm flows (LANL 1981, 6059; Longmire et al. 1996, 54168). Therefore, contaminant distributions may be expected to vary substantially, spatially as well as temporally. Results of these studies are available in a series of reports and publications (references compiled by Bennett [1990, 7507]). Starting in 1970 the Laboratory initiated a formal environmental monitoring program. That monitoring program, which is now required by DOE Order 5400.1 (DOE 1988, 0075), continues under the direction of the Laboratory’s ESH Division.

2.3.5.1 Environmental Surveillance Program

Sediments and soils in the canyon systems are routinely sampled and analyzed as part of the annual Laboratory-wide routine environmental monitoring program. Sediment samples are analyzed for the standard 10 radiochemical constituents, trace metals, volatile and semivolatile organic compounds, and PCBs (Environmental Protection Group 1994, 35363). Results are presented in the annual surveillance reports. This monitoring provides data on the environmental effects of Laboratory operations. Additionally, these data are useful in assessing both spatial and temporal variability in the concentrations of chemical and radioactive contaminants within individual canyons. Existing perimeter and on-site (within Laboratory boundaries) sediment and soil monitoring stations are located within many of the canyons on the Pajarito Plateau, as shown in Figure A-4 in Appendix A of this core document. The surveillance stream sediment samples are typically collected from sandy deposits in the active stream channel.

2.3.5.1.1 Perimeter Sediment Monitoring Stations

The perimeter sediment monitoring stations are grouped into two categories: radioactive effluent areas and other canyons. Six perimeter sediment monitoring stations are located in former radioactive effluent release areas, including three stations within the Acid Canyon/Pueblo Canyon drainage and three stations within the DP Canyon/Los Alamos Canyon drainage. Other perimeter sediment monitoring stations include Guaje at state road New Mexico (NM) 502, Bayo at NM502, Sandia at the Rio Grande, Cañada Ancha at the Rio Grande, Pajarito at the Rio Grande, Frijoles at Bandelier National Monument Headquarters, Frijoles at the Rio Grande, and six locations within Mortandad Canyon on San Ildefonso Pueblo land, including one station at the Rio Grande (see Table 2-4).

2.3.5.1.2 On-Site Sediment Monitoring Stations

The on-site sediment monitoring stations are grouped into radioactive effluent release areas, other canyons, and radioactive solid waste management areas.

TABLE 2-4

LOCATIONS OF SEDIMENT SAMPLING STATIONS

Station	North-South Coordinate[a]	East-West Coordinate[a]
Perimeter Stations		
Radioactive Effluent Release Area		
Acid/Pueblo Canyon		
Acid Weir	1,778,804	1,624,458
Pueblo 1	1,778,879	1,624,410
Pueblo 2	1,776,865	1,635,258
DP/Los Alamos Canyon		
Los Alamos at Totavi	1,772,420	1,659,928
Los Alamos at LA-2	1,777,219	1,666,924
Los Alamos at Otowi	1,773,690	1,672,338
Other Canyons		
Guaje at NM502	1,777,429	1,665,918
Bayo at NM502	1,774,424	1,662,606
Sandia at Rio Grande	1,758,987	1,665,258
Cañada Ancha at Rio Grande	NS[b]	NS
Pajarito at Rio Grande	1,747,594	1,656,959
Frijoles at National Monument Headquarters	1,737,991	1,634,384
Frijoles at Rio Grande	1,729,556	1,639,442
Mortandad Canyon on San Ildefonso Land		
Mortandad A-6	NS	NS
Mortandad A-7	NS	NS
Mortandad A-8	NS	NS
Mortandad at NM4 (A-9)	1,763,845	1,649,681
Mortandad A-10	NS	NS
Mortandad at Rio Grande (A-11)	1,756,657	1,663,882

a. Coordinates listed are based on the New Mexico planar coordinate system as used in the maps in Appendix A of this core document. All locations are shown in Figure A–4 of Appendix A.

b. NS means not surveyed.

TABLE 2-4 (continued)

LOCATIONS OF SEDIMENT SAMPLING STATIONS

Station	North-South Coordinate[a]	East-West Coordinate[a]
On-Site Stations		
Radioactive Effluent Release Areas		
Acid/Pueblo Canyon		
Hamilton Bend Spring	1,775,920	1,642,477
Pueblo 3	1,774,889	1,646,669
Pueblo at NM502	1,771,924	1,652,939
DP/Los Alamos Canyon		
DPS-1	1,774,858	1,633,325
DPS-4	1,773,290	1,637,503
Los Alamos at Bridge	1,775,613	1,618,260
Los Alamos at LAO-1	1,773,947	1,629,407
Los Alamos at GS-1	1,770,889	1,648,151
Los Alamos at LAO-3	1,773,074	1,638,048
Los Alamos at LAO-4.5	1,772,136	1,643,654
Los Alamos at NM4	1,771,536	1,651,895
Mortandad Canyon		
Mortandad near CMR Building	1,772,155	1,619,736
Mortandad west of GS-1	NS[b]	NS
Mortandad at GS-1	1,770,292	1,626,746
Mortandad at MCO-5	1,769,545	1,632,456
Mortandad at MCO-7	1,768,482	1,634,550
Mortandad at MCO-9	1,768,371	1,638,058
Mortandad at MCO-13 (A-5)	1,767,231	1,641,296
Other Canyons		
Sandia at NM4[c]	1,767,631	1,647,803
Cañada del Buey at NM4[c]	1,756,343	1,651,703
Pajarito at NM4[c]	1,754,395	1,648,529
Portrillo at NM4[c]	1,751,159	1,645,619
Fence at NM4[c]	1,751,130	1,643,542
Water at NM4[c]	1,750,028	1,640,673
Indio at NM4[c]	1,747,860	1,641,319
Ancho at NM4[c]	1,741,218	1,640,260
Water at Rio Grande	1,741,201	1,654,398
Ancho at Rio Grande	1,735,559	1,649,551
Chaquehui at Rio Grande	1,733,074	1,643,012

a. Coordinates listed are based on the New Mexico planar coordinate system as used in the maps in Appendix A of this core document. All locations are shown in Figure A–4 of Appendix A.

b. NS means not surveyed.

c. These sediment stations located at state road NM4 are the first points of public access because all Laboratory facilities in or adjacent to these canyons are located west of NM4.

Source: Environmental Protection Group 1993, 23249

On-site sediment monitoring stations located in former radioactive effluent release areas include two stations within DP Canyon, six stations within Los Alamos Canyon, and seven stations within Mortandad Canyon (see Table 2-4). Eleven on-site sediment monitoring stations, included in the other canyons category, are listed in Table 2-4.

Sediments from natural drainages around two on-site radioactive solid waste management areas, TA-49 and TA-54, are sampled and analyzed to monitor for transport of radioactivity from surface contamination. The sediment sampling locations at these areas are shown in Figure A-4 of Appendix A of this core document but are not listed in Table 2-4 because they are devoted to technical-area-specific monitoring. In 1960, a surface contamination incident occurred at TA-49 which resulted in erosional transport of radioactively contaminated soil. Eleven on-site sediment sampling locations were established in 1972 to monitor surface sediment in a natural drainage leading away from TA-49. An additional location was added in 1981 as the drainage channel changed. Nine sediment sampling locations were established in 1982 outside the perimeter fence at TA-54, Area G, to monitor possible transport of radionuclides by sheet erosion from the active waste storage and disposal area.

2.3.5.2 Geomorphic Studies

Several geomorphic studies have been completed within discrete segments of several canyons. These studies have contributed significantly to the general understanding of the age of sedimentary deposits in the canyons (Drake and Inoué 1993, 53456; Drakos and Inoué 1994, 48850; Reneau 1995, 50143; Reneau et al. 1996, 55539). Data indicate that sedimentary deposits and geomorphic surfaces in the canyons are generally less than 10,000 years old and include post-1942 historical deposits (Reneau et al. 1996, 55539).

A geomorphic study completed in 1991 (Graf 1994, 55536) provides a historic perspective for evaluating the contributions of plutonium from Los Alamos Canyon to the Rio Grande. The study used historic aerial photography and hydrologic data to evaluate the movement and deposition of sediment over time. Several conclusions were made regarding the regional balance of deposited plutonium in the sediment from 1948 to 1985, accounting for both worldwide fallout and the Laboratory contribution from Los Alamos Canyon to the northern Rio Grande.

- Worldwide fallout accounts for more than 90% of the plutonium in the Rio Grande system; the Laboratory contributes slightly less than 10%.
- Approximately half the total plutonium in the Rio Grande system resides in sediment along the Rio Grande; the remainder is stored in sediments in the Elephant Butte Reservoir.
- Most of the Laboratory contributions remain stored in sediment along the Rio Grande between the mouth of Los Alamos Canyon and Peña Blanca (just downstream from Cochiti Dam). Since 1973 when Cochiti Dam was completed, the downstream movement has ended in Cochiti Reservoir.

The geomorphic study identified locations where sediments had been deposited during specific periods. A sediment sample was collected from a floodplain near Buckman (near Cañada Ancha and east of the mouth of Sandia Canyon) that was hydrologically active between 1941 and 1968. The sample was collected specifically for the analysis of plutonium isotopes by high-sensitivity mass spectrometry. The ratio of ^{239}Pu to ^{240}Pu in the sample indicated that the plutonium consisted of an equal mixture of worldwide fallout and Laboratory-produced material transported through Acid Canyon, Pueblo Canyon, and Los Alamos Canyon. The total activity of the two plutonium isotopes (0.017 pCi/g) was less than the average value for fallout in northern New Mexico (0.023 pCi/g) (Purtymun et al. 1987, 6687). Thus, only the isotopic ratio, not an elevated concentration, identified the contribution as being from historic Laboratory releases.

2.3.6 Surface Water Monitoring

Since 1945, water-quality data have been collected and published. The USGS monitored the effects of releases of radioactive effluents and conducted geohydrological studies in the Los Alamos area for the AEC from 1949 through 1969. Results of these studies are available in a series of reports and publications (references compiled for use in the ER Project in Bennett [1990, 7507]). Starting in 1970, the Laboratory initiated a formal environmental monitoring program. This monitoring program, which is now required by DOE Order 5400.1 (DOE 1988, 0075), continues under the direction of the Laboratory's ESH Division.

The surface water sampling locations are generally collocated with the sediment sampling locations discussed in the previous section, and the rationale for location is similar. Table D-10 in *Environmental Surveillance at Los Alamos during 1991* (Environmental Protection Group 1993, 23249) (see Table 2-5) lists 10 perimeter surface water monitoring stations, and 12 on-site surface water monitoring stations as shown in Figure A-4 in Appendix A of this core document.

Chemical analyses include major ions (calcium, sodium, magnesium, potassium, chloride, sulfate, fluoride, and bicarbonate); radionuclides (tritium, ^{90}Sr, ^{137}Cs, ^{238}Pu, ^{239,240}Pu, ^{241}Am, ^{234}U, ^{235}U, ^{238}U, and gross-alpha and -beta); and trace elements. Results of chemical analyses, generally obtained on unfiltered water samples from these monitoring stations, are tabulated in Laboratory reports of special studies and in the annual environmental surveillance reports. Analyses of these unfiltered water samples are not directly comparable to New Mexico Water Control Commission standards, which are largely based on filtered water samples. References to the annual environmental surveillance reports and reports of numerous special studies are contained in Chapter 3 of this core document.

2.3.7 Reporting

The results of groundwater, surface water, sediment and soil sampling, analysis and protection efforts at the Laboratory are published in the annual environmental surveillance reports and the annual water supply reports. These two reports are described below.

2.3.7.1 Annual Environmental Surveillance Reports

The purpose of the environmental surveillance reports is to provide a comprehensive source of environmental data collected at the Laboratory. Since the early 1970s, the Laboratory has routinely collected and analyzed samples of air, water, soil, and foodstuffs throughout the Los Alamos area to determine any levels of contamination. The data collected in this program are published annually in the environmental surveillance report for distribution to the public and to local, state, and federal agencies. Included in the report are sections that explain the groundwater monitoring and protection program at the Laboratory and the results of sampling that have occurred in the subject year (LANL 1995, 50124).

2.3.7.2 Annual Water Supply Reports

The purpose of the water supply reports is to ensure a continuing historical record and to provide guidance for the management of water resources in long-range planning for the water supply system. The report publishes data on the amount of water supplied in the Los Alamos area, the conditions of the water supply wells, and the hydrologic conditions of the regional aquifer. Special studies and documentation of new supply wells are included as well as detailed records of pumping and water level measurements (LANL 1995, 50124).

TABLE 2-5

SURFACE WATER SAMPLING STATIONS[a]

Station	Latitude or Northing Coordinates[b]	Longitude or Easting Coordinates[b]
On-Site Stations		
Radioactive Effluent Release Area		
Acid/Pueblo Canyon		
Pueblo 3	1,774,889	1,646,669
Pueblo at NM502	1,771,924	1,652,939
DP/Los Alamos Canyon		
DPS-1	1,774,858	1,633,325
DPS-4	1,773,290	1,637,503
Mortandad Canyon		
GS-1	1,770,292	1,626,746
Other Canyons		
Cañada del Buey	1,766,728	1,631,875
Pajarito Canyon	1,757,344	1,642,168
Water Canyon at Beta	1,757,575	1,625,302
Sandia Canyon		
SCS-1	1,773,934	1,621,222
SCS-2	1,771,143	1,632,825
SCS-3	1,770,269	1,635,899
Ancho Canyon at Rio Grande	1,735,559	1,649,551
Perimeter Stations		
Radioactive Effluent Release Area		
Acid/Pueblo Canyon		
Acid Weir	1,778,804	1,624,458
Pueblo 1	1,778,879	1,624,410
Pueblo 2	1,776,865	1,635,258
Los Alamos Canyon		
Los Alamos at Rio Grande	1,773,653	1,672,287
Other Areas		
Guaje Canyon Reservoir	1,794,062	1,611,844
Los Alamos Reservoir	1,777,262	1,608,844
Mortandad at Rio Grande	1,756,657	1,663,882
Pajarito at Rio Grande	1,747,594	1,656,959
Frijoles at Park Headquarters	1,737,991	1,634,384
Frijoles at Rio Grande	1,729,556	1,639,442

a. Surface water sampling locations are shown in Figure IV-6 of *Environmental Surveillance at Los Alamos during 1992* (Environmental Protection Group 1994, 35363).

b. Coordinates listed are based on the New Mexico planar coordinate system as used on the maps in Appendix A of this core document. All locations are shown on Figure A-4 of Appendix A.

Source: Environmental Protection Group 1993, 23249

2.4 Sources of Potential Contamination of the Canyon Systems

Past Laboratory activities that may have contributed to the potential contamination of the canyon systems include high-explosives testing, biomedical research, nuclear reactor research, and plutonium processing among many other activities. Laboratory-derived contaminants that may be present in the canyon systems include various RCRA hazardous constituents, various radiological constituents, high explosives, PCBs, pesticides, and herbicides. Appendix D of the GPMPP (LANL 1995, 50124) provides a series of tables organized by field unit. Within each field unit, PRSs and potential contaminants associated with them that may have affected the canyon systems are identified. A current list of PRSs is available from the Laboratory Facility for Information Management, Analysis, and Display. The locations of PRSs are shown in map A-1 in Appendix A of this core document. The eight individual SAPs for canyon or canyon-aggregate specific investigations will provide (or have provided in the case of the *Task/Site Work Plan for Operable Unit 1049: Los Alamos Canyon and Pueblo Canyon* submitted in November, 1995 [LANL 1995, 50290]) detailed discussions of past and present internal and external sources of contamination for each individual canyon within the canyon systems.

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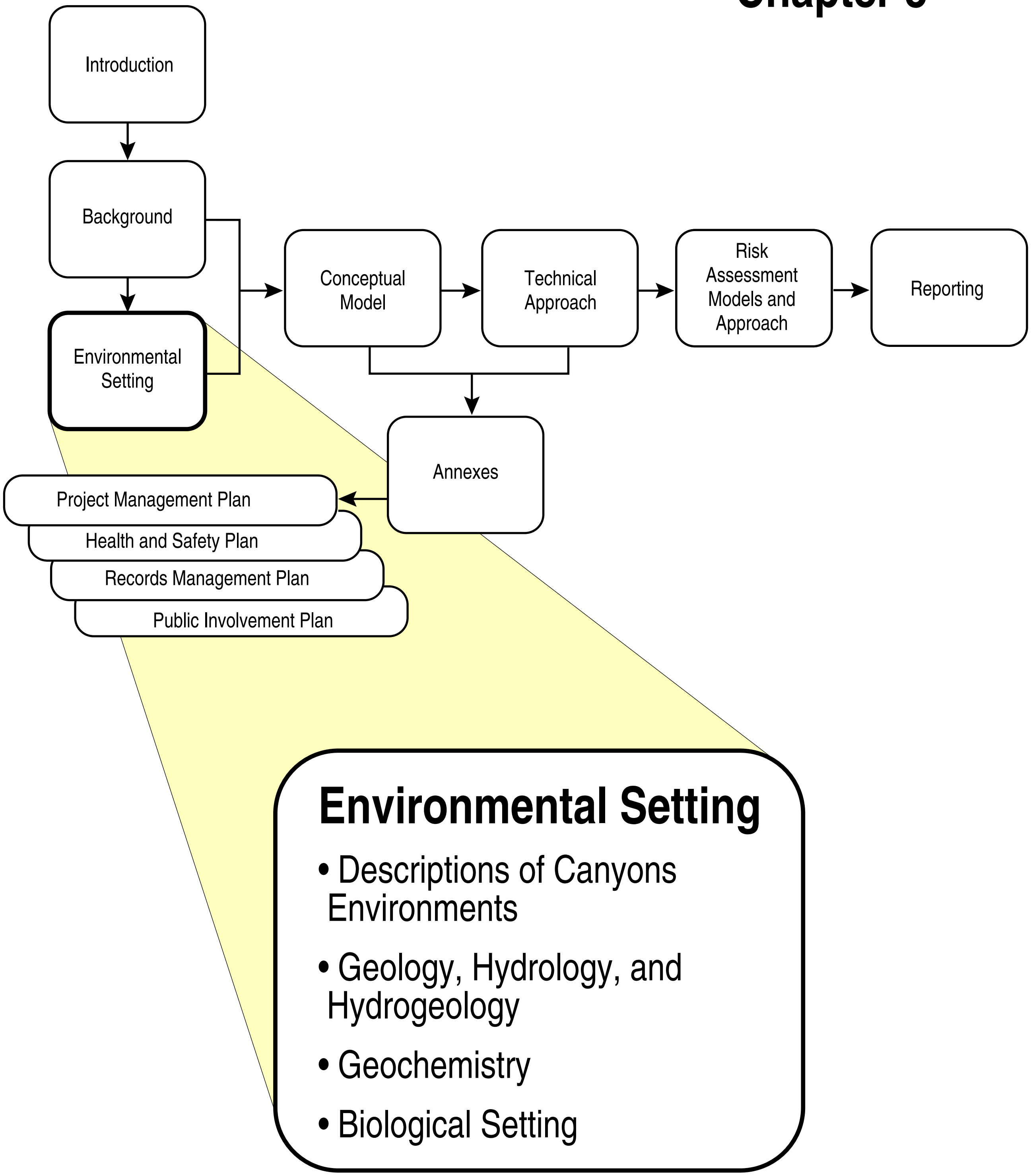
Chapter 3



Environmental Setting

- Descriptions of Canyons Environments
- Geology, Hydrology, and Hydrogeology
- Geochemistry
- Biological Setting

3.0 ENVIRONMENTAL SETTING

This chapter describes those portions of the regional environmental setting that are relevant to the canyon systems. Details of the regional environmental setting of the Laboratory are discussed in Chapter 2 of the Installation Work Plan (IWP) (LANL 1996, 55574) and in literature referenced in this chapter.

This chapter provides the technical basis for the conceptual model of contaminant occurrence, transport, and exposure route described in Chapter 4 of this core document, and identifies additional information needed for expanding the conceptual understanding of the environmental processes and assessing the magnitude and importance of potential exposure pathways within the canyon systems.

3.1 Location and Topography

The locations of all major canyons within the area affected by current and former Laboratory operations are shown in Figure 1-2 (in Chapter 1 of this core document). The west-to-east slope of the Pajarito Plateau, into which the canyons are cut, results in surface drainage patterns on the mesa tops that are generally oriented to the north, east, and south and feed into the canyons. The drainage area for the canyon systems extends from the topographic divide on the Sierra de Los Valles (to the west) eastward to the Rio Grande. During the summer, storm water runoff occasionally reaches the Rio Grande via the canyon systems.

Detailed descriptions of the canyons can be found in Section 3.6.2.2.3 of Revision 3 of the IWP (LANL 1993, 26078). Table 3-1 summarizes elevation, watershed area, and channel length information for each of the canyons. Figure A-1 in Appendix A of this core document shows the watershed boundaries for each of the canyon systems.

3.2 Climate

Los Alamos County has a semiarid, temperate, mountain climate, as summarized in Chapter 2 of the IWP (LANL 1996, 55574) and discussed in detail by Bowen (1990, 6899). The climate in the various canyon systems influences soil development (Birkeland 1984, 44019) and the transport of contaminants in surface and subsurface environments. The speed, frequency, direction, and stability of the wind can influence the airborne transport of contaminants; the form, frequency, intensity, and evaporation potential of precipitation can strongly influence surface water runoff and infiltration within the canyons.

3.2.1 Winds

The Laboratory measures winds at four meteorological stations. One of these stations, the East Gate station, located between Los Alamos Canyon and Pueblo Canyon, has provided data continuously since 1987 (Bowen 1990, 6899).

Surface winds measured at the East Gate station are generally light, with strong winds often occurring in the spring. The predominant direction for all winds is from the south and southwest (Environmental Protection Group 1994, 35363). These data imply that any airborne contaminants within the canyon systems would be dispersed primarily toward the northern and eastern boundaries of the Laboratory and over the eastern portion of the Los Alamos townsite. As shown in Figure 3-1, during 1989 wind speeds registered at the East Gate station were less than 5.5 mph 38% of the time and greater than 11 mph 21% of the time. The wind roses in Figure 3-1 also illustrate variability in wind speed and direction across the plateau.

TABLE 3-1

ELEVATION, WATERSHED AREA, AND CHANNEL LENGTHS OF CANYONS

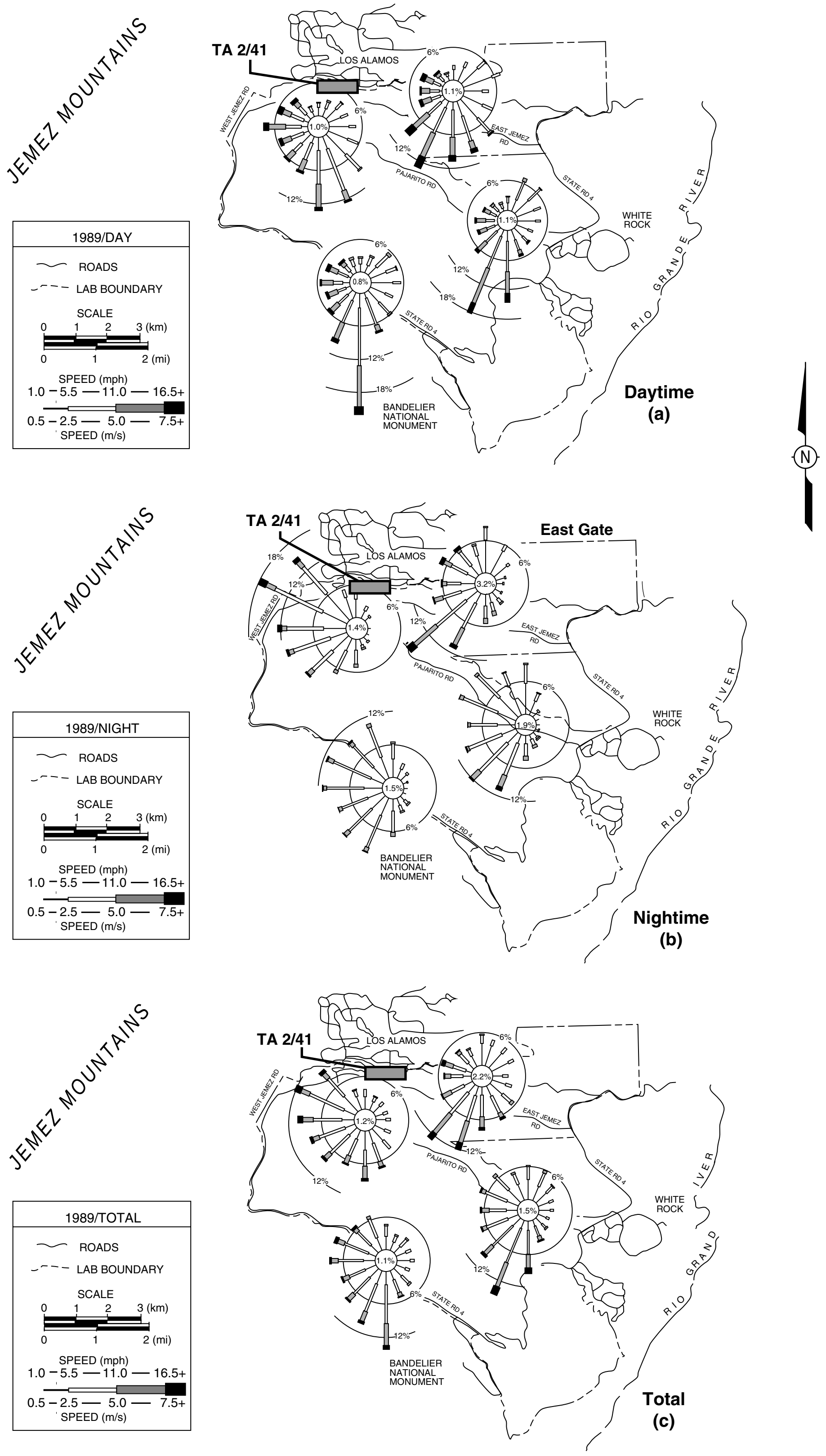
Canyon Name	Mean Elevation		Maximum Elevation		Minimum Elevation		Watershed Area		Channel Length	
	Feet	Meters	Feet	Meters	Feet	Meters	Square Miles	Square Kilometers	Miles	Kilometers
Ancho	6609	2015	7285	2220	5410	1649	6.7	17.4	7.3	11.8
Barrancas	6606	2014	7278	2218	5910	1801	4.9	12.7	5.5	8.9
Bayo	6625	2019	7401	2256	5790	1765	4.0	10.4	8.2	13.2
Cañada del Buey	6620	2018	7232	2204	5510	1679	4.3	11.1	8.2	13.2
Cañon de Valle	8268	2520	10389	3167	6812	2076	4.2	10.9	7.8	12.6
Chaquehui	6435	1961	6767	2063	5404	1647	1.6	4.1	3.0	4.8
Fence	6711	2046	7094	2162	6426	1959	1.1	2.9	3.1	5.0
Frijoles	7758	2365	10195	3107	5357	1633	19.1	49.5	14.9	24.0
Guaje	8118	2474	10497	3199	5661	1725	16.9	43.8	16.4	26.4
Indio	6636	2023	6863	2092	6380	1945	0.5	1.3	1.2	1.9
Los Alamos	7773	2369	10450	3185	5504	1678	14.1	36.5	18.9	30.4
Mortandad	6698	2042	7417	2261	5611	1710	6.0	15.5	9.8	15.8
Pajarito	7469	2277	10434	3180	5422	1653	8.0	20.7	14.8	23.8
Potrillo	6704	2043	7289	2222	5804	1769	3.4	8.8	6.9	11.1
Pueblo	7301	2225	9157	2791	6304	1921	8.3	21.5	10.5	16.9
Rendija	7581	2311	9826	2995	6299	1920	9.5	24.6	9.0	14.5
Sandia	6636	2023	7468	2276	5489	1673	5.5	14.3	10.0	16.1
Threemile	7110	2167	7446	2270	6738	2054	1.7	4.4	2.4	3.9
Twomile	7754	2363	9822	2994	6938	2115	3.1	8.0	5.2	8.4
Water	7557	2303	9943	3031	5427	1654	9.8	25.4	14.5	23.3

Source: Compiled by the Facility for Information Management, Analysis, and Display (FIMAD), Los Alamos National Laboratory, based on a digital model of the area.

The prevailing winds on the mesa tops suggest the directions that airborne particles will move after they have reached that elevation; however, conditions in the canyons may be quite different from those on the mesa tops. Thus, the transport of airborne particles within the canyons may follow a different pattern. A diurnal pattern of wind movement has been deduced from regular observations. During the day the winds tend to blow up-canyon from the east; at night the winds tend to blow down-canyon from the west. Shear winds have also been noted across the canyons.

3.2.2 Precipitation

The average annual precipitation in Los Alamos County varies from 13 in. (330 mm) at lower elevations to the east to 23 in. (584 mm) at higher elevations in the Sierra de los Valles (Bowen 1990, 6899). Approximately 50% of the precipitation on the Pajarito Plateau occurs during brief, intense thunderstorms in July and August, which often cause significant surface water runoff. The prevalence of short, intense storms is important in causing surface erosion and surface water transport, processes that move surface



Source: Environmental Protection Group 1990, 6995

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Figure 3-1. Wind roses at Laboratory stations during 1989.

contaminants into and within the canyon systems, particularly during the summer months. Approximately 20% of the normal annual precipitation occurs as snowfall in December, January, and February; the remaining 30% is distributed throughout the other seven months of the year. Winter snowfall averages 51 in. (1,295 mm) at the Los Alamos townsite with typically lesser amounts to the east and greater amounts to the west (ESG 1989, 6894).

3.3 Sediments and Soils

This section discusses sediments and soils within the canyon systems, including soils and sediments on the canyon floors and soils on the canyon walls.

3.3.1 Sedimentary Deposits

Sedimentary deposits within the canyon systems consist mainly of alluvium, colluvium, and landslide deposits. Erosion within the canyons occurs by

- rockfall, landslides, and colluvial transport from the canyon walls;
- runoff into and within the canyons;
- water transport within the streams in the canyons; and
- wind transport.

Processes and rates of erosion and deposition of the soils and sediments on the mesa tops and in the canyons are not well understood. The erosion rate of the Bandelier Tuff is not well established and may be highly variable, both spatially and temporally. The cliff-forming units of the tuff appear to be eroded primarily by spalling of large blocks of rock, which results in lateral retreat of the cliff face. This process appears to predominate over vertical incision (downcutting) by surface runoff. The rates and mechanisms of erosion are expected to depend on slope steepness, orientation, and vegetation patterns and probably vary widely.

The floors of individual canyons are underlain by variable thicknesses of alluvium interbedded with colluvium and other mass wasting deposits. These deposits constitute both the matrix for potential groundwater storage and storage areas for contaminants. The history and characteristics of these deposits, including their age, thickness, and residence times, have important implications for understanding the nature and variations in the alluvial groundwater and the length of time that contaminants will remain in the canyons.

The recent alluvial history of the canyons on the Pajarito Plateau is complex—some sediments within the stream channels are mobilized during every flood and others adjacent to or deeper beneath the channels are progressively buried and remain stable for long periods (Reneau and McDonald 1996, 55538; Reneau et al. 1996, 55539). For example, a 13-ft-deep (4.0-m-deep) trench excavated in Cabra Canyon, a tributary to Rendija Canyon immediately north of the Los Alamos townsite, revealed cycles of alternating sediment deposition and channel incision over the last 6,000 years (Gardner et al. 1990, 48813). In Cabra Canyon there has been a net accumulation of sediment over this period, although sediment deposition was interrupted by at least three episodes when channels were incised at least 3 to 6 ft (0.9 to 1.8 m), and the previously stored sediments were transported downstream. In DP Canyon, a tributary to Los Alamos Canyon on the north side of Technical Area (TA) -21, up to 6 ft (1.8 m) of sediment has been locally deposited since 1943. These young sediments in DP Canyon have been partially excavated by renewed channel incision (Reneau 1995, 50143), a process also observed in other canyons. In many canyons on the Pajarito Plateau the burial of the base of young trees indicates that a foot or more of historic (post-1942) sediment deposition on floodplains or low terraces (banks) is common. Erosion of sedimentary deposits and associated contaminants is probably caused by both vertical scouring and lateral cutting of streams during large floods. Plateau-wide summaries and syntheses of canyon-floor alluvial history are presented in Reneau and McDonald (1996, 55538) and Reneau et al. (1996, 55539).

Mass wasting processes are potentially important because they can move large volumes of material from the canyon walls to the canyon floors. In part, they create a geologic hazard in the canyon floors. For example, records for the last four decades indicate that fences in Los Alamos Canyon at TA-2 have been impacted by one boulder weighing 300 pounds or more every two years on average (McLin 1993, 50127). Mass wasting may be an important contaminant transport pathway, especially near outfalls and mesa-edge material disposal areas. Such sites will be investigated as part of the Resource Conservation and Recovery Act (RCRA) facility investigations for other operable units. An additional potential consequence of mass wasting is the burial of contaminated sediments in the canyon floors by debris derived from the canyon walls, including massive rockfalls. Such burial of alluvium by rockfall debris would tend to reduce the ability of the streams to erode and transport the sediment and locally increase the residence times of contaminated sediment in the canyon floors.

3.3.2 Soils

Soils on the Pajarito Plateau were initially mapped and described by Nyhan et al. (1978, 5702) and are discussed in Chapter 2 of the IWP (LANL 1996, 55574). The Nyhan study included only Laboratory-controlled lands and certain United States (US) Forest Service lands within Los Alamos County.

The soils were formed in a semiarid climate and were derived from chemical, biological, and physical weathering of local bedrock units, fallout pumice deposits, eolian deposits, and sediments derived from these geological materials (Nyhan et al. 1978, 5702). A large variety of soils have developed on the Pajarito Plateau as the result of interactions of the underlying bedrock, slope, and climate. The mineral components of the soils are in large part derived from the Bandelier Tuff, but dacitic lavas of the Tschicoma Formation, basalts of the Cerros del Rio volcanic field, and sedimentary rocks of the Puye Formation are locally important, and additional material may be transported to the canyons from the mesa tops by wind. Alluvium derived from the Pajarito Plateau and from the east side of the Jemez Mountains contributes to soils in the canyons and also to those on some of the mesa tops (LANL 1996, 55574).

The soils on the slopes between the mesa tops and canyon floors have been mapped as mostly steep rock outcrops consisting of approximately 90% bedrock outcrop and patches of shallow, undeveloped colluvial soils. South-facing canyon walls are steep and usually have little or no soil material or vegetation; in contrast, the north-facing walls generally have areas of very shallow, dark-colored soils and are more heavily vegetated. The canyon floors generally contain poorly developed, deep, well-drained soils (Nyhan et al. 1978, 5702).

Estimates of soil erosion by surface water transport, contaminant concentrations, and contaminant inventories in the soil and sediments within the canyon systems help assess the importance of sediment transport of contaminants. Lane et al. (1985, 6604) provide methods to estimate these parameters. The test case modeling and evaluations in that study were performed for the Los Alamos Canyon and Pueblo Canyon watersheds using data developed for the Formerly Utilized Sites Remedial Action Program study (LANL 1981, 6059).

3.4 Geology

The following discussion highlights details about the general geology, the rock types and their relationship to one another (stratigraphy), stratigraphic variations with location, rock mineralogy, and the geologic structure of the Pajarito Plateau and its canyons. Section 2.4 of the IWP provides additional information on the regional setting and general geology of the Pajarito Plateau (LANL 1996, 55574).

3.4.1 Geologic Overview

The Laboratory extends over the Pajarito Plateau, an east-sloping, dissected tableland bounded on the west by the eastern Jemez Mountains (Sierra de los Valles) and on the east by White Rock Canyon of the Rio Grande (Figure 3-2). The geology of the Pajarito Plateau reflects the interplay of volcanism in the Jemez Mountains and surrounding areas with the development of the Rio Grande rift, a series of north-south trending fault troughs extending from southern Colorado to southern New Mexico (Figure 3-2). Volcanism over the last 13 Ma (million years) has built up the highlands area of the Jemez Mountains, while the contemporaneous tectonic rifting has resulted in subsidence of the area extending from the eastern margin of the Jemez Mountains to the western margin of the Sangre de Cristo Mountains. This area of subsidence, locally termed the Española basin of the Rio Grande rift, is a graben between two larger basins—the Albuquerque basin to the south and San Luis basin to the north (Kelley 1978, 11659). During this interplay of volcanism and rifting, erosion has removed materials from the highlands areas to the west and deposited them downslope to the east into the rifted lowlands, which were contemporaneously receiving sediments from other sources. The Pajarito Plateau has developed in and now occupies the western part of the Española basin (Figure 3-2).

Figure 3-3 is a general geologic map highlighting the dominantly volcanic rock types of the area. Appendix A, Figure A-3 of this core document is a more detailed geological map encompassing the Pajarito Plateau. The gently east-sloping Bandelier Tuff covers the Pajarito Plateau (Figure 3-4). Deep canyons are incised into the Bandelier Tuff and expose it to depths of up to several hundred feet below the general level of the plateau. From west to east, these canyons cut progressively deeper into the Bandelier Tuff and, near the Rio Grande, some of the deeper canyons expose older lavas and sedimentary rocks. Figure 3-5 and Figure 3-6 schematically portray the complex interfingering of volcanic rocks and sediments that occurs below the Bandelier Tuff. Volcanic rocks of the Tschicoma Formation and their derivative sediments (fanglomerate facies of the Puye Formation) extend eastward under the plateau where they interfinger with Santa Fe Group rocks and basaltic rocks of the Cerros del Rio volcanic field (also called “basaltic rocks of Chino Mesa”).

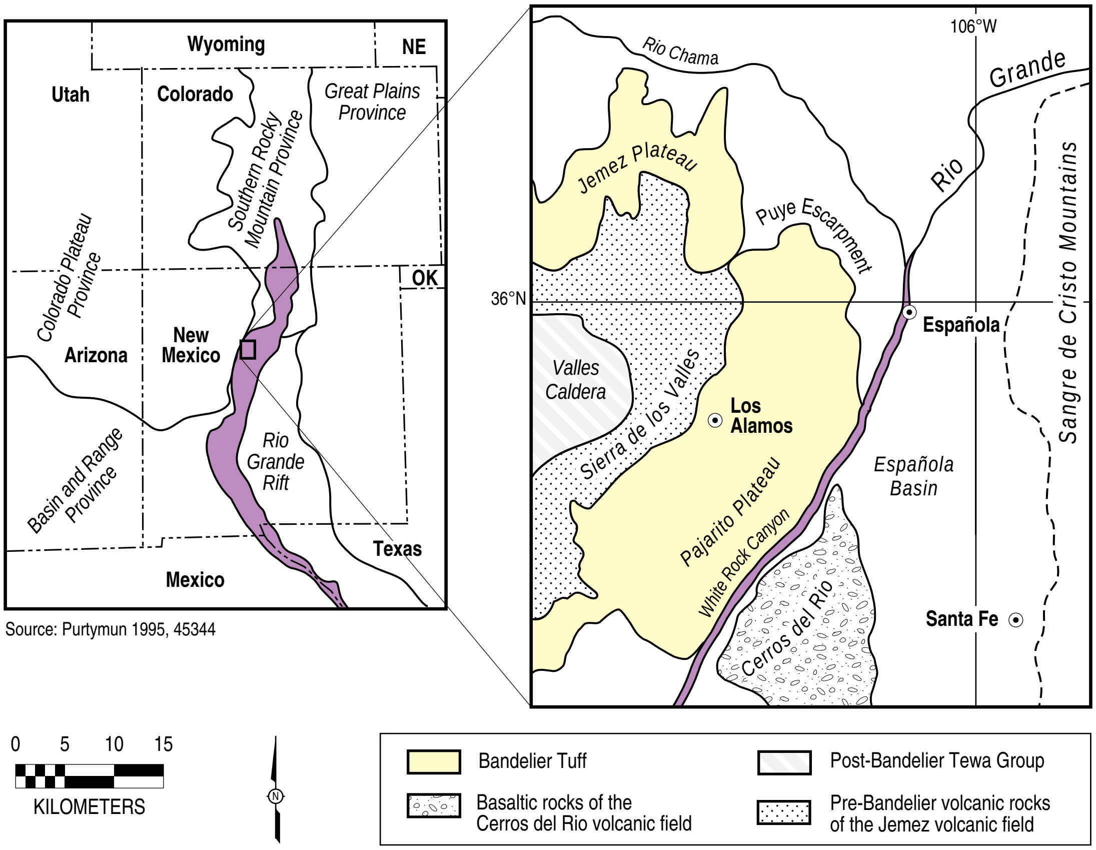
3.4.2 Stratigraphy

The following descriptions cover the rock units relevant to the canyons investigations, starting with the oldest (deepest) and proceeding to the youngest (topmost). Fossil evidence, stratigraphic correlations, and radiometric measurements provide the approximate ages of most of the bedrock units. The bedrock units and their ranges of approximate radiometric ages are listed below in ascending order.

1. Santa Fe Group: 4 to 21 Ma (Manley 1979, 11714)

2. Tschicoma Formation: 2.53 to 6.7 Ma (Dalrymple et al. 1967, 49924)

3. Puye Formation: 1.7 to 4 Ma (Turbeville et al. 1989, 21587; Spell et al. 1990, 21586), which includes a fanglomerate facies, an axial facies (Manley 1979, 11714; Turbeville et al. 1989, 21587), and a lacustrine facies



Source: Purtymun 1995, 45344

F3-2 / CORE DOC / 031997

Figure 3-2. Physiographic features of the Pajarito Plateau.

4. Basaltic rocks of the Cerros del Rio volcanic field (also known as “basaltic rocks of Chino Mesa”) (2 to 3 Ma) (Gardner and Goff 1984, 44021; WoldeGabriel et al. 1996, 54427)

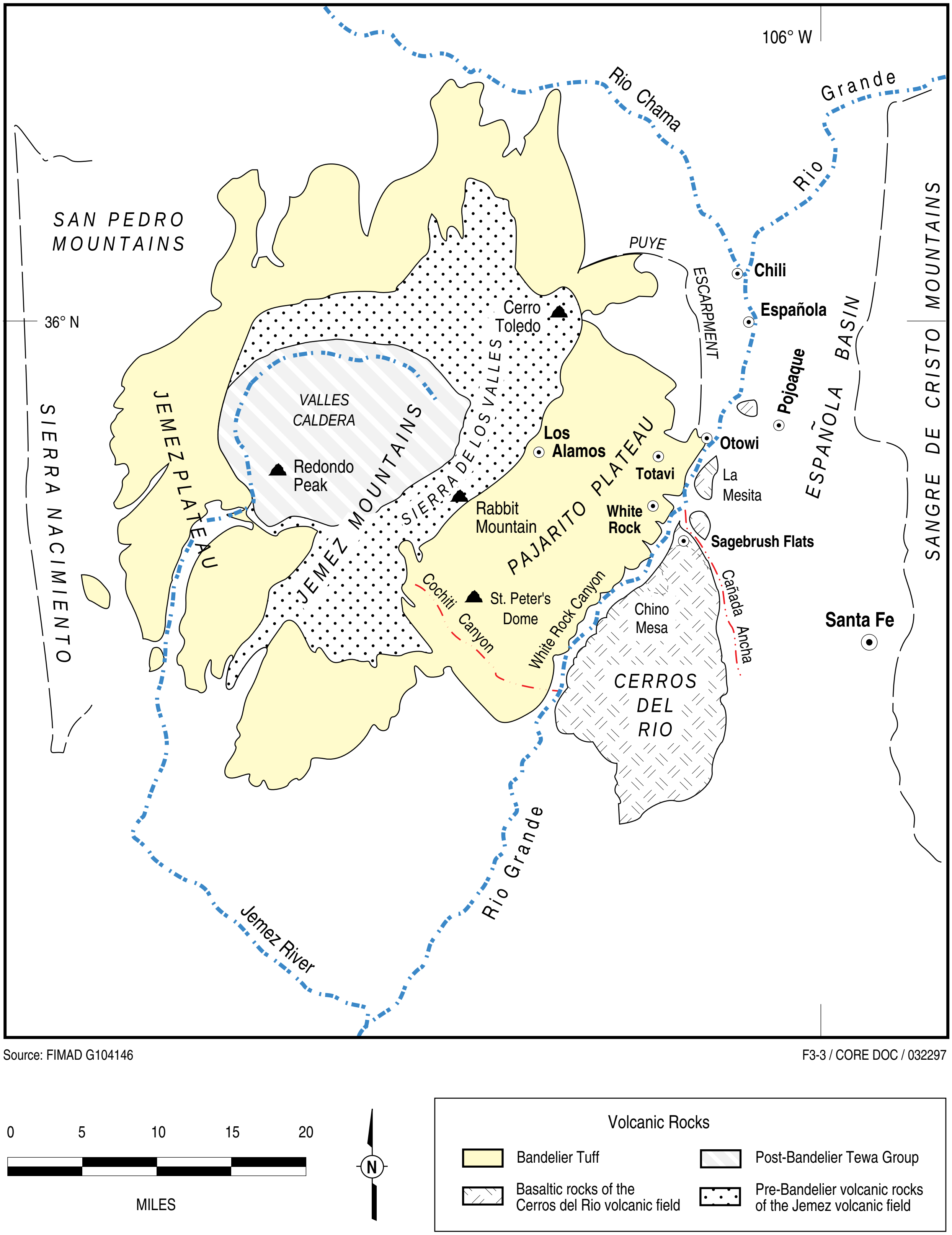
5. Otowi Member of the Bandelier Tuff: 1.61 Ma (Izett and Obradovich 1994, 48817; Spell et al. 1996, 55542)

6. Volcaniclastic sediments and tephras of the Cerro Toledo interval

   The age of this unit is bracketed by the ages of the underlying Otowi Member (1.61 Ma) and the overlying Tshirege Member (1.22 Ma) of the Bandelier Tuff.

7. Tshirege Member of the Bandelier Tuff: 1.22 Ma (Izett and Obradovich 1994, 48817; Spell et al. 1996, 55542)

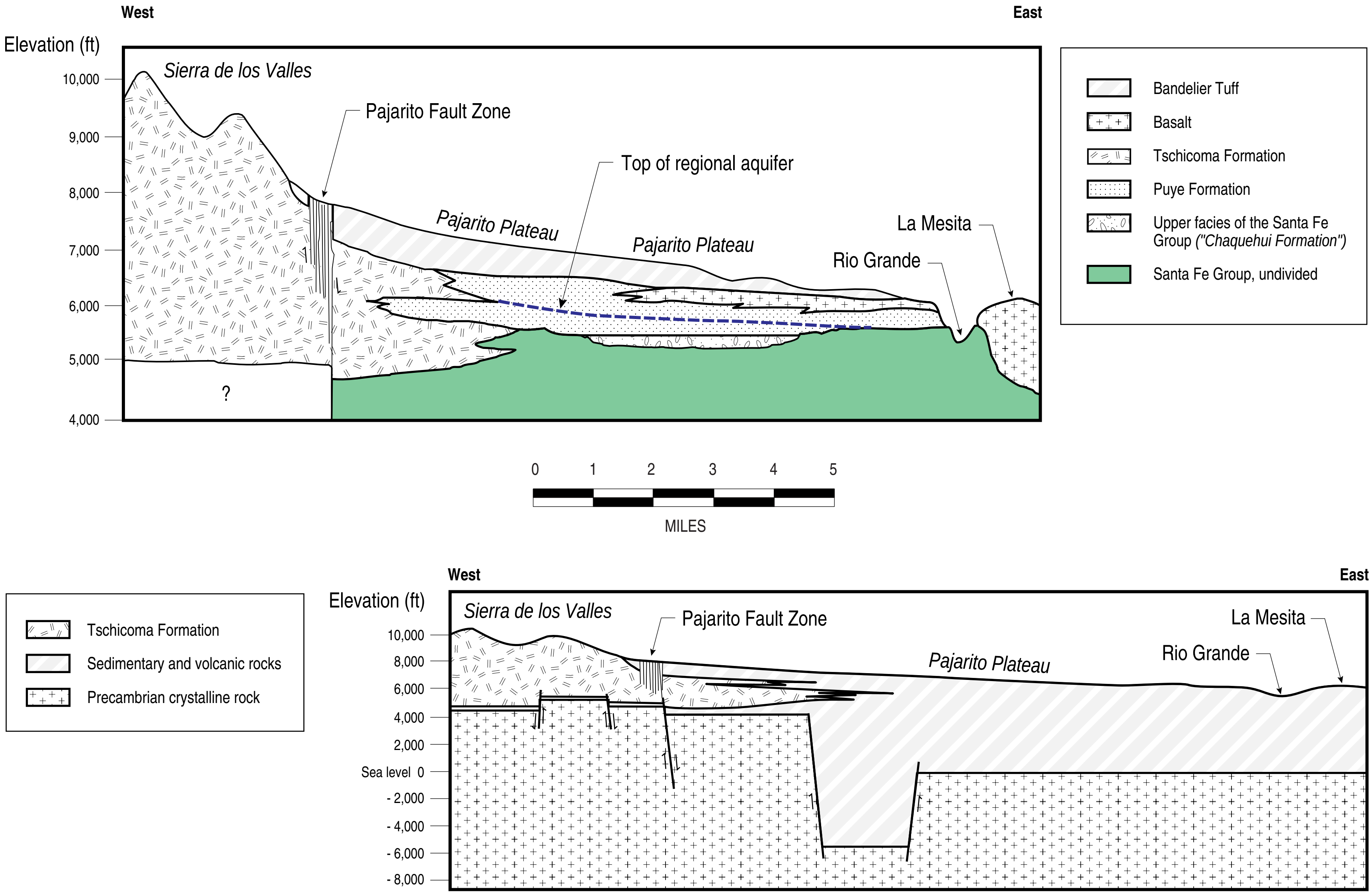
A geologic map (Appendix A, Figure A-3 of this core document) originally published by Smith et al. (1970, 9752) shows the distribution of these bedrock units across the Pajarito Plateau. Other general geological maps covering this area are those by Griggs (1964, 8795), Kelley (1978, 11659), and Goff et al. (1990, 21574). More detailed geological maps covering portions of the Laboratory include those by Baltz et al. (1963, 8402), Rogers (1995, 54419), Vaniman and Wohletz (1990, 21589), Reneau et al. (1995, 54405), and Goff (1995, 49682). Figure 3-3 shows area locations, and Figure 3-5 and Figure 3-6



Source: FIMAD G104146

F3-3 / CORE DOC / 032297

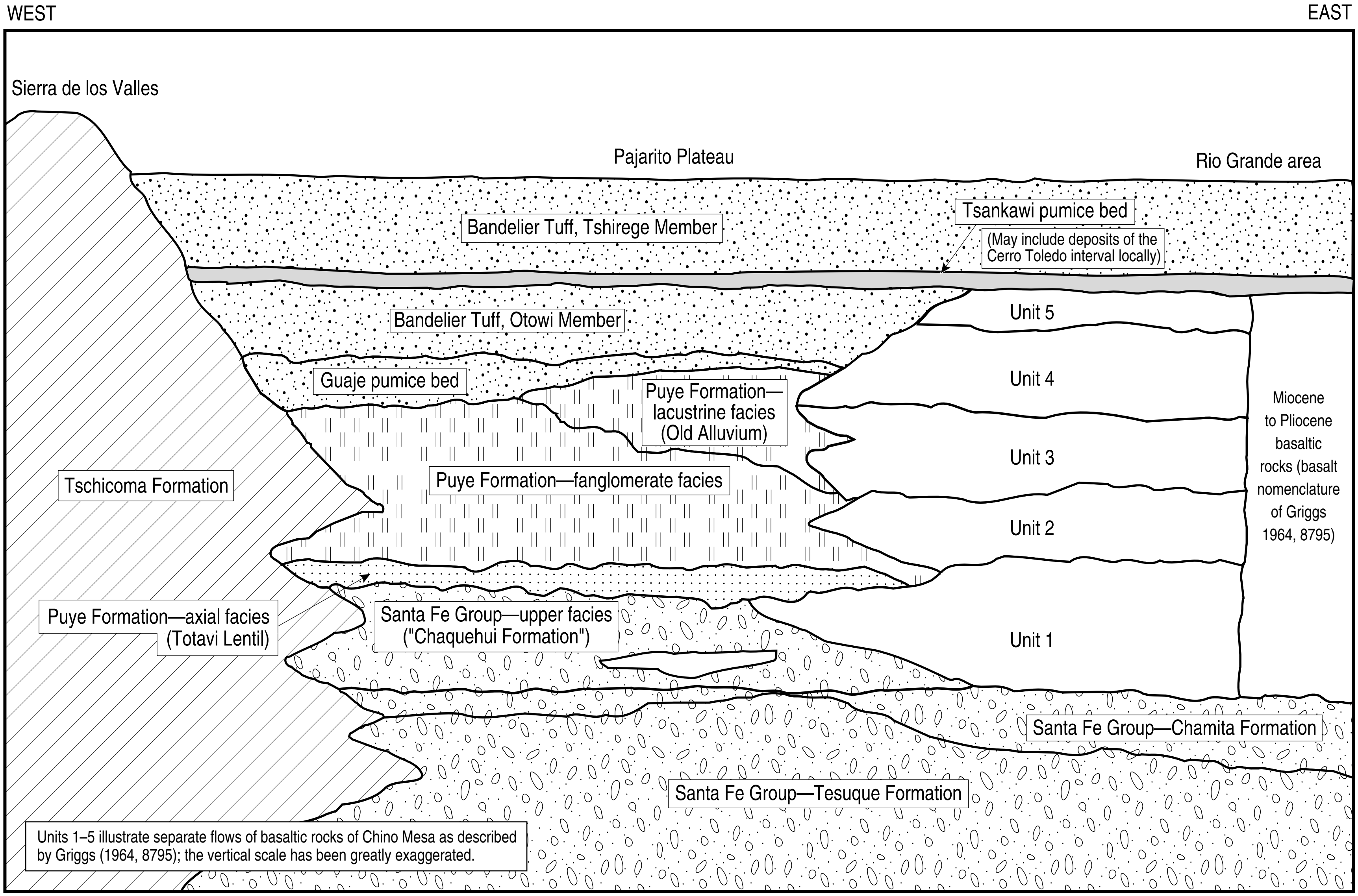
Figure 3-3. General geologic and geographic features of the Pajarito Plateau and surrounding area.



Source: Purtymun 1995, 45344

F3-4 / CORE DOC / 032297

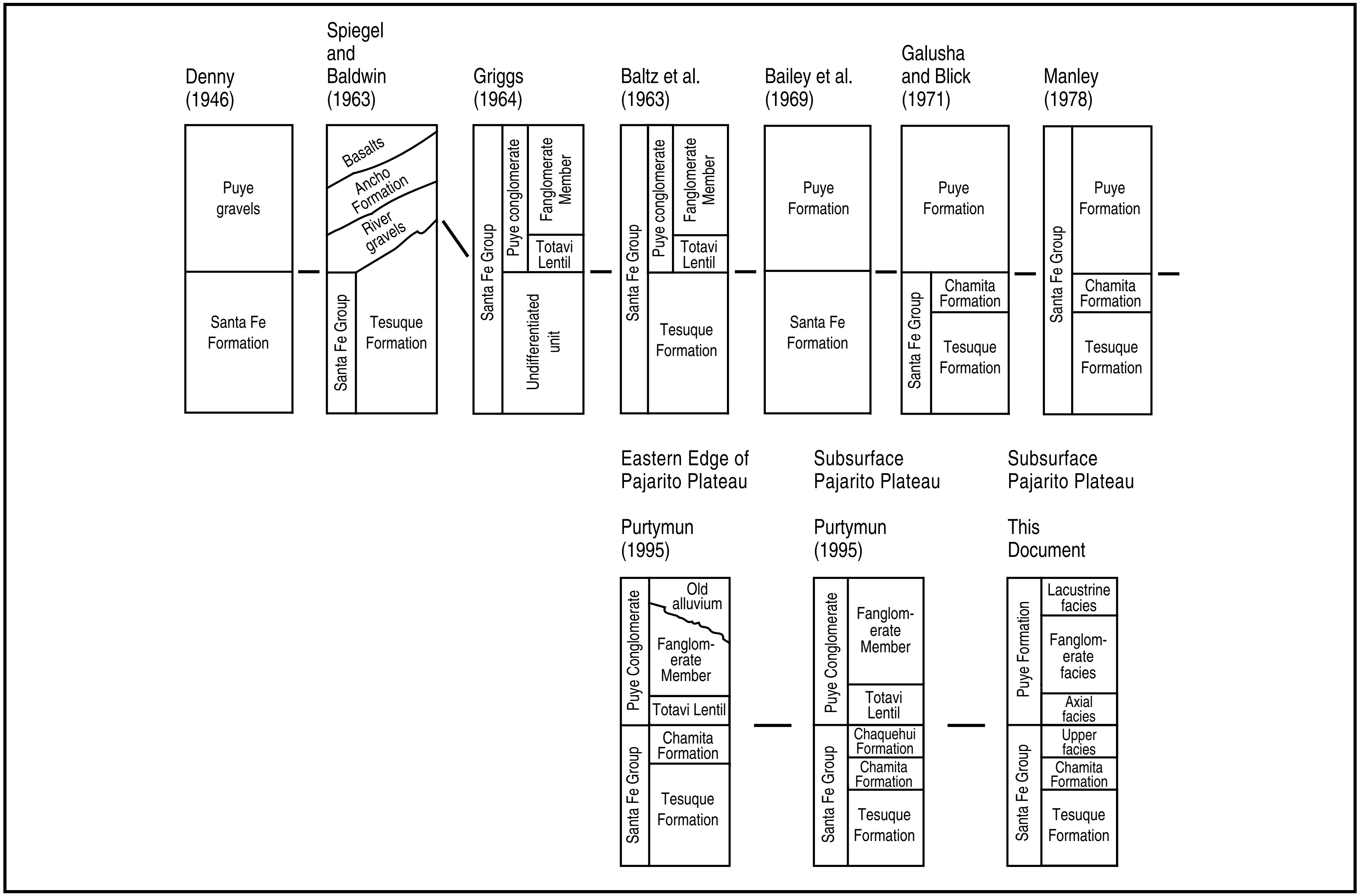
Figure 3-4. Generalized geologic cross sections of the Pajarito Plateau.



Source: Modified from Griggs 1964, 8795 and Purtymun 1995, 45344

F3-5 / CORE DOC / 031097

Figure 3-5. Schematic cross section of the Pajarito Plateau showing complex interfingering of volcanic and sedimentary rocks.



Source: Modified from Purtymun 1995, 45344

F3-6 / CORE DOC / 032197

Figure 3-6. Stratigraphic relationships and evolution of nomenclature for pre-Bandelier Tuff rocks of the Pajarito Plateau.

illustrate the stratigraphic units referred to in the following sections. Additional information on the surface geology, and the locations of canyons discussed in the following sections can be found on Figure A-3, Appendix A of this core document.

3.4.2.1 The Santa Fe Group

Rocks of the Santa Fe Group crop out in lower Los Alamos Canyon, near the mouth of Guaje Canyon, and along the margins of the Rio Grande from Otowi Bridge south to White Rock. Galusha and Blick (1971, 21526) subdivided the Santa Fe Group into formations and members based on geologic mapping and fossil assemblages of late Tertiary mammals (Figure 3-6). Manley (1979, 11714) refined the stratigraphy of the Santa Fe Group with additional mapping and dates of interbedded volcanic ash layers, lava flows, and dikes. The description herein (see Figure 3-5 and Figure 3-6) follows the nomenclature of Galusha and Blick (1971, 21526) as modified by Manley (1979, 11714) and Purtymun (1995, 45344).

In the vicinity of the Pajarito Plateau, the stratigraphy and geochronology of the Santa Fe Group is poorly understood because of the near continuous blanket of younger volcanic deposits. Based on exposures near the Rio Grande, the Santa Fe Group beneath the Pajarito Plateau is believed to include, in ascending order, the Tesuque Formation and the Chamita Formation. Purtymun (1995, 45344) has also given the name “Chaquehui Formation” to distinctive coarse-grained sediments at the top of the Santa Fe Group on the Pajarito Plateau based on evidence from deep well boreholes on the Pajarito Plateau.

“Chaquehui Formation” is not a formal geologic name at present and there is disagreement among geologists as to whether it should be recognized separately from the Chamita Formation.

3.4.2.1.1 The Tesuque Formation

The Tesuque Formation is a massive, thick unit consisting of arkosic sediments, derived primarily from Precambrian basement and Tertiary volcanic sources to the east and northeast of the Española basin. This unit is a light pink-to-buff siltstone and silty sandstone with a few lenses of pebbly conglomerate and clay. It is poorly to moderately consolidated and has an age range of about 7 to 21 Ma (Manley, 1979, 11714; Cavazza 1989, 21501). Spiegel and Baldwin (1963, 54259) describe the Tesuque Formation at the southern end of the Española basin, including the exposures in the vicinity of Otowi Bridge and along White Rock Canyon. This formation exists in deep well boreholes under the Pajarito Plateau and is the primary aquifer for municipal and industrial water supply in Los Alamos County. The Tesuque Formation contains basalt at a depth of 2,219 ft (67.6 m) in Otowi well O-1 (Purtymun 1995, 45344).

3.4.2.1.2 The Chamita Formation

The Chamita Formation overlies and interfingers with the Tesuque Formation. It consists of arkosic siltstones, sandstones, pebbly conglomerate, and includes two prominent beds of white ash. This formation is thickest in the northern part of the Española basin and thins to less than 30 ft (9.1 m) or is absent under most of the Laboratory. Aldrich and Dethier (1990, 49681) suggest that the Chamita Formation north of the Pajarito Plateau may be as old as 12 Ma and the age estimates for the overlying “Chaquehui Formation” (see below) support that suggestion. However, paleomagnetic data in the area indicate an age range of 4.5 to 6 Ma (MacFadden 1977, 21569), and tephra dates by Manley (1979, 11714) support a younger age of about 5 Ma for at least part of the formation. Because the Chamita and Tesuque Formations may not be distinguishable in borehole cores and cuttings, it may be necessary to group these formations as “undifferentiated Santa Fe Group” during borehole investigations.

3.4.2.1.3 The "Chaquehui Formation"

Sedimentary deposits referred to as the "Chaquehui Formation" by Purtymun (1995, 45344), and shown as upper facies of the Santa Fe Group on Figure 3-5 and Figure 3-6, are made up of mixtures of volcanic debris from the Jemez Mountains and arkosic materials from the highlands to the north and east. Because of their coarse-grained nature, these rocks are an important aquifer for municipal and industrial water supply in the Los Alamos area (Purtymun 1995, 45344). The "Chaquehui Formation" overlies the Chamita Formation in well boreholes on the Pajarito Plateau. However, because it contains interbedded basalt lava flows dated at 8 to 9 Ma (Laughlin et al. 1993, 54424), it is equivalent in age to older parts of the Chamita Formation. The "Chaquehui Formation" forms a transitional interval between older Santa Fe Group rocks and overlying volcaniclastic rocks derived from the Jemez Mountains. The presence of coarse-grained arkosic materials within the "Chaquehui Formation" suggests that these deposits may represent axial deposits of an ancestral Rio Grande within the Chamita Formation.

3.4.2.2 The Tschicoma Formation

The Tschicoma Formation of the Polvadera Group makes up the rugged highlands west of Los Alamos and crops out in the headwaters of the larger canyons that cut the Pajarito Plateau. Deep well boreholes along the western perimeter of the Laboratory intersect this unit at depths of several hundred feet or more, but the Tschicoma Formation is generally absent in boreholes penetrating the central and eastern parts of the Laboratory.

The Tschicoma Formation consists of numerous thick lava flows derived from a series of volcanic domes that predate the Bandelier Tuff. Fragmental deposits of ash and lava debris occur in the distal parts of the formation. It has a variable thickness due to the lenticular shape of its lava flows, and is at least 2,500 ft (762 m) thick in the Sierra de los Valles. The Tschicoma Formation thins eastward under the Bandelier Tuff on the Pajarito Plateau where it interfingers with the penecontemporaneous Puye Formation. The lower parts of the Tschicoma Formation may interfinger with the upper Santa Fe Group.

Tschicoma Formation lava flows range in composition from andesite to low-silica rhyolite but are dominantly dacites. The rocks are mainly gray to purplish gray, but in places they are reddish brown. These flows display pronounced jointing and have bottoms commonly marked by blocky breccia. Lavas contain glassy and microcrystalline groundmass; the glass is generally devitrified giving the rocks a stony appearance.

Radiometric ages for the Tschicoma Formation in the vicinity of Los Alamos range between 3.7 and 6.7 Ma (Dalrymple et al. 1967, 49924). Turbeville et al. (1989, 21587) report an age of 2.53 Ma for a Tschicoma ignimbrite within the Puye Formation. In the northern part of the Jemez volcanic field, the Tschicoma Formation is bracketed in age by the underlying Lobato Basalt (7.4 Ma) and the overlying El Rechuelos Rhyolite (2.0 Ma) (Loeffler et al. 1988, 54409).

3.4.2.3 The Puye Formation

The Puye Formation is a large apron of alluvial fans which were shed eastward from the Jemez volcanic field into the Española basin, covering the Santa Fe Group rocks west of and along the Rio Grande. Intersected by most deep water wells on the Pajarito Plateau (Dransfield and Gardner 1985, 6612; Purtyman 1995, 45344), this formation crops out in canyons north of Los Alamos Canyon. Turbeville et al. (1989, 21587) estimated its areal distribution at 200 km^2 (518 mi^2) and its volume at ~15 km^3 (~3.6 mi^3). Its age is generally placed at between 1.9 and 3.5 Ma, but it may be as young as 1.6 Ma and as old as 6.7 Ma because of its expected temporal and spatial association with eruption of the Tschicoma Formation. The lithology of the Puye Formation is dominated by conglomerates and gravels consisting of subrounded dacitic and andesitic lava clasts in a sandy matrix. At least 25 ash beds of dacitic to rhyolitic composition are interbedded with the conglomerates and gravels (Turbeville et al. 1989, 21587), and basaltic ash and lacustrine layers are present along the eastern margins of this formation. Showing considerable lateral variation in textures and composition, the formation reaches a maximum thickness of ~700 ft (~213 m) in Pueblo Canyon (Griggs 1964, 8795) but thins to 50 ft (15 m) in areas north of the Pajarito Plateau (Dethier and Manley 1985, 21506). In the central and eastern portions of the Laboratory, it is ~600 ft (~183 m) thick and is interbedded with basaltic lavas of the Cerros del Rio volcanic field. The Puye Formation as defined by Griggs (1964, 8795) originally included three units, in ascending order: an axial facies (called the “Totavi Lentil” by Griggs [1964, 8795]); a fanglomerate facies; and a lacustrine facies (called “older alluvium” by Griggs [1964, 8795]) (Figure 3-5 and Figure 3-6).

3.4.2.3.1 Axial Facies of the Puye Formation

The axial facies of the Puye Formation (also called “Totavi Lentil” or “Totavi Formation”) overlies the Santa Fe Group and crops out at Totavi and in areas to the east in lower Los Alamos Canyon and within White Rock Canyon to the south (Griggs 1964, 8795). It is generally ~50 ft (~15 m) thick under the eastern Pajarito Plateau but thickens in a northwest direction. It consists of coarse, poorly consolidated conglomerate containing cobbles and boulders of quartzite, granite, and pegmatite. The axial facies forms the oldest deposits in the Puye Formation in many areas but also interfingers with the lower part of the fanglomerate facies.

The axial facies is thought by many geologists to represent ancestral Rio Grande channel gravels and is believed to be a separate unit from either the finer grained Chamita Formation or the fanglomerate facies of the Puye Formation, resulting in considerable disagreement on the preferred nomenclature for this unit. It is a channel fill deposit as opposed to an alluvial fan deposit, which characterizes most of the overlying fanglomerate facies, and its composition is more akin to the Chamita Formation than to the fanglomerate facies, which is of dominantly volcanic rock types. For these reasons Turbeville et al. (1989, 21587) distinguished the Totavi deposits from the Puye Formation and assigned them a formation rank. However, because the stratigraphic uncertainties are not yet fully resolved, this core document retains the assignment of these rocks to the Puye Formation as originally defined by Griggs (1964, 8795). The age of the axial facies is poorly constrained but is probably between 2.4 and 3.5 Ma (Turbeville et al. 1989, 21587).

3.4.2.3.2 Fanglomerate Facies of the Puye Formation

The fanglomerate facies is the dominant unit of the Puye Formation beneath most of the Laboratory areas. Fanglomerate is a general term meaning a rock unit composed of poorly sorted conglomerates deposited as an alluvial fan. The fanglomerate facies contains angular-to-subangular cobbles and boulders of latite, quartz latite, dacite, rhyolite, and tuff in a matrix of silts, clays, and sands. Lenses of silt, clay, and pumice are common. It is interbedded with basaltic rocks of the Cerros del Rio volcanic field in the eastern and central part of the Laboratory. The fanglomerate facies is widespread beneath the Pajarito Plateau and caps the prominent cliffs (Puye Escarpment) along the Rio Grande north of Otowi Bridge.

3.4.2.3.3 Lacustrine Facies of the Puye Formation

Griggs (1964, 8795) included lake beds (the lacustrine facies) as the uppermost part of the Puye Formation. He differentiated them from the fanglomerate facies based on the presence of lake clays and ancient stream gravels that fill channels cut into the fanglomerates. Basaltic rocks of the Cerros del Rio volcanic field are also found in these channels (Griggs 1964, 8795). The lacustrine facies is present in lower Los Alamos Canyon and extends both northward and southward in discontinuous outcrops for several miles. However, it is apparently of limited extent beneath the Pajarito Plateau, being reported only in the borehole for well PM-1 near the eastern edge of the plateau.

3.4.2.4 Basaltic Rocks of the Cerros del Rio Volcanic Field ("Basaltic Rocks of Chino Mesa")

The basaltic rocks of the Cerros del Rio volcanic field crop out primarily on the eastern side of the Rio Grande, and occur in the subsurface below much of the Pajarito Plateau (Dransfield and Gardner 1985, 6612; Broxton and Reneau 1996, 55429). Outcrops within the Laboratory area occur in most canyons along the southern and eastern margins of the plateau. The stratigraphic nomenclature for these basalts has varied with different workers (e.g., Smith et al. 1970, 9752; Kelley 1978, 11659; Griggs 1964, 8795; Aubele 1978, 54426; Galusha and Blick 1971, 21526). Kelley (1978, 11659) mapped four different units of the Cerros del Rio Basalts, one of which (the Cubero Basalts) includes the five units of the basaltic rocks of Chino Mesa (Griggs 1964, 8795). Some of the older basalt flows that have been included in this formation may belong to the Santa Fe Group.

The basaltic rocks of the Cerros del Rio volcanic field form thick lava flows separated by interflow breccia, scoria, and ash. The lavas were erupted from numerous vents both east and west of the Rio Grande. These basalts are interbedded with the upper part of the fanglomerate facies of the Puye Formation. Griggs (1964, 8795) identified five lava-flow units (see Figure 3-5). The lower unit, Unit 1, crops out near river level in White Rock Canyon. Unit 2 overlies Unit 1 and forms the main cliffs along White Rock Canyon. It is the most prominent basalt found in boreholes below the central and eastern portions of the plateau, reaching a maximum thickness of 500 ft (152 m) in well PM-4. Unit 3 includes a series of flows emplaced in old stream channels, cropping out in lower Los Alamos Canyon, Sandia Canyon, and Mortandad Canyon. Unit 4 consists of two lava flows that cap the mesa south of lower Los Alamos Canyon where they overlie the Puye and Tesuque Formations. Unit 5 comprises cinder cones and surface basalt flows on Chino Mesa and on the mesa between lower Ancho Canyon and Chaquehui Canyon.

The basaltic rocks of the Cerros del Rio volcanic field include buried remnants of maar volcanoes in White Rock Canyon (Aubele, 1978, 54426; Heiken et al. 1996, 54425). The aprons of fragmental debris surrounding these buried craters consist of thin layers of basaltic ash and sediments. The maar deposits resulted from steam explosions that occurred where basalt erupted through an aquifer or standing body of water.

3.4.2.5 The Bandelier Tuff

The Bandelier Tuff consists of the Otowi and Tshirege Members, which are stratigraphically separated in many places by the tephras and volcaniclastic sediments of the Cerro Toledo interval. The Bandelier Tuff was emplaced during cataclysmic eruptions of the Valles caldera between 1.6 and 1.2 Ma ago. It is perhaps one of the best studied tuff units in the world, the subject of numerous geological studies since the early 1960s. The tuff is composed of pumice, minor rock fragments, and crystals supported in an ashy matrix. It is a prominent cliff-forming unit because of its generally strong consolidation. In the Tshirege Member, this consolidation is largely due to compaction and welding at high temperatures after the tuff was emplaced. Its light brown, orange brown, purplish, and white cliffs have numerous, mostly vertical fractures (called joints) that show average spacing of between several feet and several tens of feet. The Tshirege Member includes thin but distinctive layers of bedded sand-sized particles, called surge deposits, that demark separate flow units within the tuff. Most Laboratory facilities are located on the tuff, which is covered by thin discontinuous soils on mesa tops and alluvial deposits of variable thickness on canyon floors. Because the Bandelier Tuff is the most prominent rock type on the Pajarito Plateau, its detailed stratigraphy is of considerable importance and is discussed further below (see also Broxton and Reneau 1995, 49726).

3.4.2.5.1 The Otowi Member

The Otowi Member crops out in several canyons but is most extensive in Los Alamos Canyon and in canyons to the north (see Appendix A, Figure A-3). Griggs (1964, 8795), Smith and Bailey (1966, 21584), Bailey et al. (1969, 21498), and Smith et al. (1970, 9752) are important references describing the nature and extent of the Otowi Member. It consists of moderately consolidated (indurated), porous, and nonwelded vitric tuff (ignimbrite), that forms gentle, colluvium-covered slopes along the base of canyon walls. The Otowi ignimbrites contain light gray-to-orange pumice, supported in a white-to-tan ash matrix (Broxton et al. 1995, 50119; Broxton et al. 1995, 50121; Goff 1995, 49682). The ash matrix consists of glass shards, broken pumice and crystal fragments, and fragments of perlite.

The Guaje Pumice Bed occurs at the base of the Otowi Member, making a significant and extensive marker horizon in many well boreholes. The Guaje Pumice Bed (Bailey et al. 1969, 21498; Self et al. 1986, 21579) contains well-sorted pumice fragments whose mean size varies between 0.8 and 1.6 in. (2.0 and 4.1 cm). Its thickness averages ~28 ft (~8.5 m) below most of the plateau with local areas of thickening and thinning. Its distinctive white color and texture make it easily identifiable in well borehole cuttings and core, and it is an important marker bed for the base of the Bandelier Tuff.

3.4.2.5.2 Tephras and Volcaniclastic Sediments of the Cerro Toledo Interval

The Cerro Toledo interval is an informal name given to a sequence of volcaniclastic sediments and tephras of mixed provenance that separates the Otowi and Tshirege Members of the Bandelier Tuff (Broxton et al. 1995, 50121; Goff 1995, 49682; Broxton and Reneau 1995, 49726). Although it is intercalated between the two members of the Bandelier Tuff, it is not considered part of that formation. Outcrops of the Cerro Toledo interval generally occur wherever the top of the Otowi Member appears in Los Alamos Canyon and in canyons to the north. The unit contains primary volcanic deposits normally assigned to the Cerro Toledo Rhyolite as described by Smith et al. (1970, 9752) as well as intercalated and reworked volcaniclastic sediments not normally included in the Cerro Toledo Rhyolite. The occurrence of the Cerro Toledo interval is widespread; however, its thickness is variable ranging from several feet to more than 100 ft (30.5 m) thick.

The predominant rock types in the Cerro Toledo interval are rhyolitic tuffaceous sediments and tephra (Stix et al. 1988, 49680; Heiken et al. 1986, 48638; Broxton et al. 1995, 50121; Goff 1995, 49682). The tuffaceous sediments are the reworked equivalents of Cerro Toledo Rhyolite tephra that erupted from the Cerro Toledo and Rabbit Mountain rhyolite domes (see Figure 3-3) located in the Sierra de los Valles. Primary pumice-fall and ash-fall deposits occur in some locations. The pumice falls tend to form porous and permeable horizons within the Cerro Toledo interval, and locally they may provide important pathways for moisture transport in the vadose zone. Clast-supported gravel, cobble, and boulder deposits made up of porphyritic dacite derived from the Tschicoma Formation are interbedded with the tuffaceous rocks, and in some deposits, dacitic materials are volumetrically more important than rhyolitic detritus. These coarse dacitic deposits are generally confined to areas near the axes of paleochannels (Broxton and Reneau 1996, 55429; Broxton et al. 1995, 50121; Goff 1995, 49682).

3.4.2.5.3 The Tshirege Member

The Tshirege Member is the upper member of the Bandelier Tuff and is the most widely exposed bedrock unit of the Pajarito Plateau (Griggs 1964, 8795; Smith and Bailey 1966, 21584; Bailey et al. 1969, 21498; Smith et al. 1970, 9752). Emplacement of this unit occurred during eruptions of the Valles caldera ~1.2 Ma ago (Izett and Obradovich 1994, 48817; Spell et al. 1996, 55542). The Tshirege Member is a multiple-flow, ash-and-pumice sheet that forms the prominent cliffs in most of canyons on the Pajarito Plateau. It also underlies the canyon floor in all but the middle and lower reaches of Los Alamos Canyon and in canyons to the north. The Tshirege Member is generally over 200 ft (61 m) thick. Its thickness exceeds 600 ft (183 m) near the southern edge of the Laboratory at TA-49 but is thinner (often <200 ft [<61 m]) to the north and east (Broxton and Reneau 1996, 55429).

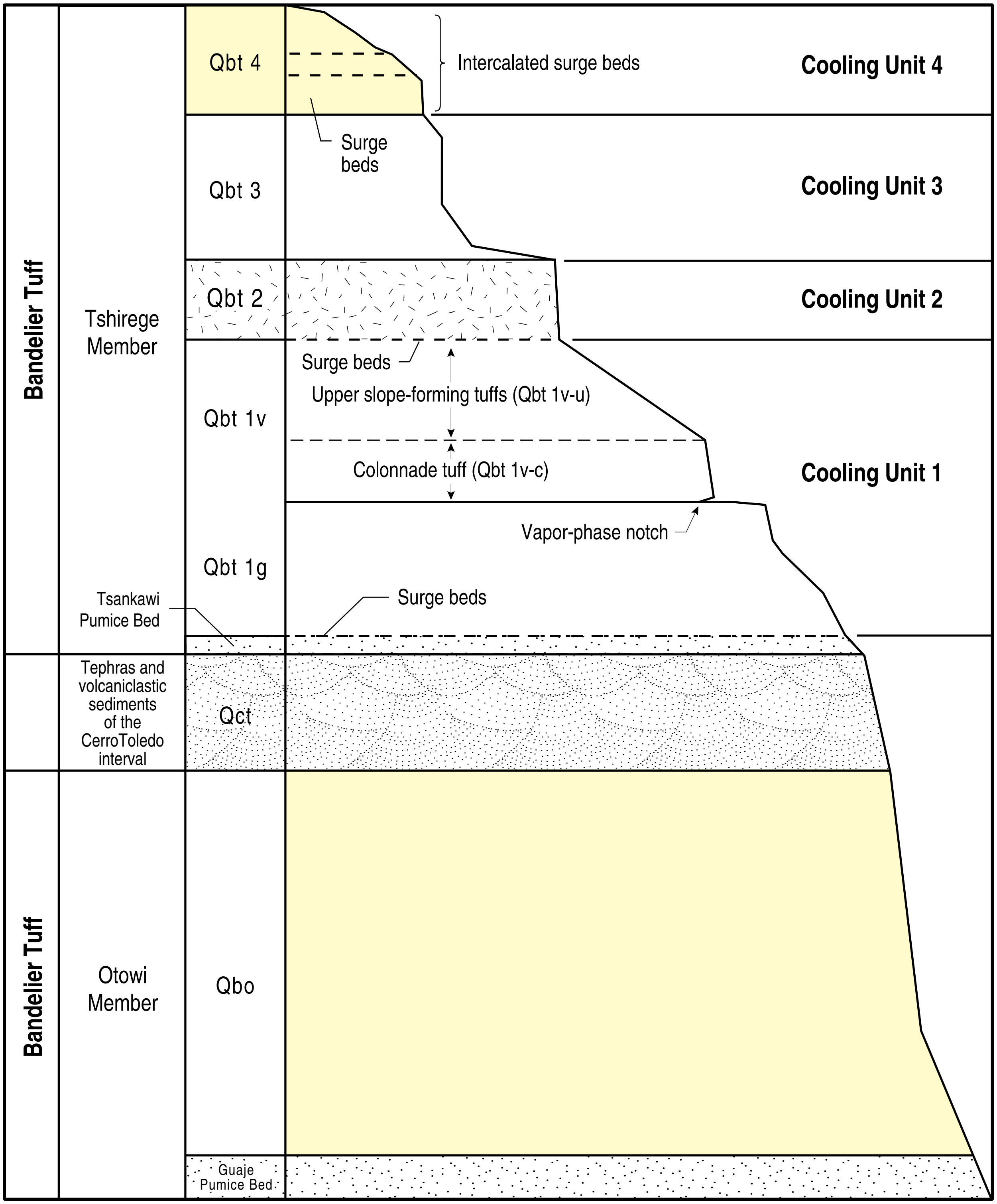
The Tshirege Member differs from the Otowi Member most notably in its generally greater degree of welding compaction. Time breaks between the successive emplacement of flow units caused the tuff to cool as several distinct cooling units. For this reason the Tshirege Member is a compound cooling unit, consisting of at least four cooling subunits that display variable physical properties vertically and horizontally (Smith and Bailey 1966, 21584; Broxton et al. 1995, 50121). These variations in physical properties reflect zonal patterns of varying degree of welding and glass crystallization that accompanies welding (Smith 1960, 48819; Smith 1960, 48820). The welding and crystallization variability in the Tshirege Member produce recognizable vertical variations in its properties such as density, porosity, hardness, composition, color, and surface weathering patterns.

The Tshirege Member can be divided into mappable subunits (Figure 3-7) based on a combination of hydrologic properties and lithologic characteristics. There is a certain amount of confusion due to the inconsistent use of subunit names for the Tshirege Member (Baltz et al. 1963, 8402; Weir and Purtymun 1962, 11890; Crowe et al. 1978, 5720; Vaniman and Wohletz 1990, 21589; Vaniman 1991, 9995; Goff 1995, 49682; Broxton et al. 1995, 50121). Figure 3-8 shows correlations of subunit designations applied by various workers. To avoid such confusion, this discussion follows the nomenclature of Broxton and Reneau (1995, 49726).

Broxton et al. (1995, 50121) provide extensive descriptions of the Tshirege Member cooling units. Because the canyons crossing the Pajarito Plateau cut through the Tshirege Member with increasing depth to the east, all of these units crop out at some point in the floors and walls of most canyons. Also, the degree of welding in each of the cooling units generally decreases from west to east, reflecting the higher emplacement temperatures near the tuff's source in the Valles caldera. Densely welded in the Sierra de los Valles, the Tshirege Member shows a gradual decrease in welding eastward, such that only cooling unit 2 shows much welding in most canyons of the Laboratory. The follow paragraphs describe, in ascending order, subunits of the Tshirege Member.

The Tsankawi Pumice Bed forms the base of the Tshirege Member. Where exposed, it is commonly 20 to 30 in. (51 to 76 cm) thick. This pumice-fall deposit contains moderately well sorted pumice lapilli (diameters reaching about 2.5 in. [6.4 cm]) in a crystal-rich matrix. Several thin ash beds are interbedded with the pumice-fall deposits.

Qbt 1g is the lowermost subunit of the thick ignimbrite sheet overlying the Tsankawi Pumice Bed. It consists of porous, nonwelded, and poorly sorted ash flow tuffs. The "g" in this designation stands for "glass" because none of the glass in ash shards and pumices shows crystallization by devitrification or vapor phase alteration. This unit is poorly indurated but nonetheless forms steep cliffs because of a resistant bench near the top of the unit which forms a harder, protective cap over the softer underlying tuffs. A thin (4 to 10 in. [10 to 25 cm]), pumice-poor, surge deposit commonly occurs at the base of this unit.



Source: Broxton and Reneau 1995, 49726

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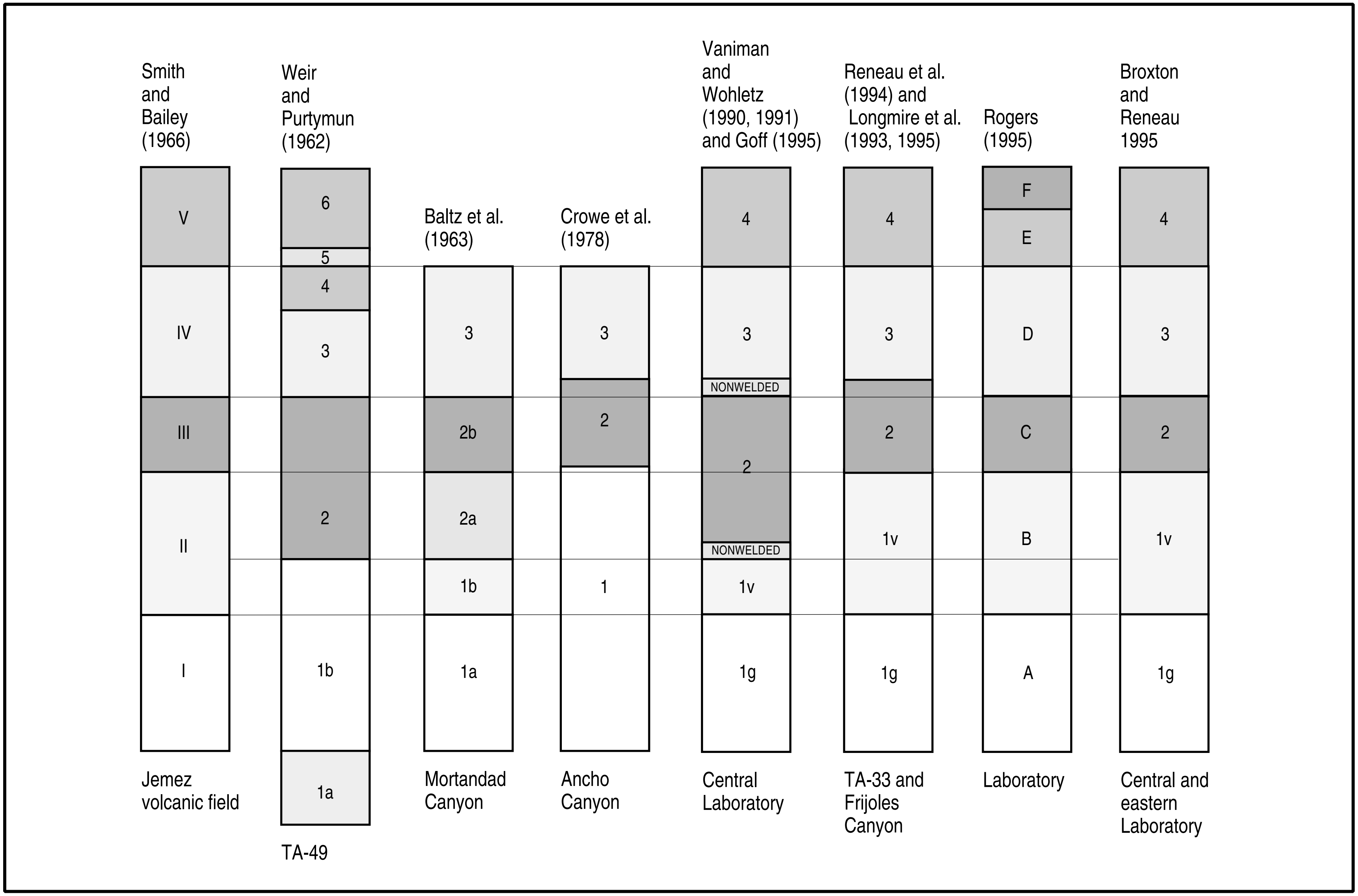
Figure 3-7. Illustration of the Bandelier Tuff weathering profile and unit subdivisions.



Source: Slightly modified from Broxton and Reneau 1995, 49726

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Figure 3-8. Correlation of rock unit names applied to the Tshirege Member of the Bandelier Tuff.

Qbt 1v forms alternating cliff-like and sloping outcrops composed of porous, nonwelded, but crystallized tuffs. The “v” stands for vapor-phase crystallization, which has converted much of the glass in shards and pumices into a devitrified form of microcrystalline aggregates. The base of this unit is a thin, horizontal zone of preferential weathering that marks the abrupt transition from glassy tuffs below to devitrified tuffs above. This feature forms a widespread mappable marker horizon (locally termed the vapor-phase notch) throughout the Pajarito Plateau, which is readily visible in many canyon walls. The lower part of this unit is orange brown, resistant to weathering, and has distinctive columnar (vertical) joints; hence the term colonnade tuff is appropriate for its description. A distinctive white band of alternating cliff- and slope-forming tuffs overlies the colonnade. The tuffs of Qbt 1v are commonly nonwelded (pumices and shards retain their initial equant shapes) and have an open, porous structure.

Qbt 2 forms a distinctive, medium brown, vertical cliff that stands out in marked contrast to the slope-forming, lighter colored tuffs above and below. A surge horizon commonly marks its base in the eastern part of the Laboratory, and it displays the greatest degree of welding in the Tshirege Member. It is typically nonporous and has low permeability relative to the other units of the Tshirege Member. Vapor-phase crystallization of flattened shards and pumices is extensive in this unit.

Qbt 3 is a nonwelded to partially welded, vapor-phase altered tuff, which forms many of the upper cliffs in the mid-to-lower reaches of canyons on the Pajarito Plateau. Its base consists of a purple gray, unconsolidated, porous, and crystal-rich nonwelded tuff that underlies a broad, gently sloping bench developed on top of Qbt 2. This basal, nonwelded portion forms relatively soft outcrops that weather into low, rounded mounds with a white color, which contrast with the cliffs of partially welded tuff in the middle and upper portions of Qbt 3.

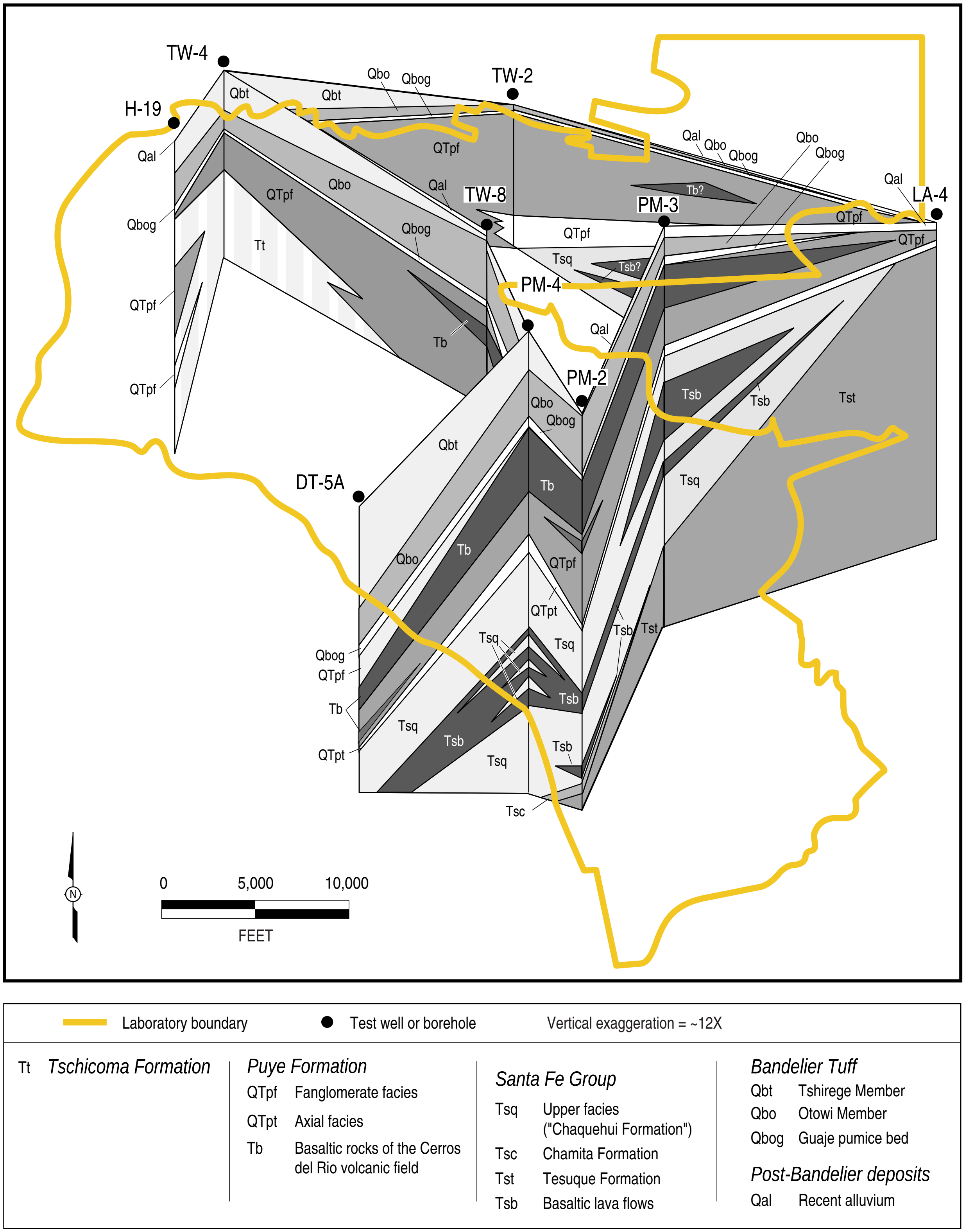
Qbt 4 is a partially welded to densely welded ignimbrite characterized by small, sparse pumices and numerous intercalated surge deposits. This unit crops out on the mesa tops in the western part of the Laboratory, but it is missing from mesa tops over the mid-to-eastern Pajarito Plateau. It forms the bedrock unit in the canyon floors along the western part of the Laboratory near the Sierra de los Valles.

3.4.3 Stratigraphic Variations

The interfingering nature of the pre-Bandelier stratigraphic units is an important concept in understanding the nature of bedrock units below the Pajarito Plateau. While the Bandelier Tuff forms a nearly continuous blanket of bedrock across the plateau, deeper rock units have a distribution that varies considerably with location. Purtymun (1995, 45344) describes these stratigraphic variations in numerous well borehole logs. Figure 3-9 is a fence diagram depicting stratigraphic variations in nine of the deepest boreholes across the Laboratory.

In Figure 3-9 the bedrock units are designated by (1) geologic time—Q for Quaternary, QT for Quaternary-Tertiary, and T for Tertiary—and (2) formation name for which the first lower case letter designates the formation—b for Bandelier Tuff, p for Puye Formation, t for Tschicoma Formation, and s for the Santa Fe Group—and the second lower case letter designates the member rank in the formation. Noting that some of the wells sited in canyon floors do not penetrate the Tshirege Member, the following discussion highlights some of the stratigraphic variations (from the surface downward) shown by the fence diagram.

The Tshirege Member (Qbt) thickens to the west and south on the Pajarito Plateau. The Otowi Member (Qbo), however, is thickest in the vicinity of TW-8, near the middle of the plateau. The fanglomerate facies of the Puye Formation (QTpf) thickens northward and westward but thins where it onlaps and interfingers



Data source: Purtymun 1995, 45344

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Figure 3-9. **Correlation of bedrock units between deep boreholes penetrating the Pajarito Plateau in and around the Laboratory.**

the Tschicoma Formation (Tt) on the west. Basaltic rocks of the Cerros del Rio volcanic field (Tb) are interbedded with the Puye Formation, and underlie much of the central and eastern portion of the Laboratory at a depth of several hundred feet. The axial facies of the Puye Formation (QTpt) forms a consistent boundary at the base of the Puye Formation along the mid and eastern portions of the plateau. It caps a notable thickness of Santa Fe Group rocks. The upper facies of the Santa Fe Group ("Chaquehui Formation") (Tsq) appears to be thickest along an axis trending northeasterly through the middle part of the plateau. The Chamita Formation (Tsc) is only penetrated by the deepest wells sited within the central part of the Laboratory. It appears to thin northward as the underlying Tesuque Formation (Tst) rapidly thickens in that direction. Basaltic lava flows (Tsb) are intercalated in the Santa Fe Group deposits.

3.4.4 Mineralogy

Mineralogy plays an important role in defining the physical and chemical properties of rock units on the Pajarito Plateau. The sorptive properties of rocks are largely determined by the types and distributions of minerals present. Similarly, hydrologic properties are partly determined by mineralogy and textural characteristics of rocks.

The bulk tuff mineralogy of the Bandelier Tuff varies as a function of stratigraphic position (Broxton et al. 1995, 50121). The Bandelier Tuff and the Cerro Toledo interval are characteristically composed of feldspar + quartz ± tridymite ± glass. Minor constituents include smectite, hornblende, mica, magnetite/maghemite, hematite, calcite, and kaolinite.

Volcanic glass is the major constituent (>60%) of the Otowi Member, the tuffs of the Cerro Toledo interval, and unit Qbt 1g of the Tshirege Member. The volcanic glass occurs as pumices and ash shards of the sandy matrix. Quartz and sanidine feldspar are two other major constituents of these glassy tuffs; these crystalline phases occur as phenocrysts and as relatively minor devitrification products of fine ash. The volcanic glass is unaltered, and the absence of significant amounts of glass alteration minerals, such as clays and zeolites, strongly suggests that these tuffs have had limited contact with groundwater since their deposition. However, 9 to 32% smectite was observed in the upper part of the Otowi Member in the borehole for well LAOI(A)-1.1 in Los Alamos Canyon. Mineralogic studies have not identified smectite in other boreholes. The presence of abundant smectite in the borehole for well LAOI(A)1-1 may represent either translocated clays washed downward through fractures from overlying stream alluvium or *in situ* glass alteration in a water recharge zone along fractures beneath canyon floors.

Volcanic glass disappears abruptly at the top of Qbt 1g in the Tshirege Member. In the units above Qbt 1g, the Tshirege Member consists primarily of feldspar + quartz ± cristobalite ± tridymite. The amounts of cristobalite and tridymite vary inversely reflecting different degrees of *in situ* devitrification and vapor-phase alteration in the upper tuff units.

Smectite, magnetite, and hematite occur in small amounts (<2%) throughout the Bandelier Tuff. These three trace minerals are important because they have sorptive capacities for certain radionuclides and could provide natural barriers to their migration. Smectites are highly selective for adsorbing cationic radionuclides (Grim 1968, 48814). Magnetite and its alteration products (such as hematite) have an affinity with uranium and actinide species through surface complexation (Allard and Beall 1979, 48810; Allard et al. 1982, 48811; Hsi and Langmuir 1985, 48816; Ho and Miller 1986, 48815). Although these minerals occur in small quantities, they are disseminated throughout the stratigraphic sequence. Their combined abundance, small grain size, and large surface area per unit volume provide increased sorptive capacity relative to the bulk rock.

3.4.5 Geological Structure

Groundwater zones beneath the Pajarito Plateau may be recharged in part by the vertical migration of water from canyon-floor alluvium. The vertical migration of alluvial groundwater may be partly controlled by faults and fractures. However, the role of faults and fractures as components of the hydrologic system is poorly understood at this time.

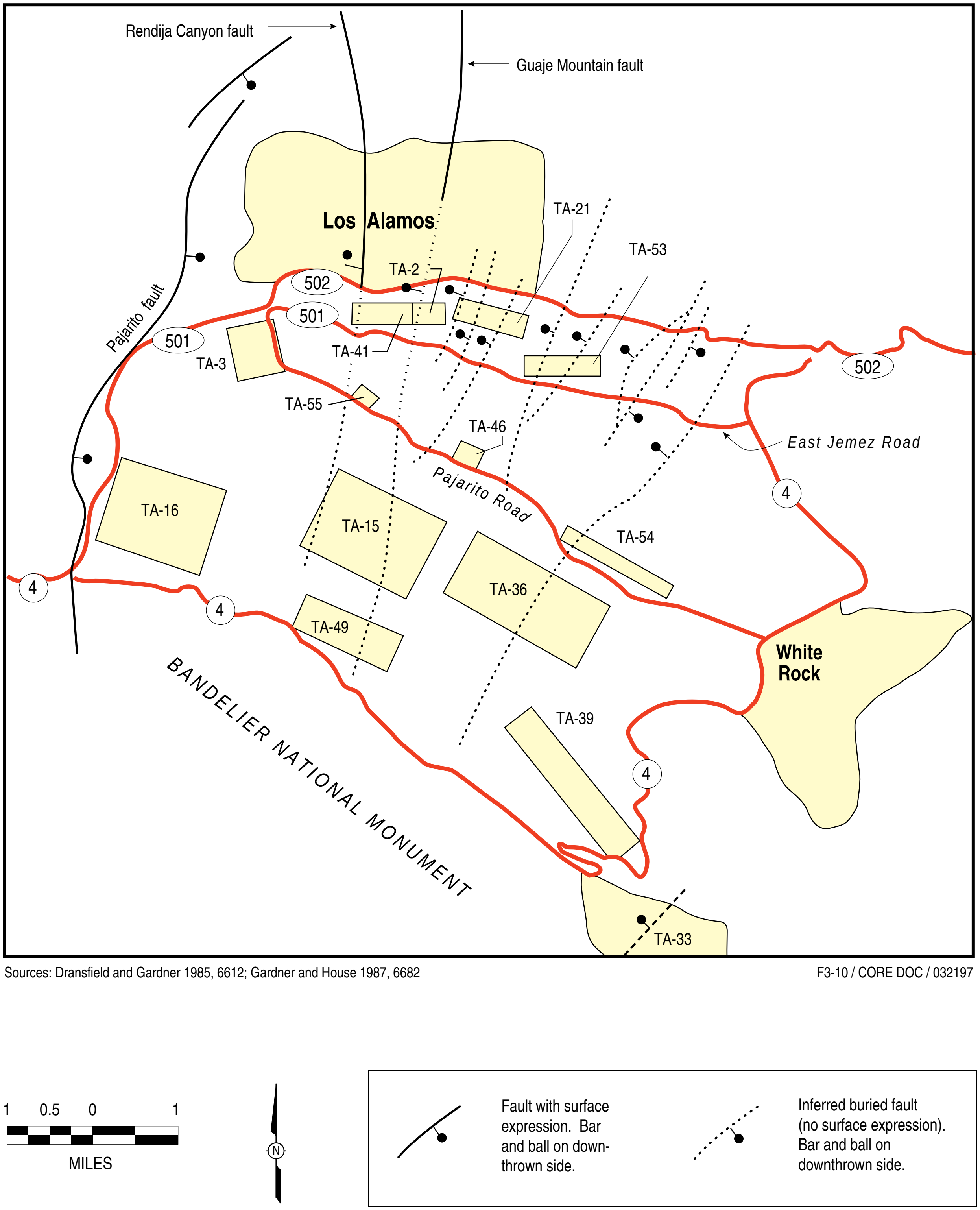
The Pajarito Plateau is on the western margin of the Española basin of the Rio Grande rift, a tectonically active region. The Pajarito fault system, the major border fault on the west side of the basin, delineates the boundary between the eastern Sierra de Los Valles and the western part of the plateau. This fault system has experienced Holocene movement and historic seismicity (Gardner and House 1987, 6682; Gardner et al. 1990, 48813). Characterized by northerly trending normal faults that intertwine along their traces, the Pajarito fault system shows dominantly down-to-the-east movement and produces a series of prominent fault scarps west of the Laboratory (Figure 3-10). The vertical throw on this fault system is over several hundred feet south and west of the Laboratory but decreases northward of Los Alamos Canyon where the fault system is less prominent.

In addition to the main traces of the Pajarito fault system, other faults cut the Pajarito Plateau. The Rendija Canyon fault is a normal fault trending north-south in the west-central part of the plateau; it crosses Pueblo Canyon near its confluence with Acid Canyon and Los Alamos Canyon near TA-41 but does not have clear surface expression south of Sandia Canyon. The Guaje Mountain fault parallels the Rendija Canyon fault and is projected to cross Los Alamos Canyon near TA-2 although there is no clear offset of the Tshirege Member south of North Mesa. North of the Laboratory both of these faults have down-to-the-west movement and zones of gouge and breccia up to several meters wide, and produce visible offset of stratigraphic horizons and recognizable scarps. However, these features are not apparent within most of the Laboratory. Vaniman and Wohletz (1990, 21589) and Wohletz (1995, 54404) project these faults south of Los Alamos Canyon, based on Tshirege Member rock fracture density variations, orientations, and size. Such methods of fault identification in the Tshirege Member may be valuable means by which to help identify other tectonic zones in canyons that could be potential pathways for water infiltration.

Dransfield and Gardner (1985, 6612) integrated a variety of data to produce structure contour maps and paleogeologic maps of the pre-Bandelier-Tuff surface beneath the Pajarito Plateau. Their maps reveal down-to-the-west normal faults cutting subsurface rock units. These buried faults do not obviously displace the overlying Bandelier Tuff south of Los Alamos Canyon, indicating that most of these fault movements predate deposition of the Bandelier Tuff. More recent structure contour maps, isopach maps, and paleogeologic maps of the Pajarito Plateau are presented in Davis et al. (1996, 55446) and Broxton and Reneau (1996, 55429).

3.5 Surface Water Hydrology

The water that flows through the canyon systems is used by wildlife, livestock, and potentially by humans and therefore constitutes a significant transport pathway to these potential receptors. Studies of both surface water, described in this section, and groundwater, described in Section 3.6, provide the background of known conditions needed to assess the importance of these transport pathways and to improve the understanding of surface water transport and transport through the unsaturated and saturated zones within the canyon systems.



Sources: Dransfield and Gardner 1985, 6612; Gardner and House 1987, 6682

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Figure 3-10. Locations of known and inferred faults at the Laboratory and in the surrounding area.

Surface water flows provide the primary mechanism for redistributing and transporting contaminants that remain from early Laboratory operations and discharges from currently operating facilities. The primary mechanisms that affect mobilization of contaminants within the various canyons include sediment transport, contaminant dissolution and desorption, runoff, infiltration, and percolation. Effluent-supported flow from Laboratory and Los Alamos County sanitary wastewater treatment plants located in some of the canyons also affects the mobilization of contaminants.

Aspects of surface water hydrology that are relevant to potentially contaminated areas include

- areas and pathways of surface water runoff and sediment deposition;
- rates of soil erosion, contaminant dissolution and desorption, transport, and sedimentation;
- locations and sizes of areas of disturbed and undisturbed surface soils;
- relationships between infiltration and runoff;
- presence and effectiveness of adsorptive media in retarding infiltration of water-borne contaminants; and
- fate of infiltrating water.

The hydrology of the canyon systems is thoroughly discussed in Section 2.1.3 of the Hydrogeologic Workplan (LANL 1996, 55430); Section 2.4.2 of the IWP (Revision 6) (LANL 1996, 55574); and Section 2.6.2 of the IWP (Revision 3) (LANL 1993, 26078). The discussion in this section elaborates on surface water as a contaminant transport pathway within the various canyons of the Pajarito Plateau.

3.5.1 Surface Drainages

The Rio Grande is the master stream in north-central New Mexico. Much of the surface water flow and groundwater discharge from the Pajarito Plateau canyon systems ultimately arrives at the Rio Grande.

3.5.1.1 Rio Grande

The Rio Grande at Otowi has a drainage area of 14,300 mi^2 (37,037 km^2)in southern Colorado and northern New Mexico. The instantaneous discharge for the period of record has ranged from a low of 60 cubic feet per second (cfs) (1.70 m^3/sec) measured in 1902 to a high of 24,400 cfs (691 m^3/sec) measured in 1920. The river transports about 1 million tons of suspended sediments past Otowi annually (Graf 1993, 23521).

Essentially all Rio Grande flow downstream of the Laboratory passes through Cochiti Reservoir, which began filling in 1976. It is designed to provide flood control, recreation, and fishing development. The dam is expected to trap at least 90% of the sediments carried by the Rio Grande (Graf 1993, 23521). Before 1976, sediments transported by the Rio Grande collected in Elephant Butte Reservoir, which was built in 1916.

3.5.1.2 Descriptions of Canyon Streams

Section 3.1 describes the locations and general topography of the canyons, and Table 3-1 summarizes elevation, watershed area, and channel length information. Figure A-1 in Appendix A of this core document shows watershed boundaries.

Most surface water in canyons on the Pajarito Plateau occurs as ephemeral (flowing in response to precipitation), intermittent (flowing in response to availability of snowmelt or groundwater discharge), or interrupted (alternating perennial, ephemeral, and intermittent stretches) streams. Currently, only seven of the canyons are known to contain perennial (flowing continuously) reaches within Laboratory boundaries (Pajarito Canyon, Twomile Canyon, Threemile Canyon, Cañon de Valle, Sandia Canyon, Ancho Canyon, and Chaquehui Canyon).

Figure A-4 in Appendix A of this core document shows the location of canyons, springs, and other features mentioned in this section. Sections 2.6.2.2.1 through 2.6.2.2.10 of the IWP (Revision 3) (LANL 1993, 26078) provide the basis for the brief description of surface water occurrence in each canyon. Canyons systems and their surface water characterization are described from north to south in the following paragraphs.

Guaje Canyon contains an interrupted stream. It has a perennial reach extending from springs located upstream of Guaje Reservoir to some distance downstream of the reservoir and an intermittent reach downstream to the confluence with Los Alamos Canyon. Rendija Canyon, Barrancas Canyon, and Bayo Canyon contain ephemeral streams with no springs or perennial reaches. Snowmelt runoff from all four canyons does not reach the Rio Grande.

The stream in Pueblo Canyon is mostly ephemeral, but it has a short intermittent reach downstream of Acid Canyon, which is fed by water emerging from alluvium. Continuous, effluent-supported flow occurs in the lower reach of Pueblo Canyon because it receives discharge from the Los Alamos County Sewage Treatment Plant (STP) located between Pueblo Canyon and Bayo Canyon. This flow continues into the lower reach of Los Alamos Canyon. Snowmelt runoff from the upper reaches of Pueblo Canyon occasionally extends downstream as far as the Los Alamos townsite, but normally does not reach Laboratory property.

Los Alamos Canyon contains an interrupted stream. Several perennial springs are present in the upper reaches of Los Alamos Canyon and in its main tributary, Quemazon Canyon. These upper reaches are perennial from the springs to within a few hundred yards of Los Alamos Reservoir. Below the reservoir, flow is seasonally variable, controlled by releases from the reservoir. In lower Los Alamos Canyon during most of the year, surface water flow results from discharge from the Los Alamos County STP. This flow combines with perennial flow from Basalt Spring on San Ildefonso Pueblo land and often extends to the Rio Grande.

Sandia Canyon contains an ephemeral stream within Laboratory boundaries and has neither perennial springs nor perennial reaches. A significant effluent-supported flow arising from the major discharge of treated sanitary sewage effluent occurs in Sandia Canyon and typically extends approximately 2.5 to 3 mi (4.0 to 4.8 km) downstream. Approximately 3 mi (4.8 km) east of the Laboratory boundary, a perennial spring, known as Sandia Spring, flows for a few hundred yards. This flow does not normally reach the Rio Grande. Significant snowmelt runoff does not occur within Sandia Canyon.

Mortandad Canyon contains a stream that is entirely ephemeral; neither perennial springs nor perennial reaches occur in this canyon. Surface water flows from the National Pollutant Discharge Elimination System-permitted outfall of the Laboratory's Radioactive Liquid Waste Treatment Plant at TA-50 and from cooling tower outfalls; surface flow typically extends approximately a mile downstream of the TA-50 outfall. Significant snowmelt runoff does not occur within Mortandad Canyon. Cañada del Buey joins Mortandad Canyon about 0.5 mi (0.8 km) upstream from the confluence of Mortandad Canyon with the Rio Grande. Cañada del Buey contains a stream that is entirely ephemeral. The Los Alamos County-operated sanitary wastewater treatment plant in White Rock discharges into Cañada del Buey at a point about 0.5 mi (0.8 km) east of the Laboratory boundary. This discharge results in effluent-supported flow that regularly extends to the Rio Grande.

Pajarito Canyon contains an interrupted stream fed by several perennial springs in the upper reaches of Pajarito Canyon. Perennial flow is followed by an intermittent reach to within approximately 0.5 mi (0.8 km) west of the Laboratory boundary. Pajarito Canyon then has an ephemeral reach extending downstream to a point approximately 1 mi (1.6 km) east of the Laboratory's west boundary. At this point, Homestead Spring supports another perennial reach for at least several hundred yards, followed by an intermittent and/or ephemeral reach that may extend to near the confluence with Threemile Canyon.

Both Twomile Canyon and Threemile Canyon contain ephemeral and/or intermittent streams. East of the confluence with Threemile Canyon, Pajarito Canyon is ephemeral across Laboratory land to a point approximately 0.4 mi (0.64 km) upstream from its confluence with the Rio Grande. Pajarito Spring is located at that point and supports perennial flow to the confluence with the Rio Grande. In most years, snowmelt extends onto Laboratory land down to or below the confluence with Threemile Canyon. Snowmelt runoff occasionally extends downstream as far as the Rio Grande.

Potrillo Canyon and Fence Canyon contain streams that are entirely ephemeral with no perennial springs or perennial reaches. No significant snowmelt runoff occurs within either of these canyons.

Water Canyon contains an interrupted stream fed by several perennial springs in the upper reaches of Water Canyon, including Armstead Spring, American Spring, and other springs in the upper reaches of Cañon de Valle. These springs support perennial reaches followed by intermittent reaches limited to the area west of the Laboratory boundary. Water Canyon and its major tributary, Cañon de Valle, are ephemeral from the western Laboratory boundary across Laboratory land to a point below the confluence with Potrillo Canyon. Snowmelt runoff in Water Canyon seldom extends downstream as far as the eastern Laboratory boundary; however, occasionally it extends to the Rio Grande.

Ancho Canyon contains a stream that is ephemeral within Laboratory boundaries to a point approximately 0.8 mi (1.3 km) upstream from its confluence with the Rio Grande. At this point, a perennial spring, known as Ancho Spring, supports a perennial flow to the Rio Grande. Ancho Canyon has no significant snowmelt runoff.

Chaquehui Canyon contains a stream that is ephemeral to a point approximately 0.5 mi (0.8 km) upstream from its confluence with the Rio Grande. A perennial spring, known as Doe Spring, is located at that point and supports perennial flow for a short distance, followed by a short intermittent reach. Spring 9 and Spring 9A, located about 0.25 mi (0.4 km) upstream from the confluence with the Rio Grande, support perennial flow again. Perennial flow occurs from these two springs to the Rio Grande. No significant snowmelt runoff occurs in Chaquehui Canyon.

3.5.2 Normal Seasonal Runoff

Runoff from summer storms on the Pajarito Plateau typically reaches a maximum discharge in less than 2 hours after rainfall ceases and generally has a duration of less than 24 hours (Purtymun et al. 1990, 6992). A high discharge rate results in large masses of suspended and bedload sediments being carried for long distances, occasionally to the Rio Grande. The most extensive studies of thunderstorm runoff were conducted in the Los Alamos Canyon/Pueblo Canyon system, specifically in DP Canyon. In 1967, 23 runoff events were measured. These events carried a total of 88,000 kg (194,260 lb) of sediments in 36,800 m^3 (1,299,400 ft^3) of water (Purtymun and Johansen 1974, 11835).

Spring snowmelt runoff is generally of low discharge lasting several weeks to several months and, in some of the canyons, occasionally reaches the Rio Grande. For example, between 1975 and 1986 snowmelt reached the Rio Grande a total of 205 days, occurring in only 5 of those years and averaging approximately 41 days per year or approximately 4.7% of the total number of days in the 12-year period (McLin 1992, 12014).

Because of relatively low flow rates, effluent from the Los Alamos County STP located between Pueblo Canyon and Bayo Canyon provides a minor sediment transport mechanism, but effluent from the plant results in flow through the lower part of Pueblo Canyon into lower Los Alamos Canyon during most of the year. This flow transports some of the contaminated sediments from Pueblo Canyon into Los Alamos Canyon on San Ildefonso Pueblo land. The amounts of plutonium transported were estimated at approximately 3 to 4 mCi in 1990 and 4 to 6 mCi in 1991 (Environmental Protection Group 1992, 7004; Environmental Protection Group 1993, 23249). These annual amounts are roughly 20 to 30 times the amount carried from Pueblo Canyon into Los Alamos Canyon during four spring runoff events measured in 1975, 1979, 1985, and 1986 (Apt and Lee 1976, 5559; ESG 1980, 5961; ESG 1986, 6626; ESG 1987, 6678).

3.5.3 Flooding Potential

The climate and topography in the region of the Laboratory are conducive to short-term, high-intensity storms and rapid associated runoff. In the location standards for treatment, storage, and disposal (TSD) facilities and TSD permitting requirements under RCRA (at 40 CFR 264.18[b] and 40 CFR 270.14 [b] [11] [iii] respectively) (EPA 1994, 50122; EPA 1994, 50116), the Environmental Protection Agency (EPA) requires that the potential impacts on Laboratory facilities be evaluated for floods that might result from these storms. The Laboratory recently performed an evaluation of the estimated 100-year storms and resultant floodplain elevations for the watersheds that drain the Laboratory area (McLin 1992, 12014). For this study, researchers used the US Army Corps of Engineers computer-based flood hydrograph packages, HEC-1 (Army Corps of Engineers 1990, 44017) and HEC-2 (Army Corps of Engineers 1990, 44018), to perform the floodplain hydrologic simulations. A 6-hour storm was modeled for all the major canyons within the canyon systems. Parameter inputs (such as precipitation, surface runoff, and initial soil moisture content) were selected to represent a reasonable worst-case scenario and thus present a conservative estimate of a 100-year flood event in the various canyons (McLin 1992, 12014). A summary of the results of this study is presented in Sections 2.6.2.2.1 through 2.6.2.2.10 of the 1993 IWP (LANL 1993, 26078).

3.5.4 Infiltration

The primary mechanism of contaminant transfer between the surface and the underlying groundwater-bearing zones is infiltration of surface water carrying colloidal and dissolved contaminants. The potential for significant infiltration exists, given both the presence of coarse-grained sediments in most parts of the canyon systems and the high vertical hydraulic gradients beneath canyon streams. The surface water infiltration pathways within the canyon systems include native or disturbed soils; unconsolidated alluvium; Bandelier Tuff, Puye Formation, and basalt; faults and fracture systems; and cooling joints.

Infiltration of surface water into the alluvium commonly occurs throughout the canyon systems where alluvium is present. Limited geochemical evidence indicates infiltration of water below the alluvium at some locations discussed in the following section.

3.6 Hydrogeology

This section discusses the hydrology of the unsaturated zone beneath the alluvium and the saturated zones of the alluvium in some of the larger canyons in the canyon systems. Also discussed is the hydrogeology associated with the intermediate perched groundwater zones in the Guaje Pumice Bed, Cerros del Rio basalt, and Puye Formation, and the deep or regional aquifer in the Santa Fe Group for all the canyon systems.

3.6.1 Unsaturated Zone

Understanding the hydrogeologic properties of the unsaturated zone for the canyon systems is important because the unsaturated zone possibly serves as both a barrier to the vertical movement of liquid discharges at some locations and conduits for them at other locations.

In the central part of the Laboratory, there are more than 1,000 ft (305 m) of unsaturated volcanic tuff, sediments, and basaltic rocks. Numerous investigations focusing on hydrologic characterization of the upper 100 ft (30.5 m) of Bandelier Tuff have been conducted in the Los Alamos area since the 1950s (for example, Abrahams et al. 1961, 8134; Weir and Purtymun 1962, 11890; Abrahams 1963, 8149; Purtymun and Koopman 1965, 11839; Purtymun and Kennedy 1971, 4798; Purtymun et al. 1978, 5728; Abeele et al. 1981, 6273; Kearl et al. 1986, 8414; Purtymun et al. 1989, 6889; Stoker et al. 1991, 7530). The vadose zone below 100 ft (30.5 m) is not as well characterized.

Features of the unsaturated tuff that control the rates of vertical contaminant transport (Kearl et al. 1986, 8414) include the following:

- physical properties (density, porosity, and specific gravity);
- geohydrologic properties (saturated and unsaturated permeabilities, conductivities, and moisture characteristic curves);
- properties of fractures and joints (frequency, orientation, degree of interconnectedness, and filling materials);
- properties of mapping unit contacts or paleosurfaces (flow paths or barriers);
- geochemical properties (specific surface area, ion exchange capacity, retardation factors, and mineralogy);
- depth to groundwater; and
- pore water chemistry.

The movement of water through the unsaturated zone has been demonstrated in some locations at the Laboratory. A recent study of Mortandad Canyon concluded that moisture containing tritium from Laboratory effluents has migrated vertically at least 200 ft (61 m) beneath the canyon floor (Stoker et al. 1991, 7530).

Special low-detection-limit (0.1 pCi/L) measurements of tritium (Longmire et al. 1996, 54168) have confirmed the presence of recent recharge to the regional aquifer at several locations within the canyon systems. In addition to tritium, the presence of other contaminants, particularly chloride, nitrates, and ^{90}Sr, has been observed in both the alluvium and the underlying intermediate perched zones in other canyons of the canyon systems (LANL 1995, 50290).

The significance of fault zones, including the Guaje Mountain fault zone, the Rendija Canyon fault zone, and the Pajarito fault zone, as areas of potential groundwater recharge is uncertain. Moreover, the significance of fractures and joints in the tuff as potential conduits for recharge is uncertain. Ongoing research at the Laboratory and investigations of the canyons will obtain data to address this issue.

Most of the available data on hydrologic properties of the tuff have been obtained on cores collected from boreholes. A limited amount of data on *in situ* properties are available in the vicinity of the TA-54 waste disposal facilities on Mesita del Buey.

Approximately 30 cores of the Otowi Member of the Bandelier Tuff have been analyzed in detail for hydrologic properties. Most of these cores came from boreholes in Los Alamos Canyon, Mortandad Canyon, Sandia Canyon, and Potrillo Canyon. No unsaturated hydrologic properties have been measured for the units underlying the Bandelier Tuff.

The hydraulic properties determined in core samples are summarized in Table 3-2 (Rogers and Gallaher 1995, 48845). The following discussion summarizes the available information on the properties of the Otowi Member of the Bandelier Tuff (the unit immediately underlying the alluvium in the upper reaches of many canyons).

TABLE 3-2

HYDRAULIC PROPERTIES OF ALLUVIUM AND BANDELIER TUFF[a]

Property	Alluvium	Tshirege	Tsankawi	Otowi
ρ_b (g/cm^3)[b]	1.42 ± 0.17 (9)	1.23 ± 0.16 (89)	1.25 ± 0.19 (20)	1.18 ± 0.096 (32)
θ_{sat} (%)[c]	43.3 ±4.3 (8)	48.9 ± 6.0 (89)	49.0 ± 9.8 (19)	46.9 ± 5.26 (32)
S(%)[d]	46.8 ±28.9 (8)	35.6 ± 23.8 (86)	46.8 ± 28.4 (19)	33.0 ± 9.9 (31)
K_{sat} (cm/sec)[e]	4.4×10^{-4} (2)	3.2×10^{-4} (67)	1.3×10^{-3} (10)	6.3×10^{-4} (25)
log K_{sat}[f]	–3.64 (2)	–3.85 ± .50 (67)	–3.25 ± 0.70 (10)	–3.57 ± 0.49 (25)
θ_r (%)[g]	3.8 (2)	2.1 ± 2.7 (52)	1.7 ± 2.7 (9)	2.6 ± 2.7 (21)
α (1/cm)[h]	0.385 (2)	0.120 ± 0.033 (52)	0.187 ± 0.194 (9)	0.0066 ± 0.0030 (21)
N[i]	1.558 (2)	1.759 ± 0.341 (52)	1.481 ± 0.246 (9)	1.711 ± 0.218 (21)

a. Figures are mean values ± one standard deviation with the number of observations in parentheses (Rogers and Gallaher 1995, 48845).

b. ρ_b = grain density

c. θ_{sat} = effective porosity

d. S = saturation

e. K_{sat} = saturated hydraulic conductivity

f. log K_{sat} = logarithm to the base ten of saturated hydraulic conductivity

g. θ_r = residual saturation

h. α = a constant (units 1/cm) used in calculating residual water content

i. N = curve-fitting parameter for moisture retention curves (van Genuchten 1980, 49927)

3.6.1.1 Porosity

The rocks of the Bandelier Tuff tend to have relatively high porosities, ranging from 30 to 63 vol % on tuff samples collected within the Laboratory boundaries. Porosity values are lower in more densely welded tuff (see Section 2.4.2.3.2 of the IWP [Revision 6] [LANL 1996, 55574]). The effective porosity (interconnected or fluid accessible porosity) ranges from 18 to 52 vol % (Stephens and Associates 1991, 27618; Stoker et al. 1991, 7530).

3.6.1.2 Moisture Content

Moisture content of the Otowi Member of the Bandelier Tuff has been measured in three boreholes (one borehole in Sandia Canyon and two boreholes in Mortandad Canyon) to assess the movement of water through the unsaturated zone. The moisture content of the Otowi Member in these boreholes is moderate to high, generally ranging from 20 to 40 vol % (Stephens and Associates 1991, 27618; Stoker et al. 1991, 7530). These values are considerably higher than those typically reported for the mesa tops and in some cases approach full saturation (Weir and Purtymun 1962, 11890; Section 2.4.2.3.3 of the IWP [Revision 6] [LANL 1996, 55574]). In contrast, moisture contents on the upper Otowi Member range from 8 to 13% in the mesa-top borehole 49-2-700-1 at TA-49. Results of this investigation suggest that greater infiltration of water occurs beneath the canyon floors than through the mesa tops.

3.6.1.3 Hydraulic Conductivity

Hydraulic conductivity is a measure of the potential for fluid flow within a porous solid material. Saturated cores of the Otowi Member of the Bandelier Tuff have hydraulic conductivities that range from 8.3×10^{-6} to 7.8×10^{-3} cm/s. The hydraulic conductivity varies with moisture content; values for unsaturated tuff are two to five orders of magnitude lower than those for saturated tuff (5.6×10^{-8} to 5.6×10^{-11} cm/s for welded tuff and 3.1×10^{-6} to 3.3×10^{-9} cm/s for nonwelded tuff) (Stoker et al. 1991, 7530; Section 2.4.2.3.5 of the IWP [Revision 6] [LANL 1996, 55574]).

The variation in hydraulic properties with water content is described by the moisture characteristic curve, which relates water content of the solid phase to suction, tension, or negative pressure head. The moisture characteristic curve is also used to determine the relative hydraulic conductivity, which can be used to calculate water flux at water contents below full saturation (see Section 2.4.2.3.4 of the IWP [Revision 6] [LANL 1996, 55574]). Numerous moisture characteristic curves have been determined on crushed Bandelier Tuff. A limited amount of *in situ* moisture characteristic data are available, particularly for the low water contents generally found in the Bandelier Tuff (Abeele 1984, 6520).

3.6.2 Groundwater Zones

Groundwater occurs in three modes in the Los Alamos area: (1) water in shallow alluvium in some of the larger canyons, (2) intermediate perched zone groundwater (a perched groundwater body lies above a less permeable layer and is separated from the underlying aquifer by an unsaturated zone), and (3) the regional aquifer.

3.6.2.1 Alluvial Groundwater

Surface water infiltration creates saturated zones in the alluvium of some of the canyons within the canyon systems. The thickness of the alluvium within a given canyon ranges from several feet to as much as 100 ft (30.5 m). The alluvium in those canyons that head on the Jemez Mountains is generally composed of sands, gravels, pebbles, cobbles, and boulders derived from the Tschicoma Formation and Bandelier Tuff on the flanks of the mountains. The alluvium in the canyons that head on the plateau is comparatively more finely grained, consisting of sands, silts, gravels, and clays derived from the Bandelier Tuff and local soils (see Section 2.6.2.3.1 of the IWP [Revision 3] [LANL 1993, 26078]). Saturated hydraulic conductivity of the alluvium typically ranges from 10^{-2} cm/s for a sand to 10^{-4} cm/s for a silty sand (Abeele et al. 1981, 6273).

In contrast to the underlying volcanic tuff and sediments, the alluvium is quite permeable. Surface water infiltrates the alluvium until downward movement is impeded by the less permeable tuff and sediments of the unsaturated stratum, which results in accumulation of water in a shallow alluvial groundwater zone. Partial depletion by evapotranspiration, movement into the underlying geologic formations, and the limited lateral extent and thickness of the alluvium precludes its use as a reliable and continuous water supply; however, occasional use by humans is possible where water quality permits. The alluvial groundwaters flow laterally in an easterly, down-canyon direction. Tracer studies in Mortandad Canyon have shown that the velocity of alluvial groundwater varies from approximately 60 ft (18.3 m) per day in the upper reach to approximately 7 ft (2.1 m) per day in the lower reach of the canyon (Purtymun 1974, 5476). Purtymun (1975, 11787; 1973, 4971) has summarized the occurrence of alluvial groundwaters by drainage area.

The quality of the alluvial groundwaters of the canyon systems is variable depending on the location and history of any effluent discharges. Contaminants in soils, sediments, and surface waters enter the alluvium and migrate downgradient. Rates of contaminant migration differ with contaminant due to differing adsorption and precipitation reactions that occur along the transport pathway. The saturated alluvium is of interest because

- surface water (and any contaminants) that recharges alluvium will migrate downgradient, be available for uptake by plants, and possibly become available locally at discharge points downgradient for consumption by animals and humans (see Appendix K of the IWP [Revision 3] [LANL 1993, 26078]) and

- the alluvial groundwater that recharges the underlying Bandelier Tuff may contaminate the intermediate perched zones and the much deeper regional aquifer within the Santa Fe Group.

3.6.2.2 Intermediate Perched Groundwater Zones

Saturated conditions are known to exist within the canyon systems at depths between the alluvium and the regional aquifer in the Guaje Pumice Bed, Cerros del Rio basalts, and the Puye Formation in the middle and lower reaches of Pueblo Canyon and Los Alamos Canyon and in the lower reach of Sandia Canyon. Depth to perched water ranges from approximately 90 ft (27 m) in the middle reach of Pueblo Canyon to approximately 450 ft (137 m) in lower Sandia Canyon. The vertical and lateral extent of the perched groundwaters, the nature and extent of the perching units, and the potential for migration of perched water to the regional aquifer are not fully understood. It is also not known whether the perched groundwater systems are hydraulically interconnected.

Perched groundwater also occurs in the Bandelier Tuff and the Tschicoma Formation on the eastern flank of the Jemez Mountains and on the west side of the Laboratory. These perched waters discharge to several springs (including American Spring and Armstead Spring) and provide flow for the gallery in Water Canyon (see Section 2.6.2.3.2 of the IWP [Revision 3] [LANL 1993, 26078]).

The presence of chemical components of high explosives and volatile organic compounds (which are probably residues from firing sites at TA-16) in spring water issuing from the upper part of the Tshirege Member into Cañon de Valles indicate local recharge to the springs.

3.6.2.3 Regional Aquifer

The regional aquifer occurs in the Puye Formation and the Santa Fe Group at depths below the mesa tops ranging from approximately 1,200 ft (366 m) along the western margin of the Pajarito Plateau to approximately 600 ft along the eastern margin. The regional aquifer is separated from the water in the alluvium and intermediate perched groundwater zones in the volcanic rocks by 350 to 620 ft (107 to 189 m) of tuff and volcanic sediments (Environmental Protection Group 1993, 23249). Continuously recorded water level data collected in test wells since 1992 indicate that throughout the Pajarito Plateau the regional aquifer responds to barometric pressure variations and earth tides in a manner typical of confined aquifers. Purtymun (1984, 6513) summarizes aquifer hydraulic characteristics as determined during regional aquifer tests or during periods of production from supply wells and test holes.

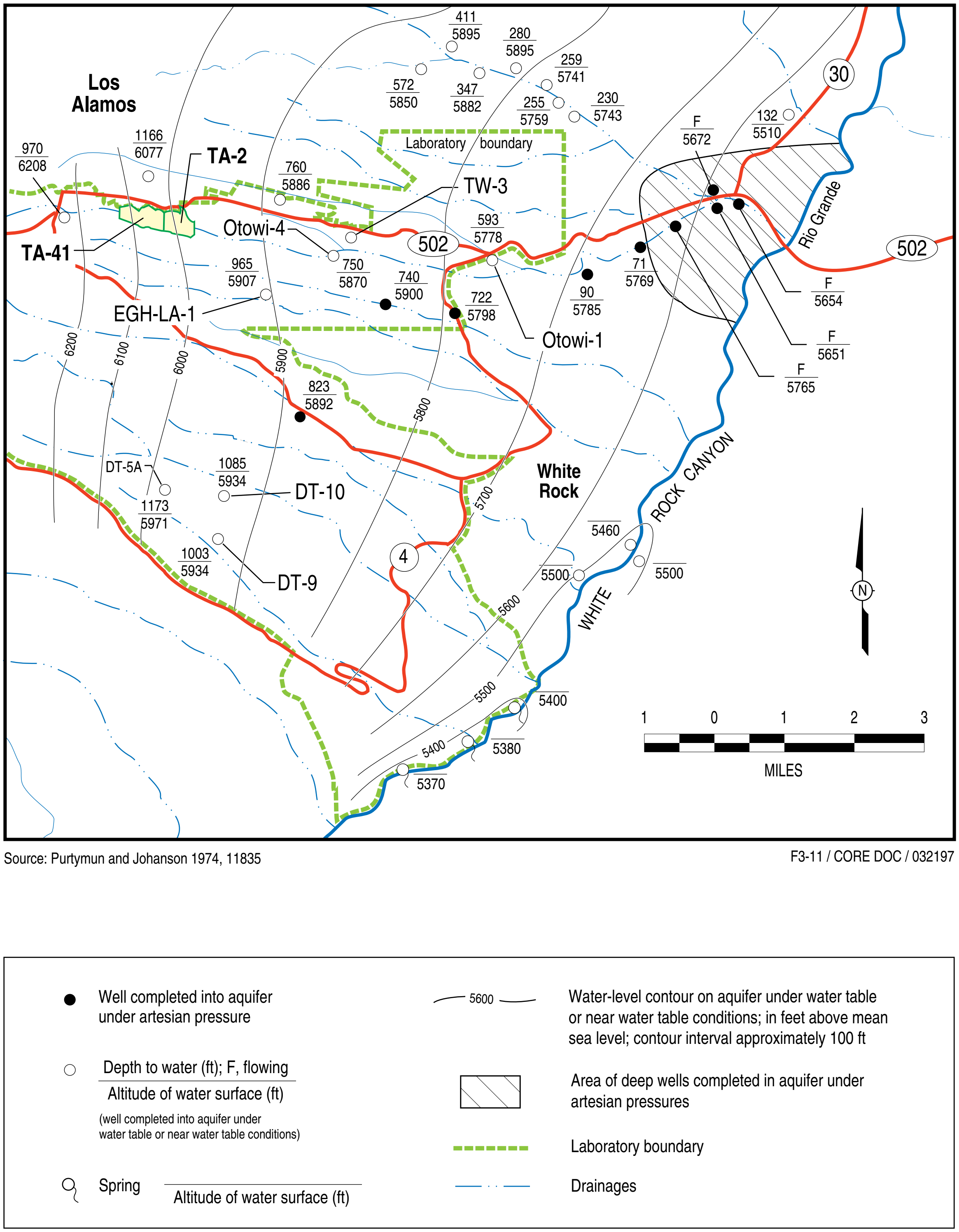
Groundwater-level measurements taken in deep observation wells located on the Pajarito Plateau indicate that the elevation of the potentiometric surface of the regional aquifer rises westward from the Rio Grande through the Santa Fe Group and the lower part of the volcanic and sedimentary rock units beneath the central and western part of the Pajarito Plateau (Purtymun and Johansen 1974, 11835) (Figure 3-11).

The primary recharge area to the upper saturated zones of the regional aquifer is inferred from the east-sloping piezometric surface to be located on the eastern flanks of the Sierra de los Valles, but neither the locations nor the major mechanisms of recharge are known. The piezometric surface gradient suggests that groundwater flows from the Jemez Mountains east and east-southeast toward the Rio Grande, where a portion of the water is discharged into the river through seeps and springs (Purtymun et al. 1980, 6048).

Other possible zones of recharge to the regional aquifer and to the intermediate perched zones include canyon floors supporting alluvial groundwater systems and the Guaje Mountain, Rendija Canyon, and Pajarito fault zones. However, recent studies suggest that the Pajarito Plateau portion of the regional aquifer at depth appears to be recharged by a combination of lateral flow parallel to the Rio Grande rift supplemented by inflow from the Sangre de Cristo Mountains (LANL 1996, 55430).

The piezometric surface gradient of the regional aquifer averages approximately 60 to 80 ft per mile within the Puye Formation. Along the eastern edge of the Pajarito Plateau, as the water in the aquifer enters the less permeable sediments of the Santa Fe Group, the gradient increases to 80 to 100 ft per mile. The rate of movement of water in the upper section of the aquifer varies depending on the materials in the aquifer. Aquifer tests indicate that movement ranges from 20 ft per year in the Tesuque Formation to 345 ft per year in the more permeable Puye Formation (Purtymun 1984, 6513).

The age of the regional aquifer groundwater has been estimated using ^{14}C and ^{3}H dating. Age estimates vary widely from a few tens of years using ^{3}H techniques to over 40,000 years using ^{14}C techniques (Section 3.7.5). Research continues on determining the actual age and causes for the present wide disparity in estimates of age.



Source: Purtymun and Johanson 1974, 11835

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Figure 3-11. Generalized water-level contours and piezometric surface contours of the regional aquifer.

3.7 Surface Water and Groundwater Chemistry and Contaminant Occurrence

This section presents a summary of water-quality data and a discussion of the geochemistry of surface water and of groundwater within the alluvium, the intermediate perched zones of the Guaje Pumice Bed, and regional aquifer in the Puye Formation and the Santa Fe Group. Water-quality data consisting of major ions, trace elements, radionuclides, organic compounds, and stable isotopes have been collected for nearly 50 years at the Laboratory. This section also identifies additional information and data needs related to expanding the conceptual understanding of environmental and geochemical processes occurring within the canyon systems and assessing the magnitude and importance of transport pathways and potential exposure pathways within the canyons.

As mentioned previously, since 1971, surveillance and monitoring data have been published annually by the Laboratory. The annual surveillance reports of 1971 through 1976 were published under the authorship of the data compilers (Kennedy et al. 1971, 4800; Herceg 1972, 31458; Herceg 1972, 4955; Herceg 1973, 4966; Schiager and Apt 1974, 5467; Apt and Lee 1975, 5488; Apt and Lee 1976, 5559). Reports of 1977 through 1989 were authored by the Laboratory Environmental Surveillance Group (ESG); these reports are cited in the references as ESG. Reports from 1989 to 1993 are authored by the Laboratory Environmental Protection Group; these reports are cited in the references as Environmental Protection Group.

The annual reports through 1989 contained data collected in the previous year. Since 1989, the reports have contained data collected two years previously. Much of the data used in this section was taken directly from those reports. For brevity, annual reports of surveillance data are often cited hereafter as ESG and the date or date range of the annual report(s) containing the data used, for example (ESG 1971–1995). Where a specific source of data has been used in discussion, the specific report is cited.

3.7.1 Relevance of Geochemical Data

Existing water-quality data show that tritium, chloride, nitrate, ^{90}Sr, and other contaminants, which could have come either from the Laboratory or from other sources such as atmospheric fallout, road salt, or sanitary wastewater discharges, occur in both surface waters and groundwaters associated with the canyon systems (ESG 1971–1995) (Longmire et al. 1996, 54168). The potential for receptors to be exposed to contaminants drives the need for improved understanding of contaminant transport pathways through the unsaturated and saturated zones within the canyon systems.

The predominant geochemical mechanisms affecting mobilization and transport of contaminants within the canyon systems are precipitation/dissolution and adsorption/desorption reactions and possibly colloidal transport, specifically

- sorption of contaminants on surface sediments that are dispersed during surface water runoff and sediment deposition,
- sorption of contaminants on geological media causing retardation of contaminant migration in the subsurface,
- chemical precipitation and dissolution of contaminants in discrete phases, and
- rate of movement of infiltrating water.

Geochemical data needed for impact assessment include chemical analyses of surface waters and groundwaters (for dissolved and suspended constituents); mineralogical composition of different aquifer materials and surface sediments; and retardation factors or adsorption capacities of different aquifer materials and surface sediments for americium, cesium, plutonium, strontium, uranium, and possibly other contaminants.

3.7.2 Surface Water and Sediments

Results of surface water and sediment monitoring and hydrologic investigations conducted in each of the various canyons are presented in each of the eight sampling and analysis plans (SAPs) or task/site work plans for the canyons investigations that have been or will be prepared. Each of the canyons is unique with respect to the number and scope of prior investigations, the extent of surface water and sediment monitoring, contaminant releases that have occurred over the past five decades, and the nature and extent of contamination. Complete discussion of these issues for each canyon is beyond the scope of this core document. Presentation and discussion of the available data on contaminant distribution in sediments in Los Alamos Canyon and Pueblo Canyon and relevant sediment transport processes are presented in the *Task/Site Work Plan for Operable Unit 1049: Los Alamos Canyon and Pueblo Canyon* (LANL 1995, 50290). The discussion in this work plan illustrates the great spatial variations in contaminant concentrations and contaminant inventories that resulted from decades of sediment transport over long distances from the sources.

A surface water sampling station that is of equal importance to investigations in each of the canyons is located west of the Laboratory boundary in Los Alamos Canyon (near Los Alamos Reservoir). It is intended to measure background water quality and background levels of potential contaminants. Measurements at this station (Table 3-3) indicate that concentrations of individual major ions (calcium, sodium, magnesium, potassium, chloride, sulfate, and bicarbonate), except for bicarbonate, are commonly less than 20 mg/L and that radionuclide activities are near regional fallout levels (except for tritium). Silica, in the form of $H_4SiO_4^0$, is the predominant dissolved species in these background surface waters as a result of the dissolution of soluble silica present in the Bandelier Tuff. The pH values range from slightly acidic (6.8) to alkaline (8.1) (ESG 1971–1995). Background surface waters are a calcium-sodium-bicarbonate type with total dissolved solids (TDS) concentrations generally less than 150 mg/L (ESG 1971–1995).

3.7.3 Alluvial Groundwater

The quality of the groundwater in the alluvium of the canyon systems is monitored as part of the Laboratory Environmental Surveillance Program by a system of shallow alluvial groundwater monitoring stations (see Appendix E of the Groundwater Protection Management Program Plan [GPMPP] [LANL 1995, 50124] and Chapter 2, Section 2.3.3.3 of this core document). Results of shallow alluvial groundwater monitoring and investigations conducted in the various canyons is presented in each of the eight SAPs or task/site work plans for canyons investigations that have been or will be prepared. Table 3-4 summarizes the Department of Energy's derived concentration guides for public dose from radionuclides in waters in uncontrolled areas and drinking water systems for several radionuclides of interest in the shallow alluvial groundwater.

Figure 3-12 shows the values of the saturation index (SI) for three solid phases potentially in equilibrium with the solution phase for Los Alamos Canyon alluvial groundwater. The SI is a measure of the degree of under- or over-saturation of a solid phase in water [$SI = \log_{10}$ {activity product/solubility product}]; at equilibrium SI = 0). Dissolved silica concentrations in alluvial groundwater are calculated to be in equilibrium with silica glass but oversaturated with respect to cristobalite. These phases are abundant in the alluvium that was derived from the Bandelier Tuff (Broxton et al. 1995, 50121), and they could be important adsorbents for radionuclides (such as ^{90}Sr and ^{137}Cs) found in alluvial groundwater. Calculations also show that background alluvial groundwater is undersaturated with respect to calcite and oversaturated with respect to feldspars and other silicates observed in the Bandelier Tuff.

TABLE 3-3

BACKGROUND WATER QUALITY DATA FROM LOS ALAMOS RESERVOIR

Element/Parameter	**Value**
pH (field)	8.1
Total dissolved solids (mg/L)	181
Radiochemical (pCi/L)	
^{3}H	300 (300)[a]
^{90}Sr	N/A[b]
^{137}Cs	2.9 (1.1)
^{238}Pu	0.004 (0.016)
$^{239,240}Pu$	0.018 (0.014)
^{241}Am	N/A
Gross-alpha	1
Gross-beta	4 (1)
Gross-gamma	110 (90)
Major Constituents (mg/L)	
SiO_2	39
Ca	8
Mg	2.6
K	3
Na	6
Cl	6
F	0.2
CO_3	<5
HCO_3	29
$PO_{4-}P$	0.0
SO_4	5
$NO_{3-}N$	<0.04
CN	<0.01
Trace Metals (mg/L)	
Ag	<0.0006
Al	0.14
As	<0.0020
B	<0.020
Ba	0.0158
Be	<0.0010
Cd	<0.0020
Cr	<0.0050
Co	<0.0020
Cu	<0.002
Fe	0.14
Hg	<0.0001
Total uranium (μg/L)	<0.6

a. Radioactivity counting uncertainties (+/– 1 standard deviation) are shown in parentheses.

b. N/A means analysis not performed, lost, or not completed.

Source: Environmental Protection Group 1994, 35363

TABLE 3-4
DOE-CALCULATED DERIVED CONCENTRATION GUIDES

Nuclide	Uncontrolled Areas (pCi/L)	Drinking Water Systems (pCi/L)
^{3}H	2,000,000	80,000 (MCL[a] = 20,000)
^{90}Sr[b]	1,000	40 (MCL = 8)
^{137}Cs	3,000	120
^{234}U	500	20
^{235}U	600	24
^{238}U	600	24
^{238}Pu	40	1.6
^{239}Pu[b]	30	1.2
^{240}Pu	30	1.2
^{241}Am	30	1.2
Natural uranium	0.80 mg/L	0.030 mg/L (MCL = 0.020 mg/L)

a. MCL = EPA maximum contaminant level for drinking water at 40 CFR 141 (EPA 1994, 50118)
b. Guides for ^{239}Pu and ^{90}Sr are the most appropriate to use for gross-alpha and gross-beta, respectively.

Source: DOE Order 5480.11

3.7.4 Intermediate Perched Groundwater Zone

The results of the intermediate perched zone groundwater monitoring and investigations conducted within Los Alamos Canyon and Pueblo Canyon are discussed in detail in the *Task/Site Work Plan for Operable Unit 1049: Los Alamos Canyon and Pueblo Canyon* (LANL 1995, 50290). Analyses of groundwater samples from TW-1A, TW-2A, LADP-3, and Basalt Spring indicate recent recharge from the alluvium to the intermediate perched zone in Los Alamos Canyon and Pueblo Canyon. Analyses of samples from LAOI(A)-1.1 do not contain Laboratory-derived contaminants and may represent background conditions in the Guaje Pumice Bed (Longmire et al. 1996, 54168).

3.7.5 Regional Aquifer

The quality of the groundwater in the regional aquifer is measured at monitoring wells located in and around the Laboratory as part of the Laboratory's Environmental Surveillance Program (see Appendix E of the GPMPP [LANL 1995, 50124] and Chapter 2, Section 2.3.3.1 of this core document). The results of the regional aquifer monitoring and investigations conducted in the various canyons is discussed in detail in each of the eight SAPs or task/site work plans for canyons investigations that have been or will be prepared.

3.7.5.1 General Chemistry

Groundwater of the regional aquifer is characterized by more alkaline pH values (8.1 to 8.2) than those measured on groundwater samples collected from the alluvium (7.0 to 7.3) and from the intermediate perched zones (7.3 to 7.7) (Environmental Protection Group 1994, 35363). TDS concentrations of natural groundwaters are influenced by hydrologic properties of the aquifer matrix, residence time and age

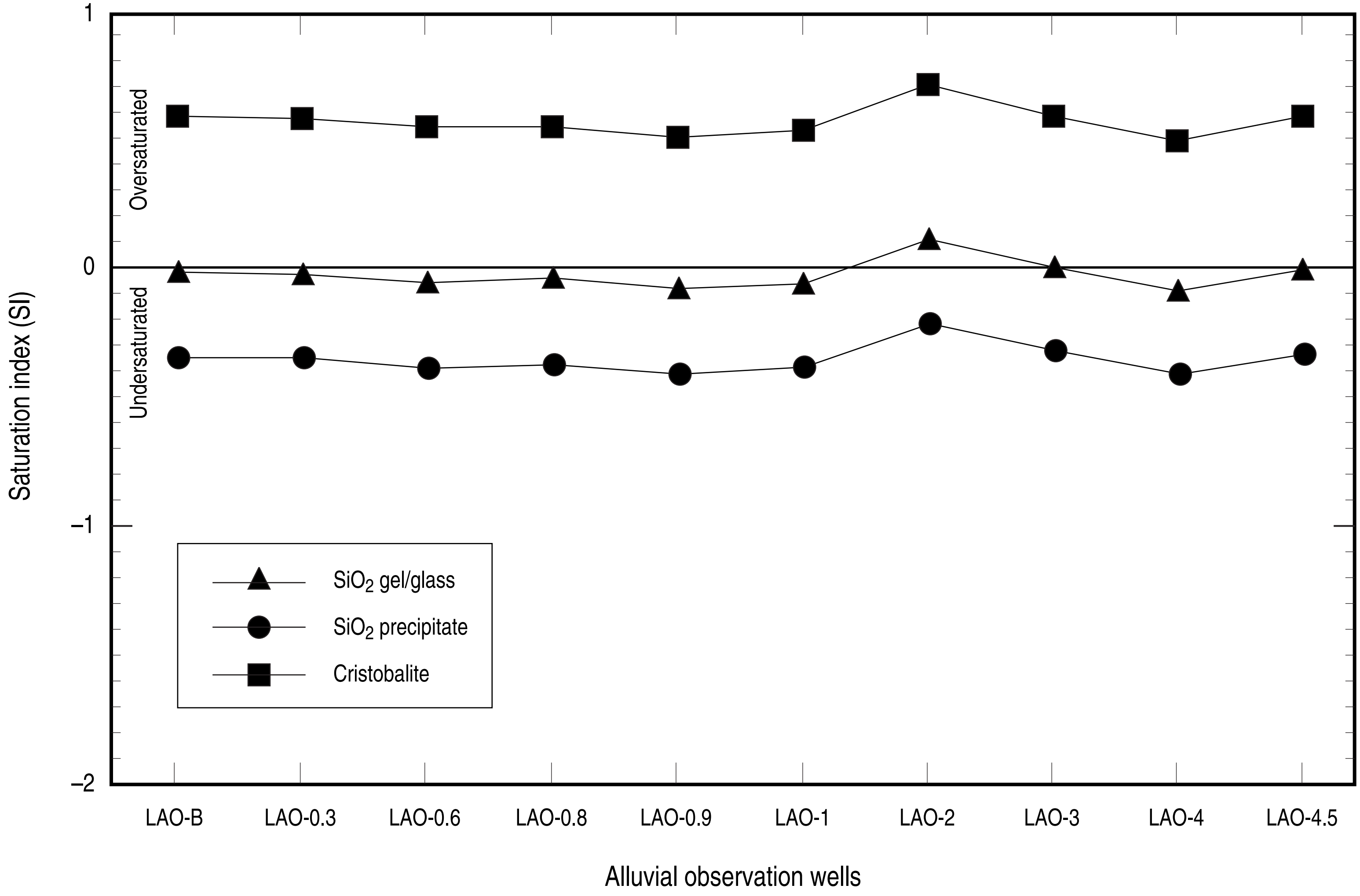

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Figure 3-12. Saturation indices for silica minerals in alluvial groundwater in upper Los Alamos Canyon.

of the water, and geochemical interactions between the water and the aquifer matrix. The TDS concentrations of groundwater samples collected from the regional aquifer are generally less than the TDS of those collected from the intermediate perched zone in Los Alamos Canyon and Pueblo Canyon. The average background TDS in groundwater in the Guaje Pumice Bed in LAOI-1.1A during 1994 and 1995 was 166 mg/L (Longmire et al. 1996, 54168). From 1984 to 1988, the average TDS concentration in groundwater samples collected from TW-3, located below the confluence of Los Alamos Canyon and DP Canyon, was 129 ± 49 mg/L. Calcium tends to be the predominant cation, and bicarbonate is the dominant anion. However, at depth within the regional aquifer, sodium is the dominant cation in groundwater, which suggests that cation exchange processes are occurring and affecting the composition of the water. The increasing bicarbonate concentrations in successively deeper saturated zones is due probably to the presence of calcite ($CaCO_3$) in the Santa Fe Group and possibly due to the oxidation of natural organic matter to CO_2 (Drever 1988, 49933). Filtered groundwater samples collected from TW-3 are a calcium-sodium-bicarbonate type (Blake et al. 1995, 49931). Results of speciation calculations using MINTEQA2 (Allison et al. 1991, 49930) suggest that TW-3 groundwater is in equilibrium with calcite and that dissolved concentrations of calcium and bicarbonate are controlled by this equilibrium.

Several factors contribute to variations in chemistry of the groundwater in the Santa Fe Group. Production wells have screened intervals over hundreds of feet, and groundwater samples probably reflect contributions from different zones of the regional aquifer. In addition, unfiltered samples, which contain both dissolved constituents and constituents sorbed on suspended matter, were probably collected from the supply wells. Therefore, inferences about geochemical interactions of water and sediment based on analyses of these water samples are more ambiguous than similar inferences would be for analyses of samples from more restricted zones of saturation and analyses of only filtered samples. Analyses of filtered water samples from the regional aquifer and other water-bearing zones will be used as input to geochemical modeling to quantitatively address natural water composition and rock/water interactions influencing the fate and transport of contaminants.

3.7.5.2 Low-Level Tritium Analyses and Age Estimates

Tritium is present in contemporary precipitation on the Pajarito Plateau at levels ranging from 21 to 450 pCi/L (Adams et al. 1995, 47192). These levels reflect input from airborne releases, from atmospheric nuclear testing, and from cosmic ray production in the upper atmosphere (ESG 1971–1995; Purtymun et al. 1987, 6687). Tritium in groundwater may result from recharge of these rainwaters to the alluvium and intermediate perched zones. Flow to deeper aquifers (such as the regional aquifer) would have to be very rapid for this tritium (which has a half-life of 12.33 years) to reach the water table.

Activities of tritium in the groundwater samples collected from selected production wells in Los Alamos Canyon range from 0.58 ± 0.29 pCi/L to about 63.0 ± 2.2 pCi/L. On May 12, 1993, a sample with tritium activity of 63 pCi/L or 19.7 tritium units was collected from former water supply well LA-1 (Blake et al. 1995, 49931, Table 4, p. 28). These activities are lower than most of the range for tritium in contemporary precipitation cited above. Higher activities of tritium (700 pCi/L) were present in the atmosphere in northern New Mexico during 1962 and 1963, when tritium from atmospheric testing reached its peak (Environmental Protection Group 1993, 23249). The presence of tritium in the regional aquifer might indicate recharge by very young (approximately 30 to 50 years) water. However, samples from most of the regional aquifer production wells show such low values of tritium that they cannot contain any significant component of young water. Thus, the groundwater in the regional aquifer is generally older than the period of atmospheric nuclear testing.

3.7.5.3 Carbon-14 Age Estimates

The isotope ^{14}C decays to ^{14}N by emission of a beta particle; it has a half-life of 5730 years. Therefore, ^{14}C can be used to date materials with ages of a few hundred to tens of thousands of years. Most of the ^{14}C in the air is produced by cosmic rays in the upper atmosphere and mixes rapidly throughout the atmosphere. Measurements of ^{14}C in waters may be used to infer the time since the water last reached equilibrium with the surface air.

The maximum possible age is determined from the measured ratio of ^{14}C to common carbon, which gives an age based on the radioactive decay of ^{14}C. This value is commonly greater than the actual age because the carbon concentration in the infiltrating water is diluted by the dissolution of older (even completely nonradioactive) carbonate minerals or organic material. Estimating this dilution effect requires measurement of other carbon isotopes and assumptions about mixing. Calculating a minimum age based on the estimated dilution can lead to very young or negative ages if the carbon geochemistry is not well characterized. It is also possible that ^{14}C from other sources such as laboratory effluents or atmospheric nuclear testing (the so-called Bomb Pulse carbon) could raise the amount of ^{14}C in a sample and lead to an inferred age that is very young or even negative.

About 25 analyses of ^{14}C activity in groundwater samples collected from the regional aquifer (Santa Fe Group) in the Los Alamos vicinity have been completed. Measurements of ^{14}C indicate that groundwater in the Santa Fe Group may have maximum ages ranging from a few thousand years in the central and western part of the Pajarito Plateau up to as much as 40,000 years at the Rio Grande in Los Alamos Canyon. Deep flow paths characterized by long residence times may account for the old ages of groundwater. However, the flow paths within the regional aquifer are heterogeneous and complex; they are not well understood. The large screen lengths within the wells, the vertical gradients, and the chemical heterogeneity influence the ^{14}C age dates obtained from the regional aquifer. The ages of the water samples represent average ages for the screened interval of each well, which may include mixing of waters from one or more production zones, and not the average age for the entire saturated thickness of the regional aquifer. These results are preliminary; an improved understanding of the carbonate geochemistry of the regional aquifer and more detailed ^{14}C analyses in the future should improve the delineation of age of the regional aquifer water.

3.8 Biological Setting

3.8.1 Regional Vegetation

Northern New Mexico’s semiarid environment supports diverse plant communities whose distribution is largely determined by elevation. Generally, arid-climate vegetation dominates at low elevations, and vegetation adapted to more consistent moisture grows at higher elevations. The varied topography and vertical relief of the Jemez Mountains and the Pajarito Plateau support an especially rich and diverse subset of the regional vegetation. Vegetation types are classified into two main groups: wetland and upland. Most of the streams in Los Alamos County are ephemeral and do not support wetland vegetation. However, perennial flows from springs, Laboratory facilities, and Los Alamos County facilities create a few permanent or near-permanent streams in some canyons. These streams are discussed in Section 3.8.4. The major vegetation in the canyons is subdivided into several plant communities, all of which are upland communities.

The Plains and Great Basin Riparian-Deciduous Forest community grows at the lowest elevations in Los Alamos County along the Rio Grande floodplain, about 5,000 ft (1,524 m) above sea level. The trees that characterize this vegetation type, such as cottonwood, willow, non-native salt cedar, and Russian olive, are restricted to areas where water is available at or near the ground surface throughout the year.

Above the Rio Grande floodplain at elevations ranging from about 5,600 to 6,200 ft (1,707 to 1,890 m), one-seed juniper becomes the most common overstory species. This species is often intermixed with lesser amounts of piñon. Both of these tree species, typical of the Great Basin Conifer Woodland community, are tolerant of a relatively dry climate. Together they form an open piñon-juniper woodland at elevations of about 6,200 to 6,900 ft (1,890 to 2,103 m) on the Pajarito Plateau.

As the elevation increases toward the Jemez Mountains, the Great Basin Conifer Woodland community gradually grades into the Rocky Mountain Montane Conifer Forest community where increased precipitation allows ponderosa pine to become a dominant species at about 6,900 to 7,500 ft (2,103 to 2,286 m). White fir and Douglas fir grow along the north-facing slopes at intermediate elevations. These species are often intermixed with ponderosa pine and form a mixed-conifer community. Species of the Rocky Mountain Subalpine Conifer Forest and Woodland community occur along the extreme western edge of Los Alamos County and are more prevalent at the higher elevations of the Jemez Mountains.

3.8.2 Previous Studies

Before 1994 investigators completed several site-specific studies within or near the canyon systems. During those investigations, researchers obtained information on threatened, endangered, or sensitive species and baseline ecological data.

3.8.2.1 Plants

Several investigators surveyed the vegetation in or near the canyon systems. Table B-1 in Appendix B of this core document contains a checklist of plant species that were identified during those surveys and lists the surveys used to prepare the checklist. A number of native plants from northern New Mexico have historically been used or continue to be used by American Indians for food and beverages; medicine; smoking or chewing; construction materials; or for coloring, tanning, and soap making. A partial listing of these species that may be exposure pathways for adjacent Indian Pueblos is presented in Table 3-5.

3.8.2.1.1 Vegetation Overstory of the Canyons

Portions of the canyon systems are located primarily within a ponderosa pine community. Other overstory species found in these canyons are one-seed juniper, Gambel oak, Douglas fir, white fir, Engleman spruce, Rocky Mountain maple, thinleaf alder, water birch, New Mexican olive, and Rio Grande cottonwood. The common midstory species are Gambel oak, Fendler’s rose, piñon pine, and willow. Shrub layer dominance depends on topography and elevation and can include skunkbrush sumac, big sagebrush, rubber rabbit brush, willow, chokecherry, and Gambel oak.

3.8.2.1.2 Vegetation Understory of the Canyons

The understory of Los Alamos Canyon and Pueblo Canyon is predominately blue grama grass, brome grass, and cheat grass. In the upper portions of the canyons, other understory species include cutleaf coneflower, wild strawberry, and James geranium. In the middle portions of the canyons, other understory species include redtop (a grass), raspberry, mountain muhly, bluegrass, sedge, western wheatgrass, dropseed, and needle grass. In the lower portions of the canyons, other understory species include rushes, bluegrass, Fendler's rose, western wheatgrass, dropseed, and needle grass. Open meadows are dominated by bluegrass, tarragon, and trailing fleabane. Forbs such as golden aster, tarragon, and horseweed reside in the middle and lower portions of the canyons. Along the stream channels, stinging nettle dominates a plant assemblage composed of sweetclover, horseweed, and raspberry.

3.8.2.2 Wildlife

3.8.2.2.1 Invertebrates

Terrestrial Invertebrates

At least 164 families of terrestrial arthropods have been identified on Laboratory property. Most of these families are very likely to inhabit the canyon systems (see Table B-2 in Appendix B of this core document).

TABLE 3-5

PLANT SPECIES THAT MAY BE USED BY NORTHERN NEW MEXICO INDIAN PUEBLOS

Family	Common Name	Genus	Species
Pineaceae	white fir	*Abies*	*concolor*
Aceraceae	box-elder	*Acer*	*negundo*
Compositae	yarrow	*Achillea*	*lanulosa*
Labiatae	giant hyssop	*Agastache*	*pallidiflora*
Liliaceae	wild onion	*Allium*	*spp.*
Betulaceae	alder	*Alnus*	*tenuifolia*
Amaranthaceae	prostrate pigweed	*Amaranthus*	*graecizans*
Amaranthaceae	green pigweed	*Amaranthus*	*retroflexus*
Compositae	western ragweed	*Ambrosia*	*psilostachya*
Gramineae	little bluestem	*Andropogon*	*scorparius*
Saururaceae	yerba mansa	*Anemopsis*	*californica*
Ericaceae	pointleaf manzanita	*Arctostaphylos*	*pugens*
Ericaceae	bearberry	*Arctostaphylos*	*uva-ursi*
Compositae	sagebrush	*Artemisia*	*campestris*
Compositae	sand sagebrush	*Artemisia*	*filifolia*
Compositae	fringed sagebrush	*Artemisia*	*frigida*
Compositae	Louisiana wormwood	*Artemisia*	*ludoviciana*
Compositae	big sagebrush	*Artemisia*	*tridentata*
Ascelepiadaceae	antelope horns	*Asclepias*	*asperula*
Ascelepiadaceae	dwarf milkweed	*Asclepias*	*involucrata*
Ascelepiadaceae	broad-leafed milkweed	*Asclepias*	*latifolia*
Ascelepiadaceae	milkweed	*Asclepias*	*spp.*
Leguminosae	beakpod milkvetch	*Astragalus*	*amphioxys*
Leguminosae	milkvetch	*Astagalus*	*spp.*
Chenopodiaceae	fourwing saltbush	*Atriplex*	*canescens*
Chenopodiaceae	ribscale	*Atriplex*	*powellii*
Compositae	Woodhouse bahia	*Bahia*	*woodhousei*
Compositae	desert-marigold	*Baileya*	*multiradiata*
Berberidaceae	Colorado barberry	*Berberis*	*fendleri*
Betulaceae	western water-birch	*Betula*	*occidentalis*
Gramineae	side-oats grama	*Bouteloua*	*curtipendula*
Scrophulariaceae	paintbrush	*Castilleja*	*integra*
Ulmaceae	netleaf hackberry	*Celtis*	*reticulata*
Rosaceae	mountain-mahogany	*Cercocarpus*	*montanus*
Chenopodiaceae	lamb's quarters	*Chenopodium*	*album*
Chenopodiaceae	Mexican tea	*Chenopodium*	*ambrosioides*
Chenopodiaceae	goosefoot	*Chenopodium*	*leptophyllum*
Chenopodiaceae	goosefoot	*Chenopodium*	*spp.*
Compositae	rabbitbrush	*Chrysothamnus*	*nauseosus*

TABLE 3-5 (continued)

PLANT SPECIES THAT MAY BE USED BY NORTHERN NEW MEXICO INDIAN PUEBLOS

Family	Common Name	Genus	Species
Compositae	Santa Fe thistle	*Cirsium*	*ochrocentrum*
Capparidaceae	Rocky Mtn. beeplant	*Cleome*	*serrulata*
Cornaceae	red-oiser dogwood	*Cornus*	*stolonifera*
Cataceae	pincushion cactus	*Coryphantha*	*spp.*
Euphorbiaceae	doveweed	*Croton*	*texensis*
Boraginaceae	hiddenflower	*Cryptanthia*	*sp.*
Cucrbitaceae	buffalo gourd	*Cucurbita*	*foetidissima*
Umbelliferae	wafer parsnip	*Cymopterus*	*purpureus*
Umbelliferae	wild celery	*Cymopterus*	*fendleri*
Umbelliferae	wafer parsnip	*Cymopterus*	*bulbosus*
Legumiosae	feather indigobrush	*Dalea*	*formosa*
Cruciferae	western tansy mustard	*Descurainia*	*pinnata*
Compositae	fetid marigold	*Dyssodia*	*papposa*
Cactaceae	hedgehog cactus	*Echinocereus*	*fendleri*
Ephedraceae	rough joint-fir	*Ephedra*	*nevadensis*
Ephedraceae	Torrey joint-fir	*Ephedra*	*torreyana*
Equisetaceae	smooth horsetail	*Equisetum*	*laevigatum*
Polygonaceae	redroot wild buckwheat	*Eriogonum*	*racemosum*
Polygonaceae	wild buckwheat	*Eriogonum*	*spp.*
Geraniaceae	alfilaria	*Erodium*	*cicutarium*
Compositae	western throughwort	*Eupatorium*	*herbaceum*
Compositae	throughwort	*Eupatorium*	*sp.*
Euphorbiaceae	painted-leaf spurge	*Euphorbia*	*heterophylla*
Euphorbiaceae	thymeleaf spurge	*Euphorbia*	*serpyllifolia*
Euphorbiaceae	spurge	*Euphorbia*	*spp.*
Chenopodiaceae	winterfat	*Eurotia*	*lanata*
Rocaceae	Apache plume	*Fallugia*	*paradoxa*
Oleaceae	New Mexico olive	*Forestiera*	*neomexicana*
Rosaceae	wild strawberry	*Fragaria*	*spp.*
Onagraceae	scarlet gaura	*Gaura*	*coccinea*
Leguminosae	wild licorice	*Glycyrrhiza*	*lepidota*
Compositae	gumweed	*Grindelia*	*aphanactis*
Compostiae	broom snakeweed	*Gutierrezia*	*sarothrae*
Ochidaceae	bog orchid	*Habenaria*	*sparsiflora*
Boraginaceae	stickseed	*Hackelia*	*floribunda*
Hydrophyllaceae	false pennyroyal	*Hedeoma*	*nana*
Compositae	orange sneezweed	*Helenium*	*hoopesii*
Compositae	annual sunflower	*Helianthus*	*annus*
	hog potato	*Hoffmanseggia*	*densiflora*

TABLE 3-5 (continued)

PLANT SPECIES THAT MAY BE USED BY NORTHERN NEW MEXICO INDIAN PUEBLOS

Family	Common Name	Genus	Species
Rosaceae	mountain spray	*Holodiscus*	*densiflora*
Compositae	white ragweed	*Hymenopappus*	*spp.*
Compositae	pinque	*Hymenoxys*	*richardsonii*
Polemoniaceae	blue trumpets	*Ipomopsis*	*longiflora*
Polemoniaceae	many-flowered ipomopsis	*Ipomopsis*	*multiflora*
Cupressaceae	dwarf juniper	*Juniperus*	*communis*
Cupressaceae	alligator juniper	*Juniperus*	*deppeana*
Cupressaceae	one-seed juniper	*Juniperus*	*monosperma*
Cupressaceae	Rocky Myn. Juniper	*Juniperus*	*scopulorum*
Zygophyllaceae	California caltrop	*Kallstromia*	*californica*
Gramineae	junegrass	*Koeleria*	*cristata*
Leguminosae	bush peavine	*Lathyrus*	*eucosmus*
Compositae	white aster	*Leucelene*	*ericoides*
Compositae	dotted gayfeather	*Liatris*	*punctata*
Umbelliferae	osha	*Legusticum*	*poteri*
Campanulaceae	western cardinal flower	*Lobelia*	*cardinalis*
Solanaceae	wolfberry	*Lycium*	*pallidum*
Compositae	purple aster	*Machaeranthera*	*canescens*
Compositae	purple aster	*Machaeranthera*	*spp.*
Malcaceae	mallow	*Malva*	*parviflora*
Cactaceae	pincushin cactus	*Mammillaria*	*spp.*
Labiatae	field mint	*Mentha*	*arvensis*
Labiatae	spearmint	*Mentha*	*spicata*
Loasaceae	common stickleaf	*Mentzelia*	*pumila*
Nyctaginaceae	four-o'clock	*Miribilis*	*multiflora*
Labiatae	bee-balm	*Monarda*	*menthaefolia*
Solanceae	coyote tobacco	*Nicotiana*	*attenuata*
Agave	beargrass	*Nolina*	*microcarpa*
Polypodiaceae	cloak fern	*Notholaena*	*sp.*
Cactaceae	cane cholla	*Opuntia*	*imbricata*
Cactaceae	prickly pear	*Opuntia*	*spp.*
Orbanchaceae	broomrape	*Orobanche*	*spp.*
Vitaceae	western five-leafed ivy	*Parthenocissus*	*inserta*
Scrophulariaceae	scarlet penstemon	*Penstemon*	*barbatus*
Leguminosae	white prairie clover	*Petalostemum*	*candidum*
Hydrophyllaceae	scorpionweed	*Phacelia*	*sp.*
Saxifragaceae	mock-orange	*Philadelphus*	*microphyllus*
Gramineae	common reed	*Phragmites*	*communis*
Solanaceae	New Mexico groundcherry	*Physalis*	*foetens*

TABLE 3-5 (continued)

PLANT SPECIES THAT MAY BE USED BY NORTHERN NEW MEXICO INDIAN PUEBLOS

Family	Common Name	Genus	Species
Solanaceae	groundcherry	*Physalis*	*hederaefolia*
Solanaceae	Virginia groundcherry	*Physalis*	*virginiana*
Pinaceae	pinon pine	*Pinus*	*edulis*
Pinaceae	ponderosa pine	*Pinus*	*ponderosa*
Capparidaceae	clammyweed	*Polanisia*	*trachysperma*
Salicaceae	Fremont cottonwood	*Populus*	*fremontii*
Salicaceae	aspen	*Populus*	*tremuloids*
Portulacaceae	common purslane	*Portulaca*	*oleracea*
Portulacaceae	notchleaf purslane	*Portulaca*	*retusa*
Pedaliaceae	unicorn-plant	*Proboscidea*	*sp.*
Rosaceae	wild plum	*Prunus*	*americana*
Rosaceae	chokecherry	*Prunus*	*virginana*
Umbelliferae	mountain parsley	*Psudocymopterus*	*montanus*
Pinaceae	Douglas-fir	*Pseudotsuga*	*menziesii*
Leguminosae	lemon scurfpea	*Psoralea*	*lanceolata*
Rutaceae	hoptree	*Ptelea*	*trifoliata*
Fagaceae	Gambel oak	*Quercus*	*gambelii*
Compositae	prairie coneflower	*Ratibida*	*columnifera*
Anacardiaceae	smooth sumac	*Rhus*	*glabra*
Anacardiaceae	threeleaf sumac	*Rhus*	*trilobata*
Saxifragaceae	wild current	*Ribes*	*inebrians*
Saxifragaceae	gooseberry	*Ribes*	*inerme*
Leguminosae	New Mexico locust	*Robinia*	*neomexicana*
Rosaceae	wild rose	*Rosa*	*woodsii*
Compositea	coneflower	*Rudbeckia*	*lancinata*
Polygonaceae	curlyleaf dock	*Rumex*	*crispus*
Polygonaceae	canaigre	*Rumex*	*hymenosepalus*
Polygonaceae	wild dock	*Rumex*	*mexicanus*
Salicaceae	willow	*Salix*	*spp.*
Labiatae	Rocky Mtn. sage	*Saliva*	*reflexa*
Chenopodiaceae	greasewood	*Sarcobatus*	*vermiculatus*
Compositae	threadleaf butterweed	*Senecio*	*douglasii*
Liliaceae	false Soloman's seal	*Smilacina*	*racemosa*
Solanaceae	horse-nettle	*Solanum*	*elaeagnifolium*
Solanaceae	Fendler wild potato	*Solanum*	*fenderi*
Solanaceae	wild potato	*Solanum*	*jamesii*
Leguminosae	silky sophora	*Sophora*	*nuttalliana*
Malvaceae	globe-marrow	*Sphaeralcea*	*spp.*
Compositae	common dandelion	*Taraxacum*	*officinale*

TABLE 3-5 (continued)

PLANT SPECIES THAT MAY BE USED BY NORTHERN NEW MEXICO INDIAN PUEBLOS

Family	Common Name	Genus	Species
Compositae	Indian tea	*Thelesperma*	*megapotamicum*
Cruciferae	Wright's mustard	*Theypodium*	*wrightii*
Typhaceae	broad-leaved cattail	*Typha*	*latifolia*
Compositae	crownbeard	*Verbesina*	*encelioides*
Leguminosae	American vetch	*Vicia*	*americana*
Vitaceae	canyon grape	*Vitis*	*arizonica*
Copositae	cocklebur	*Xanthium*	*strumarium*
Liliaceae	banana yucca	*Yucca*	*baccata*
Liliaceae	narrowleaf yucca	*Yucca*	*glauca*

Source: Dunmire and Tierney 1995, 55535

Aquatic Invertebrates

Few studies of aquatic invertebrates have been conducted in Los Alamos County. Eighty-one aquatic insect families have been collected to date. Five species of aquatic mollusks were found on Laboratory property, and further surveys are expected to yield additional species.

3.8.2.2.2 Vertebrates

Fish

No fish have been found on Laboratory property, although some were observed in and downstream from Guaje Reservoir and Los Alamos Reservoir and below Ancho Springs at the confluence of White Rock Canyon and the Rio Grande. Fish habitat exists in the Rio Grande at the confluence of each canyon within the canyon systems.

Reptiles and Amphibians

In 1978 Bogart (circa 1978, 50038) surveyed for reptiles and amphibians in Los Alamos County and found eight reptile and amphibian families (see Table B-3 in Appendix B of this core document).

Birds

More than 200 bird species have been identified in Los Alamos County (Travis 1992, 12015), which include at least 112 species of birds known to breed in the area. Of the breeding bird species, 39 are permanent residents and 59 are migratory summer residents. Other surveys have also gathered information on local bird activities (Kennedy 1988, 50037; Kennedy 1989, 04-0318; Sinton and Kennedy 1993, 04-0312). Additionally, bird transects have been established in Los Alamos Canyon (LANL 1995, 50290). Table B-4 in Appendix B of this core document contains a checklist of the birds expected to be found in or near the canyon systems.

Mammals

Twenty-nine small mammal species have been found in the Laboratory area. Mule deer and elk are the most visible large mammals in the region. These species generally winter in the lower elevations of the Pajarito Plateau, including many of the mesas and canyons along the central and eastern portions of Los Alamos County. Large mammals generally spend the summer at higher elevations in the Jemez Mountains. However, recent surveys in the Los Alamos County area indicate that growing numbers of large mammals reside throughout the year at lower elevations. Table B-5 in Appendix B of this core document contains a list of the mammal species found in the Laboratory area.

3.8.2.3 Threatened, Endangered, and Sensitive Species

3.8.2.3.1 Plants

Foxx and Tierney (1980, 5949; 1984, 5950; 1985, 5951) completed several National Environmental Policy Act compliance surveys of threatened and endangered plant species and found none. Several species have low to moderate potential for occurring in several canyon systems (Table 3-6).

3.8.2.3.2 Wildlife

The occurrence of threatened, endangered, and sensitive wildlife species in canyon systems has been determined from literature reviews, general habitat surveys, and species-specific surveys. Table 3-6 lists federal- and state-listed wildlife species that could be found in canyon systems. Kennedy (1988, 50037) reported two diurnal raptors (Cooper's hawk and the red-tailed hawk) nesting in Los Alamos County. Both species are classified as sensitive by the state of New Mexico and have nested in ponderosa pines in the canyons since 1983. Additional details regarding the occurrence of several of these species are discussed below.

Mexican Spotted Owl

The Mexican spotted owl inhabits mixed-conifer and ponderosa-Gambel oak forests in mountains and canyons. A potential habitat is located near the Laboratory, and spotted owl territories may extend into the canyon systems. The presence of spotted owl on Laboratory property has recently been confirmed, with at least one successful nesting being observed.

Peregrine Falcon

Peregrine falcons nest where they can establish breeding territories with areas suitable for both nesting and foraging. Optimal habitat includes both the following:

- breeding territories near cliffs that are within areas of ponderosa pine and piñon and
- large nearby gulfs of air, which permit peregrine falcons to attack their prey from above.

Topography is the primary determining factor in characterizing peregrine falcon breeding habitat (Johnson 1985, 04-0315). Peregrine falcon foraging areas may extend to 20 mi (32 km) from the nest site, but an estimated 90% of the foraging occurs within a radius of 10 mi (16 km). The northern portion of the Laboratory, including the canyon systems in that area, are within the breeding and foraging territories for the peregrine falcon. The presence of Peregrine Falcon on Laboratory property has recently been confirmed.

TABLE 3-6

THREATENED AND ENDANGERED SPECIES POTENTIALLY OCCURRING IN LOS ALAMOS CANYON AND PUEBLO CANYON

Common Name	Scientific Name	Legal Status	Habitat	Potential for Occurrence
Mexican spotted owl	*Strix occidentalis lucida*	Federally threatened	Mixed-conifer	High
Peregrine falcon	*Falco peregrinus*	Federally endangered State endangered	Ponderosa-piñon	High
Jemez Mountains salamander	*Plethodon neomexicanus*	Candidate for federal listing State endangered	Spruce-fir to mixed-conifer	Moderate to high
Spotted bat	*Euderma maculatum*	Candidate for federal listing State endangered	Riparian zones Ponderosa Spruce-fir Piñon-juniper	Moderate to high
Meadow jumping mouse	*Zapus hudsonius luteus*	Candidate for federal listing State endangered	Wetland	Moderate to high
Northern goshawk	*Accipiter gentilis*	Candidate for federal listing	Ponderosa	Moderate
Pine marten	*Martes americana*	State endangered	Spruce-fir	Moderate
Occult little brown bat	*Myotis lucfugus occultus*	Candidate for federal listing State endangered	Rivers-streams	Moderate
Helleborine orchid	*Epipactis gigantea*	State endangered	Riparian zones	Moderate
Wood lily	*Lilium philadelphicum*	Candidate for federal listing State endangered	Mixed-conifer in moist areas	Moderate
Broad-billed hummingbird	*Cynanthus latirostris*	State endangered	Riparian zones	Low to moderate
Lilljeborg's pea-clam	*Pisidium lilljeborgi*	State endangered	Lakes-ponds	Low to moderate
Western toad	*Bufo boreas*	State endangered	Lakes-ponds	Low
Common black hawk	*Buteogallus anthracinus*	State endangered	Riparian zones	Low
Bald eagle	*Haliaeetus leucocephalus*	Federally endangered State endangered	Riparian zones	Low
Mississippi kite	*Ictinia mississippiensis*	State endangered	Riparian zones	Low
Whooping crane	*Grus americana*	Federally endangered	Rivers-streams	Low
Least tern	*Sterna antillarum*	Federally endangered State endangered	Rivers-streams	Low
White-faced ibis	*Plegadis chihi*	Candidate for federal listing	Wetland	Low
Willow flycatcher	*Empidonax traillii*	Federally proposed State endangered	Riparian zones	Low
Rio Grande silvery minnow	*Hybognathus amarus*	Federally proposed State endangered	Rivers-streams	Low
Bluntnose shiner	*Notropis simus*	State endangered	Rivers-streams	Low
Say's pond snail	*Lymnaea caperata*	State endangered	Wetland	Low

Source: Foxx 1995, 50039

Jemez Mountains Salamander

The Jemez Mountains salamander inhabits cool, moist, north-facing slopes and shaded riparian areas in mixed-conifer forests between 7,185 and 10,795 ft (2,190 and 3,290 m) in elevation. This species has been found on north-facing slopes in Los Alamos Canyon and has the potential to inhabit moist riparian areas in the canyon systems (Ramotnik 1986, 1100).

Spotted Bat

The spotted bat is a federal-listed candidate and is listed by the New Mexico Department of Game and Fish State Game Commission as endangered. Under this category, a species' survival is likely to be at risk in the foreseeable future. Spotted bats are distributed throughout much of the western United States and northwestern Mexico (Watkins 1977, 04-0321), but these bats are rarely captured. The first recorded capture of spotted bats in New Mexico occurred in 1961 when two spotted bats were captured at Ghost Ranch in Rio Arriba County (Constantine 1961, 04-0316). Since then, the Museum of Southwestern Biology has captured a few specimens (Findley circa 1972, 52004). Spotted bats have been found at Lake Roberts, Mount Taylor, and the Jemez Mountains. This species, which has not previously been found in Los Alamos County, has recently been seen in Bandelier National Monument.

The spotted bat's habitat varies. It has been observed in grassland, desert shrub, piñon-juniper, ponderosa, mixed-conifer, spruce-fir, and riparian habitats (New Mexico Department of Game and Fish 1988, 50120). It has most often been seen in areas with sagebrush, rabbitbrush, short grasses, and open ponderosa pine (Tyrel and Brack 1990, 04-0313). Key habitat for this species includes the following:

- a source of water with standing pools for foraging,
- rock crevices on high cliff faces, and
- loose rocks or boulders under which to shelter during the day.

The bat's diet seems to consist mainly of nocturnal moths (Leonard and Fenton 1983, 04-0319). Bats will return to the same roost sites night after night. The spotted bat is found in caves and rock crevices in piñon-juniper, ponderosa, mixed-conifer, and riparian areas. Suitable roosting for the spotted bat exists in the canyon systems. Any spotted bats present are expected to roost in these areas.

During 1991, limited bat mist netting on Laboratory property did not capture any spotted bats. Attempts to mist net in or near the canyon systems were not successful, perhaps because of heavy rains. Surveys were conducted again in the summer of 1992. Two nights of mist netting captured no spotted bats (Tyrell and Brack 1992, 04-0314).

Meadow Jumping Mouse

The meadow jumping mouse habitat includes 2 of the following:

- permanent free-flowing water, riparian zones along streams and ditches, or wet meadows near cattail marshes associated with major rivers (Morrison 1992, 04-0320);
- dry higher ground near waterways to provide locations for nesting and hibernation;

- damp or moist soil with no standing water; and
- dense, tall vegetation (0.5 m [1.6 ft] or greater) dominated by grasses and forbs that provides thick cover and food sources.

In the Jemez Mountains and the Española area, the meadow jumping mouse is most active from June through September; breeding occurs between May and September (New Mexico Department of Game and Fish 1988, 50120). The occurrence of this species on Laboratory property has not been documented.

Northern Goshawk

The northern goshawk inhabits mature ponderosa pine forests. This species has been recorded as nesting in or near Los Alamos Canyon and hunting within the northwest portions of the Laboratory. The northern goshawk could be present in the other canyons as well.

Helleborine Orchid

The helleborine orchid is found in damp woods, seepage slopes, springs, streams, and riparian areas within the elevation range of 6,000 to 8,500 ft (1,829 to 2,591 m). The upper reaches of the canyon systems may have perennial streams that may support this species.

Wood Lily

The wood lily grows in moist shaded areas in ponderosa pine to mixed-conifer forests. The wood lily has previously been recorded in the upper reaches of Los Alamos Canyon. The habitat is dominated by ponderosa pine, which fits the requirements for this species and it may be present in similar habitats in other canyons.

3.8.3 Floodplains and Wetlands

Floodplains have been delineated in canyon systems on Laboratory land and in the surrounding area. Most wetlands are classified as intermittent riverine wetlands. Wetlands in each of the canyon systems will be described in more detail in each of the canyon- or canyon aggregate-specific SAPs.

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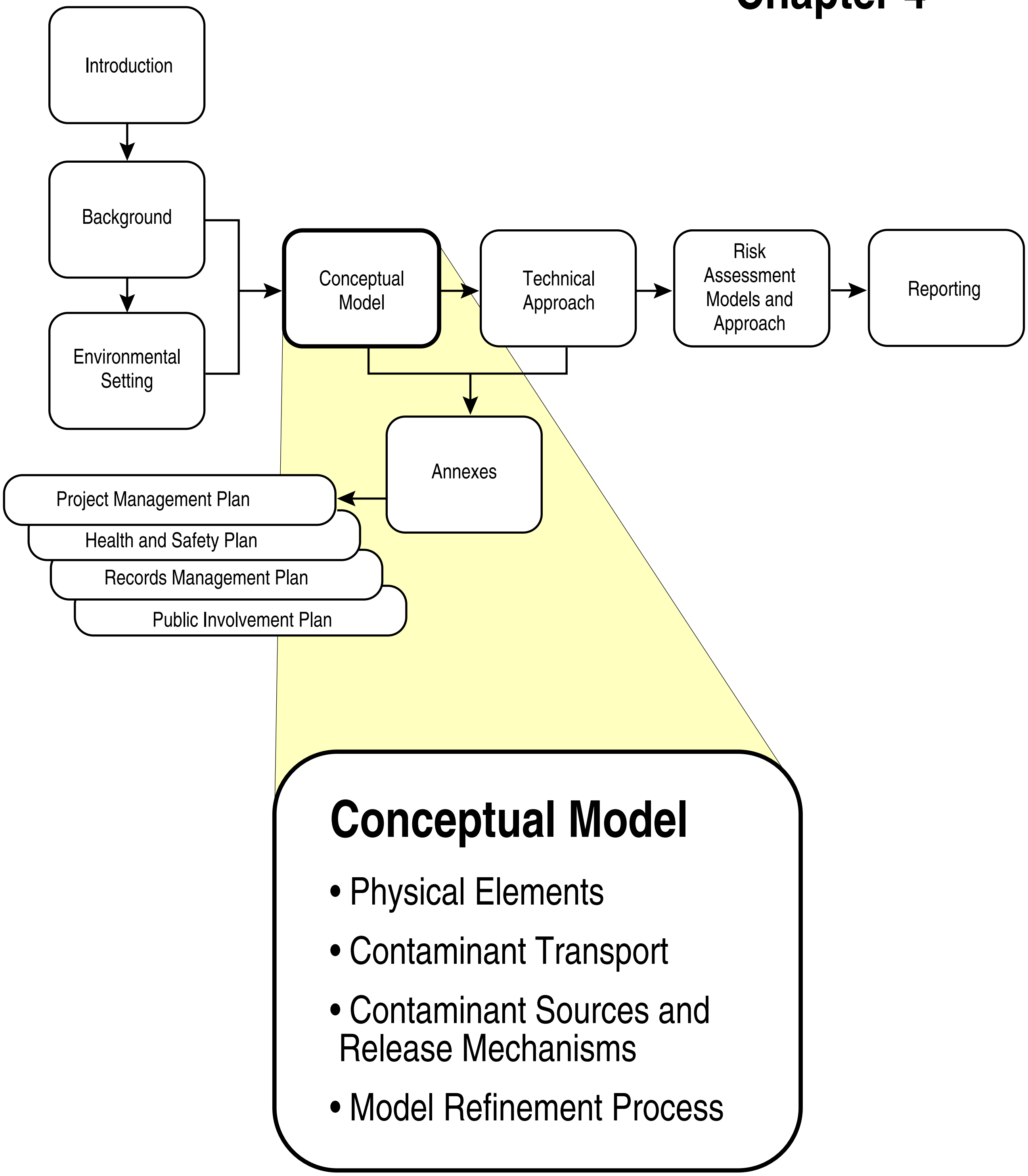
Chapter 4



Conceptual Model

- Physical Elements
- Contaminant Transport
- Contaminant Sources and Release Mechanisms
- Model Refinement Process

4.0 CONCEPTUAL MODEL

4.1 Introduction

This chapter summarizes the significant geologic, hydrologic, and biological features, events, and processes operating in the canyon systems that could reasonably affect estimates of human and ecological risk from Laboratory-derived contaminants. This chapter places these features, events, and processes within a conceptual framework that is intended to support a credible human health risk assessment for current contamination conditions and to project trends of possible future impacts. The human health risks will be evaluated, as needed, for Laboratory personnel working in the canyons and for the public occupying the canyons for a variety of purposes. In addition, impacts to the ecological system will be assessed.

The conduct of canyon investigations will involve working with the neighboring Indian Pueblos (Cochiti, Jemez, San Ildefonso, and Santa Clara) to define and evaluate impacts associated with cultural activities and resources valued by the American Indian population. This commitment fulfills part of the Laboratory's responsibility for stakeholder involvement. The approach to evaluating present-day risks is iterative, and this conceptual model does not yet fully reflect American Indian concerns. Section 4.3 discusses how the conceptual model will be revised to reflect investigation data as well as changing risk assessment objectives.

4.1.1 Purpose

The purpose of the conceptual model of contaminant occurrence, transport, and exposure route (hereafter "the conceptual model") is to incorporate known significant features, events, and processes into a comprehensive view of contaminant occurrence and transport that is then used to guide the development of the technical rationale for investigations and evaluations. The conceptual model also articulates the major assumptions (all subject to testing in the canyons investigations), the features that may need to be described more completely and accurately, and the models of processes that may need to be refined to adequately evaluate human and ecological risk. The conceptual model description helps identify the investigations needed to refine impact assessments. Sampling and analysis plans (SAPs) for canyons investigations will be designed to test major assumptions of the conceptual model. Field investigations, laboratory analyses of samples, and data assessments (discussed in Chapter 5 and Chapter 6 of this core document) will enable iterative refinement of the conceptual model, making it progressively more detailed and specific to individual canyons and reaches within canyons.

4.1.2 Relationship of the Conceptual Model to Impact Assessment

The conceptual model describes the potential pathways by which contaminants could be transported from Laboratory sources to potential receptors. It identifies connections among these transport pathways and connections among transport pathways and exposure pathways to humans, other animals, and plants.

The distinction between pathways for long-distance transport and pathways for exposure is important because some media can serve as both, and confusion can arise from the overlap. For example, wind transport is not considered to be a major route for dispersal of contamination (despite the fact that wind can transport contaminated dust from source areas) because the source of fine particulates which can be suspended by wind is limited on the surficial soils of the canyons. Moreover, canyon sediments can be relatively moist and vegetated, which reduces the potential for wind suspension; the sustained high winds needed to cause substantial transport do not normally occur. On the other hand, the inhalation of wind-suspended localized sediment that has been transported by streams is considered to be a significant pathway of exposure to humans. By contrast, surface water during floods can transport large amounts of contaminated sediments downstream. Thus, surface water is considered to be an important transport pathway, whereas wind is considered to be primarily an exposure pathway. However, definition of both pathways is necessary to determine future impact.

The exposure pathways are part of the human health and ecological risk assessment models described in Chapter 6 of this core document. The selection of potential receptors and exposure pathways defines the structure and assumptions of the assessment models. The conceptual model discussed in this chapter addresses the exposure pathways selected for consideration in the assessment models described in Chapter 6.

The potential human and ecological exposure scenarios for the canyon systems include the following:

- use by Laboratory workers engaged in occupational activities;
- recreational use;
- use by the American Indian population for residential, cultural, and religious purposes, and for farming, ranching, and hunting; and
- habitation by the local biological community, taking into consideration the effects of human occupation.

The approach to exposure is a modular one and assumes that scenarios are not exclusive; individuals and populations may have time-apportioned activities associated with any of the three exposure scenarios (American Indian, Laboratory worker, and recreational). For example, a given individual may be a member of San Ildefonso Pueblo, work at the Laboratory, and engage in hiking activities in the canyons. Exposure results will be presented in a modular fashion for specific activities and times. Therefore, activities can be aggregated as appropriate to predict potential exposures for individuals or populations engaged in such multiple activities. Chapter 6 describes these exposure scenarios in detail.

Chapter 5 and Section 6.2 of Chapter 6 discuss the methods for interpreting data, including application of recently developed techniques for analysis of spatial uncertainty, that will be used in testing hypotheses of the conceptual model, as well as risk-based decision making.

4.1.3 Development of the Generic Conceptual Model

A generic conceptual model was developed from the conceptual model in the *Task/Site Work Plan for Operable Unit 1049: Los Alamos Canyon and Pueblo Canyon* (LANL 1995, 50290) because these canyon systems are considered representative of the range of features, events, and processes occurring in the canyon systems of the Pajarito Plateau. Also, these two canyons are currently the focus of ongoing canyons investigations, and new data from these investigations will be used to make initial refinements in the conceptual model. The conceptual model is illustrated in Figure 4-1, which shows Pueblo Canyon and upper Los Alamos Canyon. Key elements of the conceptual model, including descriptions of contaminant transport pathways and mechanisms, are described in Table 4-1.

The conceptual model identifies potential sources of contamination, relevant pathways for transport, and likely pathways for exposure based on current knowledge of the distribution of contaminants in and adjacent to the canyons system. The transport pathway descriptions include the predominant release mechanisms, transport processes, and the contaminated media for each transport pathway. The conceptual model includes those elements that are likely to influence decisions about remediation in the canyon environment. Application of the conceptual model in risk-based decision making is addressed in Section 6.2 of Chapter 6 of this core document.

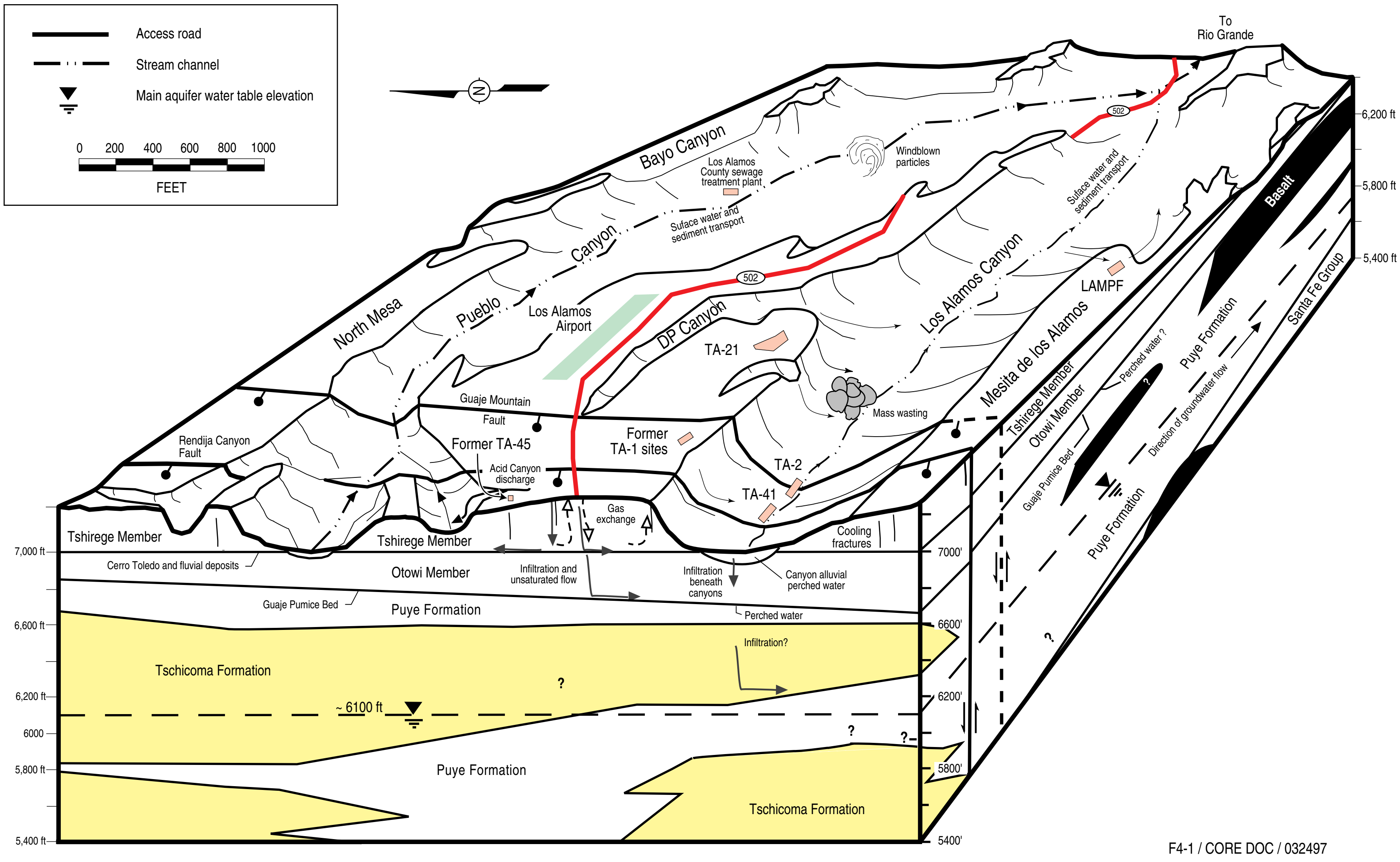


Figure 4-1. Schematic illustration of the conceptual model for contaminant transport in upper Los Alamos Canyon and Pueblo Canyon.

TABLE 4-1

ELEMENTS OF THE CONCEPTUAL MODEL FOR THE CANYON SYSTEMS

Transport Pathway/Mechanism	Concepts/Hypotheses
Surface water and sediment transport	
Surface water runoff	Precipitation will partition among evaporation, transpiration, infiltration to soil and groundwater storage, and runoff.
	Surface runoff is concentrated by natural topographic features and man-made diversions.
	Surface runoff can transport contaminants in solution, but contaminant movement associated with suspended particles or local bed sediments will dominate the transport of radionuclides and metals.
	Contaminant movement as dissolved species will be partly retarded by adsorption onto natural organic, clay, metal hydrous oxides, and other highly sorptive phases in solid porous media.
Erosion and transport of soils and sediments	Contaminants tend to adsorb onto soil and sediment particles, which can be transported by runoff and concentrated in depositional areas in the canyons.
	Contaminant transport in streams occurs predominantly by bedload and suspended sediment transport with lesser transport in the dissolved phase. Coarse- to medium-grained sand and gravel generally are transported as bedload. Fine sand, silt, and clay are transported as suspended load.
	Surface runoff has redistributed contaminants on both suspended and bedload sediments substantial distances downstream from their original sources within active channels, inactive channels, floodplains, and low terraces and has carried contaminants to the Rio Grande.
	The maximum concentration of contaminants in sediments varies with distance from the source; maximum concentrations generally decrease downstream due to dilution with clean sediments. Dilution will also tend to decrease contaminant concentrations over time if contaminant releases are stopped or reduced.
	The deposition and storage of contaminated sediments generally increase downstream. Contaminants carried by floods can be dispersed over progressively wider areas of the canyon floor downstream with the result being relatively high contaminant inventories in some downstream areas. The deposits are potentially subject to remobilization.
	Contaminant concentrations vary with depositional setting and also with the age and type of sediment deposit (for example, active channel versus floodplain deposit). Sediment deposits of similar age, particle size, and depositional setting within a given canyon reach generally will have similar contaminant concentrations.
	Contaminant concentrations vary with sediment particle size; the highest concentrations are generally found in the finer-grained fractions of sediments of a given age. However, the highest contaminant inventories in a given reach may be found in coarser-grained sediments due to their much larger volume.
	Sediment transport processes can segregate sediments by particle size, which might reconcentrate contaminants in low-energy depositional areas.
	Locally, contaminant concentrations at depth may be significantly higher than at the surface because of burial by younger and cleaner sediments.
	Residence times for contaminated sediments at different canyon sites can vary from less than one year in some active channels to hundreds or thousands of years for some floodplain sediments.

TABLE 4-1 (continued)
ELEMENTS OF THE CONCEPTUAL MODEL FOR THE CANYON SYSTEMS

Transport Pathway/Mechanism	Concepts/Hypotheses
	Channel incision, lateral bank erosion, and sediment redistribution will be most active during large floods that may have return periods of years to decades in different canyon reaches.
Groundwater transport	
Alluvial groundwater	Maximum concentrations of contaminants are initially associated with alluvial groundwater close to potential source areas.
	Dilution and attenuation by geochemical processes lead to decreased contaminant concentrations (relative to mobile or conservative species such as chloride and tritium) downgradient within a water-bearing zone.
	Alluvial groundwater is present in portions of Los Alamos Canyon, Pueblo Canyon, Pajarito Canyon, and Mortandad Canyon. In addition, alluvial groundwater may be present in portions of Potrillo Canyon, Water Canyon, Sandia Canyon, and Cañon de Valle.
	Alluvium is more permeable than underlying bedrock units; surface water infiltrates alluvium until downward movement is impeded by less permeable tuffs and sediments, at which point shallow alluvial groundwater accumulates.
	The thickness and longitudinal extent of the alluvial saturated zones vary seasonally, with maximums occurring during spring snowmelt and summer storms.
	Water in the alluvium will flow down the canyon; flow processes can be approximated by a homogeneous porous medium model.
	The rate of contaminant migration (except tritium) in alluvial groundwater is retarded relative to the water flow rate primarily by sorption onto mineral, organic, or organic-coated mineral particles in the alluvium.
	Water in the alluvium enters the underlying rock units; the migration process and rate depends on the properties of the interface between the two units.
	Recharge to intermediate zones of perched groundwater occurs in most canyons primarily from the alluvium.
Infiltration and vadose zone flow and transport	Dissolved contaminants infiltrate alluvium more readily than contaminants adsorbed onto sediment particles.
	Transport of normally insoluble or strongly sorbed contaminants in the unsaturated zone can occur by movement of colloidal-size suspended solids. Nonsorbing species (for example, tritium or anionic species) migrate in solution.
	The rates of liquid infiltration into and percolation through tuff and underlying bedrock units depends primarily on the unsaturated hydraulic properties of the rock units.
	Steady-state liquid flow at depth can be very slow in unsaturated tuff and other bedrock units.
	Joints and fractures in bedrock can provide additional pathways for relatively rapid infiltration, transient flow, and lateral transport in the subsurface.
	Fractures contribute to liquid flow and transport at moisture contents above some critical value. Below this value, flow in the rock matrix will predominate.
	The rate of contaminant migration through the vadose zone varies and may be retarded by mineral precipitation and sorption onto mineral grains in the bedrock units, especially the Bandelier Tuff.

TABLE 4-1 (continued)
ELEMENTS OF THE CONCEPTUAL MODEL FOR THE CANYON SYSTEMS

Transport Pathway/Mechanism	Concepts/Hypotheses
Perched groundwater at depth	Intermediate-depth groundwater may be more common in the canyon systems with large watersheds, particularly those that receive snowmelt and storm runoff from headwaters in the Sierra de los Valles. The lateral extent and hydraulic continuity of such perched groundwater zones are not known.
	Perched zones are found in areas where a sufficient water source is present to maintain saturation in deeper geologic units.
	Studies in Los Alamos Canyon and Pueblo Canyon indicate that perched zones in these canyons are hydrologically connected to alluvial groundwater systems.
	In addition to alluvial groundwater from canyon floors, deeper perched zones may receive recharge from watersheds west of the Laboratory.
	Intermediate perched systems have not been observed to extend laterally beneath mesas. However, lateral spreading of perched water may occur downgradient if the canyon course and the dip of the perched zone do not coincide.
	A contrast in hydraulic properties between layers can divert flow laterally and cause zones of perched groundwater to develop near stratigraphic contacts, such as the contact between subunits of the Tshirege Member or between the Guaje Pumice Bed and the underlying Puye Formation or Cerros del Rio basalts. Flow directions in these perched systems will be controlled by the dips of the stratigraphic contacts.
	Laterally diverted groundwater flow can return to the surface in springs or seeps.
	Steady-state conditions can adequately describe groundwater flow in the intermediate perched zones, although some non-steady-state rapid responses have been seen where these zones approach the alluvium or the surface.
	Contaminant concentrations in alluvial and intermediate perched groundwaters are expected to decrease with depth because of dilution and geochemical attenuation along vertical flow paths.
Vapor transport	Vapor-phase transport is important only for tritium and volatile organic compounds.
	Vapor-phase transport is controlled primarily by the vapor pressure of the contaminant and the porosity, permeability, moisture content, and moisture characteristic properties of the unsaturated medium (soil, sediment, or rock).
	Exchange of pore gas with the atmosphere (a significant mechanism for tritium release) is controlled by temperature gradients and atmospheric pressure variations.
	Fractures in bedrock can facilitate gas exchange between rock and the atmosphere. In certain environments water vapor exchange can be a significant component of overall water flux.
Regional aquifer and saturated zone flow and transport	Numerous permeable units in the Puye Formation, the Tshicoma Formation, and the Santa Fe Group comprise the regional aquifer.
	Water in the regional aquifer moves generally eastward from the Jemez Mountains toward the Rio Grande under natural gradients.

TABLE 4-1 (continued)
ELEMENTS OF THE CONCEPTUAL MODEL FOR THE CANYON SYSTEMS

Transport Pathway/Mechanism	Concepts/Hypotheses
	The hydraulic gradient of the regional aquifer averages about 60 to 80 ft/mi within the Puye Formation and increases to 80 to 100 ft/mi along the eastern edge of the plateau as groundwater enters the less permeable sediments of the Santa Fe Group.
	Based on aquifer tests, the rate of groundwater movement in the regional aquifer ranges from 20 ft/y in the Tesuque Formation to 345 ft/y in the more permeable Puye Formation.
	The regional aquifer is recharged in part from the west, probably from the Jemez Mountains, with possible contributions from fault and fracture zones on the Pajarito Plateau and, at some locations, from alluvial groundwater and intermediate-depth perched groundwater. Natural recharge through undisturbed Bandelier Tuff on the mesa tops is believed to be insignificant.
	A portion of the regional aquifer discharges into the Rio Grande through springs and seeps. Springs fed by the regional aquifer discharge an estimated 4,300 to 5,000 acre-ft of water annually to the portion of the Rio Grande adjacent to the Laboratory.
	Contamination of the regional aquifer has occurred near the Rio Grande and elsewhere through infiltration below low-elevation canyon floors, recharge on the Pajarito Plateau, or poorly constructed wells.
	The regional aquifer in the Los Alamos area is the only aquifer capable of producing a large-scale municipal water supply.
	The regional aquifer exhibits artesian conditions in the eastern part of the Pajarito Plateau near the Rio Grande; recharge for this portion of the aquifer may originate in the Sangre de Cristo Mountains.
	If present, Laboratory-derived contaminants in the regional aquifer will tend to be highly diluted compared with potential recharge sources such as contaminated alluvial groundwater.
Atmospheric transport pathways/mechanisms	
Wind-borne dust	Entrainment is limited to contaminants in surface sediments.
	Entrainment, dispersal, and deposition are controlled by sediment properties, surface roughness, vegetative cover, terrain, moisture content, and other climatic factors.
	Entrainment, dispersal, and deposition are affected by wind speed, stability of the wind direction, and precipitation.
Gas/vapor dispersion	Gas exchange between the subsurface and the atmosphere provides the release mechanism for volatile contaminants.
	Gas exchange between the rock or soil and the atmosphere is a function of temperature and pressure gradients.
	Fractures can facilitate gas exchange between rock and the atmosphere.
	Atmospheric conditions affecting vapor dispersal include wind speed, stability of the wind direction, and precipitation.
Biological pathways - transport and exposure	
Plant uptake	The ability of plants to absorb contaminants depends on soil and water chemistry, soil microflora activities, contaminant characteristics, climatic conditions, and the characteristics of individual plant species.

TABLE 4-1 (continued)

ELEMENTS OF THE CONCEPTUAL MODEL FOR THE CANYON SYSTEMS

Transport Pathway/Mechanism	Concepts/Hypotheses
	Contaminants in the rooting zone can be assimilated into the roots and redistributed throughout plant tissues. The rooting zone can include alluvial groundwater.
	Contaminants in plant tissues can be redistributed by herbivore feeding and by erosional transport of dying leaves, branches, stems, and roots.
	Certain contaminants, such as tritium, can be transpired to the atmosphere.
	Plant surfaces such as stems and leaves can be contaminated by resuspension of contaminated soil by wind or rain splash.
Animal uptake	Animals can ingest contaminants by consuming water from streams or wells (for example, stock tanks).
	Animals consume leaves, stems, roots, and plant products (such as nectar) and any contaminants they contain. Certain contaminants can be progressively concentrated in the food chain through bioaccumulation.
	Animals also consume contaminants that adhere to the surfaces of plant tissues. Predatory animals ingest contaminants that are in or on their prey.
	Animals can ingest soil intentionally or incidentally while grooming.
	Animals can inhale contaminants absorbed to airborne particles.
	Animals can absorb contaminants through abraded or injured skin while bathing or swimming in contaminated water.
	Animal behavior patterns and the elimination of feces and urine can disperse contaminants away from source areas.
	Humans and other animals can consume the flesh from contaminated animals that have moved away from contaminated areas.
	Behavior can decrease the degree of exposure to environmental contaminants because food or water might not be obtained from a single site, or behavior might cause animals to be exposed to multiple, antagonistic contaminants.
Bioturbation	Burrowing invertebrates (such as earthworms) and vertebrates (such as pocket gophers) redistribute contaminants vertically and horizontally.
	Large, hoofed animals can alter the characteristics of the plant cover and the soil surface.
Biotic/abiotic interaction	Vegetative cover affects erosion by both water and wind. Animal feeding behaviors affect vegetative cover.
	Disturbance of the soil surface by vertebrates also affects the rates of erosion processes.

The remainder of this chapter discusses the elements of this conceptual model in detail and the process by which revisions to it will be made as new data are acquired and the knowledge and concerns of stakeholders are addressed.

4.2 Contaminant Transport Conceptual Model

This discussion is organized around the major transport processes of the conceptual model, starting with the processes having the greatest ability to disperse and transport contaminants and finishing with the processes having the least ability, as follows:

- Surface water and sediment transport
- Groundwater transport
- Atmospheric transport
- Biological transport

4.2.1 Surface Water and Sediment Transport and Resultant Exposures

Sediment transport by surface water is believed to be the predominant mechanism for redistributing contaminants in canyon systems. Carried by storm event runoff, contamination from mesa-top release sites could enter surface water drainages. Contaminants are also released directly into stream channels by effluent discharge and by dispersion during explosive tests at canyon-floor firing sites. Contaminants dispersed near firing sites either in canyons or on mesa tops can also potentially be remobilized and transported into channels. The present inventory of contaminants in canyons is probably dominated by those released as liquid effluent from outfalls, which subsequently are adsorbed onto sediment particles. Contaminants in liquid form will preferentially bind to the finer-grained particles, which results in higher concentrations in the finer-grained sediment fractions.

While runoff-derived contamination entering these canyon drainages is mainly bound to the sediments, the more soluble contaminants tend to remain in solution. Larger particles and shrapnel dispersed from explosives testing may remain intact and be transported as particles on the stream bed. The rate of sediment transport by storm events is governed by the energy or carrying power of the specific event. Because of the year-to-year variability in rainfall in this semiarid climate, flood magnitude also varies greatly between years. Transport of contaminants to the Rio Grande by surface water has occurred since the 1940s, and it is expected that, given sufficient storm events, over time much of the remaining sediment will eventually be moved across the Laboratory boundary to the Rio Grande (LANL 1993, 26077).

Sediment transport occurs during floods, snowmelt events, and sustained releases from outfalls, such as that from the Los Alamos County Sewage Treatment Plant. The largest floods, and therefore the largest potential for sediment redistribution, are caused by summer thunderstorms. Sediment transported by these flows is either redeposited downstream at various locations or transported to the Rio Grande. One effect of continued sediment transport over time is to decrease the total inventory of contaminants in some upstream areas and increase the inventory in some downstream areas. For example, the largest portion of the plutonium originally discharged from former Technical Area 45 into Acid Canyon is believed to reside within inactive channel deposits in lower Pueblo Canyon 5 to 10 km downstream from the original source (LANL 1995, 50290).

Sediments and associated contaminants deposited in different geomorphic locations, such as active channels, inactive channels, and floodplains or low terraces, will remain in place for varying lengths of time. Transport of sediments in active channels can occur during relatively frequent, moderate-sized storm or snowmelt flows, whereas transport of sediments currently residing in floodplains and low terraces requires infrequent large floods during which the stream channel can erode laterally. Contaminants in floodplains and low terraces may remain in storage for decades or longer.

Contaminants that are associated with sediments and transported by surface water can be available for uptake by humans, other animals, and plants through the following pathways:

- ingestion of unfiltered water from streams,

- ingestion of sediments,
- inhalation of airborne particulates derived from the sediments,
- dermal contact,
- inhalation of combustion products of contaminated plants,
- consumption of contaminated plants and animals, and
- direct exposure to sediments containing gamma-emitting radioactive contaminants.

4.2.2 Groundwater Transport and Resultant Exposures

Groundwater transport of contaminants in sediment or bedrock, under both saturated and unsaturated flow conditions, is considered a potential transport pathway in some of the larger canyon systems. Groundwater occurs in three types of saturated zones: the alluvium, intermediate perched zones, and the regional aquifer. Each of these saturated zones acts as a transport pathway, and potentially, as an exposure pathway. Groundwater in unsaturated zones is considered to be primarily a transport pathway between saturated zones, not an exposure pathway, although some uptake may occur in plants rooted near shallow (alluvial) groundwater zones. In addition, water in these zones is not sufficient in either quantity or continuity to provide a reliable drinking water source for humans; however, water from these zones may be evaluated as an occasional exposure pathway.

Groundwater in the alluvium and the intermediate perched zones supplies water for plants directly through the plant root system, and for wildlife and livestock through return flow into streams or springs. Groundwater in the regional aquifer provides municipal and industrial water to Los Alamos County through the county water distribution system. The regional aquifer, through private wells and some springs in the area, is also a source of water to residents, livestock, wildlife, and plants at San Ildefonso Pueblo. Some occasional surface and alluvial water use by humans may occur under the American Indian Scenarios. Therefore, groundwater is also considered to be an important exposure pathway.

Contaminants could migrate between the three saturated zones. Contaminants will migrate laterally down the canyon through the alluvium in interaction with the surface water. Groundwater from the alluvium may be an important source of recharge for intermediate perched zones.

Potential recharge zones for deeper groundwater (the intermediate perched zones and regional aquifer) include fault and fracture zones such as the Pajarito fault, the Rendija Canyon fault, and the Guaje Mountain fault. Flow can also occur through the porous matrix of the nonwelded Otowi Member of the Bandelier Tuff under saturated flow conditions (perhaps at the contacts of bedrock units beneath the alluvium). Relatively rapid infiltration may be occurring beneath the alluvium in Los Alamos Canyon by unsaturated flow through the porous matrix of the Otowi Member of the Bandelier Tuff (Rogers and Gallaher 1995, 48845; Rogers et al. 1996, 55543). However, the hydraulic connection between the alluvium and the intermediate perched zones is not yet fully understood. Without such an understanding, the possibility of multiple connections, including pathways to the regional aquifer, must be considered a working hypothesis to be evaluated.

Currently the extent and thickness of, and the direction and rate of groundwater flow within, the known intermediate perched zones at the Laboratory are poorly understood. Likewise, hydraulic connections among the three fully saturated zones and the groundwater flow rates along those connections are not well understood. Hydraulic interconnections between the alluvium and the intermediate perched zones are known to exist in Los Alamos Canyon and Pueblo Canyon and also may be present elsewhere. A better understanding of the intermediate perched zones and the interconnections with the alluvium is important to evaluating potential exposures to humans and the environment by these pathways.

Groundwater in the regional aquifer generally has long residence times, with little evidence of a hydraulic connection between the alluvium and the regional aquifer except in lower Los Alamos Canyon. However, rapid recharge of the alluvial groundwater to the regional aquifer can occur in the lower reaches of canyons where the distance between the two hydrogeologic units is minimal (≤100 ft).

Groundwater in the alluvium has historically had the highest concentrations of contaminants of any groundwaters in the area. Groundwater within the intermediate perched zones generally contains lower concentrations of the known contaminants. Groundwater in the regional aquifer generally appears to be uncontaminated; however, low concentrations of contaminants have been detected intermittently in some surveillance samples collected from the regional aquifer (LANL 1996, 55430). Laboratory-derived tritium is the contaminant of main concern because of its mobility. Investigations will be performed as they relate to identified sources, pathways, and areas of release of hazardous constituents and their impact on canyon systems.

4.2.3 Atmospheric Transport and Resultant Exposures

Transport of fine-sediment particles by wind can be a means of dispersing contaminants. Current understanding of wind patterns in the canyons and the interaction between mesa-top and canyon winds is preliminary; however, wind resuspension and transport of sediments out of the canyons is not expected to be a significant contaminant transport pathway. However, local resuspension of contaminated sediment by winds is considered to be one of the predominant pathways for radiological exposure to humans because dust can easily be lifted high enough to be inhaled.

The predominant wind direction on the Pajarito Plateau is from the south/southwest. Diurnal variations are important, with local east winds during the day and local west winds (drainage winds) at night. Wind directions on the mesa tops are considered to be at least partially independent of those in the canyons. For example, during the warmer months south or southwest winds on the mesa tops can induce north or northwest canyon winds. This coupling of wind directions, called a wind rotor, has been observed in Los Alamos Canyon; other canyons may also be susceptible to such interactive processes.

Wind speed on the mesa tops is sufficient to transport contaminated dust from the mesa tops to the canyons, especially during the spring when the winds are strongest. However, the Environmental Restoration Project is in the process of remediating mesa-top contaminated sources, gradually eliminating them as a source of wind-borne contaminants reaching the canyons.

Sediment suspension by wind is affected by the distribution of particle sizes in the sediment, moisture content, snow cover, and vegetative cover. All these factors suggest that wind suspension of sediments will be less effective in the canyons (which typically are relatively well-vegetated and moist) than is wind suspension of dust on the mesa tops (which typically are thinly vegetated and dry). The broader and shallower reaches of the canyons are more favorable sites for wind suspension of sediments. Wind-borne transport of contaminants out of the canyons is probably relatively insignificant except, possibly, in broader and shallower reaches that also contain high contaminant inventories. However, the impact of the suspended sediments will depend on the particle size to which the contaminants are bound. Particles greater than 10 μ are generally not inhaled, and penetration to deep lung tissue is greatest for particles 2.5 μ and smaller. Although high contaminant concentrations are often associated with fine-grained sediment samples, no data have been obtained to establish whether this correlation results from contaminants binding to the smallest particles in those samples.

4.2.4 Biological Transport and Resultant Exposures

Biological transport is considered to be less important than surface water and sediment transport or groundwater transport as a means of dispersing contaminants. However, uptake and transport of contaminants by plants and animals are important components of exposure pathways. Plants and animals can assimilate contaminants from water, sediments, and soils into tissues. Some contaminants can concentrate in animal and plant tissues to significantly higher concentrations than in the original media.

The availability of soil- or sediment-borne contaminants to plant tissues depends on soil chemistry, which is influenced by soil microflora, mineralogy, and the chemical and physical characteristics of the contaminants. Contaminants in the root zone of plants can be assimilated by roots and redistributed to different parts (such as leaves, stems, seeds, or fruits) or products (such as nectar or pollen) and be made available for ingestion by biological receptors. Certain contaminants, such as tritium (in the form of tritiated water), can be assimilated by the roots and subsequently transpired to the atmosphere through leaves and needles. Concentrations in plants are also influenced by climatic conditions such as rainfall and vary with exposure to sunlight, plant species, and specific contaminants.

Plant surfaces can become contaminated by deposition of airborne contaminants or by rain splash. These contaminants can then be assimilated by the plant and gradually released to soils by subsequent rainwash or by wind-aided dry removal. The dropping of leaves and other dead or dying plant tissues also returns contaminants to the ground where they are subject to erosion or dissolution.

Animals (including humans) can ingest contaminants that are in plants (or on plant surfaces), other animals, or the soil. Incidental ingestion of soil by animals occurs during grooming and feeding. The amount of soil that is ingested incidentally while feeding is affected by where and how the animals forage. Some animals also ingest soil intentionally. The extent to which animals redistribute contaminants depends on their behavior, physiology, and the characteristics of individual contaminants.

In the process of obtaining food and shelter, certain burrowing vertebrates and invertebrates cause soils to be redistributed laterally and vertically. This process, called bioturbation, can cause surface contaminants to become buried and underground contaminants to be brought to the surface. Currently the potential significance of bioturbation in the canyon systems is unknown.

Erosion is affected by plants and animals. Dynamic and heterogeneous plant communities produce vegetative cover that affects erosion rates. The characteristics of these plant communities are affected by interactions with animals, including humans. Large hoofed animals can also affect erosional processes by disturbing the soil surface.

4.3 Refinement of the Conceptual Model

The conceptual model will be refined by new data from the sampling and analyses proposed in the SAPs for canyon investigations, work at other operable units, the site-wide studies of the Earth Science Council, and investigations coincident with new well installations proposed under the Laboratory's Groundwater Protection Management Program Plan (LANL 1995, 50124) and Hydrogeologic Workplan (LANL 1996, 55430). Exposure pathways will continue to be refined through new information obtained from Indian Pueblos and other affected populations as well as by other ecological data as they become available.

The process by which refinement will occur is a major feature of the technical approach, and is discussed in detail in Chapter 5 and Chapter 6 of this core document. The procedures for communicating refinements to the conceptual model during the course of the canyons investigations will be through the reports prepared upon completion of investigations in each canyon or canyon aggregate and through the SAPs for investigation of each canyon or canyon aggregate conducted in sequence as described in Chapter 7 of this core document.

REFERENCES FOR CHAPTER 4

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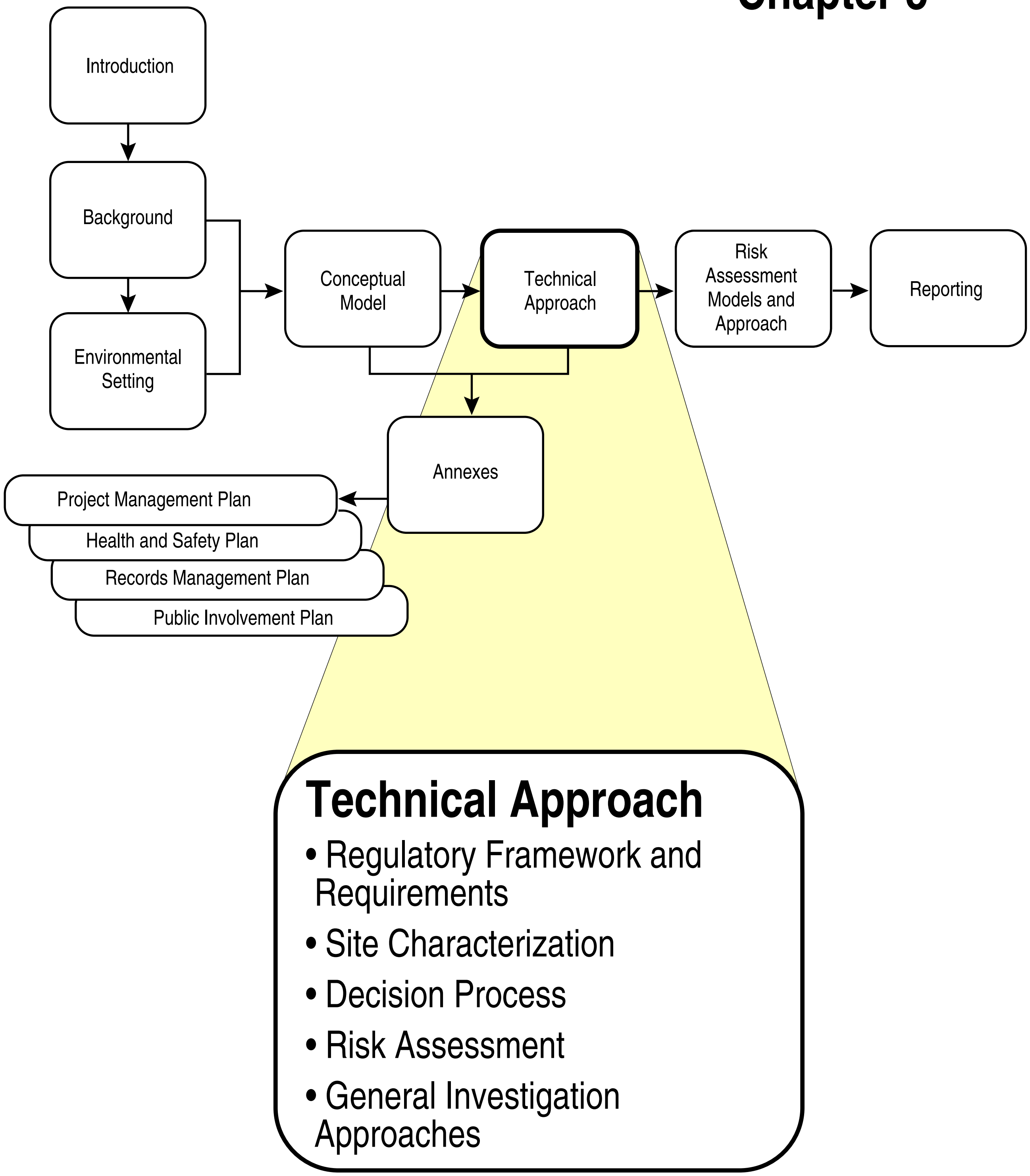
Chapter 5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5.0 TECHNICAL APPROACH

This chapter describes the general technical approach for conducting the canyons investigations. Details of the approach taken during the investigation of each canyon or canyon aggregate will be consistent with the general approach and will be discussed in each of the sampling and analysis plans (SAPs).

Relatively few solid waste management units (SWMUs) are located within canyon systems; most SWMUs are associated with Laboratory facilities and operational areas on the mesa tops. Sediments and surface water derived from these mesa-top SWMUs may be important sources of the contaminants that are found in the canyon systems. Contaminants have also been introduced into the canyons through Laboratory operations on canyon floors (for example, the SWMUs at Technical Areas [TAs] -2, -18, and -41 facilities, and firing sites at TAs -10, -36, and -39) and through direct discharge of effluent from outfalls. Some effluent discharges in the past predated the National Pollutant Discharge Elimination System (NPDES) permitting, and some were accidental. NPDES-permitted discharges are not solid wastes; therefore, the consequences of these discharges are not subject to corrective action. The combination of possible sources of any contamination in the canyon systems complicates investigations and decisions regarding any corrective action.

Because canyon-floor SWMUs are contained in other operable units, investigations of them are addressed in numerous Resource Conservation and Recovery Act facility investigation (RFI) work plans prepared in the Laboratory's Environmental Restoration (ER) Project. Consequently, the technical approach for the canyons investigations as described in this core document is focused on general characterization of the canyon floors and refinement of the conceptual model of contaminant occurrence, transport, and exposure route (discussed in Chapter 4 of this core document), (hereafter "the conceptual model"), to evaluate present-day human health and ecological risk, as needed, and potential future impacts from Laboratory-derived contaminants.

5.1 Summary of Canyons Investigations Technical Approach

5.1.1 Purposes of Canyons Investigations

The purposes of the canyons investigations are to evaluate present-day human health and ecological risks from Laboratory-derived contaminants within the canyon systems and to assess future impacts from the transport of these contaminants. Specifically, canyons investigations will

1. determine to what extent stream channels and underlying groundwater of the canyons have been affected by Laboratory releases;

2. reexamine contaminant transport mechanisms, refine the conceptual model, and model contaminant transport; and

3. assess present-day risk to human health and ecological systems and evaluate the potential for transport of contaminants to cause human health and ecological risk in the future.

In addition to surface waters in the active canyon channels and groundwater below the canyon floors, the canyons investigations are focused on those parts of the canyon floors that contain post-1942 stream sediment deposits. Mesa tops, alluvial and colluvial deposits on canyon walls, and drainages off canyon walls may contain contaminants from individual potential release sites (PRSs) and will be characterized as part of RFIs conducted for other operable units.

Although assessments of present-day and potential future impacts to canyon ecosystems are necessary to address the requirements for the canyons investigations in the Hazardous and Solid Waste Amendments (HSWA) Module, as discussed in Chapter 1 of this core document, much of the work to define potential future impacts will be integrated into a broader program of studies, which is currently being defined by the ER Project in consultation with the New Mexico Environment Department (NMED), the Department of Energy (DOE), the Environmental Protection Agency (EPA), and tribal representatives from neighboring Indian Pueblos.

5.1.2 Characterization Approach

The characterization approach for canyons investigations is a *focused* sampling strategy designed to minimize the additional information needed to meet the objectives by collecting data specifically to test working hypotheses derived from the conceptual model and to enable performance of present-day human health and ecological risk assessments.

The SAPs for the focused sampling strategy will be implemented using a flexible and iterative characterization approach. The technical team that prepares and implements the SAPs will include scientists with wide-ranging field experience and expertise under the direction of a technical manager with broad familiarity with the appropriate disciplines in field sampling, analysis, and decision-making. The characterization approach requires active and continual participation by the technical team and frequent dialogue with regulators so that the strategy can be modified as new field data are received. Consequently, measurement and analysis options and the number and locations of sampling sites will be partly determined on the basis of field information.

The strategy is discussed in more detail in Section 5.3.4. Application of the strategy through iterative sample collection and analysis, and evaluation of new data to reduce uncertainty in the spatial distribution of contaminants and in risk-based decision making are addressed in Section 6.2 and Section 6.4.1 of Chapter 6 of this core document.

The success of this approach depends on rapid analysis and integration of data to ensure that modification to the sampling plans can be implemented during the field investigations, if necessary. The conceptual model, as discussed in Chapter 4 of this core document, will be continually evaluated and revised as needed, and SAPs will be revised accordingly on the basis of information gathered during field investigations.

5.1.3 Risk Assessment

Human health risks associated with present-day chemical and radiological contamination will be evaluated, as needed, using various land use scenarios that are relevant to specific portions of the canyon systems. For example, residential use is considered only for those reaches of the canyons where the canyon floor is wide enough for permanent residential construction. In general, human health risks are evaluated for likely future use in a canyon reach using current conditions of contaminant distribution and concentration. The conceptual model plus the results of contaminant fate and transport modeling will be used to project future risk. If contaminant concentrations are expected to increase in exposure media in the future, the scope and significance of the anticipated risk will be assessed.

Data collected from sampled media (sediment, air, surface water, and groundwater) will be used to describe and progressively refine distributions of contaminant concentrations on several spatial scales for use in present-day human health risk assessment by an iterative process (see Section 6.2 of this core document). Representative contaminant concentrations in air and water will be determined for an appropriate volume of the exposure medium (for example, a water-bearing zone or portion thereof).

Ecological risk will be evaluated for selected receptors indicative of the overall health of the canyons ecosystem. For both human health and ecological assessments, the relative impacts of potential remedial actions (if target risk values are exceeded) will be considered.

5.1.4 Impacts through Contaminant Transport

In addition to concerns regarding present-day human health risk from the affected media, it is also necessary to address concerns regarding possible future impacts from the contaminants when and if they are redistributed in or transported out of the canyons to other locations and other media.

The conceptual model of the present-day locations of contaminants and the transport processes and pathways by which the contaminants are expected to move (Chapter 4 of this core document and, specifically, Table 4-1), is viewed as a set of hypotheses to be tested by the interpretation of data obtained in these investigations. The field sampling and analysis approach and the methods for data evaluation described in Section 5.4.2 and Section 6.2 are designed to enable testing of hypotheses of the conceptual model and revision of the conceptual model as appropriate. These hypotheses will be specific to each canyon and will be discussed in the SAP for investigation of each canyon or canyon aggregate (see, for example, Chapter 7 of the *Task/Site Work Plan for Operable Unit 1049: Los Alamos Canyon and Pueblo Canyon* [LANL 1995, 50290]).

The end product of this approach will be an improved and verified conceptual model and estimates (using numerical models discussed in Section 5.3.1, where appropriate) of quantities, concentrations, and rates of transport of contaminants in various media. This improved model will be used both to evaluate future human health and ecological risks and to guide future decisions regarding environmental management of the canyon systems.

5.1.5 General Technical Approach

The ongoing review of existing information (as presented in Chapters 2 and 3 of this core document and supplemented in the canyon- or canyon aggregate-specific SAPs) and the conceptual model directs sampling efforts toward addressing uncertainties in both the conceptual model and the specific types, locations, and concentrations of potential contaminants in each of the canyon systems. This emphasis on active reexamination of the conceptual model and of the rationale for characterization is intended to keep sampling focused on critical data needs throughout the investigations.

The general technical approach is summarized in the flow chart in Figure 5-1. The process is divided into three stages: preliminary evaluation; planning, investigation, and initial assessment; and final assessment. These stages and the tasks and decisions to be completed during them are discussed in the remainder of this chapter. More specific information about the technical approach used for groundwater investigations can be found in the Hydrogeologic Workplan (LANL 1996, 55430).

5.2 Preliminary Evaluation

The preliminary evaluation is divided into three stages: (1) define the HSWA Module requirements, (2) define archival needs, and (3) gather and synthesize existing data. This core document reviews the applicable HSWA Module requirements for the canyons investigations. The definition of archival needs

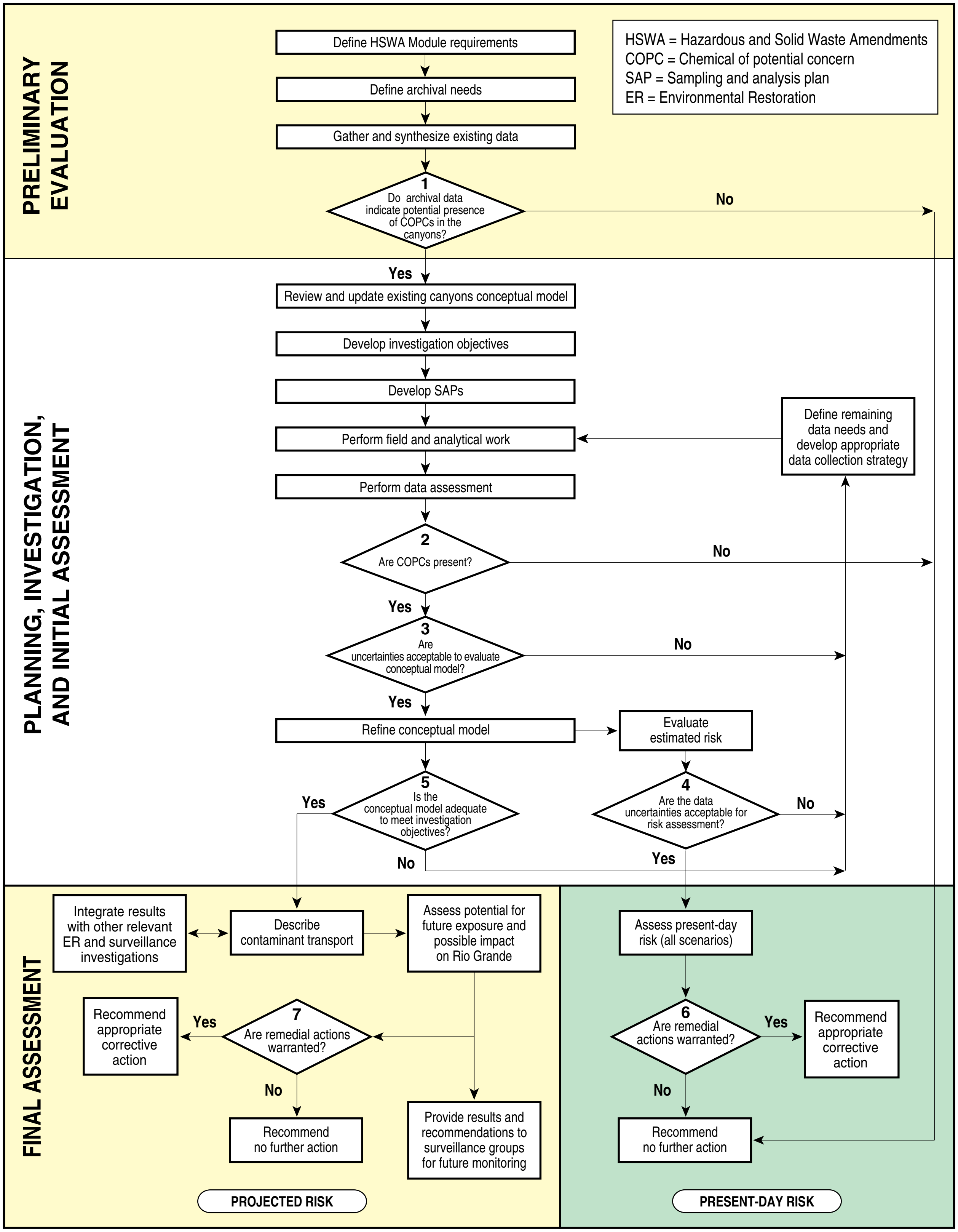

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Figure 5-1. General technical approach for the canyons investigations.

and assembling of existing data will be performed on a canyon-by-canyon basis during the development of the canyon- or canyon aggregate-specific SAPs.

5.2.1 Define HSWA Module Requirements

The language of the HSWA Module discussed in Section 1.4.1 in Chapter 1 of this core document outlines three requirements for each of the canyon- or canyon aggregate-specific SAPs for the canyons investigations. An approach for meeting each requirement is discussed below.

Requirement

“These investigations must address each canyon system as an integrated unit and evaluate them for potential impacts of contaminants from SWMUs.”

Implementation

Characterization of contaminants in sediments will span the length of the canyons but will emphasize areas closest to PRSs including SWMUs and areas of concern on mesa tops and in canyons, areas with the most significant sediment deposition, and areas critical to estimating the present-day human health risk and testing the conceptual model. Sediment sampling will be focused on (but not limited to) those sediments deposited after the Laboratory activities were initiated on the Pajarito Plateau (1943), both in channels and on floodplains. Sampling and analysis of pre-1943 alluvium may be conducted to test other hypotheses of the conceptual model.

Groundwater will be sampled and analyzed at strategic points along the length of the canyons. As outlined in Chapter 4 of the Hydrogeologic Workplan (LANL 1996, 55430), groundwater investigations are designed to reduce uncertainty about the hydrologic and geologic factors controlling groundwater occurrences and to test hypotheses regarding hydraulic connections between groundwater zones.

Requirement

“The plans must address the existence of contamination and the potential for movement or transport to or within canyon watersheds and interactions with the alluvial aquifers and the main aquifer.”

In the context of the current terminology, the “alluvial aquifers” is taken to mean the alluvial and intermediate perched zone groundwaters, where they exist, and the “main aquifer” is termed the “regional aquifer.”

Implementation

Investigations will focus on areas most likely to contain contaminants (see above), determine settings where the greatest contaminant inventories occur (such as in canyon sediments deposited after 1942), and assess the susceptibility of the contaminants to redistribution by fluvial processes, solute transport, and wind resuspension.

Plans for groundwater investigations will also focus on areas most likely to contain contaminants, such as the near-surface alluvial groundwaters downgradient of known release sites. Results of these groundwater investigations are also used for designing enhanced groundwater monitoring systems at the Laboratory, if necessary. Studies of the deep unsaturated zone and the regional aquifer will provide information about contaminants in intermediate perched zones and the top of the regional aquifer. Proposed boreholes drilled to investigate these deep groundwater systems are initially sited downgradient of potential release sites with large inventories and where Laboratory surveillance data indicate that Laboratory-derived contaminants are present in the deeper groundwater systems. Groundwater investigations will follow an iterative approach in which information obtained from each borehole will be evaluated in the context of the hydrogeological portion of the conceptual model. These ongoing evaluations may lead to changes in the locations and numbers of future boreholes. Changes in the scope of groundwater investigations will be negotiated annually with regulators (see also LANL 1996, 55430).

Requirement

"The investigations shall evaluate the potential for off-site exposure through these pathways including the ground water and possible impacts on the Rio Grande."

Implementation

Characterization activities will lead to a human health risk assessment under present-day contamination conditions for Laboratory employees, recreational users of the canyons, traditional users of the land (American Indians), and downstream residents. In addition, the data collected will be used to assess amounts of contaminants in sediments, surface waters, and groundwaters entering the Rio Grande. Information about transport pathways and processes will be summarized and used to refine the conceptual model by which the future distributions of contaminants will be projected and the potential for future exposures will be evaluated. Recommendations will be made concerning the need for remedial actions and future monitoring activities based on the refined conceptual model.

Investigations will also qualitatively assess future changes in risk due to transport of contaminants in the watersheds and in the portion of the groundwater affected by the canyon systems. The characterization results and newly-installed wells will be transferred to the control of the Laboratory Water Quality and Hydrology Group (Environment, Safety, and Health [ESH]-18) for potential use in long-term monitoring, surveillance, and regional studies after the investigations are completed. This action will ensure that later when regulatory guidance and conceptual models for the conduct of such studies are available studies of future risk can be performed.

5.2.2 Define Archival Needs

5.2.2.1 Nature and Extent of Contamination

Archival data and information needs include descriptions of the types and potential sources of contamination in and adjacent to the canyon(s) under investigation including sources that might contribute to future contaminant inventories through transport. Previous investigations of technical areas on the mesas that border the canyons and tributaries to the canyons will be reviewed as well as historical information about the past and present uses and operations in these areas.

5.2.2.2 Contaminant Transport Mechanisms

Information available on contaminant transport processes includes extensive general theoretical and observational literature and numerical models on sediment, surface water, and groundwater movement and on geochemical interaction between sediment and water. The general literature is continually reviewed by the technical investigation team and literature specific to each canyon and the processes expected to be taking place in each canyon will be reviewed for preparation of the SAPs. The team assembled for conducting investigations in the canyon systems is multidisciplinary and is familiar with both the general literature and the results of relevant prior research at the Laboratory. Because researchers at the Laboratory and under contract to the Laboratory have studied transport processes on the surface and subsurface for decades, the present team can draw upon a strong body of expertise, experience, and published literature.

5.2.3 Gather and Synthesize Archival Data

5.2.3.1 Gather Existing Data and Information

Archival data, especially that prepared by the ER Project and the Environmental Surveillance Group (ESG), will be assembled and reviewed for activities conducted in the main and tributary canyons and on adjacent mesa tops. This review will identify known and potential sources of existing contamination and sources that might contribute to future contaminant inventories through transport. New data from other ER Project investigations will be examined as they become available.

Potential data and information resources include all the publications of the United States Geological Survey covering research and monitoring from 1945 through 1970; annual surveillance reports of the ESG (and its successor, the Environmental Protection Group, now ESH-20) since 1970; reports of research conducted by Laboratory scientists and subcontractors; and results of RFIs at operable units containing potential release sites that could affect, or have affected, the canyon systems. ER Project and environmental surveillance sampling and well locations are stored at the Facility for Information Management, Analysis, and Display (FIMAD) at the Laboratory. Data from peer-reviewed literature and Laboratory investigations on plant and animal uptake parameters as well as other relevant exposure data are also reviewed.

5.2.3.2 Synthesize Existing Data and Information

The synthesis involves arranging the data spatially and temporally to reveal existing conditions and trends in contaminant occurrence and movement, likely sources of contaminant, and potential pathways and mechanisms of migration. The conceptual model is also tested with the existing data, a process that will point out inconsistencies and suggest hypotheses most in need of testing during the investigations.

The assembly and synthesis of the existing data will proceed through meetings of the technical team, a group of experts in various disciplines including geology, geochemistry, chemistry, hydrology, biology, statistics, toxicology, and risk assessment. The technical team is drawn from the Laboratory and from contractors whose personnel have special expertise and experience in environmental work at the Laboratory. Staff of the NMED Oversight Bureau also participate in evaluating the available data.

The results of this step will be summarized in each of the canyon- or canyon aggregate-specific SAPs. These SAPs will supplement the general information in this core document with details on specific potential contaminant sources, features, and processes.

5.2.4 Decision Point Number 1

> **Do archival data indicate the potential presence of chemicals of potential concern (COPCs) in the canyons?**

5.2.4.1 “No” Decision Outcome

If such a conclusion is reached, it will lead to the preparation of a report summarizing the available data and the interpretations that support a conclusion that no further investigations are needed in that canyon or canyon aggregate. Such a recommendation will be appropriate only if sufficient archival information exists to support a conclusion that no contamination above background levels (see Section 5.3.6 for a definition of COPCs) is present and that contaminants in areas adjacent to the canyon(s) are highly unlikely to reach the canyon system(s). The report will discuss the quality of the data used to support the decision, and a recommendation for no further action will be submitted for review and approval as a modification to the HSWA Module.

5.2.4.2 “Yes” Decision Outcome

The response to this decision question is “yes” in cases where previous investigations have identified potential Laboratory-derived contamination from past and present discharges and SWMUs on the mesas or in the canyons, or Laboratory-derived contaminants in the canyon system(s) under investigation. In this case, a study of the canyon system(s) must be conducted and, therefore, the process will move to the next stage, planning, investigation, and initial assessment.

5.3 Planning, Investigation, and Initial Assessment

5.3.1 Review and Update Existing Canyons Conceptual Model

The conceptual model described in Chapter 4 of this core document represents the current general understanding of the canyon systems. As the investigations proceed, the conceptual model will be refined and made more specific to each canyon under investigation by testing hypotheses derived from the conceptual model using data from the investigations.

As discussed in Chapters 3 and 4 of this core document, the dominant transport pathways for contaminants are currently believed to be the surface water and sediment system and the groundwater system. Secondary transport pathways are atmospheric and biologic transport. As detailed in Chapter 6 of this core document, the predominant exposure pathways are currently believed to be (1) ingestion of contaminated plant and animal material; (2) ingestion of water, soil, or sediment; (3) direct exposure (especially to gamma radiation); and (4) inhalation of resuspended dust or combustion of products of contaminated plant materials. The conceptual model and the exposure pathway model will be revised as additional information is acquired during the canyons investigations.

Computational models will be used to evaluate human health and ecological risks. Modeling of geochemical processes and contaminant transport, particularly over long periods, will be performed as part of the pathway analysis. This assessment includes evaluation of the potential for future exposure and evaluation of possible impacts on the Rio Grande. Table 5-1 lists representative numerical modeling codes that may be used in planning and analysis for these investigations. In addition, spreadsheet models based on EPA risk evaluation equations modified by site-specific factors will be used when assumptions of commercial codes are not appropriate for the site.

5.3.2 Develop Investigation Objectives

The development of investigation objectives follows the data quality objectives (DQO) process outlined by the EPA (EPA 1987, 21524). The DQO process focuses the objectives of the study and ensures that proposed data collection activities are developed from decision criteria and strategies. A clear definition of the key issues regarding characterization and remediation options and a sampling plan tailored to quantitative goals for data quality are expected to result from the DQO process. DQOs for sediments will be prepared for the SAPs developed for each canyon or canyon-aggregate investigation. DQOs for groundwater investigations have been developed as part of the Hydrogeologic Workplan (Section 1.5 and Appendix 4 of LANL 1996, 55430); these DQOs will be modified as necessary for each SAP.

TABLE 5-1

COMPUTATIONAL MODELING CODES

Function	Name	Source
Dose assessment	RESRAD	DOE[a]
	CAP88	EPA[b]
	VARSKIN	EPA
	MILDOS	DOE
Geochemical equilibrium	PHREEQE	USGS[c]
	WATEQFC	USGS, CU[d]
	MINTEQA2	EPA
Hydrologic transport	TRACER3D	DOE
	SESIL	EPA
	FEHM	DOE
	MODFLOW	USGS
Surface and air transport	CREAMS	USDA[e]
	GLEAMS	USDA
	AIRDOS	EPA
Geostatistical data analysis	GEOPAC	EPA
	GEOEAS	EPA

a. DOE = Department of Energy
b. EPA = Environmental Protection Agency
c. USGS = United States Geological Survey
d. CU = University of Colorado
e. USDA = United States Department of Agriculture

It is difficult to tie aspects of characterization in the canyon systems to a set of statistically determined objectives for the sampling and analysis program. EPA recognizes the difficulty explicitly in the following guidance for the DQO process:

> Every step of this guidance may not be applicable to data collection activities where specific decisions cannot be identified, such as studies that are *exploratory in nature* **[emphasis added]**. The reason for this distinction is that part of the DQO Process includes formulating statistical hypotheses. If a statistical hypothesis is not linked to a clear decision in which the decision maker can identify potential consequences of making a decision error, then some of the activities recommended in this guidance may not apply. In these cases, it may be possible to frame a *research type study question* **[emphasis added]** in the form of a decision or modify the activities described in this guidance to address the needs of the study (EPA 1987, 21524).

This passage suggests that, in some studies, technical experts must judge whether investigation objectives have been adequately met. Expert judgment is needed because the canyons investigations address multiple objectives, several of which are *exploratory in nature* and address *research type study* *questions*. The investigations also address human health risk assessment endpoints, and remediation-related decision-making objectives, the data for which will have statistically determined objectives and/or limits of uncertainty associated with them. Contaminant distributions and exposure characteristics that form the basis of risk calculations and risk-based decisions will be quantitatively described (see also Section 6.2 and Section 6.4.1 in Chapter 6 of this core document for discussion of the iterative process of risk calculation, uncertainty estimation, and data collection). Together, the effort to address these multiple objectives in the canyons investigations will be effective in evaluating present-day and potential future impacts despite difficulty in basing all decisions on tests of statistical hypotheses.

The DQO process coordinates well with the focused sampling strategy and the characterization approach (see Section 5.1.2 and Section 5.3.4.1) that will be used in characterizing the canyons. It provides the mechanism for determining the value of characterization data in refining estimates of the risk of potential remedial actions (including no further action).

5.3.3 Develop Sampling and Analysis Plans

SAPs are developed from investigation objectives. The SAPs will address surficial deposits, alluvial groundwater, and intermediate perched zone and regional aquifer groundwater. Each will present a series of issues specific to the canyon or canyon-aggregate considered significant to defining the present-day human health risk and projected future impact from Laboratory-derived contaminants and to testing and refining the conceptual model. The importance of each issue will guide the technical focus of the investigation and will influence the resources allocated to address the issue.

For surface sediments, investigations will be conducted in selected reaches of the canyon systems (see Section 5.6.1 for a discussion of the selection of reaches). For both sediment and hydrologic studies, different approaches to field activities will be tailored to the issues identified for each canyon system. The approach to each successive investigation may change to address priority issues relevant to the conceptual model as investigations in specific canyons or canyon aggregates progress and are completed, and the conceptual model of the canyon systems is refined. However, all investigations will follow the general technical approach described in this chapter.

The SAPs will be developed according to the following principles.

- Sampling and analysis will focus on resolving key uncertainties regarding processes and impacts, as defined in the conceptual model and the risk assessment models.
- Major uncertainties in the conceptual model will be addressed by sampling and analysis of critical media for key parameters.
- Sediment sampling will focus on providing the data for both a present-day human health risk assessment, as needed, and an evaluation of the hypotheses regarding transport and redistribution processes governing the pattern of contamination in the canyons. The data will also support ecological risk assessment, as needed.
- Hydrologic investigations will define the distribution of contaminants in groundwater and transport processes between groundwater zones.
- Surface water investigations will be integrated with the Laboratory's Watershed Management Program Plan, which is now being developed.

SAPs will also be developed for atmospheric and ecological subsystems, as appropriate.

5.3.4 Perform Field and Analytical Work

Characterization of contamination in the canyon systems poses unique challenges. For example, low levels of contaminants in sediments are irregularly distributed over large areas of the canyon floors. These contaminants are periodically redistributed by runoff from storm events resulting in contaminant distributions that vary significantly in both space and time.

5.3.4.1 Focused Sampling Strategy

One approach to characterization of such a large and dynamic system would be to collect samples at fixed intervals over the entire area. This approach is discounted because large portions of the canyons are likely to be uncontaminated, and indiscriminate systematic sampling of all areas is inefficient.

The alternative approach adopted here is a *focused* sampling strategy designed to maximize the information obtained to address the objectives by

1. concentrating sediment sampling and surface water and groundwater characterization activities in reaches of canyons where prior data suggest that human health risk assessments may be warranted, or are key to verifying or refining the conceptual model;
2. identifying COPCs, as defined in Section 5.3.6, in an initial sampling and analysis task wherein the analytical protocol is broad (also known as the “full-suite analyses”);
3. limiting the analytical suite for subsequent samples to contaminants known to be present and to solutes that influence contaminant mobility, as identified in the initial sampling task;
4. collecting data (including screening data) to test the components and hypotheses of the conceptual model; and
5. using statistical and numerical techniques to quantify uncertainty in contaminant distributions.

The sampling strategy will be flexible to reflect new field data as they are received. Measurement and analysis options and the number and location of sampling sites can be modified on the basis of field information. The success of such a strategy depends on timely analysis and integration of data to ensure that each input is evaluated sufficiently and in time to allow for resampling if necessary. The conceptual model is thereby adjusted continually on the basis of discovery in the field.

The thorough examination of existing information and the conceptual model enables focused sampling to address uncertainties in both contaminant distribution and transport processes. This approach avoids the collection of large quantities of data that may be irrelevant to the objectives. Reexamination of the conceptual model and of the rationale for characterization will keep sampling focused on critical data needs throughout the investigations.

5.3.4.2 Assess Data Quality

The assessment of the data quality consists of a comparison of the data collected with the objectives outlined under the DQO process. The process is relatively automatic where well-specified quantitative objectives are defined. For those aspects of the investigations for which quantitative decision criteria and limits on decision errors cannot be developed (e.g., where even the conceptual model is uncertain, and the study is exploratory in nature), the assessment will rely on expert judgment. These judgments will be documented, and subsequent decisions will be quantified where possible.

Data collected in the canyons investigations are intended to serve the dual objectives of conducting a present-day human health risk assessment as warranted by the contaminant concentrations and testing and refining the conceptual model. To meet the former objective, data must be sufficient in number and quality to establish a statistical model for the data set and confidence intervals on measure(s) of central tendency in the data set (see also Section 6.2 and Section 6.4.1 in Chapter 6 of this core document for discussion of data use in present-day human health risk assessments and the iterative process for reducing uncertainties in the spatial distribution of data). Data used to address the latter objective also lend themselves to statistical evaluation but do not need to achieve the same standards as data used for present-day human health risk assessment.

5.3.5 Perform Data Assessment

Data assessment at this stage includes comparisons with background data sets (sediment and water), evaluation of potential risk, and identification of spatial and temporal variations in contaminant concentrations.

5.3.6 Decision Point Number 2

Are COPCs Present?

COPCs are broadly defined for the canyons investigations as chemicals selected for additional (limited-suite) analyses on the basis of existing sample data (generally, full-suite analyses and historical data) and the assessment of data described in Section 5.3.5. COPCs will vary among reaches depending upon the nature of contaminant releases into the canyon at and upstream of the reach. In addition, COPCs may vary among risk assessment endpoints due to variability in the size of exposure areas and types of exposure media. Because multiple risk assessment endpoints exist, an analytical datum may be evaluated in several groupings, or decision sets, and chemicals may be identified as COPCs for certain endpoints but not others.

If no COPCs are found to be present, no further action will be recommended as discussed in Section 5.2.4.1. If COPCs are found to be present, the conceptual model will be refined as described below, and the assessment will continue.

5.3.7 Decision Point Number 3

Are uncertainties acceptable to evaluate conceptual model?

After evaluating the data set, the technical team will judge whether the remaining uncertainties in the data are acceptable for evaluating the conceptual model. Data will be evaluated for their utility in answering questions such as distributions within geomorphic units at surface and at depth, collocation of contaminants, and geochemical characteristics of contaminant binding. Statistical evaluations will be used to determine the degree of reduction in uncertainty (e.g., reduction in measurements of variance) to be gained by the collection and analysis of additional samples. These evaluations will form the basis for additional sampling and analysis needs requested by the technical team to address remaining uncertainties in the model for a given reach. Because of cost, time, and effectiveness, it may be more prudent to perform remedial actions rather that perform further characterization. Therefore, best management practices and remedial actions may be initiated in lieu of further data collection.

If reduction in uncertainties is considered necessary to answer investigation questions (the “No” path at decision point number 3) and uncertainties can be reduced significantly by collecting and analyzing more samples, then a strategy for additional data collection will be developed.

If uncertainties are acceptable and/or no reduction in uncertainty can be reasonably achieved (the “Yes” path at decision point number 3), the existing level will be deemed “acceptable,” and the conceptual model will be refined as required by the data.

5.3.8 Refine Conceptual Model

The objective of this step is to refine the conceptual model and associated assessments of impacts using analysis and interpretation of the available field and analytical data, particularly as it applies to previously identified uncertainties in the model. Refinements may include improved descriptions of horizontal and vertical distributions of contaminants, improved estimates of contaminant concentrations and inventories, and improved descriptions of significant transport processes and time-dependent variations in contamination.

From this step, the investigation process divides into one path leading to the assessment of present-day risk and the second to the assessment of projected risk.

5.3.8.1 Evaluate Estimated Risk

The present-day human health risk will be evaluated using the refined conceptual model and the initial data on COPC concentrations. Contaminant concentrations that exceed background levels will be evaluated in deterministic risk models using maximum observed concentrations and conservative upper-bound parameter estimates to determine which contaminants and exposure pathways present potential human health risks. Those contaminants that present risk exceeding levels of concern in deterministic evaluation will then be evaluated using Monte Carlo techniques based on contaminant concentrations weighted by volume of exposure medium. These simulations will partially provide the basis for defining uncertainties to be addressed in subsequent sampling and analysis (see Section 6.2 and Section 6.4.1 in Chapter 6 of this core document for details).

The first evaluations will focus on the American Indian subsistence scenarios described in Section 6.5 in Chapter 6 of this core document. These conservative scenarios will serve as an indicator of any potential risk-based concern. Less conservative exposure scenarios will also be examined at early stages to warn of any immediate health risks that might require interim measures. If risks are estimated to be near or above levels of concern, a more detailed and formal risk assessment using data with specific limits of uncertainty may be required.

As human health risk assessment models and parameters are defined, and as additional data on patterns of contaminant distribution are obtained, the human health risk process will be made more selective. This process will eliminate the additional collection of data for analytes that have concentrations above background levels but below levels of potential concern.

5.3.8.1.1 Decision Point Number 4

Are the data uncertainties acceptable for risk assessment?

At this step, a judgment is made as to whether the available data and the uncertainties in the data at appropriate spatial scales (see Section 6.2 and Section 6.4.1 in Chapter 6 of this core document) for risk assessment will enable a defensible assessment of the present-day human health risk.

If the data uncertainties are judged to be too great for a credible risk assessment, the technical team will define remaining data needs, develop an appropriate data collection strategy, and perform additional field and laboratory analyses.

This process will be repeated until the uncertainties in the data are considered to be acceptable for risk assessment. “Acceptable” in this context can be defined as (1) leading to an obvious decision or (2) it is unlikely that uncertainties can be reduced by additional sample collection and analysis.

At this point, the process continues to the final assessment stage described in Section 5.4.

5.3.8.2 Decision Point Number 5

Is the conceptual model adequate to meet investigation objectives?

This decision involves judging whether the refined conceptual model (as discussed in Section 5.3.8) sufficiently defines spatial and temporal variations in contaminant concentrations and transport processes to support the final assessments. The judgment of the adequacy of the model will involve both qualitative and quantitative assessments of uncertainties in various components of the model, as well as the potential for reductions in significant uncertainties. It is expected that the potential to resolve some uncertainties will vary between reaches and between canyons depending on the geologic data that are available (e.g., historic aerial photographs can allow good age control for sediment deposits in open areas but not under heavy forest cover).

The technical team will define remaining data needs, develop an appropriate data collection strategy, and conduct additional field and analytical work. The processes of reducing uncertainty in the data for risk assessment and for refining the conceptual model are parallel and interactive.

This process will be repeated through additional sampling and analysis (the “No” path at decision point number 5) until the uncertainties in the model are considered to be acceptable for defining spatial variations in contamination and for projecting future impact (the “Yes” path at decision point number 5).

At this point, the process continues to the final assessment stage described in Section 5.4.

5.4 Final Assessment

The final assessment is performed when characterizations of sediments, surface water, and groundwater are completed, although the assessment is actually an ongoing process during all stages of the investigation. The final assessment integrates data from all investigations in a canyon or canyon aggregate to assess present-day human health and ecological risk from all risk scenarios and to assess how potential future contaminant transport may change risk levels from present-day values.

Information on contaminant concentrations from well-characterized portions of the canyon floors (i.e., sampled reaches) will be used to constrain the contaminant distributions in unsampled portions. Geomorphological maps; geologic, geochemical, and hydrologic information about surface water and groundwater features; and statistical models showing trends in contaminant concentrations down-canyon(s) may be used to extrapolate contaminant distributions in unsampled areas.

5.4.1 Present-Day Risk

The assessment of present-day human health risk is conducted, finalized, and reported if COPCs are present and when the uncertainties in the data have been reduced to acceptable levels. An ecological risk assessment may also be conducted, as needed.

5.4.1.1 Assess Present-Day Risk (All Scenarios)

Canyons investigations will provide data for both radiological and nonradiological risk assessment. Risk assessments will evaluate all exposure scenarios in an iterative process (see Section 6.2 and Section 6.4.1 in Chapter 6 of this core document). The scenarios and models for human health risk assessments are described in Chapter 6 of this core document.

In general, the probability of realizing a certain level of risk will be considered a formal decision analysis process to determine the need for remedial action. Health-risk-based analyses or other criteria discussed in Chapter 6 of this core document will be used to set cleanup levels in any contaminated areas identified.

5.4.1.2 Decision Point Number 6

Are remedial actions warranted?

Based on the assessment results, a decision will be made to recommend either no further action or some corrective action. If the assessment indicates sufficiently low present-day human health or ecological risk, no further action will be recommended as discussed in Section 5.2.4.1.

If the assessment indicates significant present-day human health or ecological risk, corrective actions will be recommended. Potential corrective actions are described in Section 6.7.2 in Chapter 6 of this core document. They may include further study, long-term monitoring, or some remedial action to reduce the present-day human health or ecological risk.

5.4.2 Projected Risk

The assessment of projected risk constitutes the second of the two main objectives of the canyons investigations. Assessment will be performed if COPCs are present in the canyons regardless of whether they are determined to pose significant risk by the present-day human health or ecological risk assessments.

5.4.2.1 Describe Contaminant Transport

The assessment of projected impacts requires a description of transport mechanisms within the canyon systems. The nature of the description will be (at least) at the level of a refined conceptual model that is quantified to the extent possible and may involve the use of refined numerical models (see Section 5.3.1). The results of the field investigations will be used to enhance the conceptual and/or numerical models of contaminant transport.

5.4.2.1.1 Contaminant Transport in Sediments

Estimates of contaminant inventories will be made for each geomorphic unit in the selected reaches, for each reach, and for individual canyon systems using the information collected on the nature, extent, and distribution of contaminants and the relationships between contaminant concentrations and geomorphic characteristics of the canyons. The basic approach will be to (1) evaluate and develop generalizations about relationships between contaminant concentrations and geomorphic units in each selected reach; (2) based upon the above generalizations, determine logical groupings for geomorphic units (for example, there may be no significant difference in contaminant concentrations between active and inactive channels and the two could then be grouped together); (3) estimate the volume of affected sediment for each pertinent unit; and (4) multiply volume of sediment by average contaminant concentration.

Contaminant inventories for entire canyon systems will be made by extending results of the individual reaches to those portions of the canyons that they best represent or by extrapolating between the reaches, such as using geostatistical techniques described in Section 6.2. The above estimates will vary in precision depending on local geomorphic variability, the number of chemical analyses per geomorphic unit, and their statistical variability. However, these estimates will aid in evaluating future impacts to the Rio Grande (how much of different contaminants could eventually reach the river), and will aid in prioritizing possible remediation or mitigation alternatives (i.e., where could removal or stabilization of contaminated sediments be most useful and/or most economical).

The database developed through these investigations will yield a greatly improved understanding of past and potential future contaminant transport processes. For example, the relationships between sediment particle size and contaminant concentration will allow evaluation of the relative importance of bedload transport compared to suspended sediment transport (which could vary between different contaminants and different canyons). The contaminant distributions within and between canyons, as defined by the contaminant inventories, and the associated geomorphic characterization, will allow better evaluation of future transport by defining how much of the total inventory is in locations susceptible to remobilization (i.e., adjacent to eroding banks) and how much is in more stable locations (i.e., inactive channels and floodplains away from active channels) where longer term storage is likely.

It is important to emphasize, however, that it is unrealistic to expect precise predictions of the timing and rates of future contaminant transport because of the geomorphic complexity within and between canyons, the stochastic nature of storms and floods, and inadequacies in existing sediment transport models. For example, numerical transport models are designed for sediment transport on stream beds, whereas most of the contaminant inventory in many canyons may be in geomorphic units removed from the channel, subject to remobilization only by bank erosion.

To aid in evaluating likely future transport, estimates of bank erosion rates and sediment residence times in different geomorphic units will be made based on examination of sequential airphotos and/or dating of sediment units (including use of tree rings and radiocarbon analyses), where appropriate. In addition, the data on contaminant concentrations will allow evaluation of possible downstream dilution of contaminants and possible progressive dilution over time since the initial contaminant releases, which will in turn indicate what trends should be expected in the future. Although exact predictions of future contaminant transport cannot be made, the use of a variety of data collected in these investigations will permit reasonable estimates of trends that should be expected in the future for each canyon system, and thus improved evaluation of both potential future impacts and of potential remediation or mitigation alternatives.

5.4.2.1.2 Contaminant Transport in Groundwater

Studies of the hydrogeological setting will identify the spatial distribution and hydrogeologic characteristics of groundwater zones that occur beneath the canyon floors. These studies, when combined with the locations of geologic units and structures, and knowledge of applicable hydrogeologic processes, provide a conceptual three-dimensional model of the Pajarito Plateau including its major canyons. This model, which is being developed by the ER Project's Earth Science Technical Council, forms the basis of identifying and quantifying pathways for groundwater flow and subsurface migration of contaminants.

Construction of hydrogeological cross sections, fence diagrams, structure contour maps, and isopleth maps will help delineate the geometry of the vadose zone and water-bearing zones and potential pathways connecting them. Hydrogeological data will be used as input for developing a three-dimensional model of the Pajarito Plateau. This model, when combined with hydraulic property measurements for the vadose zone(s) and saturated zone(s) (hydraulic conductivity, porosity, bulk density, matric potential, moisture content, hydraulic gradient) collected from boreholes and/or measured in observation wells, will form the framework for numerical modeling. Water level measurements will be used to define the potentiometric surface and groundwater flow directions within the alluvium and basalt, although fracture flow probably dominates within the basalt. Average groundwater flow velocities for the different water-bearing zones can be calculated.

Several computer codes are available for simulating groundwater flow and contaminant transport. One computer code developed at the Laboratory, FEHM (Finite Element Heat and Mass Transfer [Zyvoloski et al., 1995, 54420]) is being used as part of the performance assessment for TA-54 to simulate hydrological and geochemical processes influencing groundwater flow and contaminant transport. Calibration and validation of any numerical model requires that accurate and meaningful input data be collected. Consistency in sample collection, sample preparation, and physical and chemical property evaluation of the sample is critical in achieving the highest quality input data for hydrological and geochemical simulations.

Geochemical characteristics of the different groundwaters may be evaluated by performing graphical analysis of major ion and trace element solutes, confirming the presence of tritium and other contaminants, developing chloride mixing plots, evaluating stable isotope occurrence and geochemistry, conducting tracer studies, and performing geochemical modeling using MINTEQA2 (Allison et al., 1991, 49930) and PHREEQE (Parkhurst 1995, 54555). These computer codes may be used to quantify geochemical processes affecting the fate and transport of contaminants migrating from the alluvium to the intermediate perched zones within the basalt and further to the regional aquifer.

In studies sponsored by the Earth Science Council and the TA-54 performance assessment, distribution coefficients (K_d) for trace metals radionuclides (americium, beryllium, cesium, strontium, neptunium, plutonium, technicium, and uranium isotopes) are being measured under laboratory conditions using the Bandelier Tuff and other hydrostratigraphic materials to quantify migration rates of contaminants in the subsurface. These data will be used in geochemical modeling of contaminant transport processes.

5.4.2.2 Assess Potential for Future Exposure and Possible Impact on the Rio Grande

Some of the radionuclides of potential concern in the canyon systems have very long half-lives, and other contaminants (such as metals) do not break down into harmless by-products. Therefore, potential future impacts on human health and ecosystems need to be addressed.

Assessment of contaminant transport will address (at a minimum) the potential for future human and ecosystem exposure in areas both inside and outside the Laboratory boundaries and potential impacts on the Rio Grande now and in the future. For all contaminant transport pathways, issues of concern to

American Indians and the public are being identified through ongoing discussions with representatives of the neighboring Indian Pueblos and the public and will be addressed accordingly.

5.4.2.3 Decision Point Number 7

Are remedial actions warranted?

If the assessment indicates no significant future impacts downstream in a given canyon or canyon aggregate, no further action will be recommended as discussed in Section 5.2.4.1. If the assessment indicates potentially significant future impact and, specifically, increased exposure to humans and ecosystems resulting from contaminant transport out of the canyons, corrective actions may be recommended. Potential corrective actions are described in Section 6.7.2 in Chapter 6 of this core document. They may include further study, long-term monitoring, or remedial action to reduce the future impacts downstream. The data, models, and recommendations will be provided to the Laboratory surveillance groups for future monitoring, conceptual model refinement, and impact assessment.

5.5 Integration with Other Laboratory Activities

The canyons investigations are integrated with the ER Project Earth Science Council and other Laboratory-wide environmental efforts, such as the Laboratory's Environmental Surveillance Program. The data obtained will improve the understanding of the possible sources of contaminants in the canyons and the mechanisms by which the contaminants are moved in the canyons.

Other integrated activities include the proposed placement of about 80 characterization boreholes and wells in three water-bearing zones and other subsurface characterization efforts as part of studies for the Laboratory's Groundwater Protection Management Program Plan (GPMPP) (LANL 1995, 50124). The design of these programs is being coordinated among the ER Project, the Environmental Surveillance Program, and the Waste Management Program. This effort will maximize the utility of data obtained for multiple purposes including improving the understanding of the regional hydrogeology, geochemistry, contaminant transport pathways, the interconnection between water-bearing zones, permeability of the vadose zone, and contaminant occurrence, as well as enhancing the long-term surveillance and monitoring program.

Surface water investigations in the canyons are being deferred until they can be integrated with the Laboratory's Watershed Management Program, which is presently being developed. SAPs developed for surface water sampling will include the number and location of samples, sample treatments, the number of sampling rounds, and the suite of analytes.

5.6 General Technical Approach for Sediment Investigation

The general technical approach for sediment investigations in the canyon systems is similar to, and is in accordance with, the overall technical approach described in prior sections of this chapter. This section provides additional details specific to the sediment investigations, which are likely to be generally applicable to all canyons investigations. The methods of investigation are likely to be modified as field experience is gained. Modifications will be discussed in each of the canyon- or canyon aggregate-specific SAPs and published, as needed, during the course of the canyons investigations, as discussed in Chapter 7 of this core document.

5.6.1 Selection of Reaches

The sediment sampling and analysis plans in each of the canyon- or canyon aggregate-specific SAPs will focus on selected areas of the canyon floors downstream of known contaminant sources. Field surveys and mapping, as well as sampling tasks, will concentrate on canyon reaches, each approximately 0.5 to 1 km long. A "reach" refers to a specific area of a canyon that will be treated as a single unit for sampling and analysis. The reaches of a canyon proposed for detailed investigation will be described in the SAPs for each canyon or canyon aggregate. The precise length and area of each canyon reach will be defined by the geomorphic survey to encompass the local variability in geomorphic units and to constitute a reasonable area for use in the present-day human health risk assessment. Focusing on relatively short reaches of each canyon will allow the collection of high-density data in an efficient manner.

One or more of the following criteria will be used to select the reaches of each canyon for investigation:

- areas where contaminant concentrations are expected to be highest as judged from previous sampling activities and from the proximity of the canyon reach to the source areas;
- areas representing a variety of current or reasonably possible future land uses (recreational, residential, or ranching);
- areas of sediment deposition where contaminant inventories are expected to be highest;
- areas of varied geomorphic characteristics to allow better estimates of the total contaminant inventory in the canyon and of variations in contaminant distribution between reaches; and
- institutional boundaries in order to define what is leaving Laboratory property.

Each selected canyon reach will be chosen to address particular issues regarding potential contamination in individual canyons. The set of reaches is intended to represent key aspects of the entire canyon system.

5.6.2 Field Surveys and Mapping of the Canyon Reaches

Initial stages of each canyon or canyon aggregate investigation may include land, geomorphic, and field contaminant screening (e.g., radiological) surveys. The objective of these surveys is to produce detailed, accurate maps of each reach that will indicate the location, extent, and nature of geomorphic and contaminated features. In particular, the correlation between geomorphic and contaminated features, suggested by the conceptual model, will be critically examined by overlaying the results of the geomorphic and field screening surveys. If necessary, geomorphic mapping may be refined on the basis of the field contaminant measurements and may also be refined later based on analytical data.

Geomorphic and field contaminant surveys will be carried out concurrently within each canyon reach, and will involve field geologists and field-measurement specialists. Field contaminant surveys will include use of radiological instruments in canyons known to contain radioactive contaminants, and may also include use of other field measurement instruments in canyons with little or no known radioactive contaminants (e.g., laser-induced breakdown spectroscopy to detect barium contamination). In addition to measuring gross radiation, field x- and gamma-radiation spectroscopy may be used to allow specialists to gather more detailed information about contaminant distributions. These field instruments may provide data of high quality faster than the radiochemical analysis of discrete sediment samples. It is anticipated that increasing the amount and quality of data collected in the field will reduce the number of sediment samples required for chemical analysis. With detailed, accurate maps of each canyon reach, sediment samples can be collected at optimum locations to determine the nature and extent of contamination.

The general approach to land, geomorphic, and contaminant survey tasks are discussed in the following sections. Detailed approaches in each canyon or canyon aggregate will be discussed in the SAPs for investigation.

5.6.2.1 Land Survey

The canyon reaches will be surveyed according to the ER Project standard operating procedure (SOP) LANL-ER-SOP-03.01,R1, “Land Surveying Procedures” (LANL 1991, 21556), to establish the boundaries of the reach and to allow accurate mapping of the field radiological data and the sample locations. Where access to sites outside the Laboratory boundary is required, access agreements will be obtained according to LANL-ER-AP-03.4, “Obtaining Access Agreements for Non-DOE Property” (LANL 1995, 49708). Survey measurements will use the New Mexico state plane coordinate system. All survey data will be submitted to the FIMAD.

5.6.2.2 Geomorphic Survey

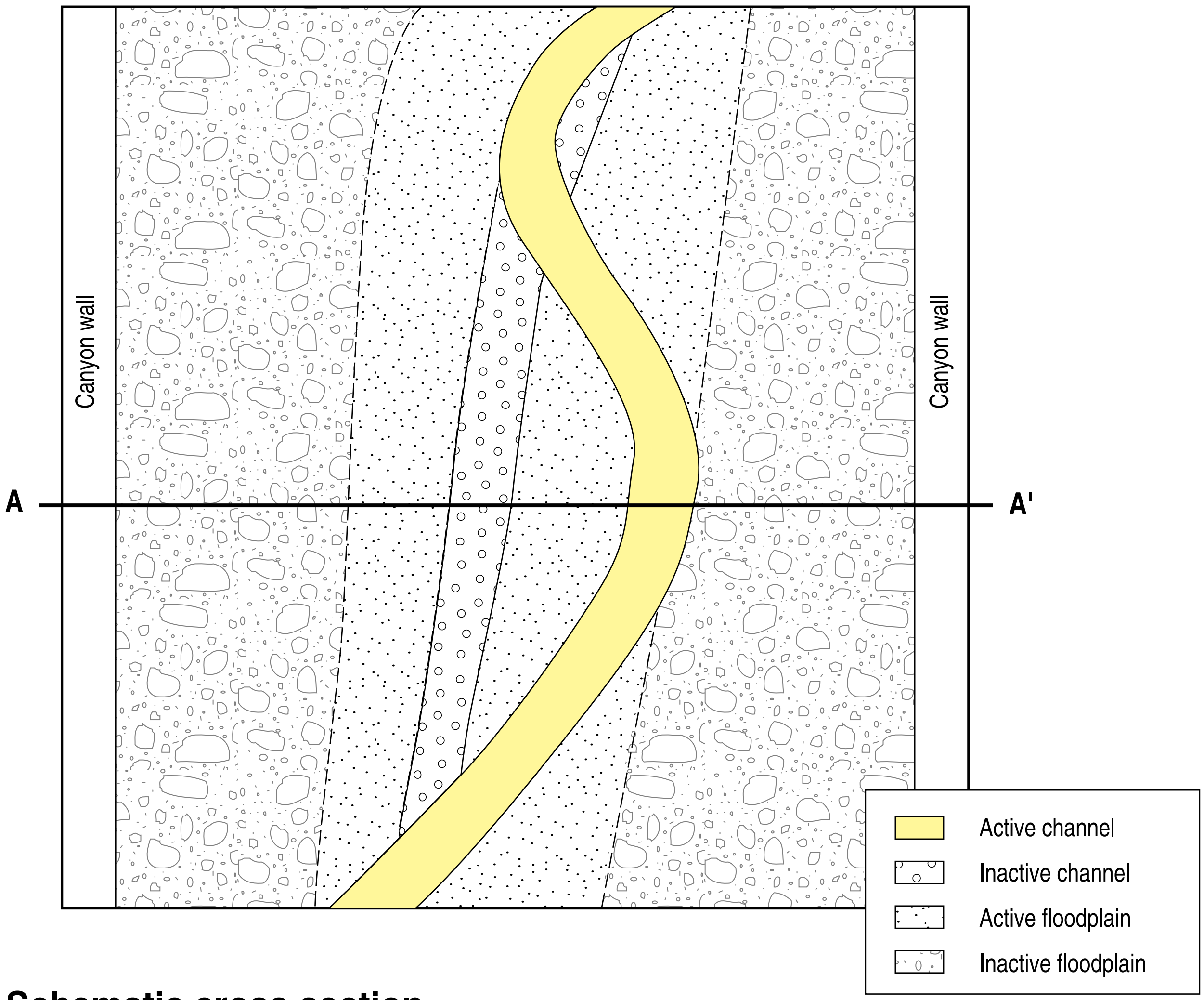
Each canyon reach will be investigated according to LANL-ER-SOP-03.08, “Geomorphic Characterization (LANL 1991, 21556).” Field activities will be documented according to LANL-ER-SOP-03.12, “Field and Laboratory Notebook Documentation for ER Earth Sciences Studies” (LANL 1991, 21556). Geomorphic characterization activities focus on identifying, describing, and mapping surface deposits and land forms that provide evidence for processes that can result in storage and/or transport of contaminants. In particular, the survey will focus on identifying young, potentially contaminated sediment deposits. The identifying and mapping of the geomorphic units will be carried out by a geomorphologist, as designated by the technical team.

The geomorphic survey of each canyon reach will be guided by the conceptual model of the significant geomorphic features illustrated in Figure 5-2. It is anticipated that at least four geomorphic units will be identified for each reach: the active channel, inactive channels, active (post-1942 deposition) floodplains, and inactive (pre-1943) floodplains. Laboratory-derived contaminants are expected to occur in the active and inactive channels, and in the active floodplains but not in the inactive floodplain, which is defined for purposes of these investigations as that portion of the canyon floor that was last inundated by floodwaters before 1943. The latter includes a variety of geomorphic units such as terraces, fans, and colluvial deposits.

Further subdivision of geomorphic units may be required for the more complex canyon reaches. For example, several levels of inactive channel deposits and floodplains may occur within a reach and the boundary between units may not be distinct.

The following is a description of the three major geomorphic units that are considered the most likely to contain contaminants if any are present in the particular canyon being investigated.

Schematic geomorphic map



Schematic cross section

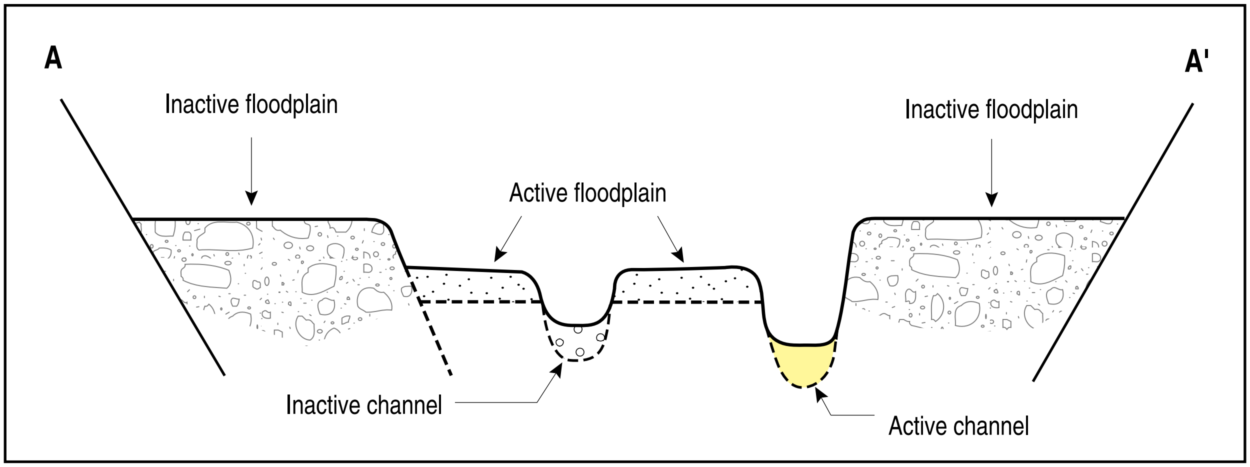


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Figure 5-2. Schematic map and cross section of canyon floor showing general geomorphic units.

5.6.2.2.1 Active Channels

Active channel sediments are dominated by coarse sand and gravel. Because heavy metals and radionuclides discharged from the Laboratory in liquid effluent preferentially adsorb to finer-grained sediment particles, it is expected that the active channels generally would contain the lowest concentrations of contaminants. In some cases, however, such as locations where fragments of shrapnel or depleted uranium are (or have been) dispersed from firing sites, higher concentrations of contaminants as larger, heavy particles may be present in active channel deposits. The sediments in the active channels are the most likely to be transported downstream, both by the relatively frequent low-magnitude floods and by occasional large floods in the canyons.

5.6.2.2.2 Inactive Channels

The inactive channels contain a combination of coarse channel sediment (deposited when the channels were active), and fine sediment (deposited by overbank floodwater after the channel became inactive). Contaminant concentrations are expected to vary, depending both on the particle size and the age of the deposit, as contaminant input will have varied over time. Sedimentologically, and in terms of contaminant concentrations, the upper layers on inactive channels may be equivalent to post-1942 layers on active floodplains. Available data suggest that inactive channel deposits in some canyons may contain large amounts of contaminants that are available for movement farther downstream either by large floods or by lateral erosion of the active channel during smaller floods. The estimation of approximate ages of inactive channel units may be possible by examining historic aerial photographs, ages of trees growing on or buried by these deposits, and other methods.

5.6.2.2.3 Active Floodplains

The active floodplains are the sites of post-1942 sediment deposition by overbank floodwaters. The sediment deposits consist of fine-grained particles deposited from the suspended load of floodwaters (generally fine sand, silt, and clay) in addition to buried coarse-grained sediment. Because heavy metals and radionuclides discharged in liquid effluent preferentially adsorb onto the fine-grained sediment, it is expected that the contaminant concentrations would be highest in sediments within the active floodplains in canyons where liquid discharges were released. The contaminant concentrations are expected to vary with the age of the deposit. The post-1942 overbank deposits may be relatively thin but widely distributed away from active channels. The sediment in the floodplains may have the longest residence times in the canyons because it probably moves little until mobilized by lateral erosion of the stream bank during large flood events or by direct scour from exceptionally deep and high-magnitude floods.

Identifying the pre-1943 and post-1942 floodplains is necessary to focus the geomorphic and contaminant surveys within the general boundaries of each reach. Boundaries of geomorphic units are commonly marked by distinct topographic breaks, although in places such boundaries may be gradational and more difficult to delineate. Direct visual observation of partially buried objects and debris, especially those that can be linked to Laboratory activities, provide conclusive evidence of post-1942 deposition events and, therefore, the general age of some geomorphic units. Further evidence for the age of geomorphic units can be obtained by observing the nature and age of vegetation in different areas of the reach, such as whether the bases of trees are buried by sediment. Flood debris, such as driftwood, may provide additional evidence of the extent of historic flooding and the distribution of historic overbank sediment deposition. One goal of the contaminant survey will be to verify the boundaries of pre-1943 and post-1942 sediment deposition. The geomorphic survey will provide the information necessary to guide the contaminant survey, discussed in the following section, and the contaminant survey will be used to refine the geomorphic mapping, if needed.

5.6.2.3 Contaminant Survey

Field radiological surveys will be used where appropriate to identify the distribution of radiological contaminants. Other types of field measurements may also be conducted and may become routine as experience with those techniques is gained in the course of the canyons investigations. The techniques of the radiological surveys are well-enough established to discuss here. Other types of field measurements used in canyons investigations will be described in the canyon- or canyon aggregate-specific SAPs.

The objectives of the radiological survey are to

- provide information about the surface distribution of radiological contaminants across geomorphic units,
- provide information about the heterogeneity of contaminant distribution within geomorphic units,
- identify areas or spots where surface radioactivity exceeds background levels by a statistically significant amount and which may be candidates for detailed investigation, and
- provide information about subsurface (depths greater than one to two cm) deposits of contaminated sediments.

The first iterations of the radiological surveys may use any combination of nonintrusive surface measurements of gross-alpha, -beta, -gamma, and x-radiation without isotope-specific determination. The gross radiation survey techniques provide information about radioactivity originating from the surface of the sediment layer (for alpha radiation) or from variable thicknesses of the uppermost sediments (for gamma and beta radiation). Subsequent iterations may use intrusive subsurface measurements of gross-beta and -gamma radiation.

The radiological survey is designed to provide a large set of data for each of the geomorphic units identified by the geomorphic survey. The spacing between stationary measurement points will be varied based on the size and relative location of the geomorphic units investigated. The measurement point spacing may decrease as the boundaries between geomorphic features or deposition zones are encountered and at observed radiological anomalies. Discrete geomorphic features identified as potential deposition zones for contaminated sediments will be surveyed in more detail to provide information about contaminant distributions. The number of measurement points will depend on the size of the deposition zone, but at least three independent measurements will be obtained for a discrete feature.

Radiological anomalies may be candidates for further investigation using spectroscopic detectors. The number of measurements will be decided with the assistance of the team statistician so that a representative set of measurements is made within each canyon reach. Spectroscopic measurements may also be performed in geomorphic features identified as pre-1943 deposition zones for the purposes of comparing and establishing a local radiological background.

To determine whether contaminants are present at subsurface depths and to evaluate possible variations in contaminant concentrations between sediment layers, the vertical faces of bank cuts along active and inactive channels will also be surveyed for alpha, beta, and/or gamma radioactivity.

An important consideration in designing the field radiological measurements is an appropriate definition of the “background” radioactivity to be used as a decision level for comparison to field measurements. The decision level is often defined as the mean background value plus twice the standard deviation of the mean. Major contributions to the background count rate are emissions from naturally occurring radioactive material, cosmic rays, and electronic noise. The background level of radioactivity is expected to be different for each canyon reach, depending on the geology of the reach. The background count rate for a detector is usually determined by counting an area known to be uncontaminated and located as close to the sampling area as possible. If an estimation of local background is also of interest, the site can be surveyed and a local background count rate determined by developing a statistical trend among the lowest measurements.

5.6.3 Sampling Design

In general, the sediment SAP for each canyon or canyon aggregate may include all or part of four sampling tasks.

1. Background sample collection.

   Purpose: prepare the data set of background constituent concentrations in sediments. This step may not be necessary in future investigations if existing background data are judged to be adequate.

2. Sample collection for “full-suite” analysis.

   Purpose: analyze for the full suite of potential contaminants (organic, inorganic, and radioactive constituents) to define a limited suite of COPCs for further sediment investigations and define key contaminants for health and transport issues using risk and uncertainty analyses.

3. Sample collection for “key contaminant” analysis. (Key contaminants are those that are most important for risk assessments, or contaminants that can be measured relatively inexpensively and have been shown to be collocated with other COPCs.)

   Purpose: test hypotheses concerning spatial distributions of contaminants, sediment transport mechanisms, and assessments of future risk potential.

4. Sample collection for “limited-suite” analysis.

   Purpose: analyze for the limited suite of COPCs to refine uncertainties in the present-day human health risk assessment.

The sampling strategy for any subsequent sampling tasks will be decided based on the data collected in the initial field surveys and sampling together with analyses of that data using methods discussed in Section 6.2 and Section 6.4.1 of Chapter 6 of this core document. Requirements for additional data will be developed based on the recommendations of the technical team and through frequent dialogue with the regulators. Subsequent sampling may also address particular stakeholder concerns which may arise based on data collected early in the investigation.

5.6.3.1 Background Sample Collection

Background sediment studies already have been conducted in Los Alamos Canyon, Pueblo Canyon, Ancho Canyon, Indio Canyon, and Guaje Canyon in areas upstream of known Laboratory source areas or in pre-1943 sediments in downstream areas. The background samples from Los Alamos Canyon, Pueblo Canyon, and Guaje Canyon were analyzed for a full suite of potential contaminants to establish background levels for all, and to identify contaminants from other sources not related to the Laboratory (e.g., Los Alamos townsite-derived contaminants in some canyons). The Ancho Canyon and Indio Canyon samples were analyzed for metals. Statistical analyses of data from these completed investigations indicate that these data are probably sufficient to establish background concentrations for the remaining canyons.

5.6.3.2 Sample Collection for Full-Suite Analysis

Sediment samples will be collected in the initial sampling task and analyzed for a full suite of potential contaminants to define the limited suite of COPCs, as defined in Section 5.3.4, for subsequent sampling and analysis tasks. The results of the full-suite analyses will also be used to evaluate the comparability and representativeness of data collected in previous investigations. Full analytical suites for organic, inorganic, and radioactive constituents will be defined in the SAPs for the specific canyons and canyon aggregates. It is expected that full-suite sampling will be conducted only in some of the reaches in each canyon system, including reaches closest to contaminant sources and reaches at institutional boundaries.

In general, samples will be collected at locations where the highest radioactivity (or contamination) is measured in the contamination survey. If numerous locations with elevated levels of contamination are found in a reach, the technical team may decide to increase the number of samples collected for full-suite analysis to adequately characterize the nature of contamination. Samples will also be collected at locations where radioactivity is at background levels to assess whether radiological and nonradiological contaminants are collocated. If no radiation above background level is detected using field instruments, sample locations will be determined based on the geomorphic survey and professional judgment.

5.6.3.3 Sample Collection for Key Contaminant Analysis

Additional sediment samples may be collected to provide information about the distribution of contaminants to address hypotheses related to sediment transport mechanisms and to refine the conceptual model. Because of the prohibitive cost of full-suite analysis, it is proposed to focus the analyses on certain “key” contaminants to obtain data for a large number of samples at a reasonable cost.

The key contaminants will be selected according to the following criteria:

- any contaminant which is present at levels such that it may contribute significantly to the present-day human health or ecological risk and/or
- any contaminant for which a correlation with the concentration or behavior of other contaminants can be established and which can be quickly and inexpensively analyzed.

When present as a contaminant, plutonium is a candidate under the first criterion. A large volume of data collected to determine the present-day distribution of plutonium in the canyon systems will increase confidence in both the present-day risk and the future assessments. Under the second criterion, radionuclides such as ^{137}Cs or ^{90}Sr may be likely candidates. Cesium behaves similarly to other constituents, such as plutonium and heavy metals. A strong correlation between the concentrations of ^{137}Cs and plutonium has been noted previously in Mortandad Canyon and DP Canyon (Nyhan et al. 1982, 7164). Strontium, which usually exists as Sr^{2+} in aqueous solution, may be an analog for uranium (as the uranyl ion, UO_2^{2+}), because the two species have similar geochemical traits and are more mobile in aqueous environments than ^{137}Cs. Key contaminant concentrations will be measured in samples from particular geomorphic units, different sediment strata, and sedimentary deposits of different ages. The data will be used to

- refine estimates of distribution and variability in a rapid and cost-effective manner,
- verify the boundaries between pre-1943 and post-1942 sedimentary deposits,
- test hypotheses about contaminant transport and thereby evaluate and refine the conceptual model,
- verify any previous estimates of the contaminant inventory, and
- assess projected impacts of Laboratory-derived contaminants on off-site areas and the Rio Grande.

The location of additional sediment samples will be determined by the iterative process, described in Sections 6.2 and 6.4.1 of Chapter 6 of this core document, of testing data and defining additional sampling locations to reduce uncertainty in the spatial distributions of COPC concentrations, and on the basis of the contaminant and geomorphic surveys within each reach.

5.6.3.4 Sample Collection for Limited-Suite Analysis

Sediment samples for limited-suite analysis (for the COPCs at a minimum) will be collected to provide data for the present-day human health risk assessment and to provide additional definitions of contaminant distribution in each potentially contaminated geomorphic unit present in a reach. The specific sample locations will be identified on the basis of the geomorphic characterization and the contaminant survey measurements, according to the following criteria.

- Samples will be collected from each of three potentially contaminated geomorphic units in a reach: the active channel, the inactive channel, and the active floodplain.
- Within each potentially contaminated geomorphic unit, samples will be collected from locations at which the highest contaminant levels were measured in the contaminant survey (which may include some locations from which the samples for full-suite analysis were collected).
- Within each potentially contaminated geomorphic unit, samples will be collected from locations selected to include both the range of radioactivity and representative values.
- If no radiation above background level is detected using field instruments, sample locations will be selected to incorporate the range of physical variability observed in the geomorphic units.

- If the geomorphic complexity of the reach warrants subdivision of a geomorphic unit to a more detailed level of identification, samples may be collected from each additional geomorphic subunit.

5.7 General Technical Approach for Groundwater Investigations

Canyons groundwater investigations are integrated with the Laboratory's Hydrogeologic Workplan (LANL 1996, 55430) that was developed for the Groundwater Protection Management Program Plan (LANL 1995, 50124). The technical approach to the canyons groundwater investigation is the same as that described in the Hydrogeologic Workplan (see that document for a more thorough discussion of the nature and scope of the proposed groundwater investigations). The general approach described in the Hydrogeologic Workplan is in accordance with the overall technical approach described in Section 5.1 through Section 5.5 of this core document.

The general SAPs, well construction details, geophysical tests, and other interpretive activities are described in Section 4.1 of the Hydrogeologic Workplan. Because contaminant and hydrogeologic issues vary from canyon to canyon, individual SAPs will contain more specific information about hydrogeologic and water quality testing to be done in each canyon system.

5.7.1 Relation of Canyons Groundwater Investigations to Hydrogeologic Workplan

The Hydrogeologic Workplan (LANL 1996, 55430) describes proposed activities to characterize the hydrogeologic setting beneath the Laboratory and to enhance the Laboratory's groundwater monitoring program. The Hydrogeologic Workplan represents an integration of Laboratory projects and activities to ensure appropriate groundwater monitoring and enhanced groundwater protection.

The scope of the Hydrogeologic Workplan relies heavily on the performance of activities by the ER Project and the Nuclear Weapons Technology (NWT) Program's Monitoring Well Installation Project. The ER Project's role in the Hydrogeologic Workplan is driven by its responsibility for characterizing, assessing, decontaminating, decommissioning, and remediating sites at the Laboratory in accordance with the requirements of the HSWA Module. The objective of the NWT Monitoring Well Installation Project is to support the programmatic missions of the Laboratory and DOE by providing the Laboratory with a comprehensive groundwater characterization and monitoring network that enables groundwater protection and regulatory compliance. Both projects will provide significant characterization, assessment, and monitoring data that will be used to meet the objectives of the Hydrogeologic Workplan.

5.7.2 Evaluation of Existing Information and Modeling

The work described in the Hydrogeologic Workplan (LANL 1996, 55430) follows an iterative approach to characterizing the hydrogeologic setting and contaminants beneath the Laboratory. As discussed in Section 3 of the Hydrogeologic Workplan, the foundation for the iterative approach will be the use of a database to store and manipulate existing and newly collected hydrogeologic data and the use of modeling techniques to enhance the conceptual model of the hydrogeologic setting. New data and information will allow refinement of the conceptual model and will facilitate an iterative reassessment of DQOs for all activities.

5.7.3. Installation of Characterization Wells

The Hydrogeologic Workplan (LANL 1996, 55430) also proposes the installation of new wells to provide contaminant characterization, hydrogeologic characterization, and potential monitoring. The DQO process was used to determine the prospective number, location, and construction details of these wells.

The proposed wells include 51 alluvial wells, 32 regional aquifer wells, and 1 intermediate perched zone well. (Extensive hydrogeologic characterization information will be collected in any intermediate perched zone encountered during advancement of the regional aquifer well boreholes.) The ER Project is responsible for installing all the alluvial wells, 16 regional aquifer wells, and the 1 intermediate perched zone well. Field Unit 4 is responsible for installing all the ER Project wells except for 2 of the regional aquifer wells. Some of the alluvial wells and the intermediate perched zone well have been installed as part of the implementation of the Los Alamos Canyon and Pueblo Canyon investigations (LANL 1995, 50290).

The descriptions of the wells are summarized in Section 4 of the Hydrogeologic Workplan by “aggregates,” each representing a collection of technical areas, watershed(s), and potential contaminant sources (see Figure 1.3 and Appendix 6 in the Hydrogeologic Workplan). The boundaries for the aggregates were drawn to focus attention on specific areas of the Laboratory that collectively contain numerous sources of potential contamination. Wells to be installed by Field Unit 4 are located in canyons within or adjacent to these aggregates.

The locations of the proposed wells are shown in Figure 5-3 and Figure 5-4, which are reproduced from the Hydrogeologic Workplan. Table 5-2 lists the organization (ER or NWT) responsible for installing each of the regional wells. Although ER and NWT are sharing the responsibilities and costs for installing the new wells, the water quality, geologic, geochemical, and hydrogeologic data will be collected using procedures that satisfy all ER Project requirements.

Each of the 32 regional aquifer wells were scored using a set of criteria (see Appendix 5 of the Hydrogeologic Workplan) to assess the optimum sequence of installation. As new data become available and are evaluated, the sequence of installation can be revised by consulting with DOE and regulatory agencies as discussed further below.

5.7.4 Well Types

The DQO process outlined in the Hydrogeologic Workplan (LANL 1996, 55430) identified data needs and data collection designs where the data collection specified the use of a well. Five different categories of wells were identified to meet the data collection requirements: alluvial; intermediate perched zone; and three types of regional aquifer wells differentiated by depth and commensurate borehole dimensions, amount of core collected, and well completion details. The boreholes for all three types of regional aquifer wells will be used to collect information on intermediate perched zones, perching horizons, and the hydrogeology beneath perched zone(s) that may be encountered in advancement.

5.7.4.1 Type 1 Wells

Type 1 wells are the alluvial wells that will be installed by Field Unit 4. The following borehole advancement and installation specifications apply to these wells. Figure 5-5 is a prototype drawing of the borehole and well.

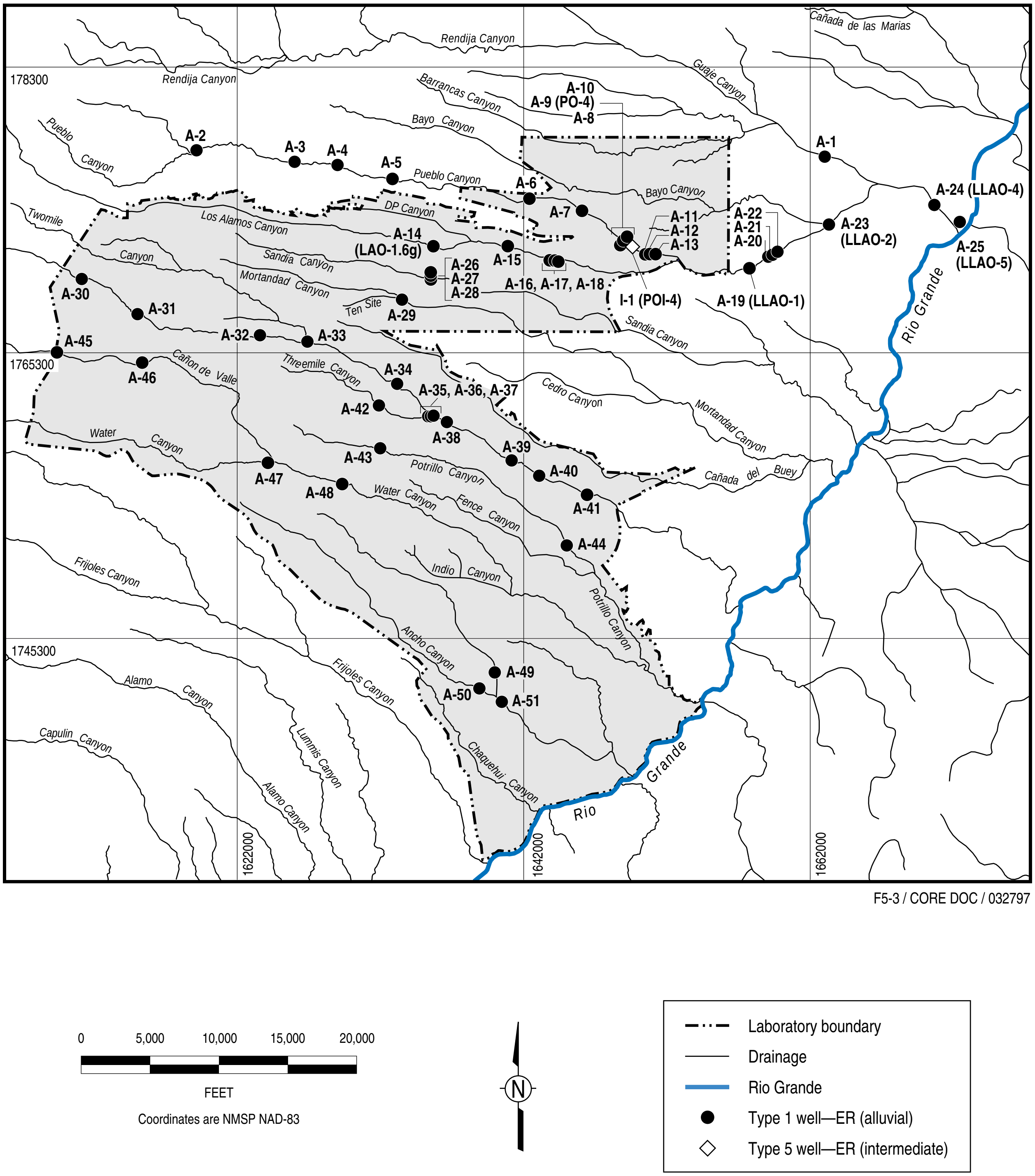

Figure 5-3. Proposed locations of alluvial and intermediate perched zone wells.

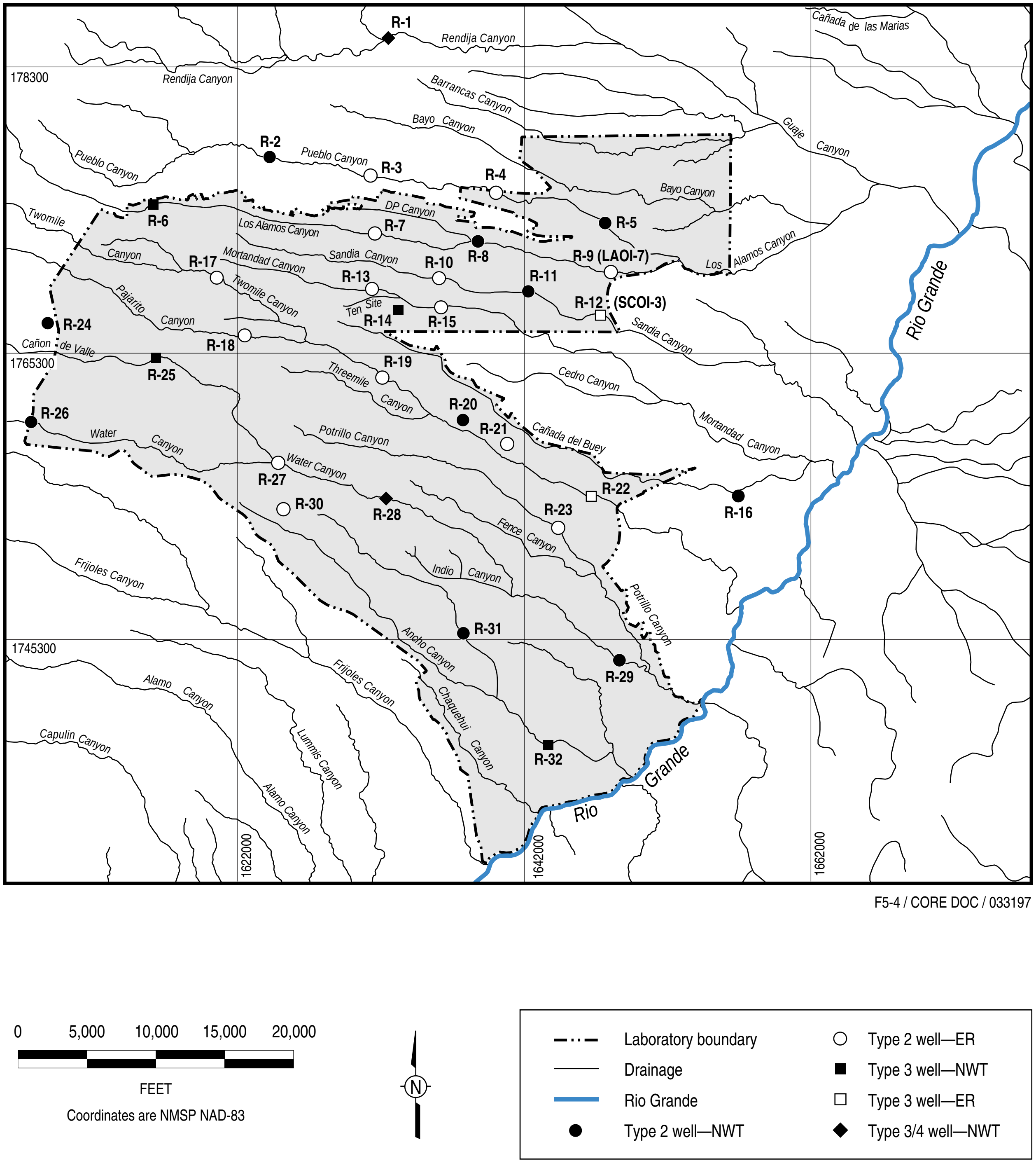

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Figure 5-4. Proposed locations of regional aquifer wells.

TABLE 5-2

INSTALLATION SEQUENCE FOR PROPOSED WELLS[a]

Borehole	Year	Funding Program[b]	Timing Score	Location
R-25	FY99	DP	20	Cañon de Valle near MDA-P
R-12	FY98	ER	20	Sandia Canyon at eastern boundary of Laboratory
R-5	FY99	DP	19	Pueblo Canyon near water supply well Otowi-1
R-31	FY99	DP	18	Ancho Canyon downgradient of Aggregate 6
R-28	FY99	DP	18	Water Canyon near WCO-1
R-7	FY98	ER	18	Los Alamos Canyon south of TA-21
R-32	FY00	DP	18	Ancho Canyon near Ancho Spring
R-22	FY98	ER	18	Pajarito Canyon at eastern boundary of Laboratory
R-2	FY00	DP	17	Pueblo Canyon near TW-4
R-18	FY99	ER	17	Pajarito Canyon above Twomile Canyon confluence
R-1	FY00	DP	15	Rendija Canyon north of Los Alamos townsite
R-9	FY97	ER	15	Los Alamos Canyon at eastern boundary of Laboratory
R-3	FY99	ER	15	Pueblo Canyon between TW-2/2A and TW-4
R-15	FY00	ER	15	Mortandad Canyon near sediment traps
R-27	FY00	ER	15	Water Canyon and Cañon de Valle confluence
R-8	FY00	DP	13	Los Alamos Canyon near water supply well Otowi-4
R-10	FY00	ER	13	Sandia Canyon south of TA-21
R-4	FY01	ER	13	Pueblo Canyon between TW-2/2A and Los Alamos County sewage treatment plant
R-20	FY01	DP	13	Pajarito Canyon near water supply well PM-2
R-14	FY01	DP	13	Mesa-top well between Mortandad Canyon and water supply well PM-5
R-13	FY01	ER	13	Mortandad Canyon downgradient of TA-50 outfall
R-19	FY01	ER	13	Pajarito Canyon upgradient of TA-18
R-17	FY02	ER	13	Twomile Canyon
R-6	FY01	DP	12	Los Alamos Canyon at western boundary of Laboratory
R-11	FY01	DP	12	Sandia Canyon near water supply well PM-3
R-23	FY02	ER	12	Potrillo Canyon at hydrologic sink
R-29	FY02	DP	11	Water Canyon near eastern boundary of Laboratory
R-24	FY02	DP	11	Mesa top west of TA-16 between Cañon de Valle and Pajarito Canyon
R-26	FY02	DP	11	Water Canyon at western boundary of Laboratory
R-16	FY02	DP	11	Cañada del Buey on the east side of White Rock
R-21	FY02	ER	11	Mesita del Buey at TA-54, MDA-L
R-30	FY02	ER	10	Frijoles Mesa at TA-49

a. Modified from Table 4-2 of the Hydrogeologic Workplan (LANL 1996, 55430) to show a FY97 start date for well R-9 (formerly LAOI-7) in Los Alamos Canyon.

b. DP = Nuclear Weapons Technology Programs

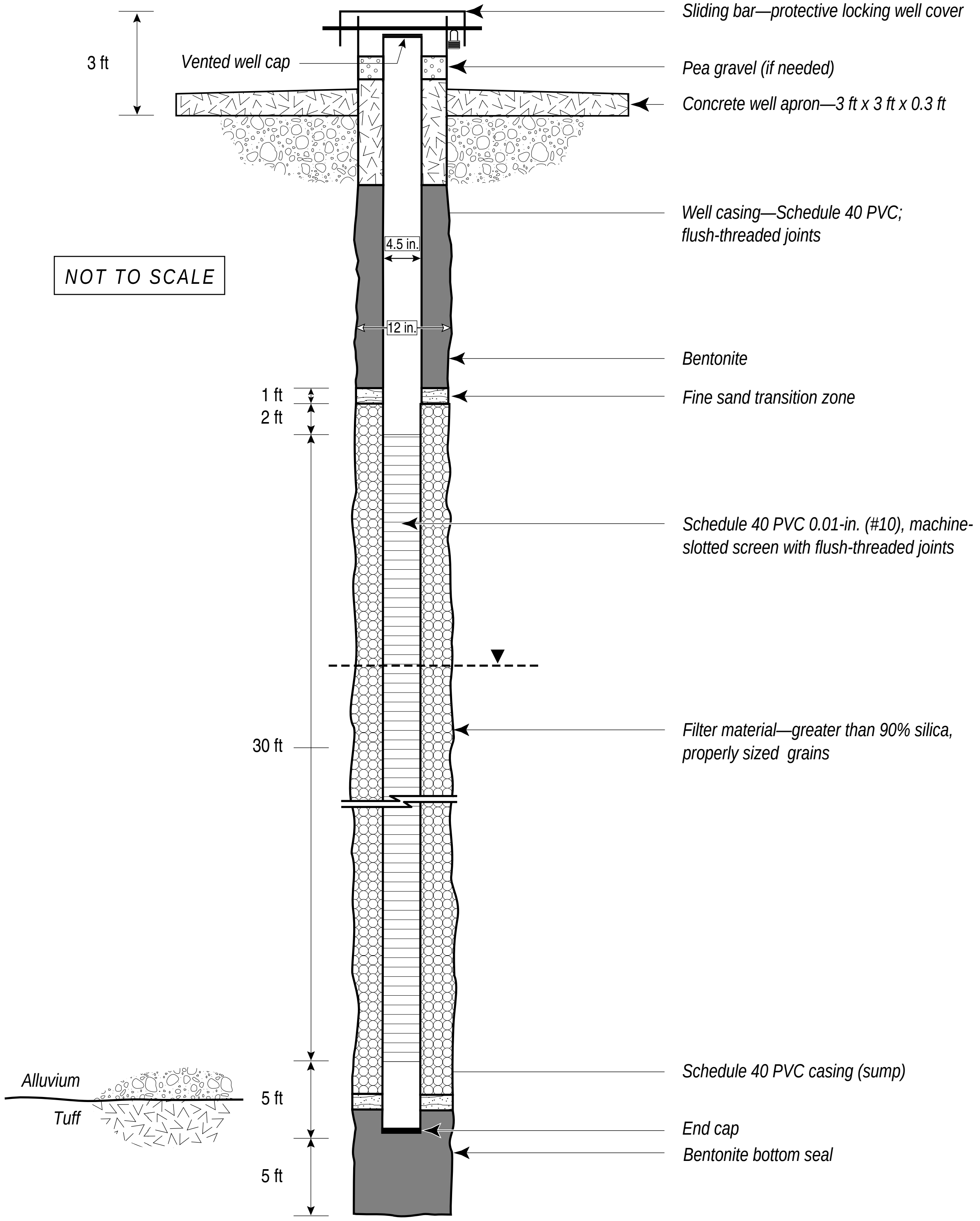

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Figure 5-5. Type 1 (alluvial) well design.

Borehole advancement and well installation specifications:

- Boreholes will be advanced using a hollow-stem auger through the alluvium to a depth 5 ft into the underlying competent layer (e.g., tuff).
- Borehole advancement strategy includes (1) drill through the alluvium into tuff with a 4.25-in. inner diameter (ID) (6.625-in. outer diameter [OD]) hollow-stem auger, (2) obtain a 5-ft core at the tuff interface, and (3) over-ream pilot hole with a 6.625-in. ID (10.75-in. OD) hollow-stem auger creating a 12-in. borehole.
- No core will be collected in the alluvium (unless specifically identified as a data need in the SAP), but approximately 5 ft of core will be collected in the competent layer. A log will be prepared based on borehole cuttings.
- The well casing and screen will consist of Schedule 40 polyvinyl chloride (PVC) pipe with a 4-in. ID (4.5-in. OD). Install a 4-in. PVC pipe inside the hollow stem with nominally a 30-ft screen (0.010-in. [#10] machine-slotted, flush threads) and a 5-ft blank casing sediment sump (bottom capped with a 0.625-in. weep hole drilled in the cap). Complete the installation with filter material to form a ≥3-in. filter pack. Anticipated water level fluctuations will be considered in the design of the wells, and screen lengths will be proposed on a well-by-well basis.
- A steel protective cover extending above ground level will be installed over the well casing. A lockable protective cover extending at least 2 ft below ground surface will be cemented in place.
- The top of the well will be finished with a concrete pad 3 ft x 3 ft x 4 in. Installation of bollards will be optional (depending on location).

5.7.4.2 Type 2 Wells

Type 2 wells are regional aquifer wells completed with a single well screen. The general objective of this well type is to provide information on subsurface lithology and intermediate perched zone and regional aquifer groundwater quality. Any intermediate perched zone groundwater encountered in drilling the borehole will be sampled for analyses after resting the borehole up to 24 hours. Perched zones that contain flowing formation water encountered in borehole advancement will be isolated by a conductor casing or other appropriate technique to prevent downward migration of water during drilling and well installation. Because of the general geology, inherent drilling complexities, and currently available cost-effective installation techniques, the Laboratory will employ a variety of drilling methods including hollow-stem auger, air-rotary/Odex-Stratex, and mud-rotary drilling.

The boreholes for these wells will be drilled 500 ft into the regional aquifer, and approximately 10% of the borehole will be cored with emphasis at intermediate perched zones and geologic contacts. The cores and cuttings will be subjected to chemical analyses and physical testing, and the borehole will be subjected to a variety of geophysical tests that will be described in the canyon- or canyon aggregate-specific SAPs. The borehole will be backfilled to the upper 100 ft in the regional aquifer, and a stainless steel well screen will be set to allow sampling in the uppermost portion of the regional aquifer. The following borehole advancement and installation specifications apply to these wells. Figure 5-6 and Figure 5-7 are prototype drawings of the borehole and well.

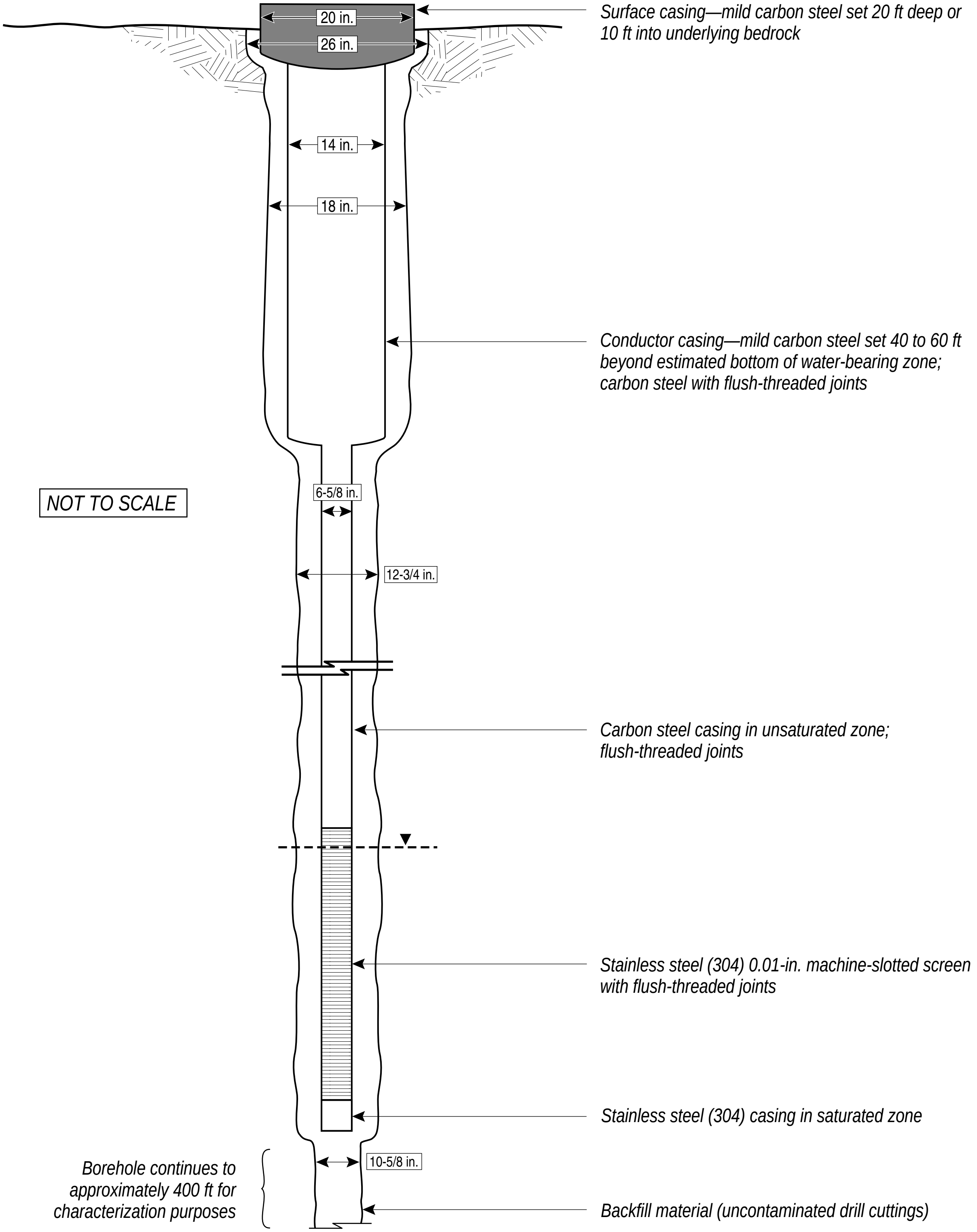

Figure 5-6. Types 2 and 3 (regional) well design.

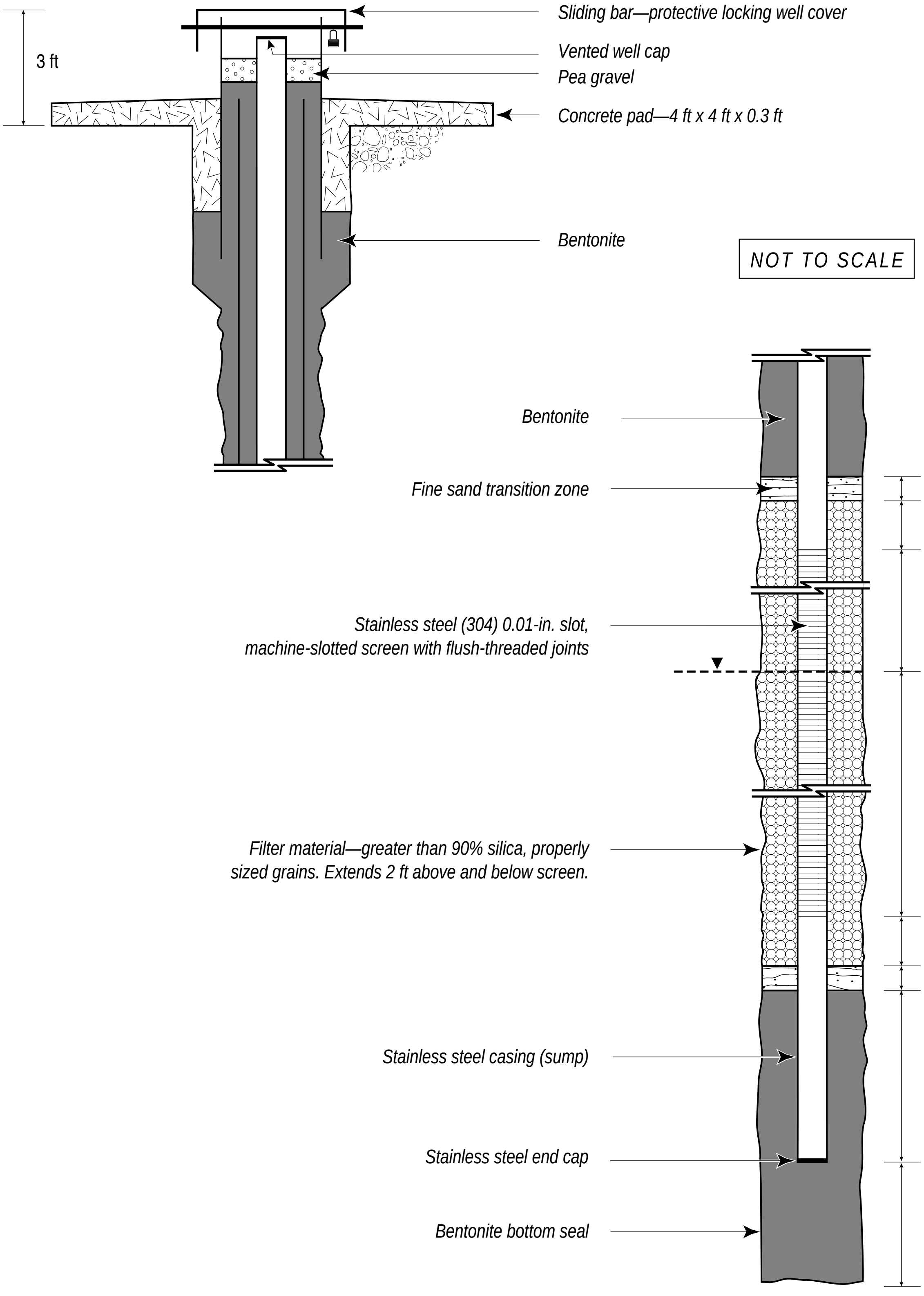

Figure 5-7. Types 2 and 3 (regional) well design detail.

Borehole advancement and well installation specifications:

- A carbon steel surface casing approximately 20 in. in diameter will be set from the ground surface to a depth of approximately 20 ft. In locations where alluvium is present, the surface casing will extend approximately 10 ft into the underlying competent layer and will be grouted in place.
- A 14-in. carbon steel conductor casing will be set to the top of the regional aquifer in accordance with the requirements of the HSWA Module. The conductor casing will prevent migration of fluids between any perched intermediate zones and the regional aquifer.
- Boreholes will be advanced with 10% core collection to a depth 500 ft into the regional aquifer and backfilled up to the upper 100 ft of the regional aquifer. A single stainless steel screen approximately 100 ft long will be set with 20 ft of screen above the water table. The screen size will be determined based on grain-size analysis and characteristics.
- The well will be constructed of 6.625-in. OD mild carbon steel casing from the ground surface to the top of the stainless steel screen. A transitional coupling will be installed between the two casing types to minimize the potential for corrosion. An annulus ≥3 in. will be provided. Approximately 10 ft of blank casing with an end cap will be set at the base of the screen. Centralizers will be used at approximately 100-ft intervals.
- All backfill material (grout, bentonite, and sand) will be tremied or pressure grouted in place.
- A lockable steel protective cover extending at least 2 ft below ground surface will be cemented in place over the well casing.
- The top of the well will be finished with a concrete pad 4 ft x 4 ft x 4 in. The wellhead will be surrounded with 8-ft chain link fencing that is 15 ft on a side and topped with barbed wire. One side will have a padlocked gate.
- A dedicated submersible pump and transducer will be installed in each well after well completion and development.

5.7.4.3 Type 3 Wells

Type 3 wells are identical to Type 2 wells except that the boreholes are continuously cored. The boreholes for these wells will provide a library of lithologic information that can be used to create stratigraphic cross sections throughout the Laboratory. These wells and boreholes are referred to as "library wells" or “library core holes.” The description and the specifications for borehole advancement and well installation listed for Type 2 wells also apply to Type 3 wells. Figure 5-5 and Figure 5-6 are prototype drawings of the borehole and well.

5.7.4.4 Type 4 Wells

Type 4 wells are similar to the Type 2 and Type 3 wells except that the boreholes will be advanced to the depth of 4,000 ft, no core will be collected, and the wells will be completed using a multiple completion system to collect zonal data from the regional aquifer at multiple depths. The ER Project does not have responsibility for installing Type 4 wells (see Section 4.1.1.4 of the Hydrogeologic Workplan [LANL 1996, 55430] for additional information about this well type).

5.7.4.5 Type 5 Wells

Type 5 wells are completed in an intermediate perched zone with a single screen similar to the Type 2 and Type 3 wells. One intermediate borehole was in progress during the preparation of the Hydrogeologic Workplan (LANL 1996, 55430), and it is included here as a separate well type for completeness. Also, additional Type 5 wells may be proposed if intermediate perched zones sampled during the drilling of the regional aquifer well boreholes indicate Laboratory contamination. Boreholes for Type 5 wells will be advanced with ≤10% core collection over the total depth of the borehole. The following borehole advancement and installation specifications apply to these wells. Figure 5-8 is a prototype drawing of the borehole and well.

Borehole advancement and well installation specifications:

- A carbon steel surface casing approximately 10.75-in. in diameter will be set from ground surface to approximately 10 ft below the alluvium/tuff interface. In locations where alluvium is not present, the surface casing will extend approximately 20 ft into the underlying competent layer. To install the surface casing, a pilot borehole will be advanced through the alluvium using a 4.25-in. ID hollow-stem auger (borehole 8.5 in.) collecting core with a split-spoon sampler. The pilot borehole will be over-reamed with a 14.25-in. ID hollow-stem auger.
- The borehole will be advanced using an air-rotary/Odex-Stratex with a 5.625-in. tri-cone roller bit, which cuts a 5.625-in. hole to point where core samples are to be taken.
- Over-ream the borehole with an 8.75-in. tri-cone bit, which enlarges the borehole to 8.75 in.
- Install Schedule 40 PVC well casing with a machine-slotted screen and a 25-ft blank casing sediment sump in the bottom.
- The screen size will be determined based on grain-size analysis and characteristics.
- All backfill material (grout, bentonite, and sand) will be tremied or pressure grouted in place.
- A lockable steel protective cover extending at least 2 ft below ground surface will be installed over the well casing.
- The top of the well will be finished with a concrete pad 4 ft x 4 ft x 4 in.
- A dedicated submersible pump and transducer will be installed in each well after well completion and development.

5.7.5 Annual Assessment of Groundwater Investigations with Regulators

Because the activities described in the Hydrogeologic Workplan (LANL 1996, 55430) follow an iterative approach, the Laboratory/DOE propose to install a number of regional aquifer wells each year, enter the hydrogeologic, geochemical, and water quality data derived from them into the database and conceptual model, and then meet jointly with the NMED to review and reassess DQOs and negotiate the scope and schedule for the next year's well installation. The installation schedules contained in the Hydrogeologic Workplan (see Figure 1-1 of that work plan) are intended to be comprehensive and to indicate a

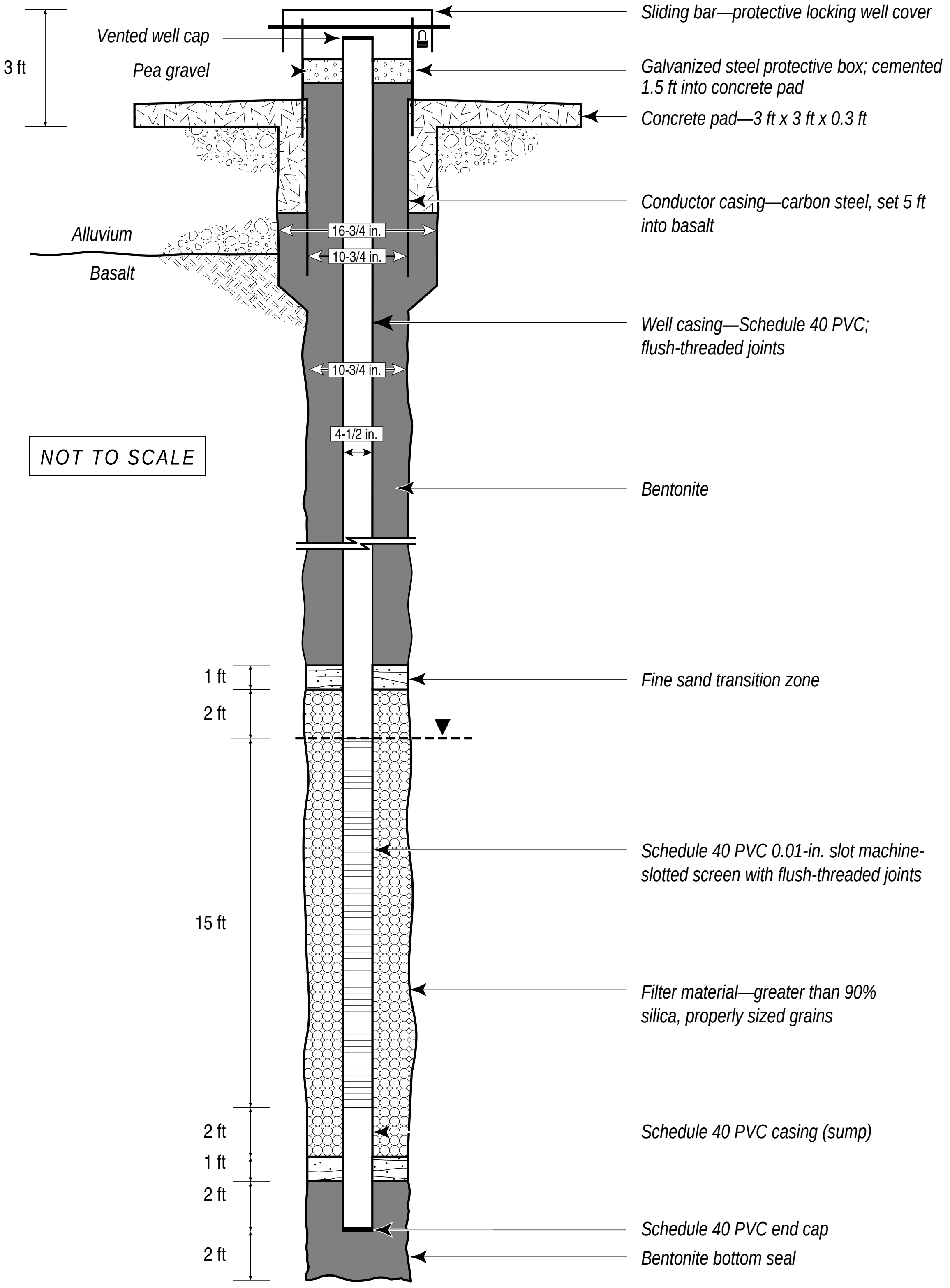

Figure 5-8. Type 5 (intermediate) well design.

prospective long-term order of well installation. However, it is technically prudent to perform the activities in an annual iterative process of data collection, review, and reassessment to take full advantage of all new information and data before locating and installing subsequent wells. This approach will ensure that characterization activities and well installation are optimized. The need for installation of subsequent wells (alluvial, intermediate perched zone, or regional aquifer wells) will always depend on data and information gained from the previously installed wells and on the interpretation of the data from those wells.

5.7.6 Expected Results of Groundwater Investigations

The expected outcomes of the activities described in the Hydrogeologic Workplan (LANL 1996, 55430) are

- refined understanding of the hydrogeologic framework at the facility, including recharge areas, hydraulic interconnections, aquifer geochemistry, flow paths, and flow rates, which are synthesized by modeling simulations;
- information sufficient either to design and implement a detection monitoring program that meets applicable requirements and/or to demonstrate that monitoring requirements can be waived; and
- defined areas of existing or potential groundwater contamination and the potential pathways of contaminant transport from the surface to the regional aquifer, with predictions of directions and rates of movement and risk based on modeling simulations.

As a result of this characterization effort, if it is determined that enhanced groundwater monitoring is necessary, an interdisciplinary Laboratory group will develop a proposed amendment to the Groundwater Monitoring Plan for submittal to the appropriate regulatory agency(ies).

5.8 General Technical Approach for Surface Water Investigations

Surface water investigations in the canyons are presently being developed as part of the Laboratory’s Watershed Management Program Plan (WMPP). The WMPP will provide a detailed framework for integrating and coordinating surface watershed activities at the Laboratory. No canyon surface water sampling is planned until the WMPP is completed.

The specific WMPP objectives are to

- integrate the activities of different Laboratory organizations to ensure a unified approach to surface water protection and to prevent duplication of effort;
- establish an information system in which all surface water-related data will be stored and which will be accessible to Laboratory organizations and stakeholders;
- address the requirements of the HSWA Module, the Clean Water Act, and other relevant federal and state environmental requirements;
- provide enhanced surface water documentation to support Laboratory-wide environmental impact statement development, as requested by the Site-Wide Environmental Impact Statement Project Office or DOE in accordance with the requirements of the National Environmental Policy Act; and
- maintain ongoing surface water protection activities and address new issues as they occur.

The WMPP will describe a program that has the following goals:

- document the surface water resource with respect to quantity and quality;
- design and implement a surface water monitoring program to support resource management concepts and comply with applicable environmental laws and regulations;
- implement a management program for surface water protection and contamination abatement, which includes specific Clean Water Act and New Mexico Water Quality Act requirements and other relevant regulatory requirements;
- summarize and identify watershed areas that may not meet New Mexico Water Quality Standards or other regulatory requirements;
- develop strategies for controlling sources of surface water contaminants and/or excessive erosion and sedimentation;
- integrate relevant aspects of Laboratory programs described in the GPMPP, the Threatened and Endangered Species Habitat Management Plan, and the Natural Resources Management Program Plan; and
- develop a watershed management work plan.

5.9 General Technical Approach for Biological Investigations

The objective of biological investigations in the canyons systems is to assess the impact of Laboratory-derived contaminants on environmental and human receptors. The objective will be achieved by examining the three components of the ecosystem summarized below.

- Ecosystem receptors (including selected species and biological communities) which are likely to be affected by Laboratory-derived contaminants will be studied. The selected species include threatened or endangered species, or surrogates for these species if examination risks further threat. The biological communities to be studied represent broad units of the ecosystem and include the aquatic, soil, plant, and animal communities.
- Wetlands, which are a critical regulated environment, will be included in the biological investigation. Wetlands are a sensitive habitat for many species, and their evaluation is integral with the aquatic community evaluation.
- The potential impact on human receptors of Laboratory-derived contaminants in plants and animals that are either part of the diet of or used in American Indian tribal ceremonies will be assessed.

5.9.1 Ecosystem Receptors

An integrated ecological risk investigation approach for the ER Project is presently under development, and it will be implemented after DOE, regulator, and stakeholder approval. The first two objectives described above will be addressed by the Laboratory-wide ecological risk investigations. The third objective will be addressed as part of canyons investigations, and the data will support human health risk for scenarios related to American Indian use. These data will also be used as a source for future site-wide ecological risk investigations. The appropriate level of detail for ecological risk assessments has not yet been determined.

Environmental sampling to evaluate exposure to ecological risk receptors will not be proposed until the assessment endpoints (see Chapter 6 of this core document for details on assessment endpoints) and their exposure units have been agreed upon with the regulators, with appropriate input from stakeholders. Negotiations are underway between the Laboratory, DOE, EPA, NMED, and the Accord Pueblos to define the assessment endpoints, exposure units, exposure models, and risk models. In addition, Laboratory personnel and subcontractors have worked and will continue to work with the Accord Pueblos to help define appropriate risk scenarios for the American Indian population in the vicinity of Los Alamos Canyon and Pueblo Canyon. When an agreement has been reached, a preliminary assessment using available data will be conducted to assess uncertainties and identify sensitive parameters in the models. The canyon- or canyon aggregate-specific SAPs will focus on collecting data for the most sensitive and uncertain parameters identified for the ecological risk assessment.

The sediment, groundwater, and surface water investigations described above will provide important data for the ecological risk assessment. For example, hydrogeologic and geomorphic units are natural sources of environmental heterogeneity within exposure units and they may form natural boundaries between some exposure units. Therefore, mapping and characterizing heterogeneous units will provide essential data to ecological exposure assessments.

5.9.2 Wetlands Investigation

Because stream flow occurs seasonally for extended periods of time, or even continuously in some canyon reaches, identifiable wetlands are present in some canyon systems. An inventory of wetlands is in preparation by the Environmental Assessments and Resource Evaluations group (ESH-20) as part of an ongoing survey of the canyons of the Pajarito Plateau. Until the wetlands have been delineated, discrete sampling in the investigations will be limited.

The biological evaluation of wetlands will be performed in collaboration with a US Fish and Wildlife Service investigation of water quality in the canyon systems of the Pajarito Plateau. Sediment and water sampling will be deferred to the Fish and Wildlife Service investigation, although sediment and surface water samples collected in the concurrent investigations described in this chapter will be used to plan future sampling efforts.

5.9.3 Biological System Contributors to Human-Health Risk

Exposure pathways for assessing human-health risk include the ingestion of fish, wildlife, native plants, and domesticated plants (see Section 6.5 in Chapter 6 of this core document). Sampling in canyons is proposed to determine the bioconcentration and potential impact of native plants, garden produce, game animals, and domestic livestock on human exposure.

American Indian populations gather wild edible plants and other plants used for ceremonial purposes. The Indian Pueblo representatives will be consulted to define significant species routinely gathered in each canyon. Because of the ceremonial significance of some of these species, sampling will be conducted by Accord Pueblo representatives. Exact sampling locations may not be disclosed. Detailed information on specific species and usage will be collected by tribal members and transmitted to the technical team in summary form to preserve cultural sensitivities.

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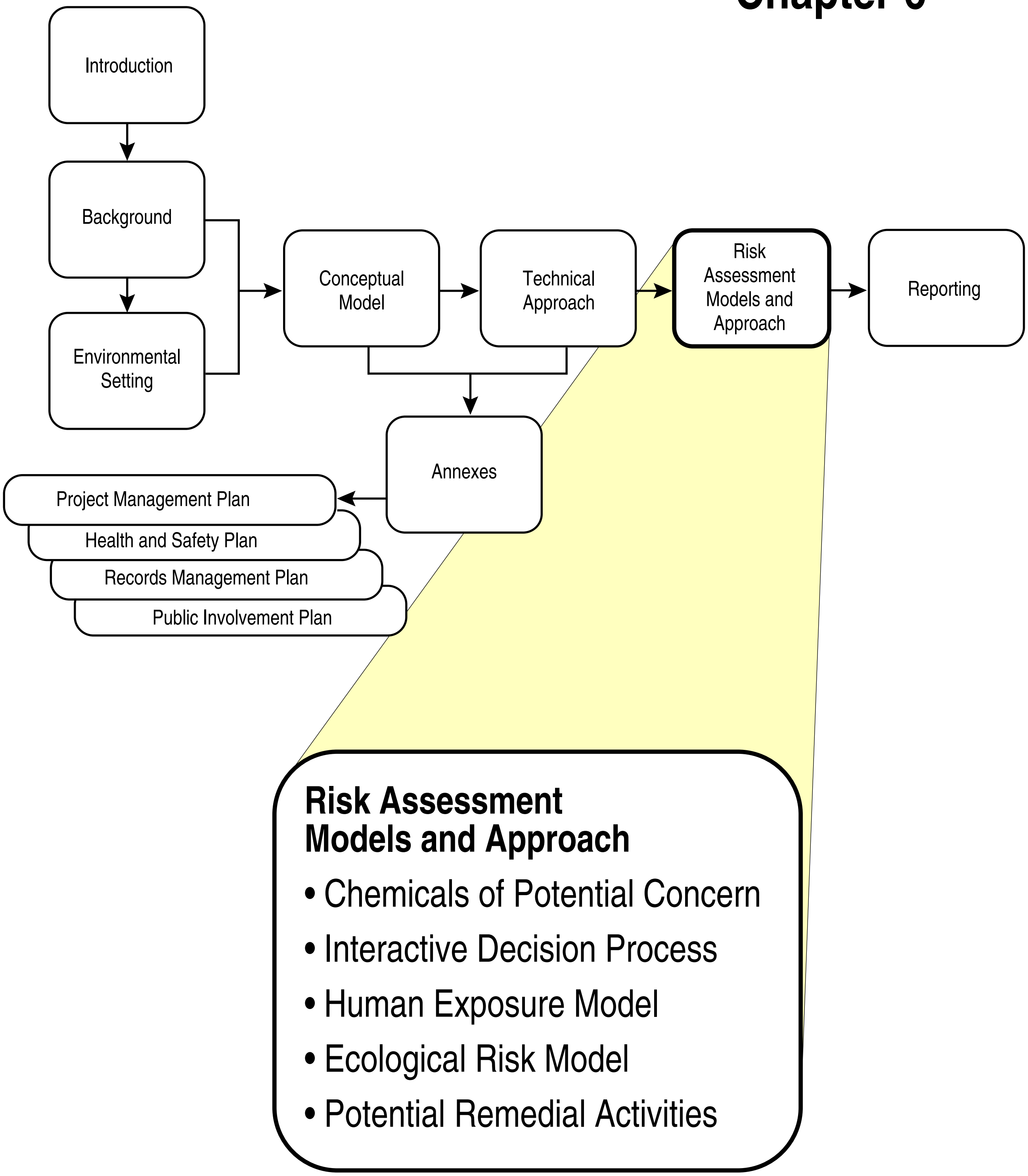
Chapter 6



Risk Assessment Models and Approach

- Chemicals of Potential Concern
- Interactive Decision Process
- Human Exposure Model
- Ecological Risk Model
- Potential Remedial Activities

6.0 RISK ASSESSMENT MODELS AND APPROACH

6.1 Introduction

This chapter presents the objectives, models, and approaches to the assessment of present-day human health and ecological risk used in the investigations to be conducted in the canyon systems.

Section 5.1.3 in Chapter 5 of this core document describes the site characterization approach to be used in these investigations. The approach attempts to take full advantage of data that are both extant and now being collected in the Environmental Restoration (ER) Project at nearby potential release sites of other operable units.

A preliminary list of potential contaminants based on a knowledge of past and present Laboratory operations and contaminant releases is included (Table 6-1) in this chapter. Those contaminants determined to be chemicals of potential concern (COPCs), as defined in Section 5.3.6 in Chapter 5 of this core document, will be retained in the analytical protocol for further investigations.

TABLE 6-1

POTENTIAL CONTAMINANTS FOR THE CANYON SYSTEMS BASED ON HISTORICAL INFORMATION

Acetone	Epoxy resins	Silver
Actinium	Ethanol	Sodium
Alcohol	Ethylene glycol	^{90}Sr
^{241}Am	Freon	^{99}Tc
Ammonium citrate (concentrated)	Fuel oil (No. 2)	Toluene
Barium	Gasoline	Trichloroethane
Benzene	High Explosives	Trichloroethylene
Beryllium	Kerosene	Tritium
Cadmium	Lead	Uranium (total)
^{137}Cs	Mercury	^{235}U
Chlorine (chloride)	Nitrates	^{238}U
Chromium (hexavalent)	Polychlorinated biphenyls	Waste oils
^{60}Co	^{238}Pu	Xylene isomers
Copper	^{239,240}Pu	
Diesel oil	Scintillation liquid	

Target human health risk values are commonly defined as an individual lifetime cancer risk greater than one in ten thousand to one in one million (10^{-4} to 10^{-6}) and a hazard index for noncarcinogens (defined as the sum of the ratios of the concentration of each contaminant to its toxicity value) of one (40 CFR 300.430[e] [2] [i] [A] [2]). The final definition of acceptable risk will be agreed upon after negotiations among the implementors (the Laboratory and the Department of Energy [DOE]), the regulators (the Environmental Protection Agency [EPA] and the New Mexico Environment Department [NMED]), Indian

Pueblos, and other stakeholders. Risk scenarios have been developed to define potential receptors and the pathways of exposure for the contaminants that may be present. An objective of this chapter is to develop those scenarios so that acceptable risk can be evaluated.

6.2 Technical Approach to Risk-Based Decision-Making

6.2.1 Overview

As described in Chapter 5 of this core document, sediment, water, and air particulate samples will be collected at selected locations in the canyon systems to provide data for the present-day human health and ecological risk assessment. Specific exposure areas for human health and ecological risk assessment have not been defined in the canyons, but are expected to range from several square feet to several square miles for different exposure pathways and scenarios. Because it is impossible to collect data at all locations where exposure is possible, a quantitative treatment of uncertainty associated with the spatial distribution of contaminants is an essential aspect of any quantitative risk assessment. Chapter 5 addresses the basic technical approach for collecting data to provide information on current contaminant distributions and concentrations in the canyons. In this section, the general methodology for using this information to quantify human health and ecological risk is presented.

The reference endpoints used to measure human health risk in the canyon systems are annual dose rate (radionuclides), lifetime incremental cancer risk (chemical carcinogens), and hazard quotient (noncarcinogens). The goal of the human health risk assessment is to determine the probability that concentrations of COPCs will result in risks exceeding target values for these endpoints in areas that could potentially correspond to exposure areas for one or more types of land use. To calculate such a probability, it is necessary to quantify the uncertainty associated with COPC distributions within the potential exposure areas. There are two major aspects of this uncertainty. The first is uncertainty associated with the spatial variability of COPCs within a defined geomorphic unit as measured by the field data. The second is uncertainty associated with the conceptual model of contaminant occurrence, transport, and exposure route (the conceptual model is discussed in Chapter 4 of this core document) (hereafter “the conceptual model”), which is the tool used for interpretation of the data.

The conceptual model contains hypotheses related to transport pathways and mechanisms of contaminant redistribution. While all of the hypotheses are expected to be tested during the canyons investigations, not all can be tested quantitatively. Those hypotheses of the conceptual model that will be quantified include: (1) that the distributions of COPCs within and among geomorphic units in a reach will show trends that can be used to minimize the number of samples collected; (2) that certain COPCs will be collocated in parts of the canyon systems and that a correlation between the concentrations can be developed and used to select sampling locations; (3) that COPC concentrations may generally decrease, but inventory may increase with distance from release sources in the upper reaches of the canyons; and (4) that variability in measured data is predictive of variability in unsampled areas. An additional parameter to be evaluated is the relation of readily-measured surface concentrations of COPCs to those at depth, which will be generally unknown at the start of the investigations.

The degree of uncertainty that is acceptable in the concentrations of COPCs is a function of the variability in concentrations, the target risk values, and the models and model parameters used to calculate risk. If preliminary remediation goals (PRGs) calculated for COPCs using the specific pathways and scenarios in Section 6.4 are either well above or well below the range of observed concentrations, a high degree of uncertainty in the variability may have a minimal impact on decision-making. For example, if the fifth and ninety-fifth percentiles of the distribution of a COPC are 0.1 and 100 ppm and, respectively, the PRG is

1,000 ppm, collecting additional data to improve confidence in the distribution may be unwarranted. Rather than attempting to specify an appropriate degree of probability in realizing a particular endpoint as the decision criterion, a cost-benefit approach to collecting additional samples will be used.

6.2.2 Uncertainty Analysis for the Distribution of Chemicals of Potential Concern

Specific methods for quantifying uncertainty in the spatial distributions of COPCs in the canyons investigations have not been finalized. The discussion here is intended to describe the general approach and techniques that will be employed.

Because exposure areas of interest differ greatly in size, data reflecting variability in distributions of a COPC must be evaluated over several spatial scales. For example, variability within and among geomorphic units is important for evaluating trends that may affect the number of samples required to achieve a given degree of certainty in the risk estimates, and variability at the high end of the observed range of the entire data set may be important to evaluate clustering of high contaminant concentrations. Figure 6-1 shows an example of the overlay of potential exposure areas associated with assessment endpoints of the American Indian exposure scenario with geomorphic units in a hypothetical canyon reach.

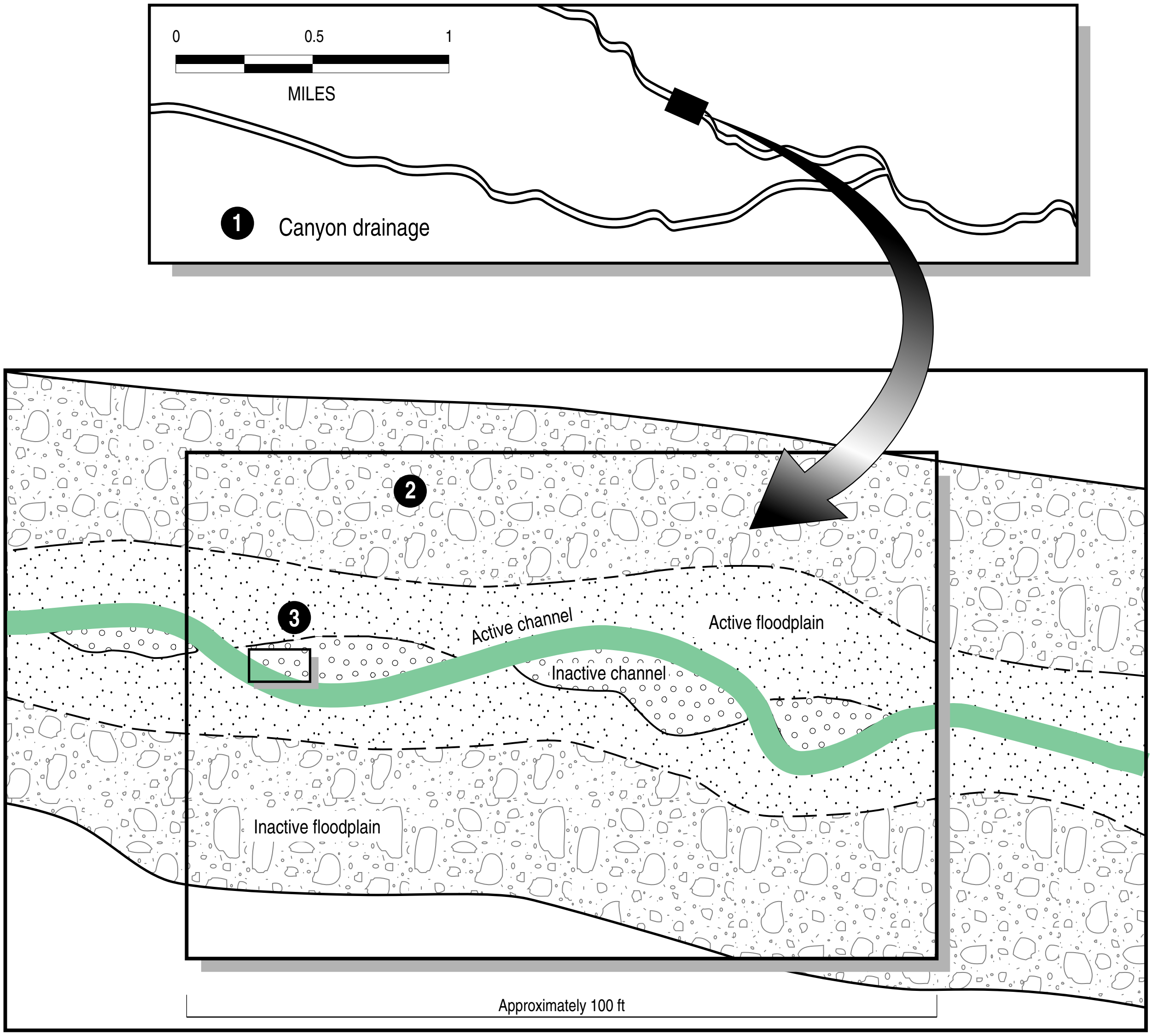
One technique for extracting the maximum amount of information regarding the spatial relationship among data points is described by Rautman (1993, 22936). The technique involves performing stochastic simulations of environmental concentrations based on limited sample data. One of the benefits of this approach is that geographic areas associated with the highest uncertainty relative to exceeding a risk level can be identified to assist in identifying locations for additional sampling and analyses. In addition, the simulations can be used to create probability maps of contaminant concentrations for similar purposes.

As additional data are collected, spatial distributions of COPCs will be revised and the ability to predict the expected value-of-information for later sampling activities will be improved. Although stochastic techniques may be employed to maximize the utility of the limited data set, the analytical data must also be used to quantify hypotheses of the conceptual model in order to develop defensible source term distributions with a limited number of samples. It is unlikely that sufficient data will be obtained to independently develop such source term distributions for every spatial scale of interest. Rather, a Bayesian statistical approach may be used with existing knowledge of contaminant distributions to create preliminary distributions that will be updated with data from additional samples. Initial hypotheses of contaminant concentration distributions can be developed from historical data and refined and validated with successive sampling.

Uncertainties associated with testing of conceptual model hypotheses, such as those identified in Section 6.2.1, may be defined individually to determine where model uncertainties are greatest. Monte Carlo methods might then be used to propagate uncertainty associated with selected tests by relating these terms in an equation whose sum is a source term for a particular exposure pathway. Additional sample collection can then be more properly focused to obtain data targeted to testing those hypotheses of the conceptual model associated with the highest degree of uncertainty.

6.2.3 Evaluation of Other Sources of Uncertainty

Uncertainty in the spatial distribution of COPCs will represent only part of the uncertainty in the final risk estimates. More difficult to quantify is the uncertainty associated with the accuracy of values calculated using transport and risk models of a particular form (these models are the quantitative, generally algebraic,



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① Approximate canyon areas for activities including ranching, gathering wild plants, hunting, and collecting firewood.

② Approximate area of a residential exposure unit encompassing house, small garden, and poultry enclosure.

③ Sediment trap, clay-sized particles; possible source term for exposure pathways such as ceremonial body painting and pottery making.

Figure 6-1. Spatial scale of selected exposure areas.

models that require a source term concentration as an input parameter). When assessing risk via indirect exposure pathways (i.e., when fate and transport modeling is performed), determination of model uncertainty is particularly important. Depending upon the particular pathways determined to be primary contributors to risk, and upon the estimated risk range relative to decision levels, treatment of model uncertainty may become key to the overall uncertainty analysis (International Atomic Energy Agency 1989, 54349; Cullen 1995, 54348). For indirect exposure pathways, both transport model uncertainty and uncertainty in the distribution of COPCs contribute to uncertainty in the exposure media source term for the risk assessment.

In general, uncertainty associated with the variability of human exposure factors such as exposure frequency and duration, body weight, and rates of ingestion and inhalation are minor compared to uncertainty in source term concentrations (International Atomic Energy Agency 1989, 54349). In the canyons present-day human health risk assessments, however, exposure factors associated with unique exposure pathways for American Indian use may contribute significantly to the overall uncertainty in risk estimates. Elicitation of exposure-related activity information from representatives of the Accord Pueblos is currently in progress to reduce uncertainty in these areas. Additionally, guidelines on the development of defensible parameter distributions based on these data, and data from the literature, will be followed to minimize the possibility that parameter distributions do not accurately reflect the state of knowledge for each parameter (Kaplan 1991, 54347; Lee and Wright 1994, 54346; Seiler and Alvarez 1996, 54345).

A prominent source of uncertainty in most human health and ecological risk assessments is the contaminant-specific toxicity value used to relate intake or dose to a particular adverse health effect. For a carcinogen, in particular, the dose-response function is itself the product of a particular model with associated uncertainties in both the dose-response model and the parameters used in the model. Although a quantitative treatment of uncertainty in both carcinogenic and noncarcinogenic toxicity values is possible, this source of uncertainty in the risk estimates is not unique to the canyons investigations and a large volume of literature exists on the subject. Present-day human health risk assessments in the canyons investigations will focus on providing information on the distributions of contaminant intake and exposure. Selected percentiles of these distributions will then be compared to appropriate toxicity values (slope factors, reference doses, and dose conversion factors), and other relevant toxicity information, and estimates of potential human health impacts will be provided. By keeping intake and exposure distributions separate from risk estimates, canyon-specific uncertainties in source term concentrations of COPCs, human exposure parameters, and model algorithms can be distinguished from toxicological uncertainties.

6.2.4 Application to Decision-Making

Initial stages of the canyons investigations will have early estimations of model parameters and source-term uncertainties. The first evaluations will focus on the American Indian subsistence scenarios described in Section 6.5. Because this is a conservative and chronic exposure scenario, these analyses will serve as an indicator of any potential risk-based concern. Semiquantitative preliminary analyses for less conservative exposure scenarios that might have a higher probability of occurrence will also be examined at early stages to warn of any immediate health risks that might require interim measures. These scenarios may include recreational use, firewood collection, or pottery making, as appropriate. Ecological risk will be assessed by evaluating scenarios that are appropriate to ecological exposure units that include canyon ecosystems. As more data are collected, the ability to perform meaningful quantitative uncertainty analyses for exposure area source terms corresponding to the multiple exposure pathways discussed in Section 6.5 will improve, and assessments will begin to include distributions of contaminant intake and exposure based on the exposure scenarios defined for the canyons. Evaluation of risks, and/or information on the probability of exceeding pathway and scenario-specific risk levels, will also incorporate a qualitative discussion of uncertainties introduced with the toxicity values for each COPC.

Risk information will be conveyed in the context of decision-making with an emphasis on incorporating the uncertainty analysis into selection of future activities (Finkel 1994, 54344). Recommendations for specific locations and types of samples to minimize uncertainty in the risk estimates will be provided, although a decision on *whether* to implement such recommendations may require input from other stakeholders.

As described in Section 6.5.4, risk estimates associated with American Indian uses will be focused primarily on providing exposure and risk information on a pathway- and activity-specific basis so that communities may appropriately manage potential impacts. Rules determining when sufficient information has been gathered will not be developed initially. A cost-benefit analysis with participation of all stakeholders may be an appropriate approach for determining when sufficient data have been gathered to address a particular assessment endpoint. To assist in this process, formal decision analysis methods can be employed to identify and rank decision options.

6.3 Identification of Chemicals of Potential Concern

6.3.1 Initial Sampling and Decision Criteria

The initial sampling in a given canyon and reach will identify and eliminate from further investigation those chemicals which are not considered to be of potential concern. The initial analyses will be used to focus additional sampling on a more limited analytical suite of COPCs as defined in Section 5.3.6 in Chapter 5 of this core document. The sampling will be stratified (in the statistical sense) according to recognized hydrogeological and geomorphologic units and considering geochemical characteristics of the contaminants (particularly mobility) that are described in Chapter 3 of this core document. A broad analytical suite is proposed initially because the number of potential contaminants in the source areas may be large, and large uncertainties remain as to whether these contaminants could reasonably be transported into the canyons, and whether depositional patterns are similar among the various contaminants.

6.3.2 Other Values Needed for Regulatory Compliance

For water sources in the canyon, canyon aggregate, or ecological exposure unit under investigation, the questions posed above regarding significant concentrations of contaminants and unacceptable risks may be simplified to: Are water sources contaminated above acceptable levels? To answer this question, results of analyses of water samples will be compared with federal maximum contaminant levels (MCLs) promulgated under the Safe Drinking Water Act (EPA 1994, 50118), the state drinking water standards (NMED 1995, 55501), the state groundwater standards (New Mexico Water Quality Control Commission Regulations 1995, 54406), or Indian Pueblo standards, as appropriate. In addition, the contribution to human health risk from COPCs identified in water sources will be evaluated for the appropriate exposure scenarios.

6.3.3 Potential Contaminants for the Canyons

Table 6-1 lists potential contaminants for the canyon systems. Existing data from previous sampling and analysis activities on mesa tops and canyons and the professional judgment of the canyons investigation technical team were used to identify this list of suspected contaminants. However, the list is not exhaustive, and the table contains some generic descriptions of classes of constituents. Table 6-2 lists the suspected contaminants with federal and state MCLs and state groundwater standards. The chemical constituents listed in Table 6-2 guide, but do not limit, the selection of analytical protocols for initial groundwater sampling activities.

TABLE 6-2
EPA AND STATE MCLs AND STATE GROUNDWATER STANDARDS

COPCs	EPA MCLs[a] (mg/L)	NMED MCLs[b] (mg/L)	NMED Groundwater Standards[c] (mg/L)
Acetone	Not listed	Not listed	Not listed
Actinium isotopes	(d, e)	(f, g)	Not listed
Alcohol	Not listed	Not listed	Not listed
^{241}Am	(d)	(f)	Not listed
Barium	2	2	1.0
Benzene	0.005	0.005	0.01
Benzo[a]pyrene	0.0002	0.0002	0.0007
Beryllium	0.004	0.004	Not listed
Cadmium	0.005	0.005	0.01
^{137}Cs	(e)	(g)	Not listed
Chloride	250[h]	Not listed	250.0
Chromium[i]	0.1	0.1	0.05
^{60}Co	(e)	(g)	Not listed
Copper	1.3[j]	1.3[j]	1.0
Petroleum hydrocarbons	(k)	(k)	(l)
Ethylene glycol	Not listed	Not listed	Not listed
Fission products	(d, e)	(f, g)	Not listed
Other polynuclear aromatic hydrocarbons	Not listed	Not listed	(m)
Fluoride	4.0[h]	4.0	1.6
Freon 11 (CCl_3F)	Not listed	Not listed	(m)
Fuel oil No. 2	(k)	(k)	(l)
Gasoline	(k)	(k)	(l)
Kerosene	(k)	(k)	(l)
Lead	0.015[j]	0.015[j]	0.05
Mercury	0.002	0.002	0.002
Naphthalenes	Not listed	Not listed	0.03
PCBs	0.0005	0.0005	0.001
^{238}Pu	(d)	(f)	Not listed
^{239,240}Pu	(d)	(f)	Not listed
Silver	0.1[h]	Not listed	0.05

TABLE 6-2 (continued)
EPA AND STATE MCLs AND STATE GROUNDWATER STANDARDS

COPCs	EPA MCLs[a] (mg/L)	NMED MCLs[b] (mg/L)	NMED Groundwater Standards[c] (mg/L)
Sodium	Not listed	Not listed	Not listed
Strontium (stable)	Not listed	Not listed	Not listed
^{90}Sr	8 pCi/L	8 pCi/L	Not listed
Toluene	1	1	0.75
1,1,1-Trichloroethane	0.2	0.2	0.06
1,1,2-Trichloroethane	0.005	0.005	0.01
Trichloroethylene	0.005	0.005	0.1
Tritium	20,000 pCi/L	20,000 pCi/L	Not listed
Uranium	0.020[n]	(g)	5.0
^{235}U	(e)	(g)	Not listed
^{238}U	(e)	(g)	Not listed
Xylenes (total)	10	10	0.62
Gross-alpha particle radioactivity	15 pCi/L[d]	15 pCi/L[f]	Not listed
Beta particle and photon radioactivity	4 mrem/yr[e]	4 mrem/yr[g]	Not listed

a. MCL concentration from *Drinking Water Regulations and Health Advisories* (EPA 1996, 55500)

b. MCL concentration from *Drinking Water Regulations,* NMED Drinking Water Bureau (NMED 1995, 55501)

c. Human health and domestic water supply groundwater standard from *New Mexico Water Quality Control Commission Regulations,* NMED Water Quality Control Commission (1995, 54406); based on dissolved (i.e., filtered) portion except mercury

d. The EPA MCL for gross-alpha particle activity requires that the total of all alpha emitters (including ^{226}Ra but excluding ^{222}Rn and uranium) not exceed 15 pCi/L (EPA 1996, 55500).

e. The EPA MCL requires that the concentration of beta particle and photon radioactivity in drinking water not exceed an annual dose equivalent greater than 4 millirem per year. In addition, the sum of the annual dose equivalent of all beta particle and photon radioactivity shall not exceed 4 millirem per year (EPA 1996, 55500).

f. The NMED MCL for gross-alpha particle activity requires that the total of all alpha emitters (including ^{226}Ra but excluding ^{222}Rn and uranium) not exceed 15 pCi/L (NMED 1995, 55501).

g. The NMED MCL requires that the concentration of beta particle and photon radioactivity in drinking water not exceed an annual dose equivalent greater than 4 millirem per year. In addition, the sum of the annual dose equivalent of all beta particle and photon radioactivity shall not exceed 4 millirem per year (NMED 1995, 55501).

h. EPA secondary maximum contaminant level (SMCL) concentration from *Drinking Water Regulations and Health Advisories* (EPA 1996, 55500). SMCLs are unenforceable guidelines.

i. Chromium standards apply to the total of trivalent and hexavalent forms.

j. The EPA MCL is under review (EPA 1996, 55500). The number presented is the EPA action level. Although the EPA MCL is under review, the NMED Drinking Water Bureau has adopted the action level.

k. EPA and NMED MCLs are available for individual chemical constituents of petroleum products, but there are no MCLs for petroleum products.

l. Section 3103 of *New Mexico Water Quality Control Commission Regulations* (1995, 54406) states that non-aqueous phase liquid shall not be present floating atop of or immersed within groundwater, as can be reasonably measured. The standard for nonaqueous phase liquid applies to the total (i.e., nonfiltered) portion of the contaminants.

m. Polynuclear aromatic hydrocarbons are listed in the narrative standard for “toxic pollutant” in Section 1101(TT) of *New Mexico Water Quality Control Commission Regulations* (1995, 54406). Any water contaminant or combination of water contaminants listed in Section 1101(TT) creating a lifetime risk of more than one cancer per 100,000 exposed persons is a toxic pollutant.

n. Proposed EPA MCL (EPA 1996, 55500). Number presented is the EPA action level.

6.4 Conceptual Model for Human Exposure

6.4.1 Relation to Conceptual Model for Contaminant Occurrence, Transport, and Exposure Route

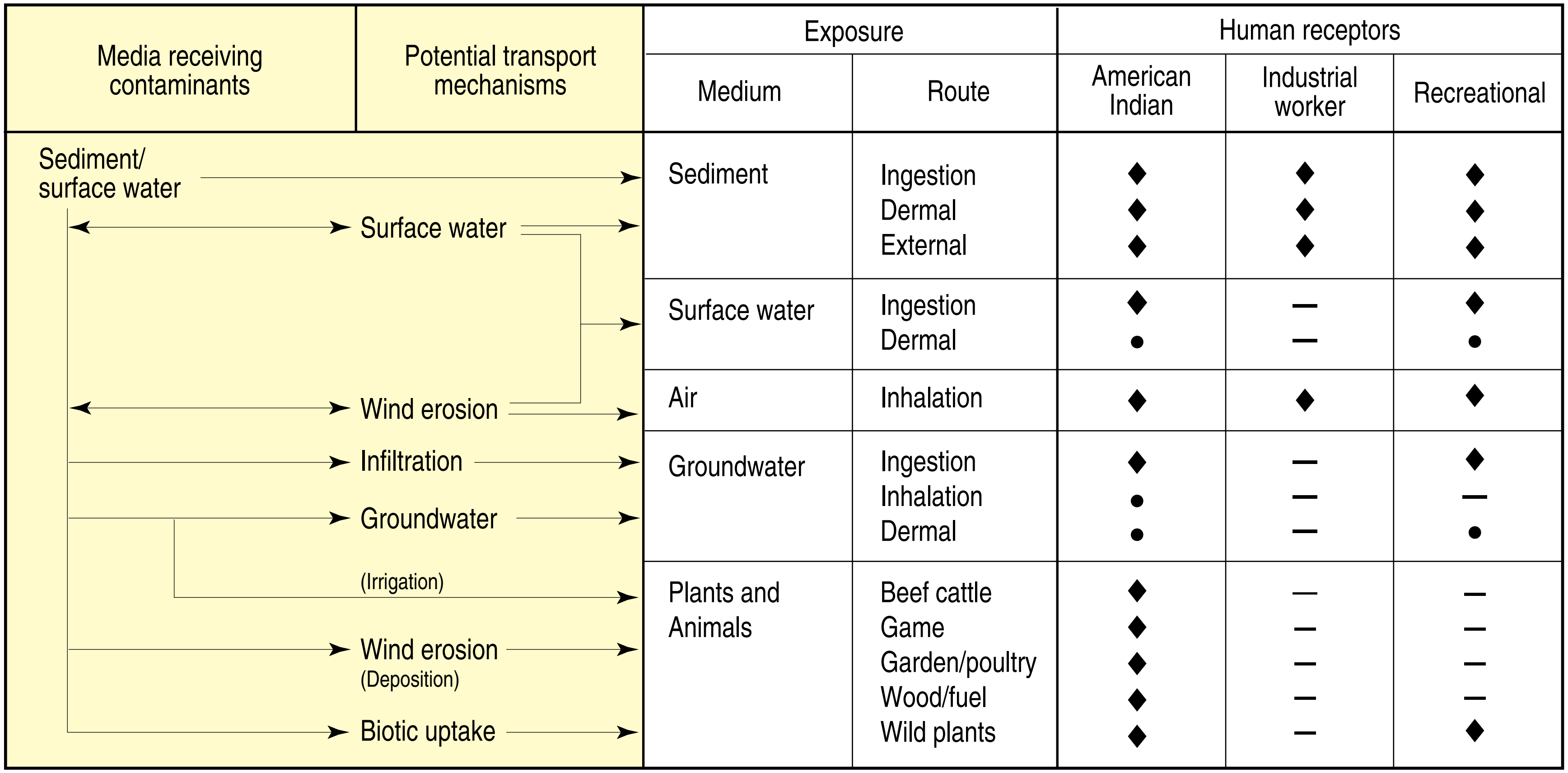
The conceptual model for human exposure, presented in Figure 6-2, identifies potentially contaminated media, release and transport mechanisms, and exposure media for COPCs. However, specific exposure scenarios and exposure routes evaluated in human health risk assessments will vary among individual canyons and canyon reaches. Conceptual exposure models are used to illustrate how constituents can move in the environment from contaminated media to receptors (the exposed population). The conceptual model presented in Figure 4-1 in Chapter 4 is formulated using available information about potential contaminants and the geochemical, geologic, geomorphologic, hydrogeologic, and biological environment. Both the exposure model and the conceptual model are used to identify appropriate media and locations for sampling and to determine if a risk to human health or the environment exists. These models will be updated iteratively as new data become available, and as parameters for the American Indian use scenario are defined.

The most current iteration of the conceptual model will be used in conjunction with available data to develop appropriate source terms for evaluating human health risks. Because canyon characterization is an iterative process of defining model uncertainties and further sampling to reduce those uncertainties, it will be necessary to evaluate and update risk predictions to adequately direct characterization activities. Early risk evaluations will be qualitative if data are insufficient to address given scenarios. These qualitative evaluations will be used to define uncertainties that need to be addressed in further investigations. As uncertainties are reduced, risk evaluations will be refined until quantitative evaluations can be performed with contaminant distributions extrapolated from available data using the refined conceptual model.

6.4.2 Potential Transport and Exposure Pathways

The primary sources of contaminant release into the canyon systems are the mesa-top activities of the Laboratory. Some releases occur within selected canyons as well. After constituents have been released into the canyon environment, they can potentially migrate via

- liquid and vapor infiltration into near-surface or subsurface soils;
- sediment transport in surface water;
- volatilization into ambient air;
- wind entrainment and deposition of contaminated dust onto surface soils and plants;
- rain splash transport of contaminated sediments onto plant surfaces;
- surface water overflow and subsequent runoff resulting in the contamination of sediments in drainage channels and, possibly, infiltration to deeper groundwater zones;
- uptake by animals from ingestion and inhalation of contaminated media;
- root uptake by plants from contaminated soils; and
- flow in alluvial or intermediate perched zone groundwater or the regional aquifer.



Exposure		Human receptors		
Medium	Route	American Indian	Industrial worker	Recreational
Sediment	Ingestion	◆	◆	◆
	Dermal	◆	◆	◆
	External	◆	◆	◆
Surface water	Ingestion	◆	—	◆
	Dermal	●	—	●
Air	Inhalation	◆	◆	◆
Groundwater	Ingestion	◆	—	◆
	Inhalation	●	—	—
	Dermal	●	—	●
Plants and Animals	Beef cattle	◆	—	—
	Game	◆	—	—
	Garden/poultry	◆	—	—
	Wood/fuel	◆	—	—
	Wild plants	◆	—	◆

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◆ Primary exposure pathway*

● Secondary exposure pathway* (quantitatively evaluated only if sample data or modeling indicate that significant exposure may occur)

— Pathway not evaluated

* Application of any particular pathway in the risk assessment for a specific canyon or canyon reach will depend on land use considerations, as discussed in Section 6.4.

Figure 6-2. Conceptual model for human exposure pathways.

Some or all of these transport pathways (the mechanisms and media by which contaminants are moved from their point of origin) and the related exposure pathways must be present for human exposure to contaminants to occur. The predominant pathways by which humans can be exposed to these transported contaminants are summarized in Figure 6-2. The most significant exposure pathways are expected to be ingestion of contaminated water from surface flow, springs, or the alluvial groundwater; inhalation or ingestion of contaminants in sediment suspended by wind; ingestion of contaminated plant or animal material; inhalation of smoke from the burning of contaminated wood; and external exposure to radiation from gamma-emitting radionuclides in sediments. Inhalation of volatile chemicals from sediments will not be evaluated because of the short residence time of these constituents in surface deposits. The exposure pathways for various land use scenarios are explained in greater detail in Section 6.5.

Alluvial and intermediate perched zone groundwaters are known to be present in some canyon systems and may be found in others during the conduct of these investigations. Risk calculations for these investigations will incorporate contaminant concentrations found in these groundwaters as appropriate, based on quantity of water available (with respect to viability as a potential water supply), quality of the water, and the actual or potential for surface expression. The potential exists for migration of contaminants from the intermediate perched zones to the regional aquifer. Investigations of canyons or canyon aggregates will provide data needed to evaluate the level of risk from exposure to potentially contaminated groundwater from each of these sources.

6.5 Land Use Scenarios and Human Receptors for the Canyons

The canyon reaches will be viewed as indicators of the broader canyon system. For land use scenarios that assume use of entire canyons or sets of canyons, the data from individual reaches will be used to model appropriate source terms for risk in the geographic zone of interest for a scenario. Initially, risks will be modeled in a qualitative manner. As more data become available, the model of contaminant concentration and distribution will be refined iteratively and the risk estimates will be updated until sufficient data exist to evaluate a specific scenario with a degree of confidence acceptable to stakeholders. This determination will be based on uncertainties in the data, predicted spatial distributions of COPCs, and toxicity criteria, as discussed in Section 6.2.

Because the site characterization is seen as an iterative approach that will progressively refine estimates and reduce uncertainties in estimates of contaminant source terms, the canyons risk evaluation will use a probabilistic approach that allows incorporation of original uncertainties and update of those uncertainties as the evaluation proceeds. To illustrate, for scenarios where a very small region of contamination will be assumed to have a major impact, e.g., gathering of clays for use in ceremonial body painting, the maximum observed contaminant concentrations at these locations will be important. However, the potential distribution of these locations is expected to be revised as additional data allow uncertainty about the distribution and maximum contaminant concentrations to be reduced. For residential scenarios where utilization of broader areas of the canyons for longer periods of time will be important, data from reaches sampled and analyzed initially will be used to develop initial distributions of a generic residential site in the canyons, establishing a likely distribution for contaminant exposures. Again, as new data allow these distributions to be refined, the probable risk will be updated.

6.5.1 Development of Land Use Scenarios

Calculations of present-day human health risk in an area are affected by the assumptions made about how the area will be used. The selection of land use scenarios defines the population exposed (receptors), the mechanisms and media by which they are exposed (exposure pathways), and the parameters describing how and to what extent they are exposed (exposure routes and uptake parameters). EPA Region VI staff have recommended in discussions regarding risk assessment that risk decisions be based on risk calculations consistent with “reasonable and likely” land use scenarios. The Laboratory has taken the position that many of its technical areas will continue to be used by the Laboratory for industrial purposes, although some sites may be released for residential or recreational purposes. Thus, risk scenarios appropriate to proposed land use will be considered.

An American Indian use scenario will also be developed and applied, where appropriate, to consider exposures by pathways specific to land uses by the neighboring Indian Pueblos. It is recognized that indigenous people may use the land in a manner that exposes them by pathways not commonly considered in traditional risk assessments. In the canyon systems, residential land use (and exposure) will be considered only within the framework of the American Indian use scenario. Residential land use will generally be considered possible in many of the same reaches where American Indian uses are feasible, if the canyon has a wide enough area above the 100 y floodplain to allow construction of permanent residences. Recreational use will generally be considered possible in all reaches of the canyon systems. Portions of the American Indian use scenario will be appropriate for evaluating recreational use in nearly all areas.

The following sections present the assumptions for three risk scenarios based on proposed land use scenarios: the continued-Laboratory-use scenario (with two potential receptors: construction workers and on-site workers); the recreational scenario (with two potential receptors: campers and trail users); and American Indian use (with five potential scenarios: residential, ranchers, hunters, traditional users, and users of the Rio Grande and Cochiti Lake). The exposure pathways discussed below under each land use scenario are preliminary and are subject to continuing negotiation with stakeholders. Both primary and secondary exposure pathways, as illustrated in Figure 6-2, are described.

The American Indian use scenarios are being developed with advice and input from the Accord Pueblos. Presented here is a first approximation of appropriate exposure pathways and land uses within canyons. Rather than grouping exposure pathways to define a scenario for the maximally exposed individual, the exposure pathways are presented separately to specify the appropriate data needed to support information about routes of exposure. Total exposure can then be calculated by summing contributions from all pertinent exposure pathways. This approach is intended to give extensive risk assessment information to the Indian Pueblos to enable them to understand and manage risks and impacts appropriately.

6.5.2 Continued Laboratory Use

Exposure pathways for workers are described below and summarized in Table 6-3.

6.5.2.1 Excavation and Construction Activities

Manual or mechanical movement of contaminated sediment during construction creates the following potential exposure pathways for on-site workers:

- inhalation of fugitive dust lofted by wind and construction activities (such as bulldozing) while operating in and adjacent to the construction site;
- ingestion of sediment or dust;

TABLE 6-3

EXPOSURE PATHWAYS FOR CONTINUED LABORATORY USE

	Exposure Scenario	
Exposure Medium	**Construction Worker: Excavation and Building Activities**	**On-Site Worker: Office and Maintenance Activities**
Dust in air	INH[a]	INH
Sediment	D[b], E[c], ING[d]	D, E, ING

a. INH = inhalation
b. D = dermal contact
c. E = external radiation
d. ING = ingestion

- dermal contact with sediment; and

- external radiation by gamma-emitting radionuclides in sediment.

6.5.2.2 Office and Maintenance Activities

Office and maintenance workers at a site may be exposed to contaminants through the following exposure pathways:

- inhalation of fugitive dust suspended by wind in ambient air,

- ingestion of sediment or dust suspended by wind,

- dermal contact with sediment, and

- external radiation from gamma-emitting radionuclides in sediment.

6.5.3 Recreational Uses

Exposure pathways for recreational users are described below and summarized in Table 6-4.

6.5.3.1 Short-Term Camping

This land use scenario assumes that individuals camping in the canyons may be exposed to contaminants over a period of several weeks twice a year. Exposure pathways are as follows:

- inhalation of contaminants in fugitive dust suspended by wind in a camping area,

- incidental ingestion of sediment (such as deposition on hands and transfer to mouth while eating or drinking),

- ingestion of internally or externally contaminated edible plants (such as piñon nuts and berries) that are growing in a camping area,

TABLE 6-4

EXPOSURE PATHWAYS FOR RECREATIONAL USE

	Exposure Scenario	
Exposure Medium	**Camper (Short-term)**	**Trail User**
Dust in air	INH[a]	INH
Sediment	D[b], E[c], ING[d]	D, E, ING
Groundwater and surface water	D, ING	D, ING
Plants and animals	ING	ING

a. INH = inhalation
b. D = dermal contact
c. E = external radiation
d. ING = ingestion

- ingestion of surface water or groundwater (water from seeps and springs used as drinking and/or cooking water),

- dermal contact with surface or groundwater (such as wash water),

- dermal contact with sediment (from bedroll or campfire area), and

- external radiation from gamma-emitting radionuclides in sediment in a camping area.

6.5.3.2 Trail User

This land use scenario assumes that individuals hiking in the canyons (but not camping overnight), bikers riding in the canyons, and horseback riders in the canyons may be exposed to contaminants for periods of less than a day for varying frequencies. Exposure pathways are as follows:

- inhalation of contaminants in fugitive dust suspended by wind while hiking or riding;

- incidental ingestion of sediment (such as deposition on hands and transfer to mouth while eating or drinking);

- ingestion of internally or externally contaminated edible plants (such as piñon nuts and berries) growing along the trail;

- ingestion of surface water or groundwater by drinking from a stream, seep, or spring;

- dermal contact with surface water (or groundwater as seeps or springs) while wading, swimming, or resting in wet areas;

- dermal contact with sediment while hiking or riding; and

- external radiation by gamma-emitting radionuclides in sediment while hiking or riding.

6.5.4 American Indian Uses

Representatives of neighboring Indian Pueblos emphasize that the residents want more detailed and specific information regarding risks so that they may become better informed and may manage risks and impacts appropriately for their communities. The following discussion of exposure pathways for a potential American Indian user of canyons is intended to provide more detailed information than is usually requested by interested members of the public (a typical risk assessment focuses on the maximally exposed individual to simplify the risk calculations as much as possible).

The difference between the typical scenario and calculations and the American Indian use scenario employed here is illustrated by the following example. Typically, risk calculations may indicate an insignificant contribution to overall dose from the hunting scenario (which primarily relates to elk, deer, and small game hunting) and discount the scenario from the detailed overall risk calculation as an insignificant source of exposure. Because for American Indians hunting is a traditional activity rather than a sport, and game meat supplies a larger than typical proportion of their diet, San Ildefonso Pueblo representatives have asked the Laboratory to monitor contamination levels in local elk. Existing data obtained from environmental surveillance reports on contaminant concentrations in elk tissue will be used where possible to calculate the contribution to human health risk from consumption of elk believed to have foraged in potentially contaminated canyon areas. Contaminant levels in elk, deer, and small game will be estimated as part of the ecological risk assessment as well, although the focus will be on a single species of the food chain. In addition, Indian Pueblo representatives will assist in identifying parameters used for risk calculations, including frequency and duration of activities that present potential exposures.

The scenarios detailed below have been submitted to the Accord Pueblos for their review, input, and concurrence on the appropriateness of each scenario. In addition, a work plan has been submitted to the Pueblos, which is designed to train interviewers to survey Pueblo members to obtain data on appropriate parameters for these scenarios. Using Pueblo members as interviewers will allow cultural sensitivities to be protected in the process. The scenarios and exposure pathways are summarized in Table 6-5.

TABLE 6-5

EXPOSURE PATHWAYS FOR AMERICAN INDIAN USE

	Exposure Scenario				
Exposure Medium	**Residential**	**Ranching**	**Hunting**	**Traditional**	**Rio Grande and Cochiti Lake**
Dust in air	INH	INH		INH	
Sediments	D[a], E[b], ING	D, E, ING		D, E, ING	
Groundwater and surface water	D, ING[c], INH[d]	ING		D, ING	D, ING
Plants and animals	ING, INH	ING	ING	D, ING, INH	ING

a. D = dermal contact
b. E = external radiation
c. ING = ingestion
d. INH = inhalation

6.5.4.1 Residential

Members of established Indian Pueblo communities (such as Totavi) or potential new communities might be exposed to contaminants via pathways not commonly evaluated in traditional risk assessments. The American Indian residents may be exposed through the following exposure pathways:

- inhalation of contaminated smoke particles from the burning of contaminated wood for heating or cooking;
- inhalation of contaminants in dust while working in the field;
- inhalation of volatile organic compounds and tritium (in tritiated water vapor) with domestic use of groundwater;
- ingestion of groundwater for drinking;
- ingestion of surficially or internally contaminated corn and other fruits and vegetables grown on-site that may be irrigated with contaminated surface or groundwater;
- ingestion of wild foods (for example, piñon nuts, wild spinach, and tea herbs) that are harvested on-site;
- ingestion of contaminated eggs or poultry;
- incidental ingestion of, or dermal contact with, surface water or groundwater (in springs or seeps) by children while swimming or wading;
- incidental ingestion of, or dermal contact with, sediments during gardening, farming, traditional, or ceremonial activities;
- dermal contact with surface water that may be used to irrigate plants; and
- external radiation from gamma-emitting radionuclides in sediments.

6.5.4.2 Ranching

Ranchers who might run cattle in the canyon floor (especially lower Los Alamos Canyon and Pueblo Canyon) might be exposed to contaminants through the following exposure pathways:

- inhalation of contaminants in dust during ranching activities;
- ingestion of surface water or groundwater by drinking from a stream, seep, or spring;
- ingestion of meat from cattle that drink contaminated groundwater or surface water (such as in a stock pond or tank) or eat plants from contaminated areas;
- incidental ingestion of, or dermal contact with, sediments during ranching activities; and
- external radiation from gamma-emitting radionuclides in sediments during ranching activities.

6.5.4.3 Hunting

Hunters taking elk, deer, or other game (such as squirrels and rabbits) that have grazed in potentially contaminated areas may be exposed through the following exposure pathways:

- ingestion of meat distributed throughout the Indian Pueblo from game whose range includes contaminated regions and
- ingestion of game tissues at the site of the hunt or later.

Exposure pathways appropriate for the trail user are also relevant for hunting (see Table 6-4).

6.5.4.4 Traditional Uses

Traditional activities of Indian Pueblo communities may expose individuals to contaminants by the following exposure pathways:

- inhalation of particulates from the burning of contaminated wood in a kiva and from contaminated dust during ceremonial activities;
- incidental ingestion of sediments or dust or dermal contact with sediments during ceremonial and/or medicinal activities;
- ingestion, inhalation, or dermal contact of medicinal and ritual plants (roots or leaves) gathered from contaminated regions (plants may be brewed, burned, or used as a poultice on the skin surface);
- incidental ingestion of clay or dermal contact with clay during ceremonial body painting;
- infants' dermal contact with groundwater from springs used in naming ceremonies; and
- external radiation from sediments during ceremonial and/or medicinal activities.

Hunters and gatherers of ceremonial or medicinal plants may also be exposed through all the exposure pathways described for trail users (see Section 6.4.3.2).

6.5.4.5 Rio Grande and Cochiti Lake

American Indians use the Rio Grande and Cochiti Lake for several specific purposes that may expose them to contaminants through the following exposure pathways:

- ingestion of homegrown fruits and vegetables irrigated with surface water from the subject sources;
- ingestion of water during recreational or ceremonial use;
- ingestion of fish and other aquatic foods; and
- dermal contact with surface water while swimming, fishing, ceremonial washing, and conducting other water-related activities.

The sampling and analysis plans (SAPs) developed for investigations in each of the canyon systems may not support a full risk assessment of the Rio Grande and Cochiti Lake scenario. Data on contaminant concentrations in sediment and water collected in individual canyon systems may be used to estimate the degree to which canyons may contribute to the known contaminant levels in the Rio Grande.

6.5.4.6 Identifying Other American Indian Exposure Sources

Members of the technical team are currently working with the Accord Pueblos to define the appropriate parameters (i.e., exposure frequency, duration, magnitude) for the American Indian use scenario. During this process, any additional concerns that arise will be incorporated into the risk evaluation. Out of respect for cultural sensitivities, some of these exposure sources may not be defined explicitly in the SAPs or in reports of risk evaluations. Efforts will be made to avoid mention of specific culturally sensitive activities presenting potential exposures, while incorporating the necessary exposure parameters. The Accord Pueblos will be asked to review the final scenario to ensure that cultural sensitivities are not infringed upon.

6.6 Ecological Risk Assessment

A Laboratory site-wide approach to ecological risk assessment is presently under development and will be based on the EPA framework for ecological risk assessment (EPA 1992, 48847; EPA 1994, 48846). The specific assessment end points, receptors, exposure units, exposure models, and risk assessment models will be determined by negotiations underway among the Laboratory, DOE, EPA, NMED, and the Accord Pueblos. The assessment of canyon ecosystems will be integrated with the Laboratory’s site-wide approach.

Although assessments of present-day and future potential impacts to the canyon ecosystems are required by the HSWA Module (EPA 1990, 1585) and discussed in this core document (see Section 1.4.1), much of the work to define potential future impacts will be integrated into a broader program of studies, which is currently being defined by the ER Project in consultation with DOE, EPA, NMED, and tribal representatives from neighboring Indian Pueblos.

6.7 Description of Potential Remedial Activities

6.7.1 Cleanup Levels

At canyon locations where present-day risk assessment calculations show that risk to human health or the ecosystem may exceed acceptable values, risk-based cleanup levels will be calculated for contaminants of concern identified by the risk assessment. Target human health risk values are defined according to guidance discussed in Section 6.1. Final definitions of unacceptable risk to human health and the environment will be agreed on after negotiations with EPA, NMED, and the Accord Pueblos. Cleanup levels for nonradiological contaminants will be calculated using EPA equations and site-specific input parameters. RESRAD or a demonstrably equivalent code will be used to calculate cleanup levels for radionuclides in soils. The range of uncertainty in cleanup levels will be presented by basing the calculation on a reasonable maximally exposed individual and a best estimate of exposure identified in the appropriate land use scenarios. As discussed in Section 6.5.4, such a maximally exposed individual will not be defined for the American Indian use scenario.

6.7.2 Potential Remedial Actions

The Installation Work Plan (LANL 1996, 55574) describes the Laboratory's approach to the Resource Conservation and Recovery Act (RCRA) facility investigation, which focuses field investigations on determining whether a corrective measures study (CMS) is necessary and on supporting the performance of a CMS, the design and implementation of an accelerated cleanup, or a recommendation for no further action. The staged approach being employed for the canyons investigations encourages the identification of key data needs in each of the canyons or canyon aggregates under investigation as early in the process as possible to ensure that data collection is always directed toward providing information relevant to refining the conceptual model for contaminant transport and to selection of a remedial action.

The following sections provide a preliminary development and screening of remedial technologies and alternatives, but detailed screening and analysis are deferred until canyon-specific data are collected. Many of these remedial alternatives can be applied on a small scale to limited areas of contamination as voluntary corrective actions (VCAs). The ER Project has established criteria for distinguishing whether a contaminated site can be classified as a VCA (Glatzmaier and Fesmire 1995, 46071).

An example of possible VCAs in the canyons would be to excavate localized areas of high radionuclide concentrations (each less than one cubic yard, a volume that can be dealt with manually) that are identified during radiological surveys in the stream bottoms and overbank deposits. Any such areas located during the surveys could be containerized for sampling by a field team to determine storage or disposal requirements, and later removed and managed appropriately. Such an operation would be efficient, would remove concentrated gamma-emitting radionuclides from the canyon system, and would avoid the potential for these sources to be dispersed by floods.

Even though the nature and extent of potential contaminants present in the canyon systems will not be determined until investigations are completed, the following general response actions are believed to be technically feasible and appropriate:

- no action;
- institutional control (such as monitoring, fences, and deed restrictions);
- containment (for example, stabilizing eroding banks);
- treatment;
- removal (excavation to a RCRA mixed-waste or radioactive-waste landfill); and
- combinations of the above (for example, sediment traps whose contents are removed periodically).

This section does not give an all-inclusive list of potential remedial alternatives. It focuses on the most likely types of response actions for the canyon systems based on existing data. As additional data are collected during the canyons investigations, applicable remedial action methods will be re-evaluated. Technical options will be compared with respect to implementation, effectiveness, and cost, allowing informed decisions to be made in selecting remedial alternatives.

6.7.2.1 No Action

The no-action category means continuation of current practices. This category allows conditions and processes currently operating to continue.

The no-action alternative may be applicable if field investigation results indicate the following conditions in the canyon under investigation:

- no contaminants are present,
- contaminants are present but at concentrations below regulatory action levels, or
- present-day risk assessment demonstrates that the extent of contamination results in no risk or an acceptable risk under an appropriate exposure scenario, and
- prediction of future conditions based on a refined conceptual model or numerical models continue to indicate that contaminant concentrations are not likely to increase.

The no-action alternative also serves as a basis for comparison with other alternatives.

To undertake no action is to refrain from intervening in the fate and transport of contaminants. No action does not necessarily perpetuate the status quo because natural processes are changing the conditions. In this context, the no-action alternative is considered passive remediation, which recognizes the effects of natural processes such as dilution, biodegradation, volatilization, photolysis, leaching, radioactive decay, precipitation, and adsorption that reduce contaminant concentrations present in specific locations and environmental media.

The no-action alternative is likely to apply to most surface locations in the canyon systems because contaminant concentrations are expected to be below levels posing significant human or ecological risk (based on values measured during the FUSRAP [LANL 1981, 6059]). Based on results of hydrological, geochemical, and geological information available at this time, as discussed in Chapter 3 of this core document, large areas where buried soil contamination or groundwater contamination occur are also likely to pose either no risk or an acceptable risk due to the low contaminant concentrations, and may require no action.

6.7.2.2 Institutional Control

If field investigation results indicate that contaminants are present in concentrations above regulatory or risk-based levels at a given canyon location, other response actions or combinations of response actions (such as monitoring, fencing, or deed restrictions) may be required. For example, the area could be fenced and monitored to evaluate the migration of contaminants over time.

6.7.2.2.1 Monitoring

Monitoring involves no substantial action on contaminated media, but it does provide information about the status of contaminants and their movement through exposure pathways. In situations in which no other action is taken, monitoring can serve not only to document passive remediation but also to provide early warning if passive remediation fails to adequately protect human health and the environment. Also, monitoring may be needed in situations in which containment, collection and removal, or treatment are undertaken. In these situations, the purpose of monitoring would be to document the effectiveness of the remedial actions and to provide early warning if the remedial action fails.

The monitoring approach applies to the alluvial groundwater, intermediate perched groundwater zones and surface drainage within the canyons. These systems have been and continue to be monitored to varying degrees.

6.7.2.2.2 Restricted Use

No remedial technology is required to implement restricted access (such as fencing or deed restrictions). Fences already exist in parts of several canyons. Also, most community developments near the Laboratory are confined to the mesa tops. The surrounding land is largely undeveloped; large tracts north, west, and south of the Laboratory boundaries are held by the Santa Fe National Forest, US Bureau of Land Management, Bandelier National Monument, US General Services Administration, and Los Alamos County. San Ildefonso Pueblo borders the Laboratory to the east. Because most of the surrounding land is controlled by federal government entities, land use restrictions have been applied and can continue to be enforced.

6.7.2.3 Containment

A likely remedial alternative for any contaminated sediments found in the canyon systems is believed to be containment followed by long-term monitoring.

Several remediation technologies can be considered for sediments, surface water, and groundwater. Sediment traps have been used in Mortandad Canyon to contain plutonium- and americium-contaminated sediments. Periodic removal of contaminated sediments is required for this containment technology. Permeable geochemical barriers can be designed to remove cations ($^{90}Sr^{2+}$ and $^{137}Cs^{+}$) and anions ($^{235}[UO_2][CO_3]_2^{2-}$ and $^{241}Am[CO_3]_2^{-}$) from surface water and groundwater. Groundwater pumping technologies can be applied to the alluvium to control groundwater flow. Application of pumping technology requires a thorough knowledge of the hydrodynamic properties of the alluvium where sufficient saturated thicknesses warrant use of this technology.

Additional containment alternatives (such as permeable berms, sediment traps, gabions, retaining walls, or levees) may be applicable to some locations within the canyon systems. These containment alternatives could be used in some locations to control or impede the erosion and transport of contaminated canyon sediments. However, additional site characterization data and better definition of potential migration pathways are required to determine whether these alternatives are appropriate and would merit further consideration. If applicable, the alternatives will be addressed during a CMS.

6.7.2.4 Treatment Technologies

Numerous technologies are associated with general response actions involving treatment of sediments or water, either *in situ* or combined with removal. Examples of *in situ* treatment technologies for contaminated sediments that may be applicable are contaminant coprecipitation, immobilization, soil flushing, vapor extraction, vitrification, and biological treatment. Possible groundwater treatments include anion and cation exchange techniques.

Insufficient data are available to determine which, if any, of these technologies may be applicable. As appropriate, treatment technologies will be evaluated during a CMS. Bench-scale and pilot studies will be used as needed to confirm the feasibility of various treatment technologies.

6.7.2.5 Removal

Removal would be followed by disposal, possibly after some treatment. Surface sediment contamination in the canyons could be remediated by removal. However, removal is not considered advantageous for areas of widespread low-level contamination because the ecological impact of disturbing large areas on the canyon floors would be substantial, and the potential is very high for mobilizing contaminants that are presently stable in sediment deposits. In addition, large volumes of material would likely be involved, which would overwhelm available facilities and require the development of new disposal sites.

6.7.2.6 Combined Technologies

Numerous possible combinations of temporary and/or permanent solutions can be envisioned. One combination with obvious potential application is the construction of sediment traps to capture contaminated sediment, which can then be removed, treated by soil washing techniques to reduce volume, and disposed of. Such sediment traps are already in operation in Mortandad Canyon; sediments are removed from these traps periodically.

Remediation efforts, if needed, will be coordinated with the Environmental Management Program and the Technology Development Program to ensure that applicable, cost-effective technologies will be used.

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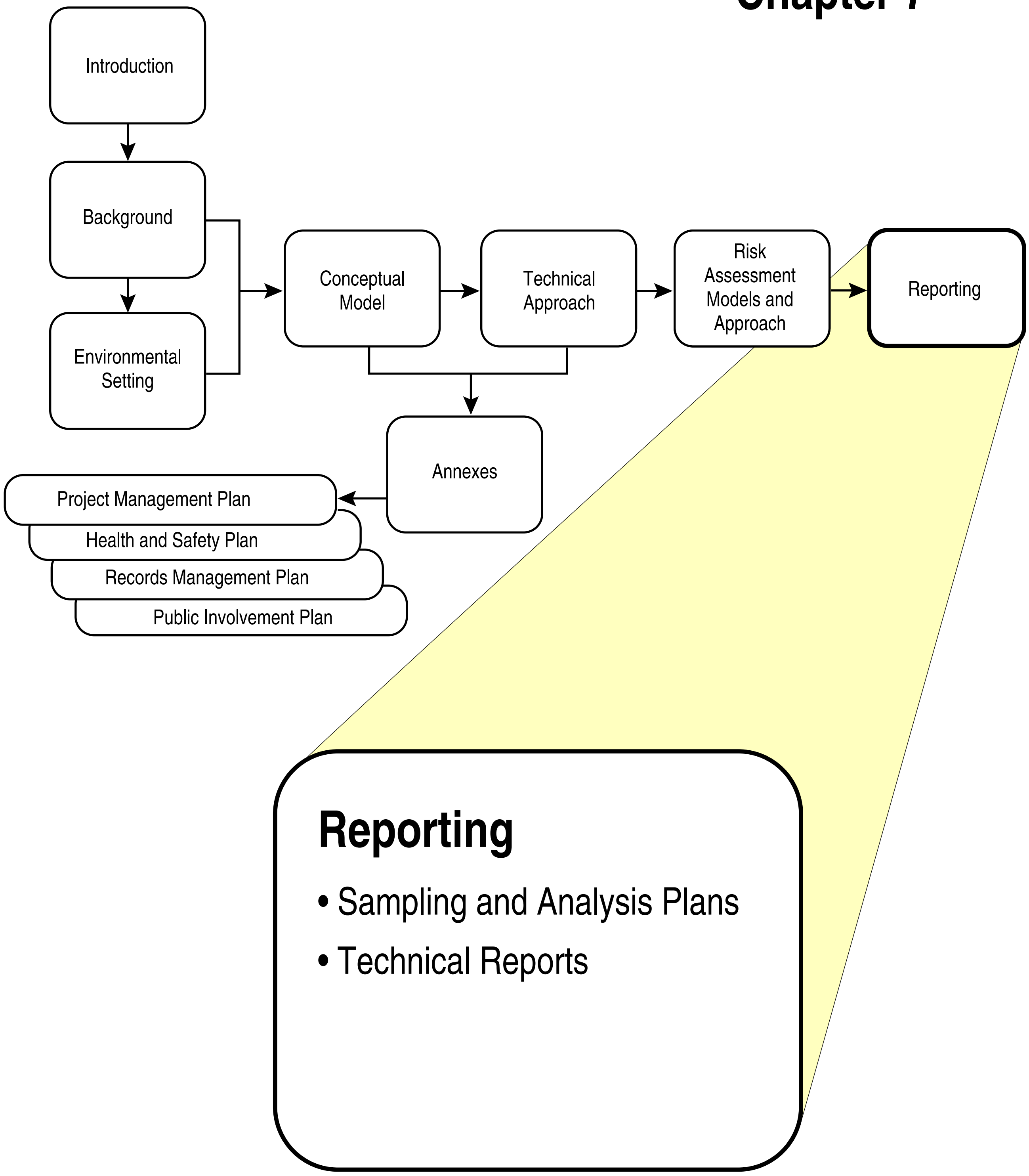
Chapter 7



Reporting

- Sampling and Analysis Plans
- Technical Reports

7.0 REPORTING

Over the course of the canyons investigations, the Field Unit 4 team and the technical team will progressively refine the conceptual model for contaminant occurrence and transport (hereafter “the conceptual model”) discussed in Chapter 4 of this core document; modify and improve the methods for geomorphic surveys, field contaminant surveys, groundwater characterization, assessment of contaminant mobility in the subsurface, and sample collection and analysis; and report findings of the individual canyon or canyon aggregate investigations with respect to contaminant occurrence and distribution and present-day human health risk assessments. The procedures for making these adjustments to the conceptual model and field and laboratory methods, and for reporting findings of individual canyon or canyon aggregate investigations will be reports as discussed briefly in this chapter.

Consistent with the general strategy of using this core document as an upper level umbrella description of the overall canyon systems and technical approach to the investigations, each canyon- or canyon aggregate-specific sampling and analysis plan (SAP) and each report will incorporate this core document by reference, and each report of investigations will reference the specific SAP for the investigations. This strategy of tiering the relevant documents will enable SAPs and reports to be focused, brief, communicative, easily prepared, and easily reviewed.

Administrative authority (AA) involvement at critical decision points during investigations is essential for the successful implementation of the iterative investigations proposed for the canyon systems. Significant modifications to the scope of work and critical decision points will be communicated to the AA through phone calls, letters, faxes, and e-mail. Anticipated modifications to the scope of work will also be addressed in the monthly Environmental Restoration Project progress reports. Significant modifications to the scope of work for any work plan will be provided to the AA for approval.

7.1 Sampling and Analysis Plans

SAPs will be prepared for investigations in each of the canyons or canyon aggregates as discussed in Chapter 1 of this core document. Each SAP will incorporate this core document by reference for most of the general information regarding the regulatory and programmatic framework for the investigation, the historical background of the area, the regional environmental setting, the conceptual model, the overall technical approach, and present-day human health risk assessment and ecological impact assessment approaches.

Each successive canyon- or canyon aggregate-specific SAP will provide specific information on historical background including observed and potential contaminants as well as contaminant sources for the specific canyon system, environmental setting including the geomorphology of the canyon(s) and the state of knowledge of groundwater bearing zones present and extent of known Laboratory-derived contamination in water and sediments, geochemistry of groundwater, and specific hypotheses of the most recent refinement of the conceptual model to be tested in the investigation. Each successive SAP will incorporate lessons learned from previous canyons investigations regarding field and laboratory methods, borehole advancement and well installation techniques, and the site characterization approach. The technical approach taken in each successive investigation, while following the general approach discussed in Chapter 5 of this core document, is expected to be modified from the previous investigation to incorporate progressive refinements to the conceptual model.

In accordance with the guidelines provided in "Quality Assurance Project Plan Requirements for Sampling and Analysis" (LANL 1996, 53450), each SAP will describe field and laboratory methods and quality assurance procedures to be used in the investigation.

7.2 Field Unit 4 Reports

A report will be prepared at the conclusion of investigations in each canyon or canyon aggregate. This document will summarize the results of the investigations, integrate all surface and subsurface data into a refined conceptual model, present estimates of transport rates of contaminants in the surface and subsurface, define present-day and future impact of contaminants on the Rio Grande, make recommendations to optimize Laboratory monitoring of contaminants in the canyon(s) system.

Reports are planned 60 days after all relevant data for an investigation are received. Tentatively, the reports will be prepared in the following format.

Abstract

Introduction—investigation objectives and approach

Methods—summarize field, analytical, and computational methods

Results—present the data

Discussion—discuss what was learned and conclusions drawn from investigation

Conclusions—highlight major conclusions, make recommendations for future SAPs, and suggest refinements to the conceptual model

REFERENCE FOR CHAPTER 7

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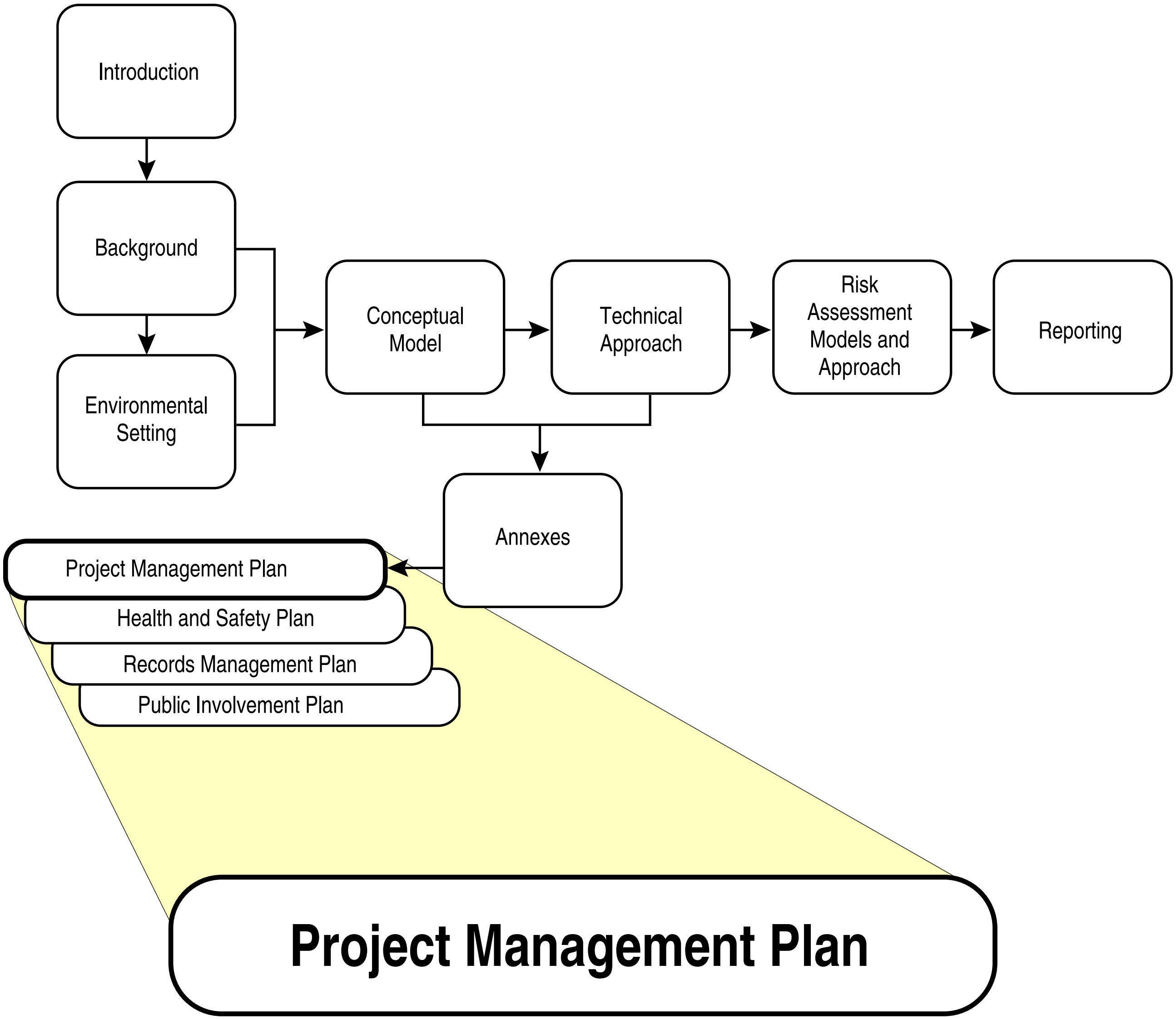
Annex I


Introduction
Background
Environmental Setting
Conceptual Model
Technical Approach
Risk Assessment Models and Approach
Reporting
Annexes
Project Management Plan
Health and Safety Plan
Records Management Plan
Public Involvement Plan
Project Management Plan

1.0 INTRODUCTION

This annex addresses the project management plan requirements of the Hazardous and Solid Waste Amendments (HSWA) Module (Task II, p. 39) of the Laboratory's Resource Conservation and Recovery Act (RCRA) Part B Permit (EPA 1990, 1585) and presents the technical approach, management structure, schedule, budget, and reporting milestones for implementing the canyon systems investigations as set forth in this document. The project management plan for the canyon systems investigations is an extension of the Environmental Restoration (ER) Project Program Management Plan given in Annex I of the Installation Work Plan (IWP) (LANL 1993, 26077) and contains no significant departures from the IWP guidelines.

2.0 TECHNICAL APPROACH

The approach used for the canyon systems investigations is based on the ER Project's overall technical approach as described in Chapter 3 of the IWP (LANL 1996, 55574). The technical approach for the canyon systems investigations is described in Chapter 5 of this core document and is illustrated in Figure 5-1 of that chapter. The general philosophy is to develop and iteratively refine the conceptual model for contaminant occurrence and transport (hereafter the conceptual model) as discussed in Chapter 4 of this core document through carefully planned stages of investigation and data interpretation. The data gathered and the subsequent interpretation will be used to define the nature and extent of contamination and the likelihood for contaminant migration in canyon systems.

The technical objectives of the canyon systems investigations, as presented in Chapter 5 of this core document, are as follows:

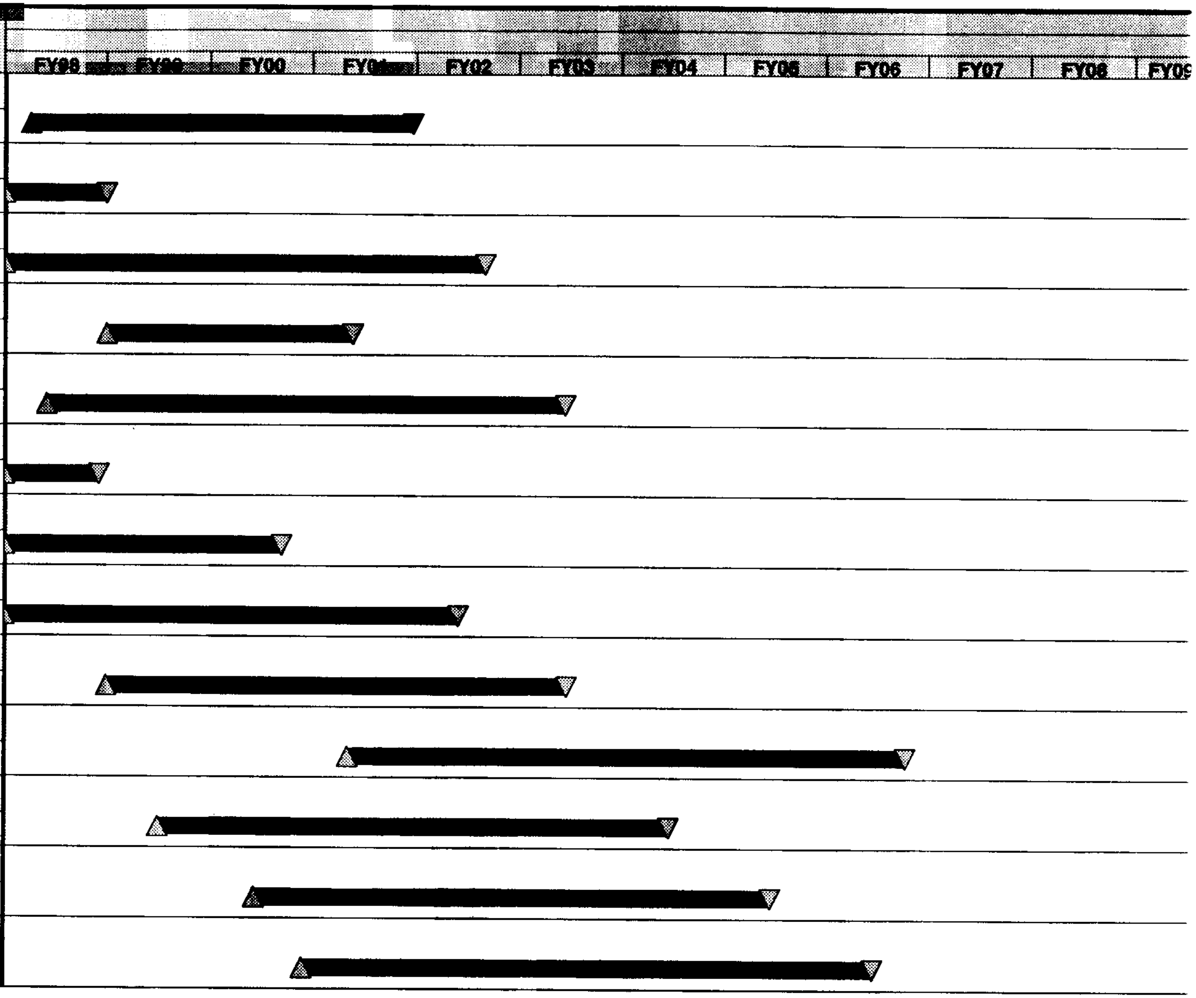
- to determine to what extent portions of the canyon systems have been or are likely to be affected by the combined releases from all sites that contribute contamination to them and
- to reexamine contaminant transport mechanisms, refine the conceptual model, and project future impacts of the contaminants in the affected media that may result from future transport of the contaminants to other locations and other media. The investigations also are intended to support an integrated assessment of the present-day impact (including human health risk) from Laboratory-derived contaminants and an evaluation of the potential for transport (through all accessible pathways) to cause off-site impacts in the future.

2.1 Technical Implementation Rationale

The scheduling of the investigations in canyons or canyon aggregates as discussed in Chapter 1 of this core document is based on the following rationale and priorities, as illustrated in Figure I-1 of this Annex.

Two relatively independent investigation paths are part of the schedule logic and the investigation rationale. These include (1) sampling and analysis of surface sediments and (2) sampling and analysis of surface water and groundwater.

Activity Description	Orig Dur	Early Start	Early Finish
+ ARCH AND BIO SURVEYS			
	928	02JAN98	19SEP01
+ CANYONS CHARACTERIZATION(MISC)			
	249	01OCT97	30SEP98
+ DEEP WELLS			
	1,160	01OCT97	31MAY02
+ INTERMEDIATE WELLS			
	588	01OCT98	14FEB01
+ ALLUVIAL WELLS			
	1,254	02MAR98	13MAR03
+ LOS ALAMOS/PUEBLO CANYONS			
	230	01OCT97	02SEP98
+ MORTANDAD CANYON			
	673	01OCT97	15JUN00
+ PAJARITO,TWO & THREE MILE CANYON			
	1,097	01OCT97	04MAR02
+ SANDIA & CANADA DEL BUEY CANYONS			
	1,109	01OCT98	20MAR03
+ GUAJE,BAYO,BARRANCAS & RENDIJA CANYONS			
	1,361	01FEB01	14JUL06
+ WATER & CANON DEL VALLE CANYONS			
	1,238	01APR99	22MAR04
+ ANCHO,INDIO & CHAQUEHUI CANYONS			
	1,251	15MAR00	23MAR05
+ POTRILLO & FENCE CANYONS			
	1,381	01SEP00	22MAR06



Project Start	01OCT89
Project Finish	09FEB07
Data Date	01OCT97
Run Date	29OCT97

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Early Bar
Progress Bar
Critical Activity

9873

Sheet 1 of 1

Figure I-1
FY98 Estimated Schedule for
Implementing Canyons Investigations

2.1.1 Sampling and Analysis of Surface Sediments

An appropriate number of reaches downstream of known Laboratory sources of contamination, as discussed in Chapter 5 of this core document, and described in detail in each of the canyon- or canyon aggregate-specific sampling and analysis plans (SAPs), will be characterized to

- determine the nature, extent, and transport of Laboratory-derived contamination in the appropriate canyons,
- evaluate present-day risk to human health and ecosystems from contaminated sediments,
- collect data to evaluate and refine the conceptual, and
- assess the projected impact of contaminated sediments on groundwaters, off-site receptors, and the Rio Grande.

The initial stages of each of the investigations include contamination and geomorphic surveys to provide information about the distribution and geomorphic controls on contaminants across the canyon floors, the heterogeneity of contaminant distribution within geomorphic units, the locations and extents of areas containing elevated contaminant concentrations that may be candidates for further investigations, and the distribution of contaminants in the subsurface. Concurrent with the mapping and survey activities, background samples (if required as noted in Section 5.6.3.1 in Chapter 5 of this core document) will be collected upstream of known Laboratory source areas to determine background concentrations of potential contaminants in sediments in the canyon systems.

Based on initial mapping and survey activities, sites will be selected for collecting and analyzing sediment samples for a full suite of potential contaminants. Results of analysis for the full suite of potential contaminants will be used to define the limited suite of chemicals of potential concern for subsequent sampling and analysis tasks. Limited suite analyses will be performed on sediments and used for determining the heterogeneity of contaminants in geomorphic units and for conducting human health and ecological risk assessments. Additional sediment samples may be analyzed for a more restricted suite of key contaminants to provide additional information about contaminant distributions and to address hypotheses related to contaminant transport mechanisms derived from the conceptual model.

2.1.2 Sampling and Analysis of Surface Water and Groundwater

The strategy for sampling surface water and groundwater will focus on characterizing the hydrology and geochemistry of the canyon systems individually and on characterizing the nature and extent of Laboratory-derived contaminants in groundwater-bearing zones. These investigations have three components that can be conducted separately:

- surface water sampling and analysis,
- alluvial groundwater sampling and analysis, and
- intermediate perched zone and regional aquifer groundwater sampling and analysis.

Though conducted separately, the results from all three components of the sampling and analysis activities will contribute to an improved understanding of the canyon systems both individually and as an integrated hydrologic system. Groundwater investigations conducted in the canyons will be integrated hydrologic system. Groundwater investigations conducted in the canyons will be integrated with work conducted under the Hydrogeologic Workplan (LANL 1996, 55430) as discussed in Section 5.7 in Chapter 5 of this core document.

The construction of new wells, collection of borehole core samples during drilling for new wells, and periodic sampling of groundwater in existing and new wells during the canyons investigations will be coordinated with the work described in the Hydrogeologic Workplan and will be discussed in each of the canyon- or canyon aggregate-specific SAPs. Sampling of the regional aquifer is limited to existing wells during the initial stages of each of the investigations. The SAPs are designed to be flexible, and the objectives and approaches will be continually refined and modified as new data are obtained.

2.1.3 Priorities

The management priorities that form the rationale for the sequence of activities described above have the following aspects:

- Investigations in Field Unit 4 are derived largely from requirements in the HSWA Module VIII of the RCRA Part B Operating Permit (EPA 1990, 1585). In this sense, the SAPs are not facilities-based RCRA facility investigation (RFI) work plans like other ER investigations at the Laboratory. Rather, priorities in these SAPs reflect the need to characterize the present-day human health and ecological risks and the projected impacts of affected media downgradient of Laboratory source areas.

- The canyon systems have the potential for residential use as well as frequent casual recreational use; thus they represent a potential source of public exposure to Laboratory-derived contaminants.

- Surface sediments are likely to contain the largest inventory of contaminants and represent the source material most likely to lead to human and ecological exposure. Furthermore, transport of these sediments by erosion processes represents the dominant contaminant transport mechanism in the canyon systems.

- Potential for contamination of the hydrologic system beneath the canyon systems is a major concern of regulators and stakeholders.

- A large volume of data on contaminants is available for some of the canyons. That data can be used to guide the planning for sampling and analysis in each canyon or canyon aggregate to achieve the investigation objectives expeditiously.

2.1.4 Quality Assurance

In accordance with the requirements of the ER “Quality Assurance Project Plan Requirements for Sampling and Analysis Plans” (hereafter the “QAPP”) (LANL 1996, 53450), each of the canyon- or canyon aggregate-specific SAPs will contain a thorough description of the quality assurance (QA)/quality control procedures and the field and laboratory investigation methods to be used in each investigation. The guidance found in the QAPP will be used to prepare these portions of each SAP.

2.2 Schedule

General schedule requirements for the Laboratory’s ER Project are described in Annex I of the IWP (LANL 1993, 26077). A projected RFI/corrective measures study (CMS) schedule for the RFI/CMS process for the canyon systems, through the completion of the final CMS report, will be published in a revision of the IWP. A revised version of this schedule will be submitted for incorporation into the Department of Energy (DOE) Environmental Restoration and Waste Management Five-Year Plan. This plan is a key budget planning document for the DOE-wide ER program.

The preliminary schedule for implementing the canyons investigations is shown in Figure I-1. This schedule has not been costed, and it represents the initial thinking of the canyons investigations technical team. Concurrent with the submission of this document, the budgets (for the fiscal years covered by this schedule) are being developed by Congress and DOE. The activities and dates shown in Figure I-1 are all subject to change based on actual budgets for Field Unit 4. The schedule of deliverables for the canyons investigations will be defined in cooperation with both stakeholders and regulators at a future date.

Implementation of investigation activities in each canyon or canyon aggregate is contingent upon regulatory review and approval of the SAPs (or task/site work plan) for each canyon or canyon aggregate and upon the availability of funding. This core document for the canyons investigations is intended to facilitate the preparation and regulatory review and approval of each of the seven canyon- or canyon aggregate-specific SAPs yet to be prepared. The *Task/Site Work Plan for Operable Unit 1049: Los Alamos Canyon and Pueblo Canyon* was submitted in November 1995 (LANL 1995, 50290). Schedules and costs will be updated through the DOE change-control process, as appropriate, with revisions submitted to the Environmental Protection Agency for approval. The following assumptions were used to generate this schedule.

- Review and approval of this core document for investigation of the canyon systems by regulatory agencies will be completed by September 1997.
- In each of the canyon or canyon aggregate investigations to follow, certain tasks (for example, geomorphic mapping) may be initiated before regulatory agencies grant final approval of the SAPs for those investigations.
- An adequate number of support personnel (such as environment, safety, and health technicians and trained drilling contractors) will be available.
- Regulatory agencies will provide approvals of this core document and each of the subsequent canyon or canyon aggregate-specific SAPs within the specified timelines.
- Investigation of the reaches specified in each canyon- or canyon aggregate-specific SAP will be sufficient to achieve both the investigation objectives and compliance with the HSWA Module requirements.

2.3 Reports

Findings of investigations in each of the canyon or canyon aggregates will be presented in reports as described in Chapter 7 of this core document. One report will be prepared at the conclusion of each canyon investigation summarizing the results of the investigation. Consistent with the requirements for RFI reports, as stated in Chapter 3 of the IWP (LANL 1996, 55574), these reports will describe the procedures, methods, and results of field investigations and will include information on the type and extent of contamination, sources and migration pathways, and actual and potential receptors. The reports also will contain adequate information to support any remedial recommendations.

2.4 Budget

The schedule is based on constrained budgets for the first two years of the investigations and preliminary cost analysis, which is subject to significant uncertainties. The projected budget is based on expected DOE funding levels and is subject to change depending on funding allocations. A change-control petition to DOE is required to augment these funding levels. Because DOE funding requests are set two years in advance, the first two years of the canyon systems investigations will be constrained by previous budget estimates. Funding requests beyond this two-year constraint will reflect the cost and schedule that most efficiently complete the investigations. Uncertainties regarding the extent of groundwater contamination, including the cost of drilling through potentially contaminated areas, could impact investigation costs substantially.

2.5 Organization and Responsibilities

The organizational structure for the ER Project is presented in Appendix I of the QAPP (LANL 1996, 53450). ER Project personnel authority and responsibilities are discussed in the following sections and identified in Figure I-2.

Records of qualifications and training of all field personnel working on the canyon systems investigation will be kept as ER records (see Chapter 5 of the IWP) (LANL 1996, 55574). Technical contributors to this core document, and to the work plan for Los Alamos Canyon and Pueblo Canyon (LANL 1995, 50290) which constitute the technical team to date, are listed in Appendix C of this core document.

The responsibilities of the positions identified in Figure I-2 are summarized in the following sections.

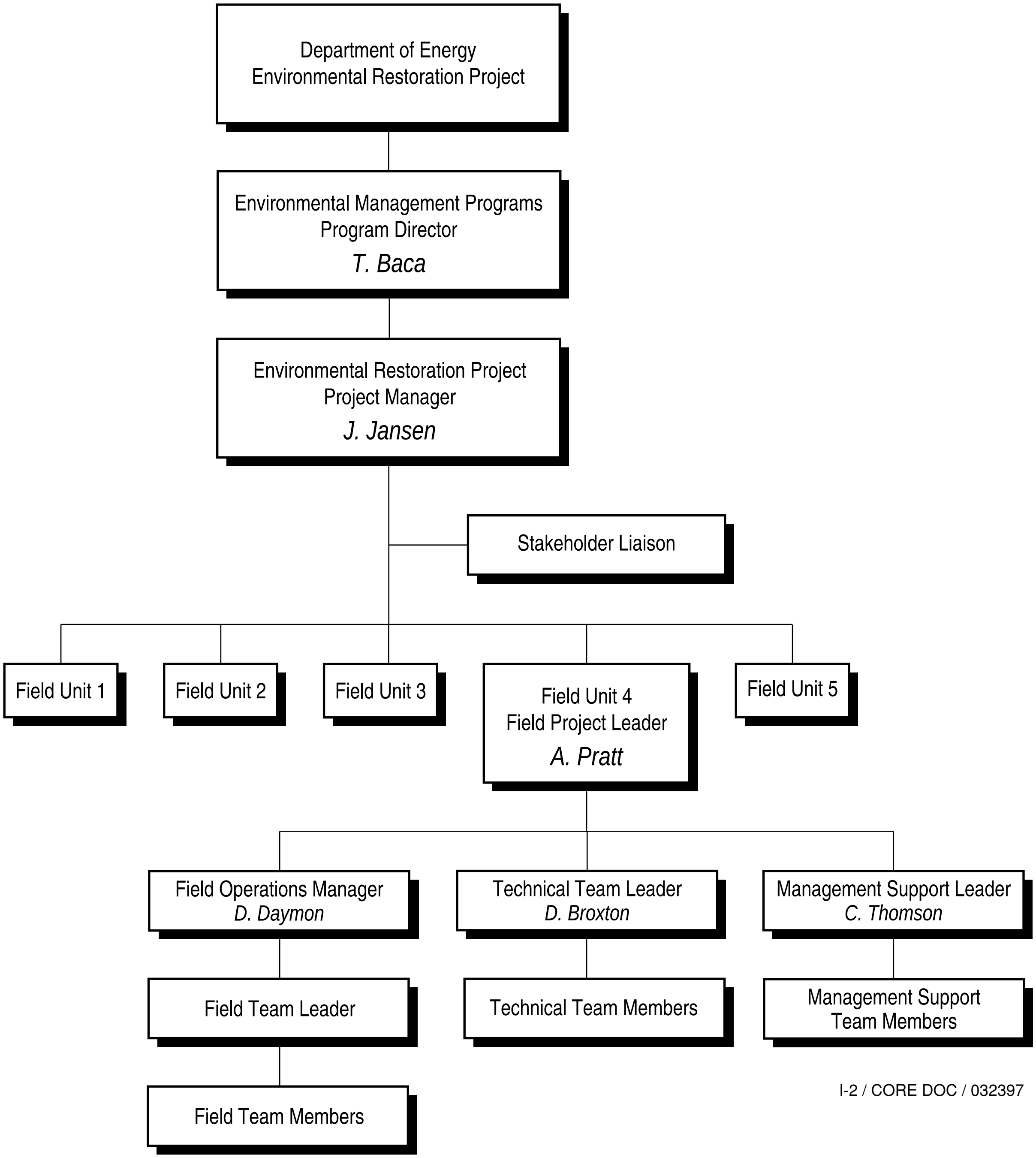
2.5.1 Field Project Leader

Responsibilities of the field project leader are as follows:

- provides overall management for field unit activities, including strategic planning and budgeting;
- prepares monthly and quarterly reports for the ER Project manager;
- oversees subcontractors, as appropriate;
- coordinates with the technical team leader and conducts technical reviews of the milestones and final reports; and
- interfaces with the ER Project quality program project leader to resolve quality concerns and to coordinate with the QA staff for audits.

2.5.2 Technical Team Members

Technical team members are responsible for providing technical input for their discipline throughout the RFI/CMS process. Technical team members have participated in the development of this core document and the work plan for Los Alamos Canyon and Pueblo Canyon (LANL 1995, 50290) with its canyon aggregate-specific sampling and analysis plan. The technical team will continue to participate in the preparation of SAPs, field work, data analysis, report preparation, and planning of subsequent investigations in the canyon systems, as necessary.



I-2 / CORE DOC / 032397

Figure I-2. Organization chart for Field Unit 4.

The primary disciplines currently represented on the canyon systems technical team are risk assessment, chemistry, geology, hydrology, hydrogeology, geochemistry, statistics, biology, archeology, and health physics. The composition of the technical team may change with time if and when the technical expertise needed to implement the canyon systems investigations changes.

2.5.3 Field Operations Manager

Responsibilities of the field operations manager include the following:

- coordinates detailed planning and scheduling for the implementation of the field activities outlined in each of the canyon- or canyon aggregate-specific SAPs,
- oversees day-to-day field operations, and
- manages field team activities.

2.5.4 Field Team Leader(s)

The field operations manager will assign field work to field team leader(s). Each field team leader will direct sampling activities using crews of field team members as appropriate for the activity. Field team leader(s) may be Laboratory personnel or subcontractors. The responsibilities of the field team leader(s) include the following:

- oversee daily field operations for the field team including planning, scheduling, and implementing field activities;
- implement the ER Project health and safety plan and the project-specific QA project plan;
- know emergency response procedures and notification requirements and their implementation;
- coordinate with field team members and technical team members, which may include sampling personnel, a site safety officer, Laboratory personnel, subcontractors, and staff members with technical knowledge of geology, hydrology, statistics, and other applicable disciplines.

2.5.5 Field Team Members

Field team members include the following, as appropriate:

- sampling personnel,
- site safety officer,
- geologists,
- hydrogeologists,
- hydrologists,
- health physicists, and
- other applicable disciplines.

All teams will have, at a minimum, a site safety officer and a qualified field sampler. They are responsible for conducting the work described in the sampling and analysis plans under the direction of the field team leader. Field team members may be Laboratory employees or subcontractors.

2.5.6 Management Support Team Members

Management support team members represent a range of functions supporting multiple aspects of Field Unit 4. Responsibilities include

- project control, including associated reporting and baseline monitoring;
- QA, including support of the QAPP and focused data validation;
- data assessment, including the coordination of chemists, statisticians, and geochemists;
- RFI reporting and document production;
- document control;
- field unit data management; and
- coordination of human and ecological risk assessment.

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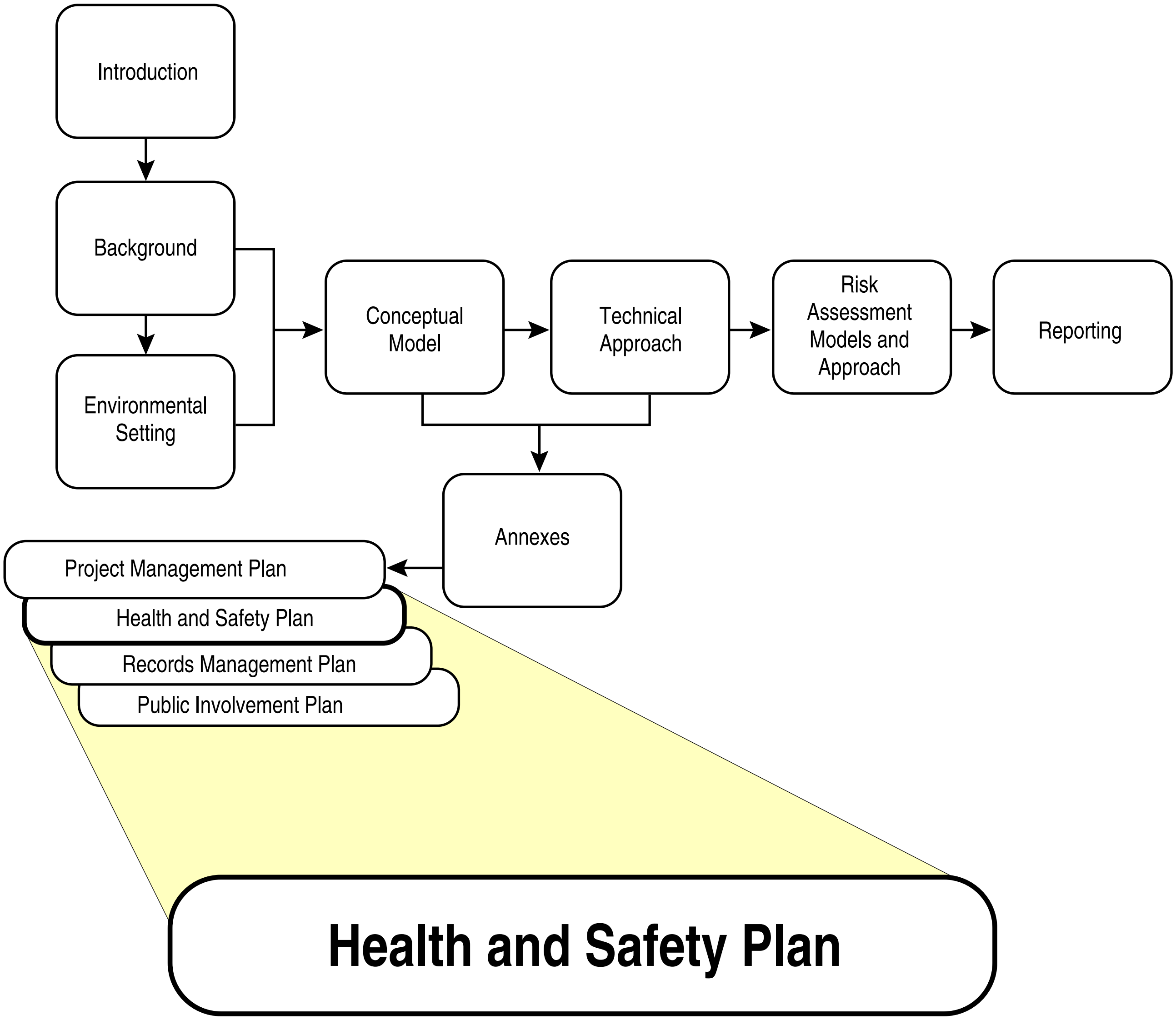
LANL (Los Alamos National Laboratory), December 6, 1996. "Hydrogeologic Workplan" (draft), Revision 1.0, Los Alamos, New Mexico. **(LANL 1996, ER ID Number 55430)**

Annex II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1.0 INTRODUCTION

This annex contains the Health and Safety Plan (hereafter the H&S plan), which has been developed for the Resource Conservation and Recovery Act (RCRA) investigations in the canyons systems. This H&S plan provides the framework within which personal protection will be provided during the implementation of the canyons investigations. Canyon- and canyon aggregate-specific H&S plans will be prepared before beginning any field task. Canyon- and canyon aggregate-specific H&S plans will describe the specific measures to be taken for personal protection during implementation of the tasks and will define individual responsibilities, which are outlined in this H&S plan. Overall H&S policy for the Environmental Restoration (ER) Project is provided in Chapter 6 of the Installation Work Plan (IWP) (LANL 1996, 55574).

As field investigations proceed, measures for personal protection may be identified that are more effective than those identified in this annex. Deviations from this H&S plan will be documented in the appropriate canyon-specific H&S plan along with the reasons for that deviation. As changes are required, this H&S plan will be updated.

This H&S plan includes an assessment of potential hazards, justification for personal protection requirements, and site-specific emergency response procedures. A copy of this H&S plan will be kept on-site at all times.

The purpose of this annex is to establish guidelines for field workers involved in the canyons investigations. A new H&S plan must be initiated for any corrective actions. In addition to general guidance in the IWP, the following regulations and standards were used to develop the procedures set forth in this plan: Laboratory policies, the controlled *ES&H Program Documents*, the Department of Energy (DOE) Orders, Occupational Safety and Health Administration (OSHA) regulations, National Institute for Occupational Health (NIOSH) standards, American Conference of Governmental Industrial Hygienists (ACGIH) recommendations, Nuclear Regulatory Commission regulations, and Environmental Protection Agency (EPA) guidance. Applicable state and local regulations also will be followed.

The responsibilities of workers with regard to H&S as described here do not distinguish whether Laboratory employees or subcontractors are implementing this H&S plan. If it is necessary to modify this H&S plan for implementation, EPA will be notified of any modifications.

Detailed background information, including descriptions of canyon-specific hazards, for the canyons investigations will be provided in the canyon- or canyon aggregate-specific sampling and analysis plans (SAPs); information provided will supplement the information contained in Chapter 2 of this core document. Detailed maps showing the locations of access roads, topography, and other H&S features are contained in Figures A-1, A-2, and A-4 in Appendix A of this core document. Additional detail as may be required for the conduct of field activities will be provided by the Laboratory's Facility for Information Management, Analysis, and Display.

2.0 FIELD UNIT WORK ORGANIZATION

The following information describes policies and standards set forth in this H&S plan, including specific lines of responsibility, standards and regulations, and requirements for audits and variances of H&S policies.

2.1 General Responsibilities

General task/site investigation responsibilities are outlined in Chapter 6 of the IWP (LANL 1996, 55574). Listed below are specific responsibilities for workers involved in the canyons investigations.

2.2 Individual Responsibilities

Within line management of the ER Project, certain Laboratory employees and subcontractors have specific H&S responsibilities. Figure II-1 shows a field work organization chart with line organization responsibilities. Other organizational charts pertinent to the canyons investigations are presented in Annex I of this document.

2.2.1 Deputy Directors

The deputy directors of the Environmental Management (EM) Program and the Environment, Safety, and Health (ESH) Division are responsible for ensuring that programmatic H&S concerns are addressed. They also are responsible for promoting a comprehensive H&S program that covers special areas such as radiation protection, occupational medicine, industrial safety, industrial hygiene, criticality safety, waste management, and environmental protection and preservation.

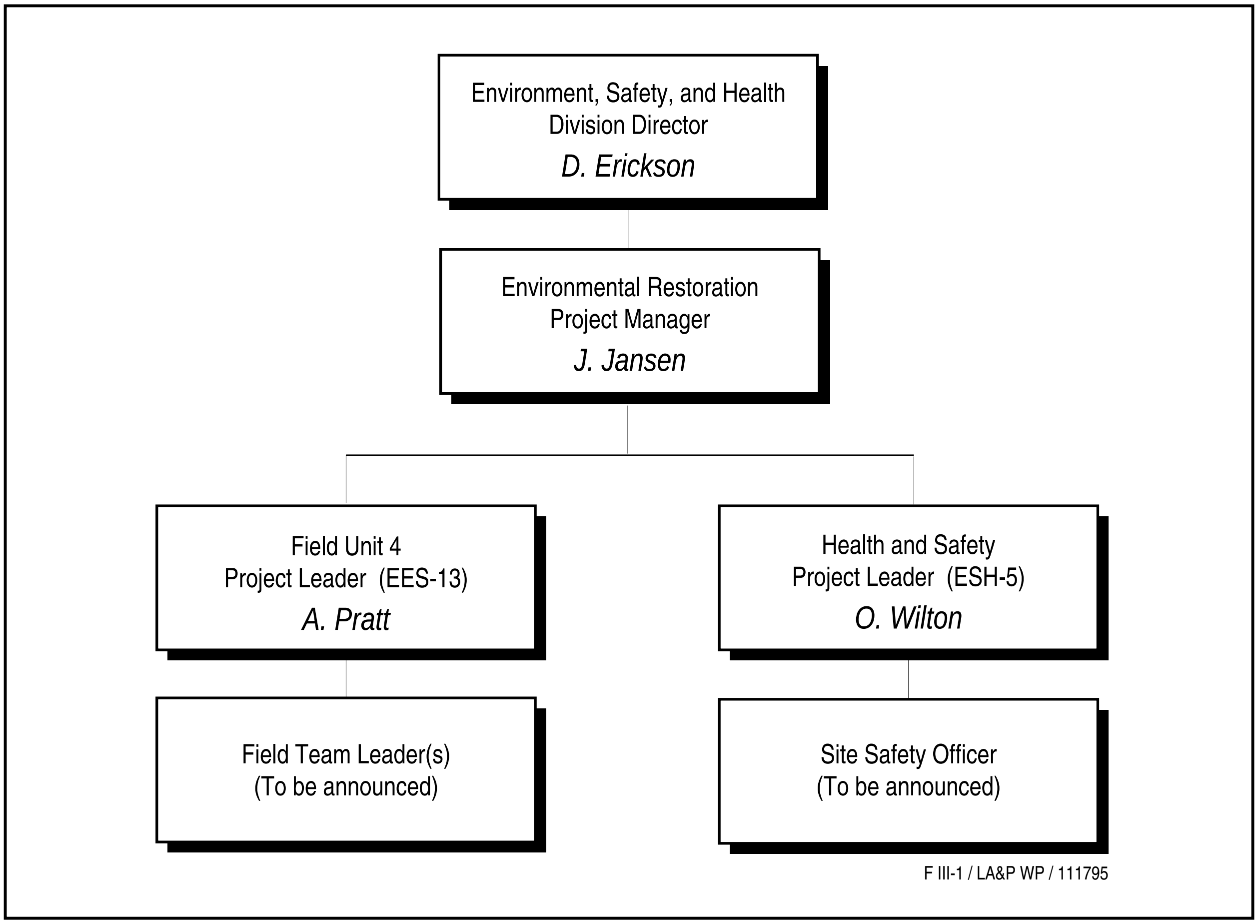

Figure II-1. Field work organization chart.

2.2.2 ER Project Manager

The ER Project manager is responsible for the overall H&S program for ER Project activities. The project manager ensures that the H&S programs are established, implemented, and supported.

2.2.3 Field Unit Health and Safety Representative

The field unit H&S representative is responsible for updating and implementing the ER Project H&S Plan (Section 6.3.3.2 in Chapter 6 of the IWP) (LANL 1996, 55574) and for reviewing operable unit H&S plans. The field unit H&S representative also is responsible for interfacing and coordinating with Laboratory personnel to use resources appropriate for the ER Project H&S program, and to ensure ER Project compliance with all applicable H&S policies and regulations. In conjunction with the field team manager, the field unit H&S representative oversees day-to-day H&S activities in the field.

2.2.4 Field Project Leader

The field project leader (FPL) is responsible for the RCRA investigations in the canyon systems. Specific H&S responsibilities include

- prepare, review, implement, and revise canyon-specific H&S documents and
- interface with the field unit H&S representative to resolve H&S concerns.

2.2.5 Field Team Leader

The field team leader is responsible for implementing the SAP, and this H&S plan, for the canyons investigations. Other H&S responsibilities include

- ensuring the health and safety of the field team members;
- assigning a site safety officer to ensure compliance with this H&S plan;
- knowing emergency response procedures and notification requirements and their implementation;
- acting as a backup to the site safety officer in the event of an emergency;
- coordinating field activities with Laboratory personnel and subcontractors, as needed;
- reading and complying with this H&S plan; and
- ensuring day-to-day compliance with the H&S procedures set forth in this H&S plan.

2.2.6 Site Safety Officer

In addition to the responsibilities outlined in Section 6.3.2.3.1 in Chapter 6 of the IWP (LANL 1996, 55574), the following responsibilities specific to the canyons investigations also will apply to the site safety officer:

- reading and enforcing this H&S plan;
- evaluating the potential hazards that may exist in the canyon systems;
- being informed about the results of sample analysis pertaining to H&S as the investigations and remediation work progress;
- concurring with the field team leader about the location of exclusion area boundaries;
- presenting safety briefings to workers;
- determining protective clothing requirements for workers;
- determining personal dosimetry requirements for workers;
- maintaining a current list of telephone numbers for emergency situations;
- having an operating radio transmitter and receiver in case telephone service is not available;
- maintaining an up-to-date copy of this H&S plan;
- maintaining an up-to-date copy of the emergency plan and procedures for the investigation;
- establishing the safety requirements to be followed by visitors;
- providing visitors with a safety briefing;
- maintaining a logbook of workers and visitors within the exclusion area at a site;
- determining whether workers can perform their jobs safely under prevailing weather conditions;
- taking control of an emergency situation;
- ensuring that all workers have been trained in the appropriate safety procedures and have read and understood this H&S plan, and that all requirements are followed during investigation activities;
- conducting daily H&S briefings for the field team leader and field team members;
- conducting daily H&S audits of the work activities; and
- having authority and requiring that field work be terminated if unsafe conditions develop or an imminent hazard is perceived.

2.2.7 Field Team Members

Field team members are responsible for conducting the assigned work in a manner that ensures that data collected are technically valid and legally defensible. In doing so, they are also responsible for observing applicable ES&H procedures; for using prescribed personal protective equipment; for promptly reporting accidents, injuries, and unsafe conditions; and for participating in required medical and biological monitoring programs.

2.3 Health and Safety Audits

H&S audits (including daily safety checks) will be performed during activities associated with this H&S plan to ensure compliance with the ER Project H&S plan (HASP). These audits will be conducted at least quarterly with a minimum of one audit during each of the individual canyons investigations.

Audits will be conducted by the site safety officer or a competent designee. Results will be documented in the standard operating procedure (SOP) training documentation checklist. The use of the checklist is outlined in ER Project SOP LANL-ER-SOP-01.01, “General Instructions for Field Investigations.” The ESH Division and EM Program deputy directors, the ER Project manager, the field unit H&S representative, and the FPL will receive copies of this report, which also will be retained at the work site. The site safety officer will coordinate with the field team leader to correct any deficiencies. Readiness checklists must be completed before starting work.

The ESH Division and the EM Program also may conduct H&S audits separately or concurrently with the internal ER Project audits to ensure compliance with the *ES&H Program Documents*, which are available on-line.

2.4 Variances from Health and Safety Requirements

When special conditions exist, a written request for a variance from a specific H&S requirement may be submitted by the site safety officer to the field team leader and the field unit H&S representative. If the field team leader and the field unit H&S representative agree with the request, the request will be reviewed by the FPL or a designee. As appropriate, higher levels of management may be consulted. The condition of the request will be evaluated and, if appropriate, a variance specifying the conditions under which the requirement may be modified will be granted in writing. The variance will become part of the canyon- or canyon aggregate-specific H&S plan.

3.0 HAZARD ASSESSMENT AND PERSONAL PROTECTION REQUIREMENTS

This section identifies potential hazards associated with the field activities within the canyon systems. Tables III-3 and III-4 (discussed and presented later in this section) summarize the anticipated initial levels of personal protection and exposure limits at potential sites within the canyon systems. Tables III-2 and III-5 (discussed and presented later in this section) summarize suspected contaminants and properties of radionuclides within the canyon systems. Specific hazard information of this type will be reviewed again before work is performed at a particular location. Training in the use of all required personal protective equipment will be provided, and only trained and/or certified workers will be allowed to use such equipment.

3.1 Identification of Hazards and Risk Analysis

The site safety officer will monitor field conditions and worker exposure to physical, chemical, biological, and radiological hazards. If a previously unidentified hazard is discovered, the site safety officer will contact the field team manager and the field unit H&S representative and will address the hazard. A safety analysis will be performed on the hazard to identify the potential harm, the likelihood of occurrence, and measures to reduce the risk. The analysis will then be written and added to the canyon- or canyon aggregate-specific H&S plan as an amendment. The amendment must be reviewed and approved by the field unit H&S representative and the FPL and signed by appropriate field team leaders and field team members, showing that they have knowledge of the newly identified hazard.

3.1.1 Physical Hazards

Injuries occur most often from exposure to physical hazards. These injuries range from minor cuts and bruises to fatalities caused by serious unexpected events. The severity of these events may be controlled by using established inspection and monitoring practices. Therefore, this section is dedicated to outlining the potential physical hazards, as well as some preventive measures, for the investigations.

3.1.1.1 Noise

Constant exposure to noise may have an adverse effect on the ability of workers to hear and understand normal speech. Before 1979, the medical profession had defined hearing impairment as an average hearing threshold level in excess of 25 dB at 500, 1,000, 2,000, and 3,000 Hz. Therefore, limits have been established to prevent hearing loss in excess of this level. Some activities during the canyon systems investigations have the potential to exceed these levels (for example, operation of drill rigs and other heavy machinery). Table II-1 shows the standards that have been established by ACGIH for noise exposure.

TABLE II-1

**AMERICAN CONFERENCE OF
GOVERNMENTAL INDUSTRIAL HYGIENISTS NOISE EXPOSURE STANDARDS**

Duration/Day (hrs)	Sound Level (dB)
16	80
8	85
4	90
2	95
1	100
0.5	105
0.25	110
0.125	115

Because decibels are logarithmic units, they cannot be added or subtracted. In fact, if the intensity of a noise is doubled, there will be a corresponding increase of only three decibels. The following are examples of some common noises and the associated levels: an average residence is approximately 50 dB, conversational speech is 60 dB, a very noisy restaurant is 80 dB, a subway is 90 dB, and a jet plane is 120 dB.

If a sound level meter is not available for monitoring noise, a simple test will identify levels above 85 dB. If at arm's length (3 ft) normal conversation is not possible, engineering controls, administrative controls, or personal protective equipment should be used.

3.1.1.2 Pinch Points

Pinch points are generally associated with activities using tools or equipment with turning or moving parts such as a drill rig, a backhoe, or even small hand tools. The moving parts may be equipped with guards. If this is the case, periodic inspections must be performed to ensure that the guards have not been removed. The guards are generally removed by field workers if the guards slow the progress of the operator or make the tool difficult to use. When inspections show that guards have been removed, the tools or equipment should be tagged and not used until the guard has been replaced.

With larger equipment, hydraulic mechanisms and tools are encountered more often. Guarding these hazardous areas is more difficult. Also, the severity of injury is much greater with hydraulic equipment because of the amount of force created by hydraulically driven machinery. Initial inspections become more important in identifying areas of concern and informing field team members of the potential hazards. The most efficient and comprehensive procedure for inspections is to require that they be performed by a competent person who has experience with that particular piece of machinery. Most equipment can be inspected in less than 30 minutes using a checklist. The site safety officer will obtain a checklist before the start of field activities.

OSHA requires that most equipment be inspected yearly. This inspection is generally conducted by the manufacturer, representative, or dealer. These inspections are to be documented and kept with the piece of equipment. This procedure ensures that the equipment is properly maintained and free of any parts that could potentially become hazardous to the operator or bystanders.

3.1.1.3 Slipping, Tripping, and Falling Hazards

Injuries from slipping, tripping, and falling hazards are the most common around drill rigs, backhoe operations, and uneven terrain. These hazards are caused by poor housekeeping, bad weather conditions, or the uneven terrain caused by soil excavation. Procedures may be developed to reduce the likelihood of injuries caused by slipping, tripping, and falling. The site safety officer will ensure that good housekeeping practices are followed. These practices include the following: keeping tools stored in an accessible but out-of-the-way place; keeping the work area free of soil piles as much as possible; reminding workers to be aware of uneven terrain; and marking trench and borehole boundaries.

3.1.1.4 Explosion, Fire, and Oxygen Deficiency

Significant potential for flammable (or combustible) and oxygen-deficient atmospheres is not anticipated while drilling, trenching, and sampling during the canyon systems investigations.

Any work with flammable materials will be done according to Laboratory Administrative Requirement 6-5, "Flammable and Combustible Liquids," and Technical Bulletins 602, "Flammable Gases," 603, "Solvents," and 604, "Epoxies," which are available on-line. The ER Project HASP also will be followed.

As necessary, measurements of explosion potential will be made in enclosed spaces or in boreholes using a combustible gas indicator (CGI)/oxygen meter. If the CGI indicator shows concentrations greater than 20% of the lower explosive limit (LEL), activities in that area will cease. The work area will be evacuated, and the appropriate safety measures will be implemented. Continued CGI readings will be made by the site safety officer to determine the appropriate time for workers to return to the area.

Oxygen levels will be measured in enclosed or confined spaces and in areas that are not ventilated frequently (for example, low-lying areas). Air-purifying respirators will be worn when oxygen concentrations are between 19 and 21%. If oxygen levels fall below 19%, the area must be evacuated, or supplied-air respirators must be furnished to workers in these areas.

Oxygen-rich atmospheres create an increased potential for fires. Therefore, if oxygen levels exceed 25%, the area will also be evacuated. If an evacuation becomes necessary, the area will be ventilated, and the site safety officer will continue monitoring oxygen levels. The site safety officer will determine when it is safe for workers to return and resume work.

3.1.1.5 Heat Stress

Heat stress occurs when the body’s physiological processes fail to maintain a normal body temperature because of excess heat. This failure is enhanced when impervious clothing is worn during hot summer months. The best cure for heat stress is prevention. Acclimation to heat is the most effective method, but drinking plenty of water, avoiding alcohol consumption, and taking frequent cooling breaks are also effective. When the body’s cooling system starts to fail, a number of symptoms begin to occur. Heat stress monitoring will be performed according to the ER Project HASP. Listed below are the physical reactions that can occur, ranging from mild to fatal.

3.1.1.5.1 Heat-Related Illness

- Heat rash is caused by exposure to heat and humid air aggravated by changing clothes. It decreases the ability to tolerate heat and becomes a nuisance. If heat rashes occur, the victim should keep the area cool and dry.

- Heat cramps are caused by profuse sweating with inadequate fluid intake and chemical replacement (especially of salts and potassium). The signs include muscle spasms and pain in the extremities and abdomen. If heat cramps occur, the victim should drink plenty of fluids, (water is best), add slightly more salt to food, and replace potassium by eating bananas.

- Heat exhaustion is caused by an increased heat stress to the body and an inability of various organs to meet the increased demand to cool the body. The signs include shallow breathing; pallor; cool, moist skin; profuse sweating; dizziness; and lassitude. If heat exhaustion occurs, it is best to get the victim to a cool shady area (not in air conditioning), allow the body to cool slowly, and give the victim plenty of fluids. Depending on the severity, the victim should wait a certain period of time before returning to the hot area.

- Heat stroke is the most severe of the heat-related injuries; it occurs when the body’s cooling system shuts down completely. The signs include red, hot, dry skin; lack of perspiration; nausea; dizziness and confusion; strong rapid pulse; and coma. The body must be cooled immediately, and the victim should be sent to the nearest hospital for immediate medical attention to prevent severe injury and/or death.

3.1.1.5.2 Work and Rest Schedule

When working in protective clothing, the following guidelines for calculating work and rest schedules should be used.

Calculate the adjusted temperature as follows.

T(adjusted) = T(actual) + (13 x sunshine fraction)

Sunshine Fraction

100% sunshine = no cloud cover = 1.00
75% sunshine = 25% cloud cover = 0.75
50% sunshine = 50% cloud cover = 0.50
25% sunshine = 75% cloud cover = 0.25
0% sunshine = 100% cloud cover = 0.00

Work Schedule

Adjusted Temperature	Active Work Time (min/hr)
75° or less	50
80°	45
85°	40
90°	35
95°	30
100°	20
105°	10
110°	0

3.1.1.6 Cold Exposure

Persons working outdoors in temperatures at or below freezing can suffer from cold-related injuries. Exposure to extreme cold for short periods of time can cause severe injury to the body surface or can result in profound generalized cooling (hypothermia), which can cause death in extreme cases. Body areas that have high surface area to volume ratios (such as fingers, toes, and ears) are the most susceptible.

Cold stress monitoring will be performed according to ER Project HASP. Listed below are the physical reactions that can occur, ranging from mild to fatal.

3.1.1.6.1 Cold-Related Illness

- Frost nip or incipient frostbite is characterized by a sudden whitening of the skin. If this occurs, the victim should warm hands slowly and change into warm, dry clothing.

- Superficial frostbite causes skin to become very waxy or white and superficially firm but flexible underneath. If frostbite occurs, the victim should go indoors and place the hands in warm (100° to

105°F) water. The affected tissue should not be rubbed. The victim should receive medical attention as soon as possible after the affected body part has been warmed.

- Deep frostbite is characterized by cold, pale, solid skin tissue that also may be blistered. Blisters should not be popped. The victim should be warmed in the same manner as above.
- Systemic hypothermia is caused by exposure to freezing or rapidly dropping temperatures. Symptoms are usually exhibited in four stages: (1) shivering; (2) apathy, listlessness, sleepiness, and (sometimes) rapid cooling of the body to less than 95°F; (3) unconsciousness, glassy stare, slow pulse, and slow respiration; and (4) freezing of the extremities. In severe cases systemic hypothermia can result in death. The victim should be moved to a warm area as soon as possible, changed into warm, dry clothing, and receive medical attention as soon as possible.

The best cure for cold-related injuries is prevention, which includes dressing in warm, insulated clothing. If the potential exists for getting wet, workers should wear wool clothing and take frequent warming breaks.

3.1.1.7 Electric Shock

Individuals working on the canyons investigations have the potential for exposure to electrical shock during drilling, trenching, and sampling activities. The source of this hazard may be from encountering overhead power lines, using portable equipment, and digging and/or hand auguring into underground utilities. Compliance with the following requirements will significantly reduce the chance of worker exposure to electrical shock.

- Only qualified and licensed workers will be allowed to operate drilling, trenching, or sampling equipment.
- Heavy equipment and energized tools will be inspected by a competent person before use and will meet all applicable local, state, and federal standards.
- While in use, drill rigs will maintain a 35-ft minimum distance from overhead power lines.
- In transit, with the boom lowered, the closest approach to a power line will be 16 ft.
- All areas to be drilled will be cleared through the Laboratory utilities manager before drilling activities begin.
- Any cord with the grounding stem removed will be taken out of service and repaired or thrown away.
- Ground fault interrupters will be used on all portable electrical equipment.

3.1.2 Chemical Hazards

Chemical hazards depend on the potential release sites located upstream or upwind from the portion of the canyon systems under investigation. Appendix D of the Groundwater Protection Management Program Plan (LANL 1995, 50124) lists all the potential release sites located within the Laboratory and their associated hazards. The SAPs will list specific chemical hazards associated with each investigation. Contamination by volatile organic compounds is not suspected for the canyon systems; Table II-2 lists the chemical hazards that may be encountered during field operations. The initial levels of required personal protection are listed in Table II-3. Possible chemical exposure hazards during the canyon systems investigations may include inhalation and ingestion of nonradioactive substances. Dermal hazard is not significant for metals in general, as long as the metals are not present as organic complexes.

TABLE II-2

SUSPECTED CHEMICAL AND RADIOLOGICAL SUBSTANCES WITHIN THE CANYON SYSTEMS

Chemical Substances	Radiological Substances
Barium	^{241}Am
Beryllium	^{137}Cs
Cadmium	^{60}Co
Chromium VI	^{238}Pu
Copper	^{239,240}Pu
Lead	Uranium (total)
Silver	^{90}Sr
Mercury	^{99}Tc
Pesticides	Tritium
PCBs[a]	^{235}U
SVOCs[b]	^{238}U
High Explosives	

a. PCB = polychlorinated biphenyl
b. SVOC = semivolatile organic compound

TABLE II-3

INITIAL LEVELS OF PROTECTION ANTICIPATED FOR THE CANYON SYSTEMS

Field Surveys	Surface Sampling	Subsurface Sampling
D[a]	C[b] D	C D

a. D = Level D personal protective equipment
b. C = Level C personal protective equipment

Table II-4 summarizes the available exposure standards and guidelines for the chemical hazards that may be encountered at a site. If unexpected chemical contaminants are identified during an investigation, the site safety officer will add them to the list of chemicals of potential concern by means of a change order form and will notify field personnel of any potential hazards, as necessary.

TABLE II-4

EXPOSURE LIMITS FOR SIGNIFICANT CONTAMINANTS

Chemical Substance	OSHA[a] PEL[b] (mg/m^3)	OSHA Ceiling (mg/m^3)	OSHA STEL[c] (mg/m^3)	ACGIH[d] TWA[e] (mg/m^3)	ACGIH STEL (mg/m^3)
Beryllium	0.002	0.005	0.025	0.002	
Cadmium (dust)	0.2	0.6			
Chromium III	0.5[f]			0.5	
Chromium IV	0.1[g]			0.05	
Mercury		0.1			
Silver (dust)	0.01				
Uranium	0.2		0.6	0.2	0.6

a. OSHA = Occupational Safety and Health Administration
b. PEL = permissible exposure limit
c. STEL = short-term exposure limit
d. ACGIH = American Conference of Governmental Industrial Hygienists
e. TWA = time-weighted average
f. As a chromous salt
g. For chromium as chromic acid

3.1.3 Radiological Hazards

Radiological hazards associated with a specific canyon or canyon aggregate will be listed in the SAP. In general, the canyon systems may contain ^{238}Pu, ^{239,240}Pu, ^{235}U, and ^{238}U plus much smaller quantities of tritium, ^{137}Cs, ^{90}Sr, and other fission products. Table II-5 summarizes the H&S data associated with these radionuclides. During field operations, if unexpected radionuclides are encountered at levels that would pose a health risk, the site safety officer will add them to the list of chemicals of potential concern by means of a change order form and will notify field personnel of any potential hazards, as necessary.

Individuals working on-site may be exposed to radioactivity during field investigations by the following three principal pathways:

- inhalation or ingestion of radionuclide particulates,
- dermal absorption of radionuclide particulates through wounds, and
- exposure to direct radiation from contaminated materials.

Soils will be screened in accordance with the ER Project HASP. If additional radionuclides are discovered during the investigations, they will be added to the list of potential hazards. The site safety officer will be responsible for adding radionuclides to the list and for notifying field personnel, as necessary.

3.1.4 Biological Hazards

Biological hazards are likely to occur in some areas of the canyon systems. Mosquitoes, ticks, spiders, and rodents (including mice and rats) are likely to be encountered. In addition, rattlesnakes may be encountered, especially near brushy or rocky areas and near structures and debris. Workers who regularly walk through such areas should wear high-top boots or snake leggings. The grass should be mowed (where appropriate) to control rodents and snakes.

TABLE II-5

RADIOLOGICAL PROPERTIES OF ENVIRONMENTALLY SIGNIFICANT RADIONUCLIDES POTENTIALLY PRESENT IN THE CANYON SYSTEMS

Radionuclide	Mode of Decay (energy, MeV)	DAC[a] (μCi/mL)	Critical Organ[b]	Radioactive Half-Life[c] (yrs)	Monitoring Instrument
^{60}Co	γ (1.17, 1.33)	1 x10^{-8}	GI[d] tract total body	5.27	GM[e], NaI[f]
^{238}Pu	α (5.50, 5.46)	3 x 10^{-12}	Bone	87.7	Alpha scintillometer, FIDLER
^{239}Pu	α (5.16, 5.11)	2 x 10^{-12}	Bone	2.41 x 10^{4}	Alpha scintillometer, FIDLER
^{240}Pu	α (5.17, 5.12)	2 x 10^{-12}	Bone	6560	Alpha scintillometer, FIDLER
^{242}Pu	α (4.90, 4.86)	2 x 10^{-12}	Bone	3.75 x 10^{5}	Alpha scintillometer
^{241}Am	α (5.49, 5.44)	2 x 10^{-12}	Bone	432.7	Alpha scintillometer, FIDLER
^{234}U	α (4.77, 4.72)	2 x 10^{-11}	Kidney	2.46 x 10^{5}	Alpha scintillometer
^{235}U	α (4.40, 4.37)	2 x 10^{-11}	Kidney	7.04 x 10^{8}	Alpha scintillometer
^{238}U	α (4.15, 4.20)	2 x 10^{-11}	Kidney	4.47 x 10^{9}	Alpha scintillometer
^{3}H	β (0.018)	2 x 10^{-5}	Total body	12.3	Liquid scintillometer
^{137}Cs	β (0.512)	7 x 10^{-8}	Total body	30.17	GM, NaI
^{90}Sr	β (0.546)	2 x 10^{-9}	Bone	29.1	GM

a. DAC = derived air concentration (DOE draft Order 5480.11)

b. Critical organ is that part of the body most susceptible to radiation damage under the specific conditions being considered.

c. Half-lives from the Knolls Atomic Power Lab “Chart of the Radionuclides” (General Electric Company 1989, 54411)

d. GI = gastrointestinal

e. GM = Geiger-Müeller detector

f. NaI = sodium iodide gamma scintillometer

If snake bite occurs, the Occupational Medicine Group (ESH-2) should be notified immediately. The only first aid treatment that should be administered is an ice pack or a cold pack placed just above the affected area to slow blood flow. The victim’s heart rate should be kept as low as possible by keeping the victim as still and calm as possible. If workers are bitten by insects, first aid creams may be applied by the site safety officer to ease the symptoms caused by the bite. If a worker is bitten by a rodent, attempts should be made to obtain the animal, and medical assistance should be sought as soon as possible.

3.1.5 Traffic

Traffic control will be maintained in and around the job site at all times to avoid worker injuries and prevent equipment damage. Work areas regularly occupied by pedestrians will be delineated so that vehicle equipment operators will not enter them. Delineation will be accomplished using barricades, warning signs, warning lights, and traffic cones.

If work takes place in or near heavy traffic areas, these areas will be appropriately marked with the aforementioned devices as necessary to protect workers. Workers will wear fluorescent orange and/or reflective clothing and vests when working in and around traffic areas.

Sufficient parking will be provided. Vehicles not being actively used will be parked so that they do not interfere with traffic. When a vehicle is being maneuvered in a confined area with limited visibility, workers positioned outside the vehicle will give assistance to the operator.

Pedestrian and civilian traffic have the right-of-way on-site. Pedestrians should be careful when they are around heavy equipment and when they are walking near roads. Pedestrians should always make eye contact and wait for a signal to proceed before passing close to or in front of operating equipment or moving vehicles.

All drivers and operators will adhere to speed limits, signs, and road markings. Equipment operators and ground workers should be especially careful when air-line respirators are in use because of the potential for injury if an air line were to become tangled in the track or wheel of a vehicle or equipment. Under no circumstances will breathing-air systems that supply air to respirators be attached to vehicles or equipment.

3.1.6 Topography

To reduce hazards associated with changes in topography, the site safety officer will inspect each site for potential hazards. Some of these hazards can be alleviated by removing any obstacles in immediate work areas, clearing icy surfaces, and placing tools in an accessible but protected area. Boundaries surrounding excavations, trenches, and boreholes will be marked. All field team members will be informed of the potentially hazardous locations and the controls for the duration of the work in each area.

3.1.7 Lightning

Lightning usually strikes the tallest object in an area and takes the most conductive route to the ground. Buildings or vehicles can provide adequate protection if a storm occurs. A large building with a metal structure is the safest because electric current will run along the outside metal frame and into the ground. An automobile with a metal roof serves the same purpose; however, convertibles or other fabric-topped vehicles are not safe because lightning can burn through the fabric.

Wood or brick buildings that are not protected by lightning rods have high potential for a strike, which travels down natural conductors such as wiring or pipes. Any contact with an underground conductor can be dangerous. Telephones, faucets, electrical equipment, and metal fences are examples of ungrounded conductors.

A person situated in the open during a lightning storm should crouch to avoid being the tallest object. A tingling sensation or hair standing on end signals that lightning is about to strike and that a crouching position must be assumed immediately. The safest crouching position is to place the hands on the knees and keep the knees and feet together while remaining as low as possible. Stretching out flat on damp soil could cause the body to attract current running into the ground from a nearby tree. Keeping feet and knees spread or placing the hands on the ground could complete a circuit and cause high-voltage current to run through the body.

A grove of trees affords more protection than a single tree. Lower ground is also safer; however, sizable ditches and ravines present the danger of a person being carried away by flood waters.

Side strikes injure more people than direct strikes. Side strikes are caused when electric current jumps from its present conductor to a more effective conductor. Because the human body is a better conductor than a tree trunk, a person should stay 6 ft away from a tree to avoid a side strike. A group of people taking shelter under a grove of trees should stand 6 ft apart to avoid side strikes from one person to another.

The force of electrical current temporarily disrupts the nervous system. Therefore, even if breathing and heartbeat have stopped, a lightning victim may not be dead. Many victims can be revived by artificial respiration and cardiopulmonary resuscitation. After the lightning flash is over, current is no longer running through the body, and it is safe to touch a lightning victim. Even a victim who seems only slightly stunned should receive immediate medical attention because internal organs may be damaged.

3.2 Task-by-Task Risk Analysis

According to 29 CFR Part 1910.120, a task-by-task risk analysis is required. These tasks are related to specific operations or activities in the field investigation. The preceding section identified the physical, chemical, radiological, and biological hazards known or suspected to be present during the canyon systems investigations. This section is designed to discuss many of the proposed tasks, identify which of the hazards apply, and estimate the likelihood of exposure. Sections 3.3, 3.4, and 3.5 identify methods for eliminating or reducing the potential exposure to the hazards associated with these tasks.

3.2.1 Drilling

The potential for exposure is high.

Associated hazards include a possibility for serious physical injury. Injuries may range from bruised and cut fingers to death. Working around a drill rig allows for entanglement and pinch points in many parts of the rig. These injuries are generally minor but have the potential for amputating fingers. Other severe injuries may occur from failure of wire rope under extreme stress. If the rope breaks under high tension, it will act as a whip, which could decapitate workers in the area.

Chemical and radiological hazards also are created when drilling disturbs or penetrates contaminated soil.

3.2.2 Hand Augering

The potential for exposure is moderate.

Associated hazards are similar to those of drilling. Because this operation will have a tendency to stir up dust, the potential for contact with contaminated soil is enhanced. Powered hand augers present hazards of operator entanglement and pinch points but to a lesser degree than drill rigs. With a nonpowered hand auger, the probability of physical injury is greatly reduced.

3.2.3 Trenching

The potential for exposure is low.

The main physical hazard associated with trenching operations results from the use of heavy equipment and the potential for cave-ins. Operators of heavy equipment are trained to be aware of workers around the area. However, operators can be distracted or lose concentration. Therefore, workers must be alert while backhoes are operating. Cave-ins can occur in trenches of all depths, but this hazard can be reduced substantially by limiting trench depths to 5 ft or less. Physical injuries as a result of cave-ins range in severity and can result in death.

Chemical and radiological hazards may be encountered while trenching is in progress. The most concentrated worker exposure may occur from the resuspension of contaminated dust. Air monitoring at this time is critical. In contrast, the accumulation of organic vapors inside the trench will most likely occur after the trench has been completed. However, this is not expected to be significant during the canyons investigations because of the lack of significant organic contamination.

3.3 Engineering Controls

OSHA regulations state that when possible, engineering controls should be used as the first line of defense for protecting workers from hazards. Engineering controls are mechanical means for reducing hazards to workers, such as the guarding of moving parts on machinery and tools or using a ventilation hood in a laboratory to remove contaminant vapors. Unfortunately, engineering controls are not as easily accomplished in an uncontrollable environment, such as the outdoors. However, the following controls are some possibilities that can be used while working in the field.

3.3.1 Engineering Controls for Airborne Dust

Hazardous airborne dust can evolve in two forms. Nuisance dust can be created as a result of earth work in dry conditions. A standard level has been established at 15 mg/m^3 for airborne dust particles. Also, radionuclides and/or hazardous substances can attach to soil particles that become entrained and can pose a hazard. Engineering controls can help prevent and/or control airborne dust.

During drilling or any other activity where localized dust is being generated, a small garden sprayer of water may be used to wet the soil enough to suppress the dust. Although this technique can be effective in some cases, sprayers do not discharge a large amount of water, and spraying must be repeated often to maintain effectiveness.

Where there are high winds in a large, dusty area with little or no vegetation, small quantities of water are not effective. In this instance, a water truck may be used to wet the area enough to suppress the dust. Frequently repeated applications are required to be effective.

3.3.2 Engineering Controls for Airborne Volatiles

Drilling and trenching activities may produce gases, fumes, or mists. These volatiles may be easily inhaled or ingested by workers with no protection. Engineering controls may be implemented to reduce the exposure to these hazards. Wind can remove toxic vapors from the work area with careful positioning of equipment, such as a drill rig. For example, a rig might be positioned so that the prevailing wind blows toward the side of the rig. This position allows the vapors to be blown away from workers behind the rig, prevents the vapors from collecting under the rig, and allows for an upwind approach for workers not performing duties related to the drilling.

Alternative ventilation methods are accomplished by mechanical means, which may not be as effective as wind in open areas but are more practical in closed or confined spaces. Fans may be used to push, or more effectively pull, contamination from a confined space. Pulling air into the confined space is more effective at removing vapors; whereas, forcing air into a confined area provides for better ensurance of acceptable oxygen levels from ambient air. This procedure has been used effectively by fire departments, which may be consulted for information on the most effective method for each situation.

3.3.3 Engineering Controls for Noise

Engineering controls for noise are difficult to implement in uncontrolled environments. Drilling and trenching are likely to produce the highest range of noise levels. On drill rigs, the highest level of noise produced is generated by the engine, which is located on the side of a drill rig. Fortunately, most of the work is performed away from the engine at the back of the drill rig. Often the rear and front of the engine are covered to further lessen noise levels. If noise levels reach 90 dB, additional barriers should be used, if possible, to reduce excessive noise exposure.

3.3.4 Engineering Controls for Trenching

Trenching often presents field workers with hazards associated with slipping, tripping, falling, and crushing-type hazards. In most cases, entry into an excavation deeper than 5 ft should be avoided whenever possible. However, it is sometimes necessary to enter these trenches to obtain the needed information. OSHA has developed regulations for trenches and excavations. Included in the regulations are engineering controls for the prevention of cave-ins. These controls include the addition of benching, sloping, and shoring to the excavation. Benching is a systematic series of steps dug around the excavation at a specified angle of repose. The angle of repose depends on the type of soil present. Sloping is a similar system of stabilizing soil that is created without the steps. Again, the angle of repose is determined by the type of soil. This method is generally used for medium-sized excavations, such as tank removal. In general, neither of these soil-stabilization methods is a convenient technique for exploratory trenches. The third method that OSHA suggests is shoring. Many different varieties of shoring are available, but the objective is the same. The sides of the excavation are supported by some type of wall that is braced to prevent cave-ins. This method is used most often in deep, narrow trenches for installing water pipes or drainage systems and in exploratory trenches. One drawback to using shoring is that it is expensive and time-consuming, especially for a trench that is scheduled to be open for only one or two days.

3.3.5 Engineering Controls for Drilling

Working with and around drill rigs presents workers with many hazards caused by the number of moving parts and the power associated with the equipment. Engineering controls for drilling operations include the installation of guarding, where possible, to prevent crushing injuries and, more importantly, an inspection program to ensure replacement of worn or broken parts. As stated, in Section 3.1.1, the inspections should be performed at the beginning of the job and regularly during the investigation.

3.4 Administrative Controls

Administrative controls are necessary when hazards are present and engineering controls are not feasible. Administrative controls are a method for controlling the degree to which workers are exposed to a hazard. Examples include the amount of time a worker spends in a hazardous area or the distance to a hazardous area. Such controls can be instituted easily in most cases and are effective measures for decreasing worker exposure.

3.4.1 Administrative Controls for Airborne Chemical and Radiological Hazards

Chemical and radiological hazards are to be monitored during the performance of duties in a contaminated zone. If the concentration of radionuclides or toxic materials exceed the limits established in this work plan, workers may be removed from the area until natural or mechanical ventilation brings the levels to background. This method would prevent the need to use personal protective equipment. In addition, workers should enter the contaminated zone only when required to do so. This method complies with DOE’s policy of maintaining exposures as low as reasonably achievable.

Because the exposure limits consider the average amount of exposure during an 8-hr day, workers exposed at a higher concentration for a portion of the day may conduct tasks in an uncontaminated area to lower the average for the day. For chemical contaminants, the higher concentrations must be lower than those considered to be immediately dangerous to life and health and the threshold limit value ceiling limits.

3.4.2 Administrative Controls for Noise

Administrative controls for noise include both time and distance. The principle is very much like the controls used for both airborne chemical and radiological hazards. Noise is discussed in Section 3.1.1.1, and guidelines on administrative controls established by ACGIH are listed in Table III-1. The intent is to increase the distance between the noise and the worker or decrease the time spent at the source. Sound pressure or intensity follows the inverse square law: as the distance from the source increases, the sound level decreases proportionally to the square of the distance.

If reduction of exposure time or distance is not possible, personal protective equipment must be worn to protect workers.

3.4.3 Administrative Controls for Trenching

Administrative controls are the most effective methods for reducing the hazards of trench excavations that may be proposed for the canyons investigation. These administrative controls were established by OSHA during the development of the regulations. The objective of administrative controls for trenching is to avoid creating a hazardous condition. All trenches should be excavated to a depth less than 5 ft, where possible. However, monitoring inside the trench and means of egress (every 25 ft) must be implemented at a depth of 4 ft. Soil piles, tools, and other debris must be stored at least 2 ft from the edge of the trench. To restrict access, all trenches must be marked when the area is not occupied.

Even though standard procedures are followed, accidents may occur because of human error or other circumstances. A backhoe operator may not see or know if workers are present in a trench. Therefore, whenever workers are in a trench, the operator must shut down the equipment until the trench has been evacuated. Inspections should be made by a competent person before any field team member is allowed to enter a trench. Additionally, workers are required to be aware of conditions inside a trench and activities going on outside the trench.

3.4.4 Administrative Controls for Working Near the Mesa Edge

Slipping, tripping, and falling hazards exist near steep slopes. These hazards may be avoided by good housekeeping in work areas near the mesa edge. Additionally, workers should not get closer than 5 ft to the edge unless close approach is really required. If necessary, barrier tape will be used to delineate this restricted area.

3.5 Personal Protective Equipment and Systems

If engineering and administrative controls are not suitable, personal protective equipment should be used as a last line of defense against hazards. This equipment may be used alone or as a supplement to existing safety systems to enhance the degree of safety for workers. Personal protective equipment is clothing or apparatus that are worn by field team members to protect them from a certain type or group of hazards. Some examples of personal protective equipment are Tyvek clothing, hardhats, gloves, safety harnesses, and respirators. The maintenance, inspection, procedures, and training for personal protective equipment usage will follow the ER Project HASP. The following sections discuss the protective equipment or systems to be used in certain situations.

3.5.1 Protection Levels and Protective Clothing

EPA has established four levels of protection for workers entering potentially hazardous sites. Potential contaminants have been identified at areas within the canyon systems. Therefore, an assessment of personal protective levels has been made based on each of the contaminants, investigation activities, and the areas to be investigated (see Table III-3). Action levels for upgrades in levels of protection are based on the above factors and are discussed in Section 3.5.2.

Level C protection will include the following:

- full-face, air-purifying respirators (approved by the Mine Safety and Health Administration and NIOSH) with cartridges or canisters capable of filtering contaminants of concern;
- contaminant-resistant clothing suitable for protection against the hazards of concern;
- inner gloves (polyvinyl chloride, latex, or nitrile);
- rubber outer gloves, which provide an effective barrier between the wearer and the contamination;
- steel-toed safety boots made of rubber or leather when disposable boot covers are worn; and
- hardhats, safety glasses, and hearing protection, as needed.

Modified Level D protection will include the following:

- cloth or Tyvek coveralls or work uniforms;
- rubber or leather outer gloves providing the best protection for the activity being performed;

- steel-toed safety boots and optional boot covers, as needed; and
- hardhats, safety glasses, and hearing protection, as needed.

The field team leaders are required to provide this equipment to each of their field team members.

The canyons investigations will be conducted according to Laboratory Administrative Requirement 12-1, “Personal Protective Equipment,” and Technical Bulletins 1201, “Eye and Face Protection,” 1202, “Protective Clothing,” and 1203, “Respiratory Protective Equipment,” which are available on-line.

3.5.2 Action Levels for Upgrade in Protection

Monitoring instruments are to be used in conjunction with laboratory analysis to establish the exposure levels of field team members. These instruments will monitor for radiation, volatile organics, corrosives, flammable vapors, and particulates. Action levels will be established based on the results obtained during site-specific monitoring. In some instances, laboratory screening and analysis with a quick turnaround will be necessary to determine the actual level of the specific chemical contaminant in air. For instance, there are no direct reading instruments for metals other than mercury, but there is a real-time aerosol monitor (RAM) that determines the amount of respirable dust present in the breathing zone. Thus, soil concentrations of metals of concern from laboratory analyses can be used to calculate the total concentration in air, based on a total particulate reading from the RAM.

Results of the calculations will be confirmed with air sampling. Air sampling during the canyons investigations will be used predominately to determine alpha contamination in air. The organization selected to implement the monitoring will supply the method of maintenance and calibration for the specific instruments to be used.

3.5.2.1 Monitoring Instruments

The monitoring instruments to be used during this investigation are listed in the following sections.

- Photoionization detectors and flame ionization detectors

  Photoionization and flame ionization detectors are used to monitor total organic vapors. A description of these detectors is located in the ER Project HASP.

- CGIs are used to monitor the concentration of flammable gases and vapors. A description of the CGI is located in the ER Project HASP.

- Oxygen meters

  Portable oxygen meters are used to measure ambient oxygen concentrations in confined spaces or areas. A description of the oxygen meter is located in the ER Project HASP.

- RAMs

  RAMs are designed to monitor respirable particulate matter (<10 μ). These instruments measure reflected light, which is converted to units of mg/m^3. These instruments are useful if there are known concentrations in soil of alpha contaminants, particulates, and metals. Soil samples will be submitted for laboratory analysis, and the results will be used to determine action levels for the contaminants that are present.

- Colorimetric indicator tubes

  Colorimetric indicator tubes may be used to quickly measure the approximate concentrations of specific vapors or gases. A description of the colorimetric indicators is located in the ER Project HASP.

- High- and low-volume air samplers

  High- and low-volume air samplers are used to collect particulates on a filter that is subsequently analyzed to determine the types and concentrations of airborne contaminants (for example, alpha contamination). A description of the air samplers is found in the ER Project HASP.

- Radiation survey meters

  A variety of radiation survey meters will be used in the investigation to determine the levels to which workers are exposed to radiation. Alpha scintillometers will be used to screen cores and workers leaving the contamination zone. A mR meter or a GM detector will be used to establish gamma (and beta) exposure to field team members. In addition, thermoluminescent dosimeters (TLDs) will be worn by all workers.

3.5.3 Action Levels

The following guidelines are to be used during the canyon systems investigations. When applicable, ER Project SOPs describe measuring procedures and frequency of monitoring.

3.5.3.1 Organic Compounds

Levels of organic contamination in canyon systems have been estimated from the historical information gathered during the preparation of this core document. In general, organic contaminants are expected to be at or near background levels. If field monitoring or laboratory analysis proves this conclusion to be unfounded, appropriate guidelines will be instituted to ensure the H&S of the workers.

3.5.3.2 Combustible Vapors

As appropriate, the CGI will be used to monitor for combustible atmospheres during drilling and trenching. One-minute readings will be used for boreholes and trenches to give the instruments time to equilibrate. At 20% of the LEL, workers will be evacuated, and engineering controls will be used to reduce the concentration of combustible vapors. Workers may resume work when levels drop below 10% of the LEL.

3.5.3.3 Particulates, Metals, Polychlorinated Biphenyls, and Alpha Contamination

As appropriate, RAMs will be used in conjunction with laboratory data to determine the concentrations in air. Samples will be obtained to determine the amount of contamination in soil, and an action level will be calculated for that particular work area.

3.5.4 Safety Systems and Equipment

A variety of safety equipment will be used to protect workers from physical hazards and to minimize exposure to hazardous chemicals and radionuclides during field activities within the canyon systems.

3.5.4.1 Hearing Protection

If noise levels are above 85 dB and neither engineering nor administrative controls are practical, hearing protection will be required. Two basic types of hearing protection are available: disposable and reusable ear plugs and ear muffs. Ear plugs may reduce noise levels 25 to 30 dB; ear muffs may reduce noise levels 35 to 40 dB if worn properly. Product information for specific protective devices will be used to determine the effective noise reduction rating.

3.5.4.2 Trench Protection

Trench boxes and trench shields have been developed for trench operations where benching, sloping, and shoring are not feasible. A trench box or shield is a box constructed from a strong metal or wood that is wide enough for workers to move around inside and perform their duties. OSHA regulations specify criteria for the trench box to be considered safe. The trench box is placed in the trench and attached to a backhoe so that it may be pulled along as the work progresses. This type of system is used often in the installation of water systems. The walls of the trench may not be viewed from the box, and protection is voided when workers leave the box.

3.5.4.3 Fire Protection

A fire extinguisher is classed by the type of fire it is designed to extinguish. However, a fire extinguisher may be effective for more than one class of fire.

- Class A - ordinary combustible materials (wood, paper, and textiles)
- Class B - flammable liquids (oil, grease, and paint)
- Class C - electrical fires
- Class D - metals capable of rapid oxidation (magnesium, sodium, zinc, aluminum, uranium, and zirconium)

3.5.4.4 Other Safety Equipment

In addition to the personal protective devices described above, other safety equipment may be used as needed. Laboratory Administrative Requirement 12-2, “Seat Belts,” (available on-line) will be followed. Warming and cooling equipment may be necessary to minimize stress from climatic conditions. Emergency equipment will also be necessary for immediate response and emergency treatment. Additionally, the location of such equipment must be clearly marked, and workers should know the location and be trained in its use.

3.5.5 General Safety Practices and Mitigation Measures

Some hazards can be minimized by implementing specific safety procedures, work practices, special equipment, worker training, and emergency response equipment in case of an accident. Sections 6.9 and 6.10 in Chapter 6 of the IWP (LANL 1996, 55574) discuss some of these practices. The following routine measures will be taken.

- Daily planning and/or preactivity meetings will be held for all workers involved in field activities. These meetings will discuss H&S concerns and refresh workers on the emergency response plans.

- Control zones will be established for safety as well as contamination and decontamination procedures. The type and size of the control zones will depend on the type of field activity to be conducted. The level of protection will be based on site-specific task/site investigation areas. For informational and medical support, control zones will have maps posted that identify direct routes to administrative and medical facilities.
- If troublesome levels of dust are generated during augering or drilling activities, water may be used to suppress dust for the protection of field workers.
- The buddy system will be employed as a general practice.

3.6 Site Access Control

3.6.1 Restricted Access and Exclusion Zones

Restricted access or exclusion zones will be established before work begins at contaminated sites to protect workers from unnecessary exposure to toxic materials and to prevent the spread of contamination. A general description of exclusion zones is found in Section 6.5 in Chapter 6 of the IWP (LANL 1996, 55574).

3.6.2 Decontamination

Workers, equipment, and vehicles that have been located in contaminated areas may carry residual contamination. Although protective clothing, respirators, and good work practices can help reduce contamination, decontamination may be necessary to prevent exposure of workers and the inadvertent spread of contaminants.

Vehicles and equipment that are suspected of being contaminated will be cleaned with high-pressure steam or equally effective systems. Vehicles and equipment suspected of being contaminated with alpha contamination will be screened with alpha survey instruments before being released from the site.

Worker decontamination can be performed in all levels of protection. Disposable protective equipment does not need to be decontaminated but should be disposed of as a hazardous waste. Reusable protective equipment must be decontaminated using a soap and water wash and two successive rinses. Visual inspections of the equipment will help determine the effectiveness of the decontamination process. As with the equipment, workers will be screened with an alpha scintillometer when working with or near alpha-contaminated material. ER Project SOPs, established to guide the decontamination process, will be maintained on-site and will be followed at all times. Worker decontamination procedures are specified in the ER Project HASP. Laboratory

Administrative Requirements for Waste Management are 10-1, “Radioactive Liquid Waste,” 10-2, “Low-Level Radioactive Solid Waste,” 10-3, “Hazardous and Mixed Waste,” and 10-5, “Transuranic (TRU) Solid Waste,” which are available on-line.

In addition to the above list, Section 6.8 in Chapter 6 of the IWP (LANL 1996, 55574) contains information on decontamination.

- The level of decontamination required will depend on the nature and magnitude of contamination and the type of protective clothing worn. Disposable clothing (for example, Tyvek) will not be washed because water may transport contamination through the paper garment to the skin.

- Waste water and materials used during decontamination will be contained for appropriate disposal. Arrangements will be made with the Laboratory for acquisition and disposal of drums containing soapy water, rinse water, methanol, and trash.

3.7 Worker Training

Worker training will follow the requirements set forth in Section 6.10 in Chapter 6 of the IWP (LANL 1996, 55574). Field workers will be given copies of all relevant SOPs and will be briefed on their use. Field workers also will read this H&S plan and Chapter 6 of the IWP.

3.8 Medical Surveillance

In addition to the guidance provided in Section 6.11 in Chapter 6 of the IWP (LANL 1996, 55574), the following paragraph describes specific program requirements.

Field team members who are exposed to contaminated materials during ER Project remedial investigation shall participate in a medical examination program provided by the Laboratory according to 29 CFR Part 1910 or DOE Order 5480.1B (Chapter VIII) requirements. Suitability of field team members for conducting field sampling activities, including respirator use, shall be evaluated and documented by a physician. Medical programs must comply with the requirements of DOE Order 5480.1B Chapter VIII or 29 CFR Part 1910, as appropriate. Laboratory Administrative Requirements 2-1, “Occupational Medicine Program,” and 6-4, “Biological Monitoring for Hazardous Materials,” and Laboratory Standard LS107-11.0, “Radiation Dosimetry Monitoring,” shall be followed. (These documents are all available on-line.)

3.9 Records and Reporting Requirements

The field unit H&S representative, working with the FPL, the site safety officer, and the field team manager, will ensure that H&S records are maintained within the appropriate Laboratory group as required by DOE orders. The records are as follows.

- DOE-AL Order 5000.3A, Unusual Occurrence Reporting
- DOE Form 5484.3, Attachment 1, Supplementary Record of Occupational Injuries and Illnesses
- DOE Form 5484.4, Attachment 2, Tabulation of Property Damage Experience
- DOE Form 5484.5, Attachment 4, Report of Property Damage of Loss
- DOE Form 5484.6, Attachment 13, Annual Summary of Whole Body Exposures to Ionizing Radiation
- DOE Form 5484.1, Attachment 14, Summary of Exposure Resulting in Internal Body Depositions of Radioactive Materials for CY 19
- DOE Form 5484.8, Attachment 10, Termination Occupational Exposure Report
- DOE Form OSHA-200, Attachment 7, Log of Occupational Injuries and Illnesses
- DOE Form EV-102A, Attachment 8, Summary of Department of Energy and Department of Energy Contractor Occupational Injuries and Illnesses

- DOE Form 5421.1, Attachment 15, Unplanned Releases Form

Copies of these reports will be stored with the appropriate Laboratory group. Specific reporting responsibilities are given in the following sections and in Chapter 1 of the Laboratory's *Environment, Safety, and Health Manual*, which is available on-line.

3.9.1 Exposure and Medical Reports

Confidential records of the medical status of each field team member, obtained through the employee medical surveillance program, will be maintained with the appropriate Laboratory group. The requirements established below must be met in addition to the requirements set forth in Section 6.11 in Chapter 6 of the IWP (LANL 1996, 55574). Field team members will be issued a radiation dosimeter by the Laboratory, according to the *LANL Radiological Control Manual* (LANL 1994, 43737).

DOE Forms 5484.1, "Summary of Exposures Resulting in Internal Body Depositions of Radioactive Materials for CY 19__," and 5484.6, "Annual Summary of Whole Body Exposures to Ionizing Radiation," will be submitted annually (by March 31) for monitored employees. Preparation of these reports will be coordinated with the Health Physics Operations Group (ESH-1).

3.9.2 Unusual Occurrences

All unusual occurrences must be reported by the field unit site safety officer to the field unit H&S representative, the field team manager, and the FPL in accordance with Section 6.9.3 in Chapter 6 of the IWP (LANL 1996, 55574).

3.9.3 Accident or Incident Reports

The FPL will submit a complete DOE Form F 5484.X for any of the following accidents or incidents, according to Laboratory Administrative Requirement 1-1, "Accident and Occurrence Reporting," which is available on-line.

- Occupational injury is any injury such as a cut, fracture, sprain, or amputation that results from a work accident or from an exposure involving a single incident in the work environment.

Note: Conditions resulting from animal bites, such as insect or snake bites, or from one-time exposure to chemicals are considered injuries.

- Occupational illness is any abnormal condition or disorder, other than one resulting from an occupational injury, caused by exposure to environmental factors associated with employment. It includes acute and chronic illnesses or diseases that may be caused by inhalation, absorption, ingestion, or direct contact with a toxic material.
- Property damage losses of $1,000 or more must be reported. Accidents that cause damage to DOE property, regardless of fault, or accidents wherein DOE may be liable for damage to a second party, are reportable if damage is $1,000 or more. Included are damage to facilities, inventories, equipment, and properly parked motor vehicles. Excluded is damage resulting from a DOE-reported vehicle accident.
- Government motor vehicle accidents resulting in damages of $150 or more, involving an injury (unless the government vehicle is not at fault), or sustaining damage of less than $150 to the

government vehicle and injury to occupants of the government vehicle occupants must be reported.

Accidents also are reportable to DOE if

- damage to a government vehicle that is not properly parked is greater than or equal to $250,
- damage to DOE property is greater than or equal to $500 and the driver of a government vehicle is not at fault,
- damage to any private property or vehicle is greater than or equal to $250 and the driver of a government vehicle is at fault, and
- any person is injured and the driver of a government vehicle is at fault.

3.10 Worker Information

The site safety officer shall ensure that the following DOE and Laboratory forms are posted where field team leaders and field team members can easily read them.

- Form F 5480.2, Occupational Safety and Health Protection
- Form F 5480.4, Occupational Safety and Health Complaint Form
- Laboratory Special Work Permit
- OSHA Job Safety and Health Protection Form

The Laboratory H&S standard concerning workers' right-to-know also shall be posted at the work site.

Other information that shall be made available to site workers include

- the IWP (LANL 1996, 55574), this document, and ancillary documents;
- pertinent Laboratory H&S documents including administrative policies and the ER Project HASP;
- field monitoring data; and
- personal monitoring data (for example, TLD results) and personal medical records for the requesting individual.

4.0 EMERGENCY RESPONSE AND NOTIFICATION

This section provides information on responding to emergency situations. Laboratory Administrative Requirements 1-2, “Emergency Preparedness,” and 1-8, “Working Alone,” and Technical Bulletin 101, “Emergency Preparedness,” were used to develop this section. (These documents are available on-line.)

4.1 Emergency Contacts

The names of persons and services to contact in case of emergencies are given in Attachment III-2 of the ER Project HASP. This emergency contact form will be copied and posted in prominent locations at the work site. Two-way radio communication will be maintained at remote sites when possible.

The emergency contact number for the Laboratory is 911.

4.2 Contingency Plans

This section considers contingency plans for specific types of emergencies. The site safety officer, with assistance from the field team manager and, if needed, the field team leader, shall have responsibility and authority for coordinating all emergency response activities until the proper authorities arrive and assume control. Evacuation plans and routes used by the Chemical Science and Technology Division and the Engineering Sciences and Applications Divisions are discussed in Section 4.2.3.

4.2.1 Fire or Explosion

In the event of a fire, the work area will be evacuated, and the Laboratory fire department will be notified. In the event of an explosion, all workers will be evacuated, and no one will enter the work area until it has been cleared by Laboratory explosion safety personnel from the Engineering Sciences and Applications Division.

If a combustible gas meter indicates gas concentrations at levels of 20% of the LEL, workers will be evacuated from that area. The site safety officer will continue monitoring to determine when equipment should be removed or when workers may re-enter the area and resume work.

4.2.2 Worker Injuries

In case of serious injuries, the victim(s) will be transported to a medical facility as soon as possible. The Laboratory fire department provides emergency transport services. Minor injuries may be treated by trained personnel in the work area. All injuries should be reported to the Occupational Medicine Group (ES&H-2). If an injured person has been contaminated with chemicals, decontamination will be performed to prevent further exposure (as outlined in the ER Project HASP) only if it will not aggravate the injury. Treatment of life-threatening or serious injuries will be undertaken first.

4.2.3 Emergency Response Plan

A map will be attached to each field copy of the site-specific H&S plans generated for work in the canyon systems. The map will define the routes to the Occupational Medicine Group (ESH-2) and the Los Alamos Medical Center.

For general emergencies that require evacuation (such as fire, medical, security, or releases), an emergency response plan specific to each of the canyon systems is required. The signal for site evacuation will be two long blasts on an air horn. The crew will gather at a muster area at or near the work site designated by the site safety officer. One person should find the nearest phone, and the evacuation route used by field workers should be away from the affected area and toward the site-specific designated muster area. At the muster area, all workers will wait until everyone in the field crew has been accounted for. The site safety officer will determine the next course of action.

A major release or fire involving hazardous or radioactive materials may warrant a different approach. This emergency will be signaled by two short blasts on an air horn. If the signal is heard, workers will meet at a predetermined area, which will be determined based on wind conditions. A portable wind sock or streamer will be positioned at each work location, and workers will be notified of the location. If the horn is sounded, all workers will move in an upwind direction as much as possible without entering a plume. If the source of the fire or release is directly upwind, workers will move away from the plume (if visible). After a safe distance has been reached, all workers are to be accounted for. The field team manager and the site safety officer will be responsible for this task. At that time, the site safety officer will determine the next course of action.

For a less severe accident, such as a minor release or small fire, site evacuation may not be necessary. This scenario will be signaled by one long blast on an air horn. All workers will meet at a designated muster area, and all workers will be accounted for by the field team leader and/or site safety officer.

These procedures will be reviewed at least once per week to remind field workers of the procedures and the signals. The signals are summarized below for easy reference. This information will be posted at prominent locations at each work location with other H&S information.

- Major fire - two long blasts on the air horn
- Major release - two short blasts on the air horn
- Minor fire or release - one long blast on the air horn

4.2.4 Additional Emergencies

For information on accidental release of hazardous materials into the environment, unusual events, site emergencies, and general emergencies, see Section 6.9 in Chapter 6 of the IWP (LANL 1996, 55574).

4.3 Notification Requirements

In emergency situations, field team members will notify the site safety officer. The site safety officer's responsibility is to notify the appropriate emergency assistance personnel (such as fire, police, or ambulance), the field team's manager, and the ESH Division Office according to DOE Order 5500.2 and DOE-AL Orders 5500.2B and 5000.3A. The ESH Division Office is responsible for implementing notification and reporting requirements according to DOE Order 5484.1A, DOE Order 5484.2, and DOE-AL Order 5484.2.

REFERENCES FOR ANNEX II

General Electric Company, 1989. *Nuclides and Isotopes*, Fourteenth Edition, General Electric Company, Nuclear Energy Operations, San Jose, California. **(General Electric Company 1989, ER ID Number 54411)**

LANL (Los Alamos National Laboratory), 1994. “LANL Radiological Control Manual,” Los Alamos, New Mexico. **(LANL 1994, ER ID Number 43737)**

LANL (Los Alamos National Laboratory), October 25, 1995. “Groundwater Protection Management Program Plan” (draft), Revision 2.0, Los Alamos, New Mexico. **(LANL 1995, ER ID Number 50124)**

LANL (Los Alamos National Laboratory), December 1996. “Installation Work Plan for Environmental Restoration Program,” Revision 6, Los Alamos National Laboratory Report LA-UR-96-4629, Los Alamos, New Mexico. **(LANL 1996, ER ID Number 55574)**

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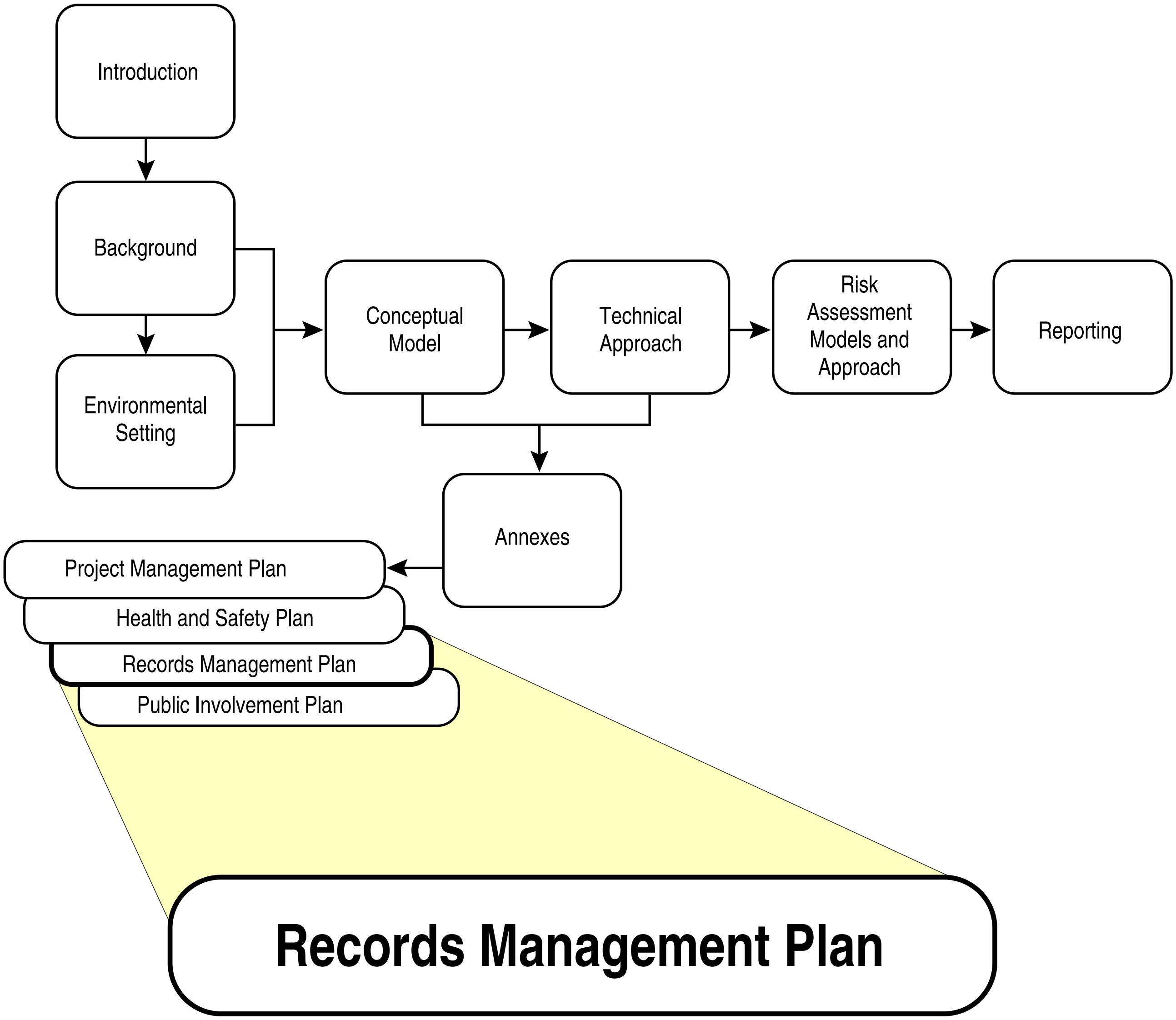
Annex III



Records Management Plan

1.0 INTRODUCTION

The Records Management Plan for the Environmental Restoration (ER) Project at the Laboratory is described in Chapter 5 of the Installation Work Plan (IWP) (LANL 1996, 55574). The purposes of the Records Management Plan are to meet the requirements for protecting and managing records (including technical data), to provide an ongoing tool to support the technical efforts of the ER Project, and to function as a support system for management decisions for the duration of the ER Project.

The ER Project uses the following statutory definition of a record (44 USC 33010):

> . . . books, papers, maps, photographs, machine-readable materials, or other documentary materials, regardless of physical form or characteristics, . . . appropriate for preservation . . . because of the informational value of the data in them.

The Records Management Plan establishes general guidelines for managing records, regardless of their physical form or characteristics, that are generated and/or used by the ER Project. The Records Management Plan will be implemented consistently to meet the requirements of the “Quality Assurance Project Plan Requirements for Sampling and Analysis” (LANL 1996, 53450) and to provide an auditable and legally defensible system for records. Another important function of the Records Management Plan is to maintain the publicly accessible documentation comprising the administrative record required by the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA).

2.0 IMPLEMENTATION OF THE RECORDS MANAGEMENT PLAN

Section 5.2.2 of the IWP (LANL 1996, 55574) describes the implementation of the Records Management Plan. Records management activities for the canyons investigations will follow the guidelines summarized in that section. As the Records Management Plan develops to support canyons investigation needs, additional detail will be provided in annual updates of the IWP.

The Records Management Plan incorporates a threefold approach based on records control and on commitment to quality guidelines: a structured work flow for records, the use of approved procedures, and the compilation of a referential information base. ER Project records are those specifically identified in quality control procedures, administrative procedures (LANL 1992, 11686), standard operating procedures, ER Project records management plans, management guidance documents, and records identified by ER Project participants as being essential to the project. Records are processed in a structured work flow. The records management procedure (LANL-ER-AP-02.1, R1, “Procedure for LANL ER Records Management”) governs records management activities, which include records identification, submittal, review, indexing, retention, protection, access, retrieval, and correction (if necessary). Other procedures, such as LANL-ER-AP-01.3, “Review and Approval of Environmental Restoration Program Plans and Reports,” LANL-ER-AP-01.4, “Distribution of Controlled Documents Prepared for the Environmental Restoration Program,” and LANL-ER-AP-01.5, “Revision or Interim Change of Environmental Program Controlled Documents” are also followed.

Records (including data) will be protected in and accessed through the referable information base. The referable information base is composed of the Records-Processing Facility (RPF) and the Facility for Information Management, Analysis, and Display (FIMAD). RPF personnel receive ER Project records, assign an ER identification number, and process records for delivery to FIMAD. The RPF will complement FIMAD in certain aspects of data capture, such as scanning. The RPF also functions as an ER Project reference library for information that is inappropriate either in form (for example, old records) or in content (for example, the *Federal Register*) for storage at FIMAD. FIMAD provides the hardware and software necessary for data capture, display, and analysis. The information will be readily accessible through a network of work stations. Configuration management accounts for, controls, and documents the planned and actual design components of FIMAD.

3.0 USE OF ER PROJECT RECORDS MANAGEMENT FACILITIES

The RPF and FIMAD will be used to manage records resulting from work conducted in the canyon systems. Interaction with these facilities is described in LANL-ER-AP-2.01 (LANL 1992, 11686), in Chapter 5 of the IWP (LANL 1996, 55574), and in other ER Project procedures and management guidance documents, as appropriate.

4.0 COORDINATION WITH THE QUALITY PROGRAM

Records will be protected throughout the process, as described in Section 5.4 of the IWP (LANL 1996, 55574) and in LANL-ER-AP-02.1 (LANL 1992, 11686). The originator is responsible for protecting records until they are submitted to the RPF. The level of protection afforded by the originator will be commensurate with the value of the information contained in the record. After a record has been received, the RPF will temporarily store the original of the record in 1-hr fire-rated equipment and will provide a copy of the record to FIMAD. The RPF will then send the original record to a dual-storage area for long-term storage in a protected environment.

5.0 COORDINATION WITH THE HEALTH AND SAFETY PROGRAM

Section 5.5 of the IWP (LANL 1996, 55574) notes two exceptions to the records storage process. The Laboratory's Occupational Medicine Group (ESH-2) will maintain medical records because of their confidential nature. Training records will be maintained by the ER Project Office and in some cases by the contractors. ER training records contain information about the completion of training, the dates of required refresher training, and the site(s) each worker visits regularly.

6.0 COORDINATION WITH PROJECT PLANNING AND CONTROL

Specific reporting requirements are ER Project deliverables and, as such, are monitored by the Project Planning and Control Team. Records resulting from work conducted in the canyons contribute to the development of these deliverables.

7.0 COORDINATION WITH THE PUBLIC INVOLVEMENT PROGRAM

The Resource Conservation and Recovery Act and CERCLA require that records be made available to the public. Two complementary approaches are being implemented: hard copy and electronic access. A community reading room allows public access to hard copies of key documents. A work station and necessary data links are being prepared to allow public access to the FIMAD database.

REFERENCES FOR ANNEX III

LANL (Los Alamos National Laboratory), March 1992. “Administrative and Quality Procedures for Environmental Restoration,” Los Alamos, New Mexico. **(LANL 1992, ER ID Number 11686)**

LANL (Los Alamos National Laboratory), March 1996. “Quality Assurance Project Plan Requirements for Sampling and Analysis,” Los Alamos National Laboratory Report LA-UR-96-441, Los Alamos, New Mexico. **(LANL 1996, ER ID Number 53450)**

LANL (Los Alamos National Laboratory), December 1996. “Installation Work Plan for Environmental Restoration Program,” Revision 6, Los Alamos National Laboratory Report LA-UR-96-4629, Los Alamos, New Mexico. **(LANL 1996, ER ID Number 55574)**

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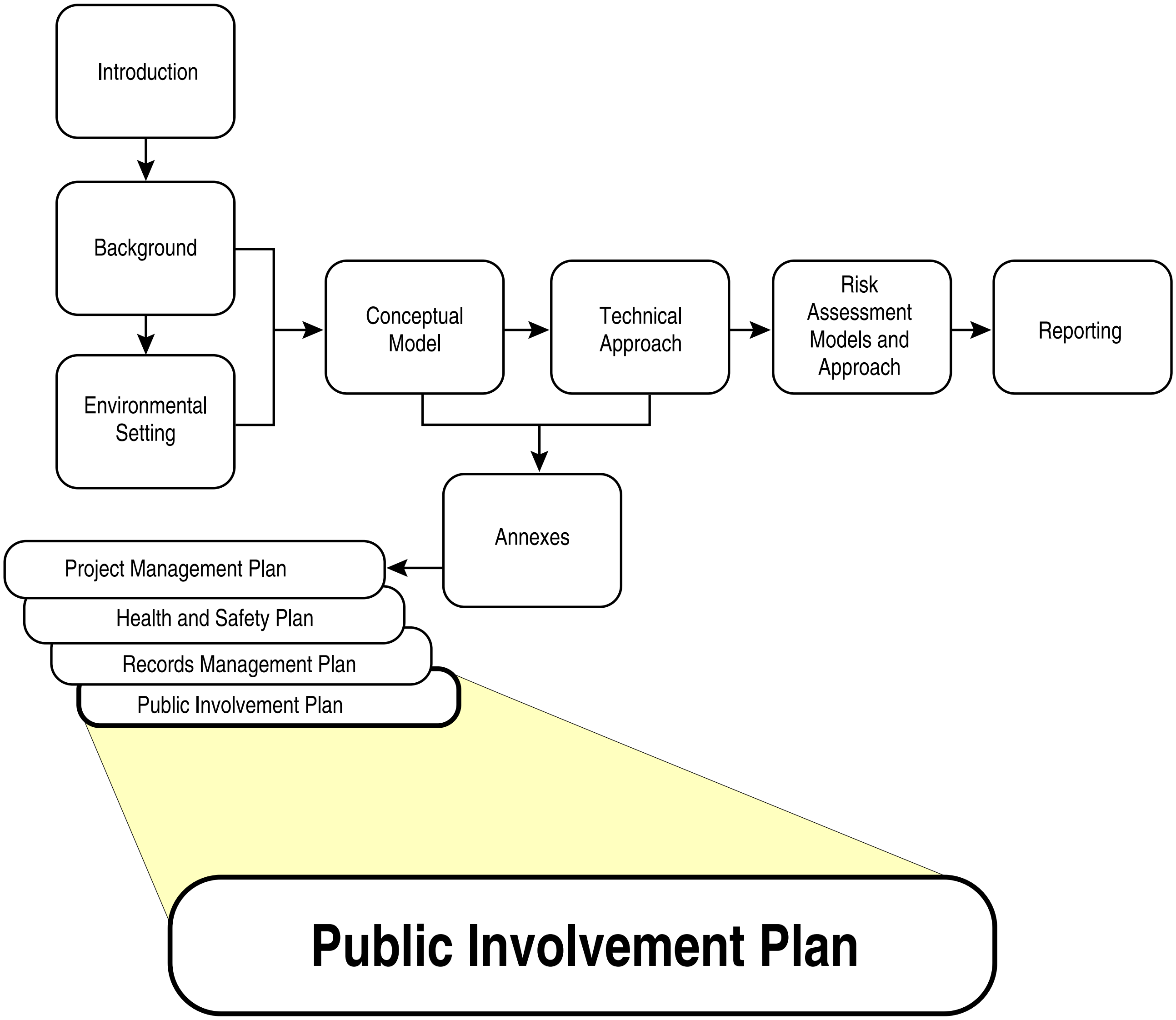
Annex IV


Introduction
Background
Environmental Setting
Conceptual Model
Technical Approach
Risk Assessment Models and Approach
Reporting
Annexes
Project Management Plan
Health and Safety Plan
Records Management Plan
Public Involvement Plan
Public Involvement Plan

1.0 OVERVIEW

The Public Involvement Plan specific to the canyons investigations follows the directives, goals, and regulatory requirements set forth in Chapter 7 of the Installation Work Plan (LANL 1996, 55574) and the "Plan for Increasing Public Participation in Cleanup Decisions for the Los Alamos National Laboratory" (Working Group and Lefkoff 1995, 44013), which was developed with public input.

This Public Involvement Plan was developed specifically to provide an avenue for meaningful public participation in making recommendations for cleanup decisions at the Laboratory. In addition, recommendations were made to develop effective communications between the neighboring communities (including the Indian Pueblos) and the Environmental Restoration (ER) Project staff during the investigation, characterization, and cleanup activities at the Laboratory.

The Laboratory, as a hazardous waste treatment, storage, and disposal facility, operates under a Resource Conservation and Recovery Act permit issued by the New Mexico Environment Department. Module VIII of this permit, the Hazardous and Solid Waste Amendments (HSWA) Module, issued by the Environmental Protection Agency (EPA 1990, 1585), governs all environmental restoration activities. The HSWA Module requires the ER Project to perform certain activities for public involvement, such as

- establishing a mailing list of interested parties;
- creating fact sheets, news releases, work plans, final reports, newsletters, and quarterly technical reports;
- creating a public information repository and reading room for ER Project materials;
- conducting informational meetings for the public;
- conducting tours and briefings; and
- establishing procedures for immediate notification of neighboring Indian Pueblos or other affected parties if a newly discovered off-site release could impact them.

Although the ER Project public involvement effort has implemented these activities since 1991, beginning in 1994 the ER Project has expanded its effort to develop a more broadly based approach for outreach to other northern New Mexico communities. This effort is supported by the following goals:

- broaden the base of involved individuals and groups;
- begin to build trust by focusing on personal contact, dialogue, and mutual education;
- obtain meaningful public input on decisions regarding cleanup issues; and
- learn a better, more cost-effective way of involving the public early in major activities of the ER Project.

To accomplish those goals, the following objectives have been established:

- make information readily available and give the public the information it needs to understand ER cleanup issues and provide the ER Project with recommendations;

- respond to requests for information as soon as possible;
- increase contacts with the public in ways that encourage interaction, such as establishing dialogue with members of community organizations;
- use community leaders, as well as Laboratory and ER Project representatives who live in the neighboring communities, as community contacts;
- involve the public in the cleanup process before decisions are made;
- treat the public as equals;
- ask for assistance from community members and use them as experts on their community's concerns and needs;
- develop alternatives for determining cleanup levels and site prioritization; and
- evaluate the effectiveness and efficiency of each of the public participation activities.

2.0 PUBLIC INVOLVEMENT ACTIVITIES

2.1 Information Sheets

The Community Involvement and Outreach Office staff will prepare information sheets for the canyon systems activities and update the sheets whenever new information becomes available. Information sheets will be reviewed by ER Project staff and informally reviewed by members of the public before they are completed.

2.2 Dissemination of Information

Information on the canyon systems will be distributed via the existing mailing list of approximately 2,000 individuals and organizations. In addition, information materials will be available at the Laboratory Community Reading Room (1350 Central Avenue in Los Alamos) and in the information repositories at the public libraries of Santa Fe, Española, and Los Alamos. The Governor's Office at San Ildefonso Pueblo will also have information available to Indian Pueblo members. Anyone who would like more information about the ER Project may call 1-800-357-8301.

2.3 Community Meetings

Initially, an information meeting will be scheduled at a central location to introduce the public to the forthcoming activities in the canyon systems. The field project leader, assisted by Community Involvement and Outreach Office staff, will present information and respond to questions and concerns raised by the public. In addition, meetings will be scheduled with community groups to inform them and to establish a dialogue about their concerns and interests. These meetings may take many forms, such as meetings in homes, brown bag presentations, or more structured meetings during a group's regularly scheduled meeting time. The primary purpose will be personal interaction, dialogue, and opportunities for early involvement in ER issues.

2.4 Indian Pueblo Interaction

The interactions with the Indian Pueblos will be closely coordinated between the field project leader and the Community Involvement and Outreach Office, and the Community Involvement and Outreach Office.

2.5 Tours of the Canyon Systems Sites

It will be helpful to the public to see the actual cleanup sites associated with the canyon systems. Tours will be scheduled as potential release sites are scheduled for corrective action, during public meetings, or at the specific request of the public. For these activities, ER Project personnel will take into consideration times convenient for the public such as late afternoons, evenings, and weekends.

2.6 Responses to Inquiries

Inquiries about the canyon systems activities may be directed to the

- Field Unit 4 field project leader, Allyn Pratt, at 505-667-4308 or
- Community Involvement and Outreach staff at 1-800-357-8301.

A specific briefing may also be held upon request.

2.7 Monthly Progress Tracking System

As the canyon- or canyon aggregate-specific sampling and analysis plans are implemented, the ER Project will document technical progress in monthly progress reports. These reports will be available at the Laboratory Community Reading Room.

REFERENCES FOR ANNEX IV

EPA (US Environmental Protection Agency), April 10, 1990. Module VIII of RCRA Permit No. NM0890010515, EPA Region VI, issued to Los Alamos National Laboratory, Los Alamos, New Mexico, effective May 23, 1990, EPA Region VI, Hazardous Waste Management Division, Dallas, Texas. **(EPA 1990, ER ID Number 1585)**

LANL (Los Alamos National Laboratory), December 1996. "Installation Work Plan for Environmental Restoration Program," Revision 6, Los Alamos National Laboratory Report LA-UR-96-4629, Los Alamos, New Mexico. **(LANL 1996, ER ID Number 55574)**

Working Group and Lefkoff (Working Group for Public Participation in Cleanup Decisions and Merle Lefkoff and Associates) 1995. "Plan for Increasing Public Participation in Cleanup Decisions for the Los Alamos National Laboratory," Los Alamos National Laboratory Report LA-UR-95-381, Los Alamos, New Mexico. **(Working Group and Lefkoff 1995, ER ID Number 44013)**

Appendix A

Maps

Appendix A is made up of four oversized maps that are not included in this electronic version:

- Figure A-1. Site map for Operable Unit 1049 (FIMAD Plot ID 104253)
- Figure A-2. Land use map for Operable Unit 1049 (FIMAD Plot ID 104254)
- Figure A-3. Geologic map for Operable Unit 1049 (FIMAD Plot ID 104255)
- Figure A-4. Existing wells and monitoring stations for Operable Unit 1049 (FIMAD Plot ID 104256)

Copies of the maps may be viewed at the Laboratory’s Public Reading Room, located at 1619 Central Avenue, Los Alamos, NM.

Appendix B

Plant and Animal Checklists

TABLE B-1

PLANT CHECKLIST FOR THE CANYON SYSTEMS

Family	Scientific Name	Common Name	Indicator Status[a]
Aceraceae	*Acer glabrum neomexicanum*	New Mexico maple	Facultative[b]
Amaranthaceae	*Amaranthus retroflexus*	Pigweed	
Anacardiaceae	*Rhus radicans*	Poison ivy	
	R. trilobata	Shunkbush sumac	
Berberidaceae	*Berberis fendleri*	Colorado barberry	
Betulaceae	*Betula occidentalis*	Birch	Faculatative wetland[c]
Boraginaceae	*Cryptantha jamesii*	James hiddenflower	
	Lithospermum multiflorum	Puccoon	
Cactaceae	*Coryphantha vivipara*	Pincushion cactus	
	Opuntia spp.	Prickly pear cactus	
Capparidacieae	*Polanisia trachysperma*	Clammyweed	
Caryophyllaceae	*Arenaria fendleri*	Fendler's sandwort	
Celestraceae	*Pachystima myrsinites*	Myrtle boxleaf	Facultative
Ceratophyllaceae	*Clematis pseudoalpina*	Rocky Mountain clematis	
Chenopodiaceae	*Atriplex canescens*	Four-wing saltbush	Facultative
	Chenopodium album	Lamb's quarters	
	C. fremontii	Fremont goosefoot	
	C. graveolens	Chenopodium	
	Kochia scoparia	Summer cypress	
	Salsola iberica	Russian thistle	
Compositae	*Achillea lanulosa*	Yarrow	
	Ambrosia coronopifolia	Ragweed	
	Antennaria parvifolia	Pussytoes	
	Artemisia carruthii	Wormwood	
	A. dracunculus	False tarragon	
	A. franserioides	Ragweed sagebrush	
	A. frigida	Estafiata	
	A. ludoviciana	Wormwood	
	A. tridentata	Big sagebrush	
	Bahia dissecta	Wild chrysanthemum	
	Brickellia spp.	Bricklebush	
	Chrysopsis foliosa	Golden aster	
	Chrysothamnus nauseosus	Rubber rabbitbrush	
	Cirsium sp.	Thistle	Facultative upland[d]
	Conyza canadensis	Horseweed	
	Erigeron flagellaris	Fleabane	
	E. divergens	Fleabane daisy	
	Eupatorium herbaceum	Throughwort	
	Franseria confertifolia	Bursage	

a. Status of whether species occurs wholly or partially in a wetland or nonwetland area is given, if available.

b. Facultative means equally likely to occur in wetlands or nonwetlands (estimated probability 34–66%).

c. Facultative wetland means usually occurs in wetlands (estimated probability 67–99%) but occasionally found in nonwetlands.

d. Facultative upland means usually occurs in nonwetlands (estimated probability 67–99%) but occasionally found in wetlands (estimated probability 1–33%).

TABLE B-1 (continued)

PLANT CHECKLIST FOR THE CANYON SYSTEMS

Family	Scientific Name	Common Name	Indicator Status[a]
Compositae (continued)	*Gaillardia pulchella*	Firewheel	
	Grindelia aphanactis	Gumweed	
	Gutierrezia sarothrae	Snakeweed	
	Haplopappus spinulosus	Spiny goldenweed	
	Helianthus annuus	Sunflower	Facultative[b]
	Hymenopappus filifolius	Yellow cut-leaf	
	H. argentea	Perky sue	
	H. richardsonii	Bitterweed	
	Iva spp.	Marsh-elder	Facultative
	Senecio sp.	Groundsel	
	Solidago spp.	Goldenrod	
	Taraxacum officinale	Dandelion	Facultative upland[c]
	T. trifidum	Greenthread	
	Townsendia exscapa	Easter daisy	
	Tragopogon dubius	Salisfy, Goatsbeard	
	Verbesina encelioides	Crownbeard	Facultative
	Viguiera multiflora	Showy goldeneye	
	Xanthium strumarium	Cocklebur	Facultative
Convolvulaceae	*Ipomoea coccinea*	Star glory	Facultative
Cornaceae	*Cornus stolonifera*	Dogwood	Facultative wetland[d]
Cruciferae	*Descurainia* sp.	Mustard	
	Erysimum capitatum	Western wallflower	
	Lesquerella intermedia	Bladderpod	
Cupressaceae	*Juniperus monosperma*	One-seeded juniper	
	J. scopulorum	Rocky Mountain juniper	
Cyperaceae	*Carex* spp.	Sedge	
Eleagnaceae	*Eleagnus angustifolia*	Russian olive	Facultative wetland
Ericaceae	*Arctostaphylus uva-ursi*	Bearberry	
Euphorbiaceae	*Croton texensis*	Doveweed	
	Euphorbia dentata	Spurge	
Fagaceae	*Quercus gambelii*	Gambel oak	
Geraniaceae	*Erodium cicutarium*	Filaree	
	Geranium caespitosum	James geranium	
Gramineae	*Agropyron smithii*	Western wheatgrass	Facultative
	Andropogon scoparius	Little bluestem	
	Aristida spp.	Three-awn	
	Blepharoneuron tricholepsis	Pine dropseed	
	Bouteloua eriopoda	Black grama	
	B. gracilis	Blue grama	

a. Status of whether species occurs wholly or partially in a wetland or nonwetland area is given, if available.

b. Facultative means equally likely to occur in wetlands or nonwetlands (estimated probability 34–66%).

c. Facultative upland means usually occurs in nonwetlands (estimated probability 67–99%) but occasionally found in wetlands (estimated probability 1–33%).

d. Facultative wetland means usually occurs in wetlands (estimated probability 67–99%) but occasionally found in nonwetlands.

TABLE B-1 (continued)

PLANT CHECKLIST FOR THE CANYON SYSTEMS

Family	Scientific Name	Common Name	Indicator Status[a]
Gramineae (continued)	*Bromus anomalus*	Nodding brome	
	B. inermis	Smooth brome	
	B. marginatus	Mountian brome	
	B. tectorum	Downy chess	
	Dactylis glomerata	Orchard grass	
	Elymus canadensis	Wild rye	Facultative[b]
	Festuca octoflora	Six-weeks fescue	
	Hilaria jamesii	Galleta	
	Hordeum sp.	Barley	Facultative
	Muhlenbergia montana	Mountain muhly	
	M. torreyi	Ring muhly	
	Oryzopsis asperifolia		
	O. hymenoides	Indian ricegrass	Facultative upland[c]
	Phleum pratense	Common timothy	Facultative upland
	Poa fendleriana	Mutton grass	
	Poa spp.	Bluegrass	
	Sitanion hystrix	Bottlebrush squirreltail	
	Sporobolus cryptandrus	Sand dropseed	Facultative upland
	Stipa spp.	Needle and thread	
Labiateae	*Monarda pectinata*	Ponymint	
Leguminosae	*Lupinus caudatus*	Lupine	
	Melilotus albus	White sweet clover	Facultative upland
	M. officinalis	Yellow sweet clover	Facultative upland
	Petalostemum spp.	Clover	
	Robinia neomexicana	New Mexico locust	
	Thermopsis pinetorum	Big golden-pea	
	Vicia americana	American vetch	
Liliaceae	*Allium cernuum*	Nodding onion	
	Yucca baccata	Banana yucca	
Linaceae	*Linum neomexicana*	New Mexico yellow flax	
Loasaceae	*Mentzelia pumila*	Stickleaf	
Nyctaginaceae	*Mirabalis multiflora*	Wild four o'clock	
	M. oxybaphoides	Vining four o'clock	
Oleaceae	*Forestiera neomexicana*	New Mexico olive	Facultative upland
Onagraceae	*Oenothera* spp.	Evening primrose	
Pinaceae	*Abies concolor*	White fir	
	Picea pungens	Blue spruce	Facultative
	Pinus edulis	Pinon pine	
	P. flexilis	Limber pine	
	P. ponderosa	Ponderosa pine	Facultative upland
	Pseudotsuga menziesii	Douglas fir	

a. Status of whether species occurs wholly or partially in a wetland or nonwetland area is given, if available.

b. Facultative means equally likely to occur in wetlands or nonwetlands (estimated probability 34–66%).

c. Facultative upland means usually occurs in nonwetlands (estimated probability 67–99%) but occasionally found in wetlands (estimated probability 1–33%).

TABLE B-1 (continued)

PLANT CHECKLIST FOR THE CANYON SYSTEMS

Family	Scientific Name	Common Name	Indicator Status[a]
Plantaginaceae	*Plantago* sp.	Plantain	
Polemoniaceae	*Ipomopsis aggregata* *I. longiflora*	Skyrocket Blue skyrocket	
Polygonaceae	*Eriogonum jamesii* *E. leptophyllum* *Rumex* spp.	Antelope sage Wild buckwheat Dock	
Polypodiaceae		Fern	
Portulacaceae	*Portulaca* sp.	Purslane	
Ranunculaceae	*Clematis ligusticifolia* *C. pseudoalpina* *Delphinium* sp. *Thalictrum fendleri*	Western's virginbower Rocky Mountain clematis Larkspur Fendler meadowrue	Facultative[b] Facultative upland[c]
Rosaceae	*Cercocarpus montanus* *Fallugia paradoxa* *Fragaria americana* *Potentilla pulcherrima* *Rosa woodsii* *Rubus strigosus*	Mountain mahogany Apache plume Wild strawberry Cinquefoil Wild rose Wild raspberry	 Facultative upland Facultative
Rutaceae	*Ptelea trifoliata*	Narrowleaf hoptree	Facultative upland
Salicaceae	*Populus tremuloides* *P. angustifolia* *Salix* spp.	Aspen Narrowleaf cottonwood Willow	Facultative upland Facultative wetland[d]
Saxifragaceae	*Jamesia americana* *Philadelphus microphyllus* *Ribes cereum*	Cliffbush Mockorange Wax current	Facultative upland
Scrophulariaceae	*Castilleja integra* *Penstemon barbatus* *P. secundiflorus* *P. virgatus* *Verbascum thapsus*	Foothills paintbrush Scarlet bugler Beardtongue Variegated penstemon Mullein	 Facultative upland
Solanaceae	*Solanum nigrum* *Physalis foetens*	Black nightshade Groundcherry	
Ulmaceae	*Ulmus* sp.	Elm	
Umbelliferae	*Pseudocymopterus montanus*	Yellow mountain parsley	
Valerianaceae	*Valeriana acutiloba*	Valeriana	
Vitaceae	*Parthenocissus inserta*	Virginia creeper	

a. Status of whether species occurs wholly or partially in a wetland or nonwetland area is given, if available.

b. Facultative means equally likely to occur in wetlands or nonwetlands (estimated probability 34–66%).

c. Facultative upland means usually occurs in nonwetlands (estimated probability 67–99%) but occasionally found in wetlands (estimated probability 1–33%).

d. Facultative wetland means usually occurs in wetlands (estimated probability 67–99%) but occasionally found in nonwetlands.

Source: Foxx and Hoard 1984, 50041; Martin and Hutchins 1980, 50040

TABLE B-2

TERRESTRIAL ARTHROPOD CHECKLIST FOR THE CANYON SYSTEMS

Terrestrial Insects Found on Laboratory Property as of December 1994		
Order	**Family**	**Common Name**
Thysanura (bristletails)	Lepismatidae Machilidae	Silverfish Jumping bristletail
Collembola (springtails)	Sminthuridae Entomobryidae Isotomidae Hypogastruridae	Globular springtail Slender springtail Smooth springtail Elongate-bodied springtail
Odonata (dragonflies and damselflies)	Aeshnidae Libellulidae Coenagrionidae Gomphidae	Darner Common skimmer Narrow-winged damselfly Clubtail
Phasmida (walkingsticks)	Heteronemiidae	Common walkingstick
Orthoptera (grasshoppers and crickets)	Acrididae Gryllacrididae Gryllidae	Short-horned grasshopper Camel cricket True cricket
Plecoptera (stoneflies)	Perlidae	Common stonefly
Dermaptera (earwigs)	Forficulidae	Common earwig
Thysanoptera (thrips)	Thripidae	Common thrip
Hemiptera (true bugs)	Belostomatidae Miridae Reduviidae Phymatidae Lygaeidae Cydnidae Scutelleridae Pentatomidae Anthocoridae Coreidae Nabidae	Giant water bug Plant bug Assassin bug Ambush bug Seed bug Burrower bug Shield-backed bug Stink bug Minute pirate bug Squash bug Damsel bug
Homoptera (cicadas and kin)	Cicadidae Aphididae Cercopidae Cicadellidae Coccidaea Delphacidae Eriosomatidae Psyllidae	Cicada Aphids Spittlebugs Leafhoppers Soft scales Planthoppers Gall-making aphids Jumping plantlice
Neuroptera (net-veined insects)	Myrmeleontidae Hemerobiidae Raphidiidae	Antlion Brown lacewings Snakefly

TABLE B-2 (continued)

TERRESTRIAL ARTHROPOD CHECKLIST FOR THE CANYON SYSTEMS

Terrestrial Insects Found on Laboratory Property as of December 1994		
Order	**Family**	**Common Name**
Coleoptera (beetles)	Cicindelidae	Tiger beetle
	Carabidae	Ground beetle
	Silphidae	Carrion beetle
	Lampyridae	Firefly
	Cantharidae	Soldier beetle
	Lycidae	Net-winged beetle
	Buprestidae	Metallic wood-boring beetle
	Staphylinidae	Rove beetle
	Erotylidae	Pleasing fungus beetle
	Nitidulidae	Sap beetle
	Coccinellidae	Ladybird beetle
	Tenebrionidae	Darkling beetle
	Meloidae	Blister beetle
	Cerambycidae	Long-horned beetle
	Lucanidae	Stag beetle
	Scarabaeidae	Scarab beetle
	Chrysomelidae	Leaf beetle
	Curulionidae	Weevil
	Dermestidae	Dermestid beetle
Lepidoptera (butterflies and moths)	Papilionidae	Swallowtail
	Lycaenidae	Copper
	Hesperiidae	Skipper
	Pieridae	White, sulphur, and orange
	Nymphalidae	Brush-footed butterfly
	Satyridae	Satyr, nymph, and artic
	Noctuidae	Noctuid moth
	Sphingidae	Sphinx moth
	Saturniidae	Giant silkworm moth
	Gelechiidae	Gelechiid moth
	Geometridae	Measuring worms
	Pterophoridae	Plume moth
Diptera (flies)	Tabanidae	Horseflies and deer flies
	Therevidae	Stiletto fly
	Asilidae	Robber fly
	Bombyliidae	Bee fly
	Syrphidae	Hover fly
	Tachinidae	Tachinid fly
Siphonaptera (fleas)	Pulicidae	Dog fleas
Hymenoptera (bees, ants, and wasps)	Ichneumonidae	Ichneumonid wasp
	Cynipidae	Gall wasp
	Mutillidae	Velvet ant
	Scoliidae	Scoliid wasp
	Formicidae	Ant
	Pompilidae	Spider wasp
	Eumenidae	Euminid wasp
	Vespidae	Vespid wasp
	Sphecidae	Sphecid wasp
	Halictidae	Metallic wasp
	Megachilidae	Leafcutting bee
	Apidae	Honey bees and bumble bees

TABLE B-2 (continued)

TERRESTRIAL ARTHROPOD CHECKLIST FOR THE CANYON SYSTEMS

Noninsect Terrestrial Arthropods Found on Laboratory Property as of December 1994	
Class/Order	**Family**
Chilopoda (centipedes)	Geophilidae Lithobiidae
Diplopoda (millipedes)	Julidae
Arachnida/Acarina (spiders and mites)	Anystis Bdellidae Ascidae Bryobiidae Calligonellidae Cryptognathidae Cunaxidae Erythraeidae Eupodidae Gymnodamaeidae Laelapidae Nanorchestidae Paratydaeidae Phytoseiidae Rhagidiidae Rhaphignathidae Scutacaridae Stigmaeidae Tenuipalpidae Terpnacaridae Trombidiidae Tydeidae Tarsonemidae Zerconidae
Archnida/Araneida	Agelenidae Amaurobiidae Anyphaenidae Araneidae Clubionidae Dictynidae Gnaphosidae Hahniidae Linyphiidae
Archnida/Araneida	Lycosidae Micryphantidae Miryphantidae Oonopidae Pholcidae Tetragnathidae Salticidae Theridiidae Thomisidae
Arachnida/Opiliones	Phalangiidae

Source: ESH-20, Ecology Team, Los Alamos National Laboratory, update December 1994

TABLE B-3

REPTILES AND AMPHIBIANS IN THE CANYON SYSTEMS

Family	**Scientific Name**	**Common Name**
Bufonidae	*Bufo woodhousei*	Woodhouse toad
Colubridae	*Hypsiglena torquata* *Masticophis taeniatus* *M. flagellum* *Opheodrys vernalis* *Pituophis melanoleucus* *Thamnophis elegans* *T. sirtalis*	Night snake Stripped whipsnake Coachwhip Smooth green snake Gopher snake Western terrestrial garter snake Common garter snake
Hylidae	*Hyla arenicolor*	Canyon treefrog
Iguanidae	*Crotaphytus collaris* *Phrynosoma douglassi* *Sceloporus undulatus* *Urosaurus ornatus*	Common collared lizard Short-horned lizard Eastern fence lizard Tree lizard
Pelobatidae	*Scaphiopus multiplicatus*	Southern spadefoot
Scinicidae	*Eumeces multivirartus*	Many-lined skink
Teiidae	*Cnemidophorus velox*	Plateau stripped whiptail
Viperidae	*Crotalus atrox* *C. viridis*	Western diamondback rattlesnake Western rattlesnake

Source: Bogart circa 1978, 50038

TABLE B-4

BIRD CHECKLIST FOR THE CANYON SYSTEMS

Family	Scientific Name	Common Name
Accipitridae	*Accipiter cooperii* *A. gentilis* *Buteo albonatus* *B. jamaicensis*	Cooper's hawk Northern goshawk Zone-tailed hawk Red-tailed hawk
Aegithalidae	*Psaltriparus minimus*	Bushtit
Apodidae	*Aeronautes saxatalis*	White-throated swift
Caprimulgidae	*Chordeiles minor* *Phalaenoptilus nuttallii*	Common nighthawk Common poorwill
Carthartidae	*Cathartes aura*	Turkey vulture
Columbidae	*Columba fasciata* *Zenaida macroura*	Band-tailed pigeon Morning dove
Corvidae	*Agelaius phoeniceus* *Amphelocoma coerulescens* *Corvus corax* *Cyanocitta stelleri* *Euphagus cyanocephalus* *Gymnorhinus cyanocephalus* *Nucifraga columbiana* *Pica pica*	Red-winged blackbird Scrub jay Common raven Steller's jay Brewer's blackbird Pinon jay Clark's nutcracker Black-billed magpie
Emberizidae	*Calamospiza grammacus* *Carduelis pinus* *Coccothraustes vespertinus* *Dendroica coronata* *D. digrescens* *D. gracial* *D. petechia* *Icterus galbula* *I. spurius* *Junco hyemalis* *Loxia curvirostra* *Melospiza melodia* *Molothrus aster* *Oporornis tolmiei* *Passer domesticus* *Passerina cyanea* *P. amoena* *Pheucticus melanocephalus* *Pipilo chlorurus* *P. fuscus* *P. erythrophthalmus* *Piranga flava* *P. ludoviciana* *Pooecetes gramineus* *Spizella passerina* *Sturnella neglecta* *Vermivora celata* *V. virginiae*	Lark sparrow Pine siskin Evening grosbeak Yellow-rumped warbler Black-throated gray warbler Grace's warbler Yellow warbler Northern oriole Orchard oriole Dark-eyed junco Red crossbill Song sparrow Brown-headed cowbird MacGillivray's warbler House sparrow Indigo bunting Lazuli bunting Black-headed grosbeak Green-tailed towhee Canyon towhee Rufous-sided towhee Hepatic tanager Western tanager Vesper sparrow Chipping sparrow Western meadowlark Orange-crowned warbler Virginia's warbler
Falconidae	*Falco sparverius*	American kestrel

TABLE B-4 (continued)

BIRD CHECKLIST FOR THE CANYON SYSTEMS

Family	Scientific Name	Common Name
Fringillidae	*Carpodacus cassinii* *C. mexicanus* *C. psaltria* *Guiraco caeulea* *Hesperiphona vespertina* *Loxia curvirostra*	Cassin's finch House finch Lesser goldfinch Blue grosbeak Evening grosbeak Red crossbill
Hirundinidae	*Hirundo pyrrhonota* *Tachycineta thalassina*	Cliff swallow Violet-green swallow
Muscicapidae	*Catharus guttatus* *Myadestes townsendii* *Polioptila caerulea* *Sialis currucoides* *S. mexicana* *Turdus migratorius*	Hermit thrush Townsend's solitaire Blue-gray gnatcatcher Mountain bluebird Western bluebird American robin
Paridae	*Parus gambeli* *P. inornatus*	Mountain chickadee Plain titmouse
Picidae	*Colaptes auratus* *Melanerpes formicivorus* *M. lewis* *Picoides pubescens* *P. tridactylus* *P. villosus* *Sphyrapicus thyroideus*	Northern flicker Acorn woodpecker Lewis' woodpecker Downy woodpecker Northern three-toed woodpecker Hairy woodpecker Williamson's sapsucker
Rallidae	*Rallus limicola*	Virginia rail
Sittidae	*Certhia americana* *Sitta carolinensis* *S. pygmaea*	Brown creeper White-breasted nuthatch Pygmy nuthatch
Sturnidae	*Sturnus vulgaris*	European starling
Trochilidae	*Archilocus alexandri* *Selasphorus platycercus* *S. rufus*	Black-chinned hummingbird Broad-tailed hummingbird Rufous hummingbird
Troglodytidae	*Catherkes mexicanus* *Salpinctes obsoleuts* *Thromanes bewickii* *Troglodytes aedon*	Canyon wren Rock wren Bewick's wren House wren
Tyrannidae	*Contopus borealis* *Contopus sordidulus* *Empidonax hammondii* *E. oberholseri* *E. occidentalis* *E. wrightii* *Myiarchus cinerascens* *Sayornis saya* *Tyrannus vociferans*	Olive-sided flycatcher Western wood-pewee Hammond's flycatcher Dusky flycatcher Cordilleran flycatcher Gray flycatcher Ash-throated flycatcher Say's Phoebe Cassin's kingbird
Tytonidae	*Buto virginianus* *Glaucidium gnoma*	Great horned owl Northern pygmy owl
Vireonidae	*Vireo gilvus* *V. solitarius*	Warbling vireo Solitary vireo

Source: Travis 1992, 12015; Unpublished bird surveys of Los Alamos National Laboratory 1986, 1987, and 1988; Foxx et al. 1987, 55514

TABLE B-5

MAMMAL CHECKLIST FOR THE CANYON SYSTEMS

Family	Scientific Name	Common Name	Source
Canidae	*Canis latrans*	Coyote	b
	Vulpus vulpus	Red fox	b
Cervidae	*Cervus elaphus*	Elk	b
	Odocoileus hemionus	Mule deer	b
Cricetidae	*Clethrionomys gapperi*	Boreal redback vole	d
	Microtus longicaudus	Long-tailed vole	f,g
	M. montanus	Montane vole	d
	M. pennsylvanicus	Meadow vole	a,e
	Neotoma mexicana	Mexican woodrat	a,b,d,e,f,g
	Peromyscus boylii	Brush mouse	d
	P. difficilis	Rock mouse	d,f
	P. leucopus	White-footed mouse	a,d,e,f,g
	P. maniculatus	Deer mouse	a,e,f
	P. trueii	Pinon mouse	a,d,e,f
	Reithrodontomys megalotis	Western harvest mouse	a
	Sigmodon hispidus	Cotton rat	
Erethizontidae	*Erethizon dorsatum*	Porcupine	b
Felidae	*Felis concolor*	Mountain lion	b
	Lynx rufus	Bobcat	b
Geomyidae	*Thomomys bottae*	Bottae's pocket gopher	a,e
Heteromyidae	*Perognathus flavus*	Silky pocket mouse	f
	P. intermedius	Rock pocket mouse	f
Leporidae	*Sylvilagus audubonii*	Desert cottontail	b
	S. nuttallii	Nuttall's cottontail	e
	S. spp.	Cottontail rabbit	a
Muridae	*Mus musculus*	House mouse	a
Mustelidae	*Mustela frenata*	Long-tailed weasel	b
	Taxidae taxus	Badger	b
Sciuridae	*Eutamius minimus*	Least chipmunk	a,d,e,g
	E. quadrivittatus	Colorado chipmunk	d,f,g
	Sciurus aberti	Abert's squirrel	a,d,e
	Spermophilus lateralis	Golden-mantled sqirrel	a
	S. variegatus	Rock squirrel	a,d,f
	Tamiasciurus hudsonicus	Red squirrel	d
Soricidae	*Sorex nanus*	Dwarf shrew	a,e
	S. palustris	Northern water shrew	d
	S. vagrans	Vagrant shrew	e
Ursidae	*Ursus americanus*	Black bear	b
Verspertilionidae	*Eptesicus fuscus*	Big brown bat	c
	Lasionycteris noctivagans	Silver-haired bat	c
	Lasiurus cinereus	Hoary bat	c
	Myotis evotis	Long-eared myotis	c
	M. volans	Long-legged myotis	c

a. Ferenbaugh et al. 1982, 6393

b. Unpublished data from the Biological Resource Evaluation Team database

c. Unpublished data from the Biological Resource Evaluation Team mist netting 1991

d. Unpublished bird surveys of Los Alamos National Laboratory 1986, 1988, and 1989

e. Miera and Hakonson circa 1974, 52005

f. Kent 1986, 04-0322

g. Martin et al. 1971, 04-0323

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Appendix C

List of Contributors

Name and Affiliation	Education and Expertise	Function
Jerry Boak (CST-7)	Ph.D. Geologic Sciences 21 years experience in geologic, geochemical, and petroleum geologic research, exploration, and program management including performance assessment of the high-level radioactive waste repository program	Work plan development
Wesley L. Bradford (Los Alamos Technical Associates, Inc.)	Ph.D. Earth Sciences 31 years experience in conducting field investigations in hydrology, hydrogeology, and geochemistry and managing RI/FS environmental contamination assessments and RCRA corrective actions	Technical coordinator
David Broxton (EES-1)	M.S. Geology 20 years experience conducting field investigations in geology, geologic disposal of high-level nuclear waste, and project management	Canyons technical team leader Technical lead for geology
Florie Caporuscio (formerly ERM/Golder)	Ph.D. Geology/Igneous Petrology 10 years experience in RCRA/CERCLA and federal National Emission Standards for Hazardous Air Pollutants investigations; expertise in geochemistry as related to high-level and transuranic radioactive waste	Technical consultant
Joe Wanda Cramer (Los Alamos Technical Associates, Inc.)	39 years experience in records management, document control, and administrative support including environmental restoration	Archival research Technical and quality assurance support
Alison Dorries (TSA-11)	Ph.D. Chemistry/M.P.H. Public Health 9 years experience in toxicology, pulmonary health research, regulation development, and human health risk assessment	Technical team leader for human health risk assessment
Christy Fläming (Los Alamos Technical Associates, Inc.)	24 years experience in graphics, illustration, printing, and document production	Artist/designer Graphics team leader Word processing
Teralene Foxx (ESH-20)	M.S. Biology 18 years field ecology and waste site characterization experience; adjunct professor, University of New Mexico; author of books and publications on plant and fire ecology	NEPA biological evaluation
Bruce Gallaher (ESH-18)	M.S. Hydrology 15 years experience in waste management and contaminant hydrology	Principal investigator for hydrology
Kyle Gay (ERM Program Management Company)	M.S. Earth and Planetary Sciences 5 years experience investigating fragmental volcanic deposits; 2 years experience in RCRA, sample handling and transport, waste and data management, and work plan preparation	ER project support contractor
Rebecca M. Johnson (Los Alamos Technical Associates, Inc.)	M.A. Organizational Management 13 years experience in word processing using various software, technical editing, and administrative management	Electronic publications specialist

Name and Affiliation	Education and Expertise	Function
Danny Katzman (ERM Program Management Company)	M.S. Geology 6 years experience in geological and geomorphic investigations and site characterizations at RCRA-regulated DOE facilities; additional experience in waste management/minimization and work plan preparation	Sedimentologist
Richard Kelley (Los Alamos Technical Associates, Inc.)	B.S. Geology 17 years experience in geologic and petroleum geologic exploration including 7 years of environmental and hydrological specialization	GIS mapping consultant
Beverly Larson (ESH-20)	M.A. Anthropology/Ph.D. Candidate in Anthropology 17 years field experience, including 6 years as a Laboratory archaeologist; adjunct professor, University of New Mexico	NEPA cultural evaluation
Johnnye Lewis (Environmental Health Associates, Inc.)	Ph.D. Pharmacology/Toxicology 20 years experience in environmental health with current focus on development of interdisciplinary models to address community health risks and concerns	Canyons decision support team
Patrick Longmire (CST-7)	Ph.D. Aqueous Geochemistry 17 years experience in field hydrogeochemistry, soil chemistry regulatory oversight (NMEID), the UMTRA project, and RCRA/CERCLA remediation (Roy F. Weston)	Technical lead for aqueous geochemistry
Pamela Maestas (Los Alamos Technical Associates, Inc.)	B.A. Human Resources Management 1 year experience as an electronic publications specialist, 2 years experience in word processing, data entry, and various software	Electronic publications specialist
Mary Ann Mullen (ESH-20)	M.S. Statistics 2 years experience with the Laboratory Environmental Restoration Project; expertise in statistical ecology and environmental sciences	Statistician
Orrin Myers (EES-15)	Ph.D. Wildlife Biology 10 years experience conducting field investigations on effects of environmental contaminants on wetland and terrestrial wildlife populations, including 4 years in ecological risk assessment	Technical lead for ecological risk assessment
Maureen Oakes (CIC-1)	B.S. Biology 6 years experience writing and editing technical documents, including environment, safety, and health and environmental restoration documentation	Technical writer/editor
Donna O'Donnell (Los Alamos Technical Associates, Inc.)	6 years experience in project control and data management	Project planning specialist
Ralph Perona (Neptune and Co., Inc.)	M.S. Environmental Health 6 years experience in human health risk assessment, environmental fate and transport modeling, and health/environmental education	Human health risk assessment; chemical and radiological exposure modeling
Lynn Phipps (Los Alamos Technical Associates, Inc.)	B.A. Fine Arts 22 years experience in technical illustration and graphic design	Artist/designer

Name and Affiliation	Education and Expertise	Function
Deidre´ Plumlee (Ray Rashkin Associates, Inc.)	A.A. Graphic Communication 2 years experience as an electronic publications specialist; 2 years experience creating and publishing a magazine that was distributed in the United States and Canada	Electronic publications specialist
Allyn Pratt (EES-13)	B.S. Environmental Science/M.B.A. 19 years experience in natural resource management, project management, and environmental management	Field Unit 4 project leader
Steven Reneau (EES-1)	Ph.D. Geology 18 years experience in geosciences; 8 years at the Laboratory, including 6 years evaluating surface transport of contaminants for the Environmental Restoration Project	Technical lead for geomorphology
Tim Renn (ERM Program Management Company)	B.S. Civil Engineering 4 years experience in RCRA/CERCLA waste site characterization, project management support for CERCLA removal actions, technical writing, and report preparation	ER project support contractor
Judith H. Reynolds (Los Alamos Technical Associates, Inc.)	M.A. Liberal Arts/History 33 years in library research, archiving, and editing; the last 15 years as senior technical editor and document specialist	Technical editor
Randy Ryti (Neptune and Co., Inc.)	Ph.D. Biology 16 years experience in environmental science problems, including 4 years supporting the Environmental Restoration Project in the areas of statistical analysis and decision support	Lead statistician
Marja Shaner (EM/P&PI)	B.A. Languages/Paralegal degree 12 years experience at the Laboratory, primarily in environmental law, community involvement, and public outreach	Primary contact for public involvement
Catherine Smith (Los Alamos Technical Associates, Inc.)	Ph.D. Analytical Chemistry 10 years experience in analytical chemistry with emphasis on environmental characterization; expertise in quality assurance for analytical services and analytical data quality evaluation	Technical consultant
Alan Stoker (Science Applications International Corporation)	Environmental Engineering Degree 20 years experience at the Laboratory with main expertise in hydrogeology, environmental monitoring, water quality, and water resources investigations for NEPA, RCRA, and CERCLA compliance	Technical consultant for hydrology
Brad Wilcox (EES-15)	Ph.D. Watershed Management 10 years experience in hydrology and natural resource management and waste site characterization	Hydrologist

Name and Affiliation	Education and Expertise	Function
Ken Wohletz (EES-1)	Ph.D. Geology 20 years experience researching volcanic rocks and geothermal processes; 5 years experience in environmental geology and the influence of fracture characteristics on contaminant migration	Geologist