# Work Plan for Pajarito Canyon

## Environmental Restoration Project

## September 1998

A Department of Energy
Environmental Cleanup Program

Los Alamos
NATIONAL LABORATORY

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## TABLE OF CONTENTS

**APPENDIXES**



**FIGURES**

**TABLES**

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## EXECUTIVE SUMMARY

*This Resource Conservation and Recovery Act (RCRA) facility investigation (RFI) work plan establishes the technical approach and methodology for environmental investigation of Pajarito Canyon at Los Alamos National Laboratory (hereafter "the Laboratory"). This work plan is tiered to the Core Document for Canyons Investigations (LANL 1997, ER ID 55622) (hereafter "the core document") and references the core document for general background information, technical approach, and risk assessment approach.*

*Potential release sites (PRSs) on adjacent mesas and on the canyon floor have introduced potential contaminants (including high-explosives, metals, and radionuclides) to Pajarito Canyon during the past 50 years. Current data indicate that contaminants are present in some canyon-floor sediments and in some parts of the alluvial groundwater system. Based on the release history of PRSs in the drainage area, the potential exists for additional areas of contamination to occur in sediments, surface waters, and groundwater in other parts of the canyon. Currently, a portion of the canyon is used by Laboratory workers at Technical Area (TA) -18, and the lower part of the canyon may be accessible to recreational users east of TA-18. East of the Laboratory boundary, Pajarito Canyon passes through residential areas in the town of White Rock before emptying into the Rio Grande.*

### Purpose

*The purposes of the investigation are to evaluate the present-day human health and ecological risks from Laboratory-derived contaminants within the canyon system and to assess future impacts from the transport of these contaminants. To achieve these goals, the investigation will*

- *assess present-day risk to human health and ecological systems and evaluate the potential for transport of contaminants that could cause human health and ecological risks in the future;*
- *determine the degree to which the stream channel sediments, active floodplain sediments, and underlying groundwater in Pajarito Canyon have been affected by Laboratory releases;*
- *refine the conceptual model for contaminant occurrence, transport, and exposure routes and for contaminant transport pathways and mechanisms specific to the canyon system (hereafter "the conceptual model") as related to risk evaluation;*
- *assess the potential for interconnections between groundwater in alluvium, intermediate perched zones, and the regional aquifer as related to risk evaluation;*
- *provide supplemental characterization of groundwater associated with PRSs located in the main canyon and tributaries; and*
- *recommend possible remedial actions for areas on the canyon floor that are found to have unacceptable present-day human health or ecological risks.*

*This work plan presents a technical approach that will be applied to the investigation of the Pajarito Canyon system that is, or may have been, affected by Laboratory operations. This work plan provides information specific to the Pajarito Canyon system regarding historical land uses and Laboratory operations, environmental setting, the conceptual model, and a detailed sampling and analysis plan for investigations. Historical background for general Laboratory operations, the regional environmental* *setting, general technical approach to the investigation, and the general approach to present-day human health and ecological risk assessment are discussed in the core document.*

**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 (EPA 1990, 1585). The New Mexico Environment Department (NMED) is the administrative authority for the HSWA Module. This work plan addresses and satisfies portions of the requirements in Section I.5, Section Q Tasks I through V of the HSWA Module.*

*Because the Pajarito Canyon system is identified as primarily a transport pathway for contaminants migrating across and off the Laboratory rather than as the source of contaminants, a distinction is created between the HSWA Module requirements for investigations of the canyon system and the HSWA Module requirements for investigations of PRSs. The Pajarito Canyon pathway crosses private land and eventually contributes sediments, surface water, and groundwater to the Rio Grande. Because the Pajarito Canyon system and the associated transport processes, rather than distinct PRSs, are identified as the focus, the Pajarito Canyon investigation is different from PRS-based investigations in both a regulatory and a scientific perspective.*

*This work plan deals primarily with the investigation of affected media within the canyon system rather than the investigation of PRSs, although supplemental characterization of groundwater associated with PRSs is included in the planned investigations. The general technical approach presented in the core document and the sampling and analysis plan in Chapter 7 of this work plan are designed to address the broad requirements contained in the HSWA Module Sections I.5 and Q, as well as to provide data supporting risk-based decisions for the three PRSs.*

**Conceptual Model and Technical Approach**

*One of the significant distinctions of the canyons investigations compared with a PRS-based RFI is the responsibility to investigate the canyon as an integrated natural system. This integration is accomplished through a process-oriented conceptual model, which guides the technical approach to the investigations and is refined by the findings of each successive investigation through refinements in models of regional stratigraphy, groundwater and contaminant occurrence and movement, sediment transport, and geochemical interactions.*

*The investigation area is generally 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 Pajarito Canyon characterization activities, summarized in Chapter 1 and presented in Chapter 7 of this work plan, are designed to collect data for risk assessment based on present-day contaminant levels and to evaluate the potential future impacts of contaminant transport in the canyon system. Systematic characterization of the entire Pajarito Canyon system is impractical because of the large surface area of the canyon floor. Therefore, a process-oriented, iterative approach is planned to determine the nature and extent of contamination in Pajarito Canyon. The iterative approach allows the investigators to tune the characterization requirements to observed conditions in the field. This approach relies on frequent* *regulatory input and will ultimately lead to a well-defined and quantitative understanding of the natural systems involved in canyon contaminant fate and transport and defensible present-day and future risk assessments within the canyons. These investigations are integral to the overall ER Project strategy to identify major sources of contaminants for the canyon system and to reduce future contributions from those mesa-top sites that have the largest impact on the canyon system. This approach is discussed in detail in the core document.*

**Sampling and Analysis Strategy**

*Characterization activities in the Pajarito Canyon investigation are presented in detail in Chapter 7 of this work plan and will include two complementary investigation paths. These include*

- *geomorphic mapping, sampling, and analysis of surface sediments in selected reaches of the canyon floor to evaluate surface exposure pathways and*

- *sampling and analysis of surface water and groundwater to assess potential water exposure pathways as well as transport pathways and potential impacts on the different zones of saturation.*

**Sediment Investigations**

*Representative sections of the canyon floor, called "canyon reaches," will be investigated in detail to evaluate contaminant concentrations and distributions as a function of proximity to PRSs, depositional environments, the grain size of sediments, and the age of sediment deposits. Contaminant data obtained from adjacent reaches are expected to bound the range of contaminant concentrations in the unsampled canyon areas located between the reaches that will be sampled. The data collected will allow the investigation team to evaluate human and ecological risk within and between the reaches, to test hypotheses about processes that control contaminant transport and deposition, and to provide a means for testing the investigation approach.*

*The initial step in characterizing surface sediments is to prepare a geomorphic map that defines the distribution of types of surface sediments. Discrete sampling points are identified using the geomorphic map to ensure that each of the major geomorphic features is represented in the sampling plan. Initial sampling campaigns usually consist of biased sampling of appropriate geomorphic units for a broad suite of analytes to identify the contaminants that are present in the canyon system. If needed, subsequent sampling is generally limited to contaminants of concern identified during the initial sampling and analysis. Data collected for sediment investigations provide information about contaminant distributions, inventories, collocation of multiple contaminant species, and trends in contaminant concentrations over time.*

*Sediment sampling is largely restricted to post-1942 canyon deposits in both the active channels and the floodplains. Furthermore, the sampling plan uses information from investigations of mesa-top and TA-18 PRSs, history of activities at PRSs, and the geomorphic map to focus sampling efforts on those areas most likely to contain contaminants, to determine the geomorphic settings where the greatest contaminant inventories could occur (post-1942 sediments), and to assess the susceptibility of the contaminants to redistribution by wind and water.*

*In the Pajarito Canyon system, 14 canyon reaches have been selected for initial geomorphic mapping and sediment sampling based on location downgradient from PRSs and TAs where contaminants may* *have been transported to the canyon system. If contaminants are identified in specific reaches, additional reaches upstream and downstream of the contaminants will be investigated. If contaminants are not identified in any of the initial reaches investigated, no further investigations will be planned in adjacent subreaches. Mesa tops, alluvial and colluvial deposits on canyon walls, and drainages of canyon walls may contain contaminants from individual PRSs. For the most part these sites have been characterized as part of RFIs conducted by other ER Project focus areas.*

**Groundwater Investigations**

*The investigations undertaken to characterize the nature, extent, and potential surface water and groundwater transport of contaminants were developed in cooperation with other Laboratory entities also responsible for groundwater protection. These investigations are summarized in the Hydrogeologic Workplan (LANL 1996, 55430), which was initially developed for the Groundwater Protection Management Program Plan (LANL 1995, 50124).*

*Groundwater investigations focus on areas most likely to contain contaminants, such as the near-surface alluvial groundwater downgradient of known release sites and areas where Laboratory environmental surveillance data indicate that Laboratory-derived contaminants are present. Intermediate-depth perched groundwater zones and the top of the regional aquifer are being characterized (1) as potential water exposure pathways, (2) as transport pathways, and (3) for potential impacts on the different zones of saturation. Wells constructed for characterizing groundwater can be used to enhance current Laboratory groundwater monitoring systems, if necessary. In Pajarito Canyon 12 alluvial groundwater wells are planned to characterize the alluvial groundwater, and 5 regional aquifer wells are planned to characterize potential intermediate-depth groundwater and the regional aquifer.*

*Groundwater investigations follow an iterative approach in which information obtained from each borehole will be evaluated in the context of other relevant groundwater studies and the current conceptual model so that future characterization efforts can be redirected to focus on critical data needs. These ongoing evaluations will be made in collaboration with regulators and other investigators implementing the Hydrogeologic Workplan (LANL 1996, 55430) and may lead to changes in the locations and numbers of future boreholes. Changes in the scope of groundwater investigations are negotiated periodically with the administrative authority.*

**Schedule and Reporting**

*Annex I of the core document contains a preliminary schedule for conducting the Pajarito Canyon investigation. The schedule is subject to change based on future Department of Energy (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 executing the investigations described in this work plan. Because Pajarito Canyon and Threemile Canyon contain PRSs that may have impacted alluvial groundwater and possibly deeper groundwater, investigations planned as part of this work plan may provide supplemental characterization of groundwater associated with certain PRSs if deemed necessary.*

*Consistent with the technical approach, the Laboratory will notify NMED if any results indicate the need for stabilization.*

**Structure of the Work Plan**

*This work plan contains seven chapters and five appendixes as listed below.*

**Chapters**

*Chapter 1 gives a brief introduction to the overall regulatory, operational, and environmental setting and a summary of the Pajarito Canyon investigation.*

*Chapter 2 provides the historical background for the archaic and modern land uses within the investigation areas, including a discussion of possible contaminant sources based on archival data.*

*Chapter 3 describes the environmental setting for Pajarito Canyon and its tributaries and summarizes available environmental data germane to the planned investigation.*

*Chapter 4 develops the conceptual model for the Pajarito Canyon system and the implications in shaping the overall investigation efforts.*

*Chapter 5 refers the reader to the core document, which describes the general technical approach that will be followed during execution of this work plan.*

*Chapter 6 refers the reader to the core document, which explains the human health and ecological risk assessment considerations and approach for evaluating the data derived from the investigation. (Details on data collection for the present-day human health risk assessment and the ecological risk assessment are discussed in Chapter 7.)*

*Chapter 7 contains the sampling and analysis plans for the initial characterization efforts in Pajarito Canyon and describes more fully the implementation of the reach concept for sediment investigations. Surface water and groundwater investigations are described in detail, and elements of the quality assurance project plan for each investigation are included.*

**Appendixes**

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

*Appendix B lists the PRSs in the Pajarito Canyon watershed and their current status.*

*Appendix C contains drilling and well completion data for wells, boreholes, and moisture access tubes in the Pajarito Canyon system.*

*Appendix D contains the stratigraphic information that was used to construct cross sections.*

*Appendix E lists the individuals who contributed to this work plan.*

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## ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| *AA* | *administrative authority* |
| *AEC* | *Atomic Energy Commission* |
| *AOC* | *area of concern* |
| *ASTM* | *American Society for Testing and Materials* |
| *BAE* | *Burn Area East* |
| *BCA* | *Burn Cage Area* |
| *BTEX* | *benzene, toluene, ethylbenzene, xylene* |
| *BV* | *background value* |
| *C/CH* | *core hole, not completed* |
| *CA* | *composite analysis* |
| *CERCLA* | *Comprehensive Environmental Response, Compensation, and Liability Act* |
| *cfs* | *cubic feet per second* |
| *CMR* | *Chemistry and Metallurgy Research* |
| *COPC* | *chemical of potential concern* |
| *CVAA* | *cold vapor atomic absorption* |
| *CWA* | *Clean Water Act* |
| *DCE* | *dichloroethylene* |
| *D&D* | *decontamination and decommissioning* |
| *DOE* | *Department of Energy* |
| *DU* | *depleted uranium* |
| *EC* | *expedited cleanup* |
| *EDL* | *estimated detection limit* |
| *EPA* | *Environmental Protection Agency* |
| *EQL* | *estimated quantitation limit* |
| *ER* | *Environmental Restoration* |
| *ESG* | *Environmental Surveillance Group* |
| *ESH* | *Environment, Safety, and Health (Laboratory Division)* |
| *ET* | *evapotranspiration* |
| *ETVAA* | *electrothermal vaporization atomic absorption* |
| *FCP* | *final closure plan* |
| *FIMAD* | *Facility for Information Management, Analysis, and Display* |
| *FIP* | *field implementation plan* |
| *FU* | *field unit* |
| *G* | *Guaje (Canyon)* |
| *GIS* | *geographic information system* |
| *GL* | *ground level* |

| | |
|---|---|
| GPC | gas proportional counter |
| gpd | gallons per day |
| gpm | gallons per minute |
| gps | gallons per second |
| HE | high-explosive(s) |
| HEPA | high-efficiency particulate air |
| HMX | octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine (high melting explosive) |
| HNS | 2,2′,4,4′,6,6′-hexanitrostilbene |
| HPGe | high-purity germanium |
| HSWA | Hazardous and Solid Waste Amendments |
| IA | interim action |
| IC | ion chromatography |
| ICPES | inductively coupled plasma emission spectroscopy |
| ICPMS | inductively coupled plasma mass spectrometry |
| ID | identification |
| IWP | Installation Work Plan |
| $K_d$ | distribution coefficient |
| KPA | kinetic phosphorametric analysis |
| LA | Los Alamos (Canyon) |
| LACEF | Los Alamos Critical Experiments Facility |
| LANL | Los Alamos National Laboratory |
| LLW | low-level (radioactive) waste |
| LSC | liquid scintillation counting |
| M | moisture access tube |
| Ma | million years ago |
| 2MC | Twomile Canyon |
| 3MC | Threemile Canyon |
| MCL | maximum contaminant level |
| MDA | material disposal area |
| MP | measuring point |
| MS | mass spectrometry |
| MW | monitoring well |
| NA | not analyzed |
| N/A | not applicable |
| N.A. | not available |
| NaI(Tl) | thallium doped sodium iodide |
| NDT | nondestructive testing |
| NEPA | National Environmental Policy Act |

| | |
|---|---|
| *NFA* | *no further action* |
| *NM* | *New Mexico* |
| *NMED* | *New Mexico Environment Department* |
| *NMWQCC* | *New Mexico Water Quality Control Commission* |
| *NOD* | *notice of deficiency* |
| *NPDES* | *National Pollutant Discharge Elimination System* |
| *NTU* | *nephelometric turbidity unit* |
| *O* | *observation (well)* |
| *O* | *Otowi* |
| *OI* | *observation intermediate (well)* |
| *OU* | *operable unit* |
| *PA* | *performance assessment* |
| *PAH* | *polycyclic aromatic hydrocarbon* |
| *PC* | *Pajarito Canyon* |
| *PCB* | *polychlorinated biphenyl* |
| *PETN* | *pentaerythritol tetranitrate* |
| *PM* | *Pajarito Mesa* |
| *ppm* | *parts per million* |
| *PRS* | *potential release site* |
| *PTD* | *planned total depth* |
| *PVC* | *polyvinyl chloride* |
| *Qal* | *Quaternary alluvium* |
| *Qbo* | *Otowi Member of the Bandelier Tuff* |
| *Qbog* | *Guaje Pumice Bed (basalt part of the Otowi Member)* |
| *Qbt* | *Tshirege Member of the Bandelier Tuff* |
| *Qbt 1* | *cooling unit 1 of the Tshirege Member* |
| *Qbt 1g* | *cooling unit 1g of the Tshirege Member of the Bandelier Tuff* |
| *Qbt 1v* | *cooling unit 1v of the Tshirege Member of the Bandelier Tuff* |
| *Qbt 1v-c* | *colonnade tuff at the base of Qbt 1v* |
| *Qbt 2* | *cooling unit 2 of the Tshirege Member of the Bandelier Tuff* |
| *Qbt 3* | *cooling unit 3 of the Tshirege Member of the Bandelier Tuff* |
| *Qbt 4* | *cooling unit 4 of the Tshirege Member of the Bandelier Tuff* |
| *Qbtt* | *Tsankawi Pumice Bed of the Tshirege Member* |
| *Qct* | *Cerro Toledo interval* |
| *QC* | *quality control* |
| *Qv* | *Quaternary volcanics* |
| *R* | *regional aquifer* |
| *RCRA* | *Resource Conservation and Recovery Act* |

| | |
|---|---|
| RDX | hexahydro-1,3,5-trinitro-1,3,5-triazine (research department explosive) |
| RFI | RCRA facility investigation |
| SAL | screening action level |
| SAP | sampling and analysis plan |
| SDS | scrap detonation site |
| SOP | standard operating procedure |
| SVOC | semivolatile organic compound |
| SWL | static water level (below measuring point) |
| TA | technical area |
| TATB | triaminotrinitrobenzene |
| TBD | to be determined |
| TCA | trichloroethane |
| TCE | trichloroethylene |
| TD | total depth |
| TDS | total dissolved solids |
| TIMS | thermal ionization mass spectrometry |
| TNT | 2,4,6-trinitrotoluene |
| TOC | top of casing |
| TOC | total organic carbon |
| TOT | top of tubing |
| Tp | Tertiary Puye Formation |
| Tpf | fanglomerate member of the Puye Formation |
| TPH | total petroleum hydrocarbons |
| Tpt | Totavi Lentil of the Puye Formation |
| TRU | transuranic |
| Tsfuv | Tertiary Santa Fe Group upper volcaniclastic facies |
| TW | test well |
| UMTRA | uranium mill tailings remedial action |
| US | United States |
| USGS | United States Geological Survey |
| UST | underground storage tank |
| UTL | upper tolerance limit |
| VCA | voluntary corrective action |
| VOC | volatile organic compound |
| WB | water-balance |
| WL | water level |
| XRF | x-ray fluorescence |

## 1.0 INTRODUCTION

*This Resource Conservation and Recovery Act (RCRA) facility investigation (RFI) work plan describes investigations to be conducted in the Pajarito Canyon system as part of the Environmental Restoration (ER) Project at Los Alamos National Laboratory (hereafter "the Laboratory"). These investigations are being conducted by the canyons investigation team. This work plan includes a summary and evaluation of previous hydrogeologic and contaminant studies in the Pajarito Canyon system and a description of new investigations to evaluate present-day human health and ecological risk that have resulted from Laboratory releases to the canyon. The work plan also discusses the effects of current and past releases into Twomile Canyon and Threemile Canyon; both are tributaries to Pajarito Canyon.*

### 1.1 Purpose

*The purpose of the Pajarito Canyon investigation is to evaluate present-day human health and ecological risks from Laboratory-derived contaminants and to assess future impacts from the transport of these contaminants. Specifically, this investigation will*

- *assess present-day risk to human health and ecological systems and evaluate the potential for transport of contaminants that could cause human health and ecological risks in the future;*
- *determine the degree to which the stream channel sediments, active floodplain sediments, and underlying groundwater in Pajarito Canyon have been affected by Laboratory releases;*
- *refine the conceptual model for contaminant occurrence, transport, and exposure routes and for contaminant transport pathways and mechanisms specific to the canyon system (hereafter "the conceptual model") as related to risk evaluation;*
- *assess the potential for interconnections between groundwater in alluvium, intermediate perched zones, and the regional aquifer as related to risk evaluation;*
- *provide supplemental characterization of groundwater associated with potential release sites (PRSs) located in the main canyon and tributaries; and*
- *recommend possible remedial actions for areas on the canyon floor that are found to have unacceptable present-day human health or ecological risks.*

*The Pajarito Canyon investigation will characterize contaminant distributions in surface water of the active stream channel, groundwater beneath the canyon floor, and sediments in those parts of the canyon floor that are affected by Laboratory operations both on-site and potentially off-site. Mesa tops, alluvial and colluvial deposits on canyon walls, and small drainages off canyon walls may contain contaminants from individual PRSs. These sites will be characterized primarily as part of RFIs conducted by other ER Project focus areas, and the Canyons Focus Area team will concentrate on contaminants within the active stream channels. Results of field investigations conducted by other focus areas have been included in the planning and implementation of investigations conducted in the Pajarito Canyon system.*

### 1.2 Relationship to Other Documents

*This work plan is tiered to the Core Document for Canyons Investigations (hereafter "the core document") (LANL 1997, 55622), which provides the general framework for investigations in canyon systems and provides information common to all the investigations. The core document includes a description of the* *regulatory and programmatic framework for investigations, historical information on area land uses and Laboratory operations, a summary of the regional environmental setting, the generalized conceptual model for the canyon systems, the general technical approach for all canyons investigations, and the present-day human health and ecological risk assessment approach.*

*This canyon-specific work plan contains only a brief introduction and summary of the planned investigations, a discussion of the canyon's history, summaries of the environmental setting and previous investigations conducted in Pajarito Canyon, canyon-specific details on the investigation objectives and technical approach, and a comprehensive sampling and analysis plan. The format of this work plan follows that established by previous canyon-specific work plans and has been authorized by the administrative authority (NMED 1998, 58206).*

*Table 1.2-1 lists the major RFI tasks and subtasks required in Section Q of Module VIII of the Laboratory's Hazardous Waste Facility Permit (EPA 1990, 1585) and the location in this document and/or the core document (LANL 1997, 55622) where these requirements are addressed.*

**TABLE 1.2-1**

**LOCATION OF DISCUSSIONS OF HSWA* MODULE REQUIREMENTS**

| HSWA Module Requirements | Core Document | This Document |
|---|---|---|
| **RFI Task I: Description of Current Conditions** | | |
| *Facility Background* | *Chapters 2 and 3* | *Chapter 2* |
| *Nature and Extent of Contamination* | *Chapters 2 and 3* | *Chapter 3* |
| **RFI Task II: RFI Workplan** | | |
| *Data Collection Quality Assurance Plan* | *Future sampling and analysis plans* | *Chapter 7* |
| *Data Management Plan* | *Annex III* | |
| *Health and Safety Plan* | *Annex II* | |
| *Community Relations Plan* | *Annex IV* | |
| **RFI Task III: Facility Investigation** | | |
| *Environmental Setting* | *Chapter 3* | *Chapter 3* |
| *Source Characterization* | *Chapters 2, 3, 4, and 5* | *Chapter 2* |
| *Contamination Characterization* | *Chapters 2, 3, 4, and 5* | *Chapters 2, 3, and 4* |
| *Potential Receptor Identification* | *Chapters 4 and 6* | *Chapter 4* |
| **RFI Task IV: Investigative Analysis** | | |
| *Data Analysis* | *Chapters 5 and 6* | *Chapter 7* |
| *Protection Standards* | *Chapter 6* | |
| **RFI Task V: Reports** | | |
| *Preliminary and Workplan* | | *Entire Document* |
| *Progress Draft and Final* | *Chapter 7 and Annex I* | |
| **HSWA = Hazardous and Solid Waste Amendments* | | |

*The groundwater investigations in Pajarito Canyon are an integral part of the Laboratory's Hydrogeologic Workplan (LANL 1996, 55430), which was developed to implement the Groundwater Protection Management Program Plan (LANL 1995, 50124). Groundwater and surface water investigations will follow an iterative approach in which information obtained from each successive borehole, well, and sampling event will be evaluated in the context of the hydrogeological portion of the conceptual model. These ongoing evaluations will be made in collaboration with other investigations implementing the Hydrogeologic Workplan and may lead to changes in the locations, numbers, and sequence of future sampling events, boreholes, and wells. In accordance with the approach discussed in the Hydrogeologic Workplan, changes in the scope of groundwater investigations will be negotiated periodically with the regulators as described in Section 7.4.4.1.2.*

*The remainder of this introductory chapter gives a brief physical description of Pajarito Canyon and its tributaries and outlines the organization of this work plan.*

## 1.3 Location and Environmental Setting

*Pajarito Canyon is located on the Pajarito Plateau in the central part of the Laboratory (Figure 1.3-1). The canyon heads in the Santa Fe National Forest approximately 2.9 miles (4.6 km) west of the Laboratory boundary at an elevation of approximately 10,434 ft (3180 m) and trends east-southeast across the Laboratory and Los Alamos County. It empties into the Rio Grande in White Rock Canyon at an elevation of 5422 ft (1653 m). The main channel is approximately 14.8 mi (23.8 km) long, and the total watershed area is approximately 8.0 $mi^2$ (20.7 $km^2$). In addition, Twomile Canyon and Threemile Canyon are major tributaries that join Pajarito Canyon approximately 7.3 mi (11.7 km) and 4.9 mi (9.3 km), respectively, upstream of the Rio Grande. These tributaries have a total watershed area of 3.1 $mi^2$ (8.0 $km^2$) and 1.7 $mi^2$ (4.4 $km^2$), respectively (LANL 1997, 55622).*

*PRSs within the Pajarito Canyon watershed are located at former Technical Area (TA) -12 (associated with former Operable Unit [OU] 1085); TA-15 (associated with former OU 1086); TA-18 and former TA-27 (associated with former OU 1093); TA-6, -22, and -40 and former TA-7 (associated with former OU 1111); TA-3, -59, and -64 (associated with former OU 1114); TA-48, and -55 (associated with former OU 1129); TA-36 (associated with former OU 1130); TA-54 (associated with former OU 1148); and TA-8, -9, and -69 and former TA-23 (associated with former OU 1157) (Figure 1.3-2). Figure A-1 in Appendix A of this work plan shows the locations of the PRSs, and Appendix B lists the PRSs and their current status.*

*The primary Laboratory use of Pajarito Canyon has been as the location of the Los Alamos Critical Experiments Facility at TA-18. Other uses within the watershed area include surface and subsurface material disposal areas and a buffer zone for mesa-top firing site activities. To a lesser extent the canyon has been used for liquid waste disposal. These operations have been conducted since the Laboratory began operation in 1943. The early discharges were associated with outfalls, surface runoff, and dispersion from firing sites located at TA-6, -7, -8, -9, -12, -15, -18, -22, -27, and -69. Additional discharges began with the continued expansion of Laboratory operations to new sites in the 1950s through the 1970s, specifically at TA-3, -36, -40, -48, and -59. Discharges to Pajarito Canyon and its tributaries have decreased as most firing sites within the watershed have become inactive during the past few decades, and many outfalls have either been rendered inactive or rerouted to the Laboratory's sanitary waste treatment facility at TA-46 during the 1980s and 1990s. Chapter 2 of this work plan contains a more detailed discussion of past and present discharges.*

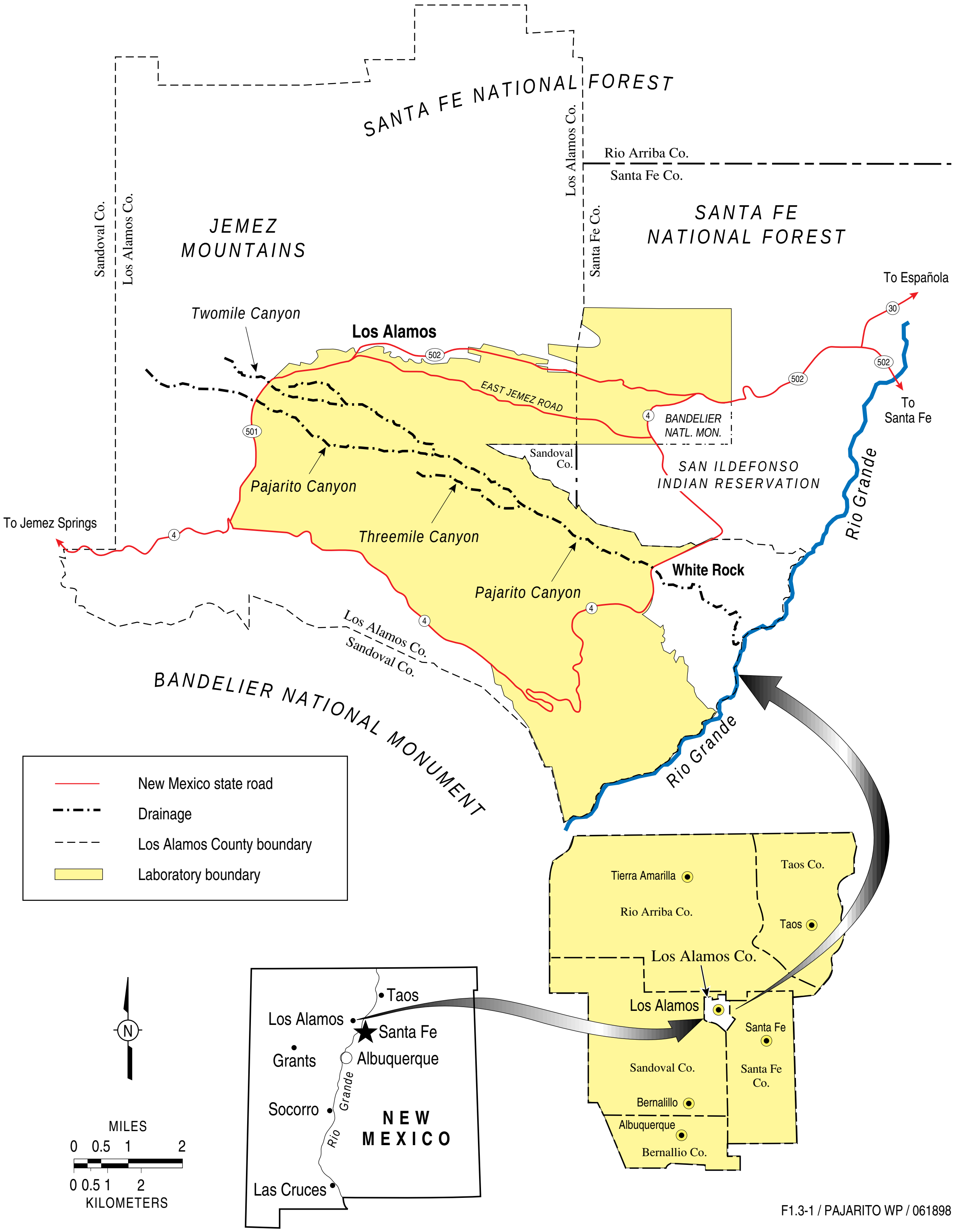


**Figure 1.3-1. Location of Pajarito Canyon and selected tributaries.**

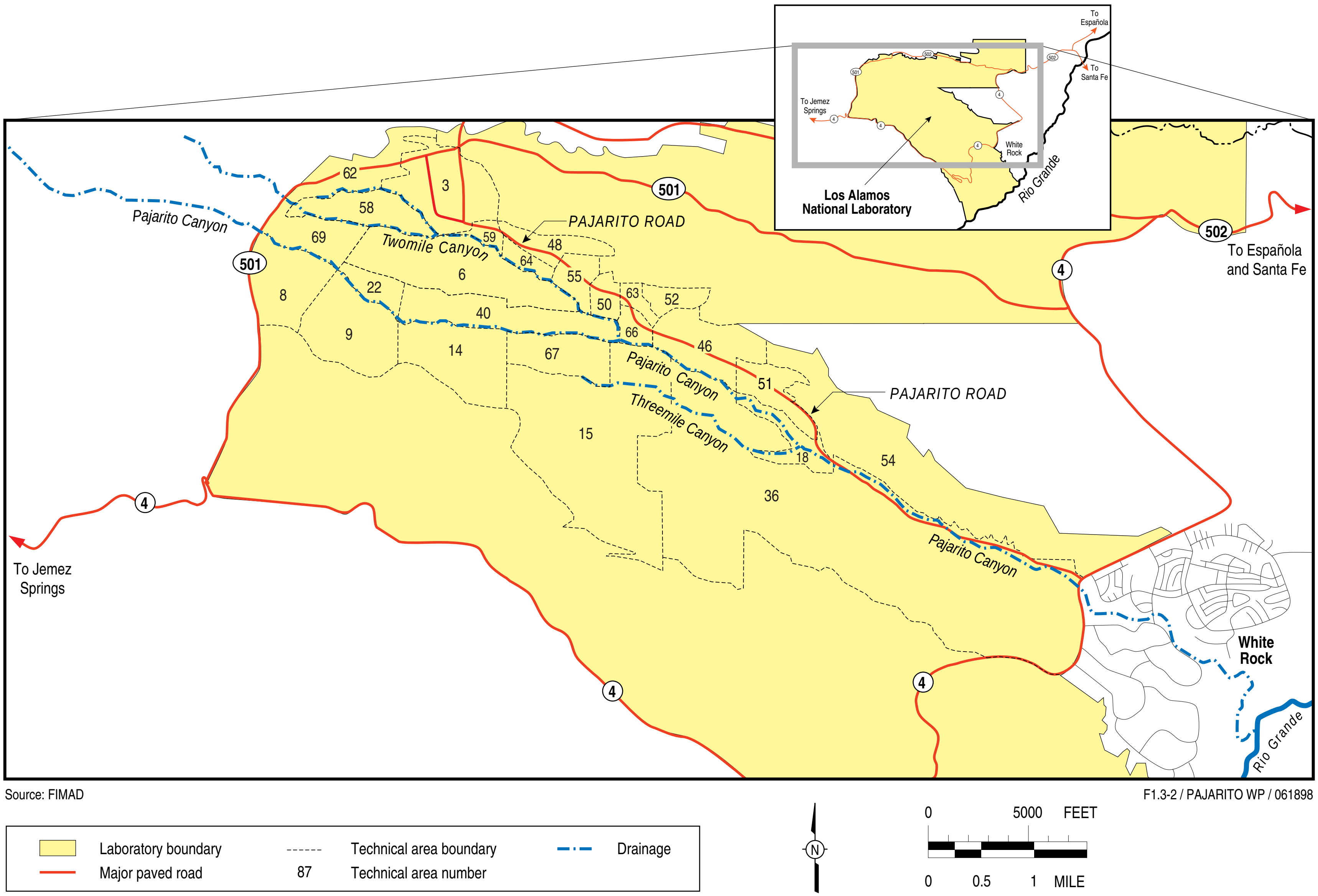


**Figure 1.3-2. Laboratory technical areas adjacent to Pajarito Canyon and selected tributaries.**

## 1.4 Summary of the Pajarito Canyon Investigation

### 1.4.1 Problem and Approach to Problem Resolution

*PRSs on adjacent mesas and on the canyon floor have introduced potential contaminants (including high-explosives, metals, and radionuclides) to Pajarito Canyon during the past 50 years. Current data indicate that contaminants are present in some canyon-floor sediments and in some parts of the alluvial groundwater system. Based on the release history of PRSs in the drainage area, the potential exists for additional areas of contaminants to occur in sediments, surface waters, and groundwater in other parts of the canyon. Currently, a portion of the canyon is used by Laboratory workers at TA-18, and the lower part of the canyon may be accessible to recreational users east of TA-18. East of the Laboratory boundary, Pajarito Canyon passes through residential areas in the town of White Rock before emptying into the Rio Grande.*

*Systematic characterization of the entire Pajarito Canyon system is impractical because of the large surface area of the canyon floor. The main channel extends 11.9 mi from the western Laboratory boundary to the Rio Grande, and two major tributaries, Twomile Canyon and Threemile Canyon, have channel lengths of 5.2 mi and 2.4 mi, respectively. Therefore, a process-oriented, iterative approach is proposed to determine the nature and extent of contaminants in Pajarito Canyon. The iterative approach allows the investigators to tune the characterization requirements to observed conditions in the field. This approach relies on frequent regulatory input and will ultimately lead to a well-defined and quantitative understanding of the natural systems involved in canyon contaminant fate and transport and defensible present-day and future risk assessments within the canyons. These investigations are integral to the overall ER Project strategy to identify major sources of contaminants for the canyon system and to reduce future contributions from those mesa-top sites that have the largest impact on the canyon system. This approach is discussed in detail in the Core Document for Canyons Investigations (LANL 1997, 55622), which was approved by the administrative authority (NMED 1998, 58638).*

*Canyons investigations can be conveniently discussed in terms of two complementary investigation paths. These include*

- *geomorphic mapping, sampling, and analysis of surface sediments in selected reaches of the canyon floor to evaluate surface exposure pathways and*
- *sampling and analysis of subsurface sediments, bedrock units, surface water, and groundwater to assess potential water exposure pathways as well as transport pathways and potential impacts on the different zones of saturation.*

#### 1.4.1.1 Surface Sediment Investigations

*Representative sections of the canyon floor, called “canyon reaches,” will be investigated in detail to evaluate contaminant concentrations and distributions as a function of proximity to PRSs, depositional environments, the grain size of sediments, and the age of sediment deposits. Contaminant data obtained from adjacent reaches are expected to bound the range of contaminant concentrations in the unsampled canyon areas located between the reaches that will be sampled. The data collected will allow the investigation team to evaluate human health and ecological risk within and between the reaches, to test hypotheses about processes that control contaminant transport and deposition, and to provide a means for testing the investigation approach.*

*The initial step in characterizing surface sediments is to prepare a geomorphic map that defines the distribution of types of surface sediments. Discrete sampling points are identified using the geomorphic map to ensure that each of the major geomorphic features is represented in the sampling plan. Initial sampling campaigns usually consist of biased sampling of appropriate geomorphic units for a broad suite of analytes to identify the contaminants that are present in the canyon system. If needed, subsequent sampling is generally limited to contaminants of concern identified during the initial sampling and analysis. Data collected for sediment investigations provide information about contaminant distributions, inventories, collocation of multiple contaminant species, and trends in contaminant concentrations over time.*

*Sediment sampling is largely restricted to post-1942 canyon deposits in both the active channels and the floodplains. Furthermore, the sampling plan uses information from investigations of mesa-top and TA-18 PRSs, history of activities at PRSs, and the geomorphic map to focus sampling efforts on those areas most likely to contain contaminants, to determine the geomorphic settings where the greatest contaminant inventories could occur (post-1942 sediments), and to assess the susceptibility of the contaminants to redistribution by wind and water.*

#### 1.4.1.2 Groundwater Investigations

*The investigations undertaken to characterize the nature, extent, and potential groundwater transport of contaminants were developed in cooperation with other Laboratory entities also responsible for groundwater protection. These investigations are summarized in the Hydrogeologic Workplan (LANL 1996, 55430), which was initially developed for the Groundwater Protection Management Program Plan (LANL 1995, 50124).*

*Groundwater investigations focus on areas most likely to contain contaminants, such as the near-surface alluvial groundwater downgradient of known release sites and areas where Laboratory environmental surveillance data indicate that Laboratory-derived contaminants are present. Intermediate-depth perched groundwater zones and the top of the regional aquifer are being characterized (1) as potential water exposure pathways, (2) as transport pathways, and (3) for potential impacts on the different zones of saturation. Wells constructed for characterizing groundwater can be used to enhance current Laboratory groundwater monitoring systems, if necessary.*

*Groundwater investigations follow an iterative approach in which information obtained from each borehole will be evaluated in the context of other relevant groundwater studies and the current conceptual model so that future characterization efforts can be redirected to focus on critical data needs. These ongoing evaluations will be made in collaboration with regulators and other investigators implementing the Hydrogeologic Workplan (LANL 1996, 55430) and may lead to changes in the locations and numbers of future boreholes. Changes in the scope of groundwater investigations are negotiated periodically with the regulators.*

### 1.4.2 Decisions

*Two primary decisions will be made based on the results of the Pajarito Canyon investigations.*

*The first decision deals with present-day risk from contaminants currently distributed in the canyon system. Is there imminent substantial endangerment to human health associated with contaminants in sediments, surface water, or groundwater in any part of Pajarito Canyon? If so, work implemented by this plan will identify areas and media in the canyon where corrective measures (for example, removal, stabilization, and institutional control) would reduce present-day risk to an acceptable level. In addition,* *the data collected will identify those PRSs within the canyon drainage area that continue to have unacceptable impacts on the canyon.*

*The second decision deals with the future impacts created if natural processes cause remobilization and redistribution of contaminants in the canyon system. Is there an unacceptable future risk or consequence that results from leaving the current inventory and distribution of contaminants in the canyons? If so, work implemented in this plan will identify areas and media in the canyon where remedial actions could reduce the anticipated future impacts to an acceptable level.*

*In addition to the primary decisions, data from the Pajarito Canyon investigation will support the Hazardous and Solid Waste Amendments (HSWA) Permit requirement to evaluate the hydrogeologic setting, with particular attention to determining whether there are connections between alluvial groundwater, perched intermediate groundwater, and the regional aquifer. The data collected will also satisfy some of the data needs identified in the Hydrogeologic Workplan (LANL 1996, 55430).*

#### 1.4.2.1 Inputs to Decision Making

*Information is needed to support risk assessments and the basis for discussion with regulators to determine when characterization of the canyon system is sufficient. Concentrations of constituents listed in Sections 7.2, 7.3, and 7.4 will be estimated in each of the media. In addition, the process-oriented approach requires that data be gathered to test assumptions and hypotheses about how contaminants are transported through the various media of the canyon system. More specific information about the current conceptual model and data needs are discussed in Chapters 4 and 7 of this work plan.*

#### 1.4.2.2 Boundaries of the Investigation

*This investigation encompasses Pajarito Canyon and its major tributaries, Twomile Canyon and Threemile Canyon, from near the western Laboratory boundary to the Rio Grande. Sediment investigations will extend laterally from the active channel to the toe of the colluvial slope at the base of the canyon walls. Sediment investigations will focus on deposits most likely to be affected by Laboratory operations (that is, those deposits that are post-1942). The vertical extent of Laboratory-derived contaminants is not yet determined, but it is expected to be largely confined to the upper 2 to 3 m (7 to 10 ft) of canyon-floor deposits. Data will be collected within representative reaches in the canyon system. If appropriate, these data will support decisions (as described below) concerning sediments within intervening unsampled sections of the canyon, as well as the canyon as a whole. The process for selecting and defining reaches is described in the Core Document for Canyons Investigations (LANL 1997, 55622) and in Chapter 7 of this work plan.*

*The boundaries of the groundwater investigations are generally similar to those of the sediment investigations with the following two exceptions. First, the groundwater investigations extend into the upper 100 ft (30 m) of the regional aquifer, the top of which is approximately 900 to 1100 ft (275 to 335 m) below the canyon floor. Second, because of poor access to the canyon floor in the upper part of Pajarito Canyon and its tributaries, some regional aquifer wells may be located on adjacent mesas.*

*The sediment investigations focus primarily on post-1942 sediment and groundwater pathways. Some potential contaminants have relatively short half-lives (for example, the half-life of tritium is 12.3 years), and their concentrations will decrease over time. Other contaminants (for example, metals, and isotopic uranium) do not decay significantly over relevant time periods. The time frame for projection of contaminant trends into the future is not yet defined, but data are being gathered to evaluate a range of different time frames.*

#### 1.4.2.3 Pajarito Canyon Decision Rules

*For each of the decisions discussed earlier (that is, imminent present-day risk and potential future risk), risk will be assessed under a set of assumptions and exposure scenarios considered to be reasonable and appropriate by risk managers. The specific rules applied to each risk-based decision are consistent with the general technical approach flow diagram in the Core Document for Canyons Investigations (Figure 5-1, LANL 1997, 55622, p. 5-4). The following decision rules will be applied.*

*What contaminants must be considered to support risk-based decisions?*

*To establish the COPCs, analytical results from each reach in Pajarito Canyon will be compared against comparable background values and other relevant standards, according to the most recent methodologies and procedures provided by the ER Project Analysis and Assessment Team. A weight-of-evidence approach will be used to determine COPCs. The weight of evidence will rely heavily on quantitative (statistical and graphical) approaches to evaluate reach data but will also benefit from known PRS sources and sampling of upstream reaches. This latter "process knowledge" evidence may lead to adding or subtracting COPCs identified from the quantitative data review. Constituents identified as COPCs will be carried forward to evaluate present-day human-health and ecological risks.*

*Are the data adequate to revise the physical process model?*

*If the major assumptions upon which estimates of contaminant distributions are based are confirmed by the data collected in this investigation, through exploratory data analysis and tests of statistical hypotheses, then the investigators will evaluate risk. Otherwise, the investigators will define additional data needs and plan additional data collection efforts to support decision-making. This step is equivalent to the scoping or site conceptual model phase of the screening-level ecological risk assessment.*

*Are the data adequate to support risk-based decisions?*

*If the uncertainty in estimated risk values is likely to influence the decision based on the risk assessment, then investigators will consider whether additional data are needed before completing the risk assessment and uncertainty analysis.*

*Is there an unacceptable present-day risk associated with contaminants in specific reaches of Pajarito Canyon?*

*Present-day risk will be evaluated by calculating action levels for present-day use scenarios. The action levels will be calculated in accordance with general EPA guidance on "Development of Risk-Based Preliminary Remediation Goals" (EPA 1991, 58234). If action levels are exceeded, then appropriate interim measures, best management practices, or corrective measures may be implemented to mitigate the present-day risk at each specific reach.*

*Are data sufficient to evaluate the final remedy selection based on both present-day and future risk in the canyon?*

*Risk assessment to support final remedy selection will consider both present and future land use scenarios and will incorporate fate and transport calculations for surface and subsurface groundwater pathways and wind resuspension and transport of sediments. Additional data needs will be identified to ensure that necessary and sufficient data are available to project future risk for all potential transport and exposure pathways within an acceptable statistical confidence interval. If data are adequate to estimate* *an acceptable future risk within an acceptable confidence interval, then no further action will be proposed. It is noted that estimated future risk will be only one input necessary to provide information for the final remediation decision.*

### 1.5 Organization of this Work Plan

*Following this introductory chapter, Chapter 2 provides background information on Pajarito Canyon and its tributaries on Laboratory property (Twomile Canyon and Threemile Canyon), including a description and history of the area and the potential sources of contaminants; Chapter 3 provides details on the canyon-specific environmental setting; Chapter 4 contains the conceptual model specific to the canyon system as an expansion in detail of the conceptual model in the core document (LANL 1997, 55622); Chapter 5, the technical approach, incorporates the core document technical approach by reference (LANL 1997, 55622); Chapter 6, the present-day human health and ecological risk assessment approach, also incorporates the core document risk assessment approach by reference; and Chapter 7 contains the detailed sampling and analysis plans for addressing the objectives discussed in Section 1.1.*

*A list of acronyms precedes Chapter 1. Definitions of unfamiliar terms can be found in Chapter 4 of the Installation Work Plan for Environmental Restoration Program (LANL 1996, 55574, p. V-1) and in the Glossary of Geology (Bates and Jackson 1987, 50287).*

### 1.6 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 measurements of length, area, and volume.*

**REFERENCES FOR CHAPTER 1**

*The following list includes all the references cited in this chapter. The parenthetical information following each reference provides the author, publication date, and ER identification (ER ID) number. This information is also included in the citations in the text and can be used to locate the documents.*

*ER ID numbers are assigned by the Laboratory's ER Project to track all material associated with Laboratory PRSs. These numbers can be used to locate copies of the documents at the ER Project's Records-Processing Facility and, where applicable, within the ER Project reference library. The references cited in this work plan can be found in the volumes of the reference library titled Reference Set for Canyons.*

*Copies of the reference library are maintained at the New Mexico Environment Department Hazardous and Radioactive Materials Bureau, the Los Alamos Area Office of the Department of Energy, and the ER Project Office. This library is a living document that was developed to ensure that the administrative authority (AA) has all the necessary material to review the decisions and actions proposed in this work plan. However, documents previously submitted to the AA are not included in the reference library.*

*Bates, R. L., and J. A. Jackson (Eds.), 1987. Glossary of Geology, Third Edition, American Geological Institute, Alexandria, Virginia.* **(Bates and Jackson 1987, ER ID 50287)**

*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 1585)**

*EPA (US Environmental Protection Agency), December 1991. "Risk Assessment Guidance for Superfund: Volume I-Human Health Evaluation Manual (Part B, Development of Risk-Based Preliminary Remediation Goals)," Interim, EPA/540/R-92/003, Publication 9285.7-01B, Office of Emergency and Remedial Response, Washington, DC.* **(EPA 1991, ER ID 58234)**

*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 50124)**

*LANL (Los Alamos National Laboratory), December 1996. "Installation Work Plan for Environmental Restoration," Revision 6, Los Alamos National Laboratory Report LA-UR-96-4629, Los Alamos, New Mexico.* **(LANL 1996, ER ID 55574)**

*LANL (Los Alamos National Laboratory), December 6, 1996. "Hydrogeologic Workplan" (draft), Revision 1.0, Los Alamos, New Mexico.* **(LANL 1996, ER ID 55430)**

*LANL (Los Alamos National Laboratory), April 1997. "Core Document for Canyons Investigations," Los Alamos National Laboratory Report LA-UR-96-2083, Los Alamos, New Mexico.* **(LANL 1997, ER ID 55622)**

*NMED (New Mexico Environment Department), March 17, 1998. "Approval of the Canyons Investigation Core Work Plan, Los Alamos National Laboratory, NM0890010515," Letter to Mr. Theodore Taylor (Project Manager, Los Alamos Area Office, Department of Energy) and Mr. John Browne (Director, Los Alamos National Laboratory) from Robert S. ("Stu") Dinwiddie (Manager, RCRA Permits Management Program, Hazardous and Radioactive Materials Bureau), Santa Fe, New Mexico.* **(NMED 1998, ER ID 58638)**

*NMED (New Mexico Environment Department), March 27, 1998 "Approval of the Sampling and Analysis Plans, Canyons Investigations, Los Alamos National Laboratory, NM0890010515," Letter to Mr. Theodore Taylor (Project Manager, Los Alamos Area Office, Department of Energy) and Mr. John Browne (Director, Los Alamos National Laboratory) from Robert S. ("Stu") Dinwiddie, Manager, RCRA Permits Management Program, Hazardous and Radioactive Materials Bureau),Santa Fe, New Mexico.* **(NMED 1998, ER ID 58206)**

## 2.0 BACKGROUND

*Chapter 2 of the Core Document for Canyons Investigations (hereafter referred to as "the core document") (LANL 1997, 55622) presents a general discussion of the location, prehistoric and historic use, and potential sources of contaminants of the canyons and a discussion of environmental protection and monitoring programs relevant to the canyons. This chapter focuses on Pajarito Canyon and its tributaries and discusses the topics in appropriate detail for a canyon-specific work plan.*

*Some of the canyon tributary names used in the historical literature are informal names, such as "Starmer Gulch" and "Arroyo de LaDelfe." Pajarito Canyon tributary names used formally and informally in this work plan are shown on Figure A-1 and are further described in Section 3.1 of this work plan.*

*In this document reference to the "Pajarito Canyon watershed" comprises the entire drainage area of the canyon and its tributaries including appropriate portions of mesa tops and canyon walls. Reference to the "Pajarito Canyon system" includes only the floor of the canyon and its tributaries, which essentially comprises the flood plain, canyon-floor sediments, stream channel, and associated deposits on the floor of the canyon. Investigations planned as part of the Pajarito Canyon work plan are primarily located within the Pajarito Canyon system.*

### 2.1 History of Pajarito Canyon

#### 2.1.1 Prehistoric Use

*Hundreds of American Indian sites from the thirteenth and fourteenth centuries, and possibly earlier, have been found on the Pajarito Plateau and within Pajarito Canyon (Steen 1977, 7148, p. 1). These sites may be identified by ruins, artifacts, pottery, or pictographs. For example, remnants of tuff boulder walls evidencing a former multiple room structure are present in Pajarito Canyon approximately 0.25 mi (0.4 km) east of its confluence with a tributary to Pajarito Canyon informally known as "Starmer Gulch." Another ruin consisting of eight cavate rooms and masonry walls is present in Pajarito Canyon west of the Technical Area (TA) -18 boundary fence (Steen 1982, 6056, p. 4). These and other sites located in the canyon may possibly correspond to the Coalition Period (A.D. 1100 to A.D. 1325) (LANL 1997, 55622, p. 2-4).*

*Threemile Mesa has seen extensive prehistoric use (Steen 1977, 7148; Steen, 1982, 6056). Ruins and artifacts are widespread across the mesa top, including some near TA-15 potential release sites (PRSs). Eighty archeological sites located on Threemile Mesa are eligible for inclusion on the National Register of Historic Places. Most of these sites are Anasazi sites dating primarily to the Coalition Period, whereas a few may date to the Classic (A.D. 1325 to A.D. 1600) or General (post A.D. 1600) historic periods (LANL 1993, 20946).*

*Evidence of sites from two general temporal groups was identified by Reneau and Raymond 1995 (58031, p. 51 et seq.) during a geologic structure assessment study conducted on Pajarito Mesa. The younger sites are located within 100 m (110 yd) of small mesa-top ruins that have been assigned to the Coalition and Classic periods (Hoagland et al. 1993, 57570). Three inferred buried sites yielded ages of approximately 7740 to 8829 B.C., which correspond to the Paleo-Indian period in New Mexico (10,000 B.C. to 5500–4000 B.C.) and would represent the oldest burial sites found on the Pajarito Plateau.*

*A cluster of seven pre-Columbian ruins present on Mesita del Buey was described in Steen 1982 (6056, p. 9). Each site typically consists of a double row of rooms with the principal axis running north/south accompanied by pottery and various stone tools. Four of the sites were excavated during the late 1970s* *and early 1980s to accommodate expansion of operations at TA-54. Numerous archaeological sites located on Mesita del Buey near TA-51 and TA-54 are eligible for inclusion on the National Register of Historic Places (Steen 1982, 6056, pp. 13–30).*

*Notable large sites are present within lower Pajarito Canyon. The Tshirege ruin is the largest village site on the plateau. The Tshirege site is estimated to contain approximately 600 rooms within the house blocks on the mesa, and many cavate rooms are situated in the low cliffs on the south side of Mesita del Buey (Steen 1977, 7148, p. 35). An Anasazi pueblo with at least 21 rooms excavated in the 1950s is located in what is now the Pajarito Acres residential section of the community of White Rock (Mathien et al. 1993, 57520). Numerous cave dwelling sites are present along the north walls of lower Pajarito Canyon and Threemile Canyon.*

*Numerous surveys and publications dating from the 1880s describe the wealth of archaeological sites present on the Pajarito Plateau. A comprehensive bibliography of archeological publications is available in Mathien et al. (1993, 57520).*

### 2.1.2 Pre-Laboratory and Early Laboratory Historic Use

*Much of the Pajarito Plateau was part of the Ramon Vigil land grant. In the late 1800s and early 1900s, the Pajarito Plateau, including portions of Threemile Mesa, was used for ranching, farming, and/or timber production (LANL 1993, 20946). Two ranches occupied Twomile Mesa before the Manhattan Project arrived on the Pajarito Plateau in 1942. Aerial photographs from 1935 show extensive farm crop areas on the mesa. Beans and corn were the principal crops grown; family vegetable gardens and fruit trees were also cultivated. A grove of apricot trees grew at TA-22 until the early 1980s. A few cattle and sheep may also have grazed in this area. The ranches may have been occupied only during the summer months, whereas the owners returned to their homes in the valley during the winter. Remnants of ranch buildings still exist (LANL 1993, 26068). TA-8, located at the western boundary of the Laboratory, contains remnants of the pre-World War II homestead known as Anchor Ranch, which occupied the site from the early 1900s to 1943 (LANL 1993, 20949, p. 2-1).*

*Beginning in the early part of the century, surface water in upper Pajarito Canyon was diverted by homesteaders for agricultural and domestic use. In 1914 a homesteader built a small earth and rock-fill dam in upper Pajarito Canyon to divert water via a wooden flume to ponds near the homestead site, which later became the Anchor Ranch. In 1943 the Laboratory raised the height of the dam to approximately 6 ft (1.8 m) and installed piping to a 30,000-gal. steel tank that was located at Anchor Site. Overflow from the tank was diverted to a pipeline leading to the Los Alamos townsite. Some of the water from Pajarito Canyon was collected in a pond at Anchor Site for backup fire protection (Black and Veatch 1946, 57905, p. 6; Hoard 1993, 57491, p 82). The diversion system was abandoned in 1960, and only the remains of the dam are now present in the canyon (Hoard 1993, 57491, p. 82).*

*Sixteen pre-Laboratory and fourteen Laboratory-era archaeological or historical sites are located in TA-6, -7, -22, and -40. Five of these sites are eligible for inclusion on the National Register of Historical Places based on their research potential. The pre-Laboratory sites date to the homesteading time period (A.D. 1890 to A.D. 1943). One Laboratory structure, TA-22-1 (the Fat Man Assembly Building), has been determined to be eligible for inclusion. Fifteen Manhattan Project and early Atomic Energy Commission era structures (circa 1942 to 1948) are to be evaluated for eligibility before they are decommissioned (LANL 1993, 26068).*

*Twenty-eight pre-Laboratory and three Laboratory-era archaeological or historical sites are located at TA-8, 9, -23, and -69. Ten of these sites are eligible for inclusion on the National Register of Historical*

*Places based on their research potential. The pre-Laboratory sites date to the homesteading to recent time periods (A.D. 1890 to A.D. 1943 and A.D. 1944 to present, respectively), the archaic time period (4000 B.C. to A.D. 400), and an Anasazi period of unknown dates. Three Manhattan Project and early Atomic Energy Commission structures (circa 1942 to 1948) are to be evaluated for eligibility before they are decommissioned (LANL 1993, 20949, p. 3-6).*

*TA-18 was the location of a former guest ranch, the Pajarito Club, which was built by Ashley Pond in 1914 and later abandoned circa 1917. A one-room cabin, known as the Romero cabin, was located on the south side of Pajarito Road across from TA-55. This cabin was moved to the Los Alamos townsite and is now a historic site next to Fuller Lodge; an earlier log homestead cabin remains at TA-18 (LANL 1993, 15310, p. 3-4). The foundation of a two-room cabin is present at the site of the water tank for TA-55, which is also located on the south side of Pajarito Road.*

### 2.1.3 Laboratory Operational Use

*The primary Laboratory use of Pajarito Canyon has been as the location of the Los Alamos Critical Experiments Facility (LACEF) at TA-18 and surface and subsurface material disposal areas (MDAs), as a buffer zone for mesa-top firing site activities, and to a lesser extent for liquid waste disposal. These operations have been conducted in and have possibly discharged to Pajarito Canyon and its tributaries since the Laboratory began operation in 1943. These early discharges were associated with outfalls, surface runoff, and dispersion from firing sites located at TA-6, -7, -8, -9, -12, -15, -18, -22, -27, and -69 (See Sections 2.3.2, 2.3.6 through 2.3.8, and 2.3.11 through 2.3.12). Additional discharges began with the continued expansion of Laboratory operations to new sites in the 1950s through the 1970s, specifically at TA-3, -36, -40, -48, and -59.*

*Environmental Restoration (ER) Project personnel have identified various industrial and sanitary waste outfalls that currently discharge, or discharged in the past, to Pajarito Canyon and its tributaries as PRSs. Other major categories of PRSs identified within the Pajarito Canyon watershed include MDAs and firing sites. The PRSs are documented in the Resource Conservation and Recovery Act (RCRA) facility investigation (RFI) work plans for Operable Unit (OU) 1085 (LANL 1994, 34755); OU 1086 (LANL 1993, 20946); OU 1093 (LANL 1993, 15310); OU 1111 (LANL 1993, 26068); 1114 (LANL 1993, 51977); OU 1129 (LANL 1992, 7666); OU 1130 (LANL 1993, 15313); OU 1148 (LANL 1992, 7669); and OU 1157 (LANL 1993, 20949). These PRSs are shown in Figure A-1 in Appendix A and are listed with current status in Appendix B of this work plan; they are discussed further in this chapter.*

### 2.1.4 Current Recreational Use

*The Pajarito Canyon watershed encompasses land managed by the Laboratory, land owned by the United States Forest Service, Los Alamos County land, and land privately owned. Currently, hiking trails provide recreational access to the portion of the canyon on Laboratory and Los Alamos County land. Local residents use a portion of the canyon east of the Laboratory boundary including White Rock Canyon for activities such as hiking, jogging, and rock climbing. The Red Dot Trail provides hiking access from the White Rock residential area down to the Rio Grande in White Rock Canyon (Hoard 1993, 57491, p. 28). A Laboratory employee exercise center (the Wellness Center) is located at the head of a drainage that discharges into the north fork of Twomile Canyon at TA-3. Outdoor facilities present at the exercise center include hiking and biking trails and a volleyball court. Hiking trails used by Laboratory employees are also present at TA-8, -9, and -22. Access to the western portion of Mesita del Buey at TA-54 is restricted; however, employees use this area for activities such as walking and jogging. There is no evidence that nonemployees use the area for recreational purposes (LANL 1992, 7669).*

### 2.1.5 Current Residential Use

*A significant portion of the residential community of White Rock, including portions of the La Senda and Pajarito Acres subdivisions, is located within the Pajarito Canyon watershed downgradient of the Laboratory boundary. Private properties and gardens are located within canyon floodplains, and this portion of the canyon receives periodic storm water runoff from Laboratory property. Residents have unrestricted access to the main Pajarito Canyon channel, which contains the Red Dot Trail that provides access to the Rio Grande in White Rock Canyon as mentioned in Section 2.1.4.*

## 2.2 Environmental Monitoring and Regulatory Compliance

*Chapter 2 of the core document (LANL 1997, 55622) provides a summary of environmental protection programs and environmental monitoring programs operated by the Laboratory for chemical and radiological quality of surface water, groundwater, and sediments at the Laboratory. A summary of environmental monitoring in Pajarito Canyon is provided in this section, and a discussion of the results of the environmental monitoring is provided in Chapter 3 of this work plan.*

### 2.2.1 Current and Proposed Environmental Monitoring

*Groundwater monitoring and protection efforts at the Laboratory have evolved from the early programs initiated by the United States Geological Survey to present efforts that include the ER Project, the Groundwater Protection Management Program Plan (LANL 1995, 50124), the Watershed Protection Management Program, the Environmental Surveillance Program, the Decommissioning Project, and emergency management and response programs. Other protection efforts include those required by various New Mexico State regulations, the Clean Water Act (CWA), the National Pollutant Discharge Elimination System (NPDES), and the Hazardous and Solid Waste Amendments (HSWA) Module of the RCRA Part B permit. Table 2.2.1-1 summarizes some the existing environmental monitoring and surveillance programs that are being implemented in Pajarito Canyon.*

**TABLE 2.2.1-1**

**SUMMARY OF LABORATORY ENVIRONMENTAL PROGRAMS RELATED TO PAJARITO CANYON**

| Environmental Program | Date Implemented | Approved Activity | Regulatory Agency | Comment |
|---|---|---|---|---|
| *RCRA Permit* | *November 1989* | *Hazardous waste storage, treatment, and disposal* | *EPA NMED* | *Compliance addressed by ESH-19 oversight* |
| *HSWA Module of RCRA Permit* | *May 23, 1990 (new requirements effective May 19, 1994)* | *RCRA corrective actions* | *EPA NMED* | *RFI currently ongoing by ER Project* |
| *NPDES Program, CWA* | *September 13, 1978 (current permit January 30, 1990, revised August 1994)* | *Discharge of industrial and sanitary liquid effluents* | *EPA NMED* | *Compliance addressed by ESH-18 oversight* |
| *NPDES Storm Water Permit, CWA* | *General permit August 25, 1993* | *Storm water associated with industrial activities* | *EPA NMED* | *Compliance addressed by ESH-18 oversight* |
| *Groundwater Protection Management Program (Hydrogeologic Workplan)* | *January 1996* | *Groundwater monitoring* | *NMED* | *Hydrogeologic Workplan approved by NMED on March 25, 1998* |
| *Watershed Protection Management Program* | *Pending* | *DOE orders compliance* | *DOE* | *Annual reports* |
| *Annual Environmental Surveillance* | *Circa 1970* | *DOE orders compliance* | *DOE* | *Annual surveillance reports* |

*Table 2.2.1-2 lists the NPDES-permitted outfalls in Pajarito Canyon and provides a summary of outfall descriptions, locations, and operational status. In recent years, many of the NPDES outfalls have been directed to the TA-46 sanitary waste consolidation station.*

**TABLE 2.2.1-2**

**NPDES OUTFALLS IN PAJARITO CANYON**

| NPDES No. | Description | Discharge Location | Active | Discharge Volume | Comment |
|---|---|---|---|---|---|
| 03A-009 | Cooling tower blowdown, treated | TA-3-102 | No | Approx. 8 gpm* intermittent | Deleted 7/31/96 |
| 03A-025 | Cooling tower blowdown, treated | TA-3-208 | Yes | Approx. 16 gpm intermittent | To be decommissioned 1998 |
| 06A-078 | Photo waste discharge | TA-22-34 | No | Approx. 5 gpm intermittent | Deleted 7/31/96 |
| 06A-100 | Photo waste discharge | TA-40-15 | Yes | Approx. 1 gpm | To be recirculated 1998 |
| 06A-082 | Photo waste discharge | TA-40-12 | Yes | Approx. 1 gpm | To be recirculated 1998 |
| 04A-101 | Noncontact cooling water | TA-40-9 | No | Approx. 2 gpm | Deleted 9/19/97 |
| 06A-081 | Photo waste discharge | TA-40-8 | Yes | Approx. 1 gpm | Deletion requested 1/12/98 |
| 06A-080 | Photo waste discharge | TA-40-5 | Yes | Approx. 1 gpm | To be recirculated 1998 |
| 06A-079 | Photo waste discharge | TA-40-4 | Yes | Approx. 1 gpm | To be recirculated 1998 |
| 05A-154 | High-explosive waste discharge | TA-40-41 | No | Infrequent | Deleted 12/6/95 |
| 06A-075 | Photo waste discharge | TA-8-21 | No | Approx. 1–4 gpm | Deleted 1/14/98 |
| 06A-074 | Photo waste discharge | TA-8-22 | No | Approx. 3–4 gpm | Deleted 9/19/97 |
| 04A-155 | Noncontact cooling water | TA-9-50 | No | Infrequent | Deleted 12/6/95 |
| 05A-066 | High-explosive wastewater discharge | TA-9-A; 21; 28; 29; 32-35; 37; 38; 40 | Yes | 1–2 gpm | Deletion requested 1/12/98 |
| 05A-067 | High-explosive wastewater discharge | TA-9-B; 41; 42; 43; 45; 46 | Yes | 1–2 gpm | Deletion requested 1/12/98 |
| 05A-068 | High-explosive wastewater discharge | TA-9-48 HE processing | Yes | 1–2 gpm | Deletion requested 1/12/98 |
| 04A-115 | Noncontact cooling water | TA-8-70 | No | Approx. 8–12 gpm intermittent | Deleted 9/19/97 |
| 04A-164 | Noncontact cooling water, water production | Pajarito Well #2 | Yes | 1000–1500 gpm | Active, discharges only during maintenance operations |
| 06A-106 | Photo waste discharge | TA-36-1 | Yes | Infrequent | Intermittent discharge from nonphoto sources |
| 04A-143 | Noncontact cooling water | TA-15-306 | Yes | 10–12 gpm intermittent | To be recirculated 1998 |
| 03A-098 | Cooling tower blowdown, treated | TA-59-1 | No | Approx. 5 gpm intermittent | Deleted 12/6/95 |
| 06A-099 | Photo waste discharge | TA-40-23 | No | Approx. 1–2 gpm | Deleted 9/19/97 |
| 04A-103 | Noncontact cooling water | TA-15-40 | No | Infrequent | Deleted 8/94 |
| 04A-102 | Noncontact cooling water | TA-15-40 | No | Infrequent | Deleted 8/94 |
| 128-128 | Printed circuit board wastewater | TA-22-91 | No | Approx. 0.5 gpm | Deleted 12/6/95 |
| O2S | Inactive sanitary sewer outfall | TA-09 oxidation pond | No | Approx. 6 gpm | Outfalls combined before 1989; deleted 8/94 |
| O11S | Inactive sanitary sewer outfall | TA-08-26 oxidation pond | | | |
| O4S | Inactive sanitary sewer outfall | TA-18 oxidation pond | No | Approx. 3 gpm | Deleted 8/94 |
| *gpm = gallons per minute | | | | | |

Source: Koch 1998,57522; Dale 1998, 57524

*The Laboratory conducts various other surface water and groundwater quality protection programs in compliance with the CWA, the Safe Drinking Water Act, the Oil Pollution Prevention Act, and the New Mexico Water Quality Control Commission regulations. The programs include the Sanitary Waste Water Consolidation Plant; Storm Water Pollution Prevention Program; Spill Prevention, Control, and Countermeasures Program; and Waste Stream Identification and Characterization Program. These programs are thoroughly discussed in Chapter 2 of the core document (LANL 1997, 55622) and in the Groundwater Protection Management Program Plan (LANL 1995, 50124).*

*One municipal supply well located in Pajarito Canyon (PM-2) provides water level and water quality information on the regional aquifer. The alluvial groundwater wells used for environmental surveillance in Pajarito Canyon are listed in Table 2.2.1-3. These three shallow alluvial groundwater wells (PCO-1, PCO-2, and PCO-3), also called observation wells, are sampled annually. These wells are located in the lower canyon along approximately a 2.5-mi (4-km) section that extends from below the confluence of Threemile Canyon and Pajarito Canyon and east of TA-18 to near the Laboratory's eastern boundary at state road New Mexico (NM) 4. Numerous other wells have been installed in Pajarito Canyon for various purposes. These wells are discussed further in Section 2.3.10 and in Chapter 3 of this work plan. Spring 4 and Pajarito Springs (referred to as Spring 4A in the environmental surveillance reports), which are located in Pajarito Canyon near its intersection with the Rio Grande, also provide groundwater data used for environmental surveillance.*

**TABLE 2.2.1-3**

**GROUNDWATER MONITORING WELLS IN PAJARITO CANYON**

| Well | Date Installed | Ground Elevation (ft) | Depth of Casing (ft) | Screened Interval (ft) | Purpose |
|---|---|---|---|---|---|
| PCO-1 | 1985 | 6687 | 12 | 4–35 | Alluvial observation |
| PCO-2 | 1985 | 6618 | 9.5 | 1.5–9.5 | Alluvial observation |
| PCO-3 | 1985 | 6543 | 17.7 | 5–17 | Alluvial observation |
| PM-2 | 1965 | 6715 | 2300 | 1004–2280 | Municipal supply well |

Source: LANL 1995, 50124

*Environmental surveillance stations for monitoring and sampling surface water and sediment are listed in Table 2.2.1-4. Three gaging stations (E240, E245, and E250) were installed in 1995 to monitor flow in Pajarito Canyon. Additional information regarding these gaging stations is presented in Chapter 3 of this work plan. Surface water sampling is conducted at a collection site near PCO-1 and a site near the intersection of Pajarito Canyon and the Rio Grande. Sediment samples are collected annually from one site located at the intersection of Pajarito Canyon and state road NM4 and from six sites (G-1 through G-6), which are located at the intersections of drainages below Mesita del Buey and on the floor of Pajarito Canyon.*

*In addition to annual environmental surveillance monitoring, a supplemental environmental surveillance study was initiated in 1993 at MDA G at TA-54. MDA G has been the principal area at the Laboratory for the storage and disposal of low-level and transuranic (TRU) radioactive waste since 1957. The study has focused on the possibility of contaminated sediment moving out of the MDA G perimeter via surface-water runoff. Since 1993 soil and single-stage water samples from the perimeter of MDA G have been analyzed annually for a limited suite of radionuclides and metals. Reports are currently available for the results of surveillance conducted from 1993 through 1995 (Conrad et al. 1995, 52014; Conrad et al. 1996,* *55621; Childs and Conrad 1997, 57518). The results of the investigations are summarized in Chapter 3 of this work plan.*

**TABLE 2.2.1-4**

**ROUTINE ENVIRONMENTAL SURVEILLANCE MONITORING STATIONS IN PAJARITO CANYON**

| Station Name | Media | Attribute | Location |
|---|---|---|---|
| *E240* | *Surface water* | *Discharge* | *Upper Canyon west of state road NM501 at Laboratory boundary* |
| *E245* | *Surface water* | *Discharge* | *Middle Canyon below confluence of Pajarito Canyon and Twomile Canyon* |
| *E250* | *Surface water* | *Discharge* | *Lower Canyon west of state road NM4 just above Laboratory boundary* |
| *Pajarito Canyon at PCO-1* | *Surface water* | *Quality* | *Near PCO-1* |
| *Pajarito Canyon at Rio Grande* | *Surface water and sediment* | *Quality* | *Pajarito Canyon above point of discharge into the Rio Grande* |
| *Pajarito Canyon at state road NM4* | *Sediment* | *Quality* | *Intersection of Pajarito Canyon and state road NM4* |
| *G-1 through G-6* | *Sediment* | *Quality* | *Toe of drainages below Mesita del Buey south of TA-54* |

### 2.2.2 HSWA Module Requirements

*Section C of the HSWA Module (EPA 1990, 1585) includes no requirements for special monitoring of the saturated alluvium, unsaturated zone, or surface water in Pajarito Canyon beyond that conducted within the current Environmental Surveillance Program by Laboratory group ESH-18 in accordance with Department of Energy (DOE) orders. Additionally, no specific perched zone monitoring in Pajarito Canyon is required by Section C of the HSWA Module.*

## 2.3 Sources of Potential Contaminants within Pajarito Canyon

*Potential contaminant sources (as PRSs) on the mesa tops and within the Pajarito Canyon watershed and their current regulatory status are listed in Appendix B of this work plan. The sequence of technical area descriptions, histories, and discussions of their associated PRSs are presented with respect to their approximate geographic location from west to east within the Pajarito Canyon watershed. The general locations of technical areas within the Pajarito Canyon watershed are shown on Figure 2.3-1; technical areas and PRSs that are discussed in this section are shown in detail on Figure A-1 in Appendix A of this work plan. Technical areas located in the Pajarito Canyon watershed that do not contain PRSs within the watershed are not described or included in this section.*

*The information compiled in this section is based on available reports and data as of circa February 1998. Additional and updated information about the status of PRSs can be obtained from the Laboratory's ER Project office and/or the Community Reading Room in Los Alamos, New Mexico, as described in Section 7.1.2.3 of the Installation Work Plan for Environmental Restoration Program (LANL 1996, 55574, p. 7-2).*

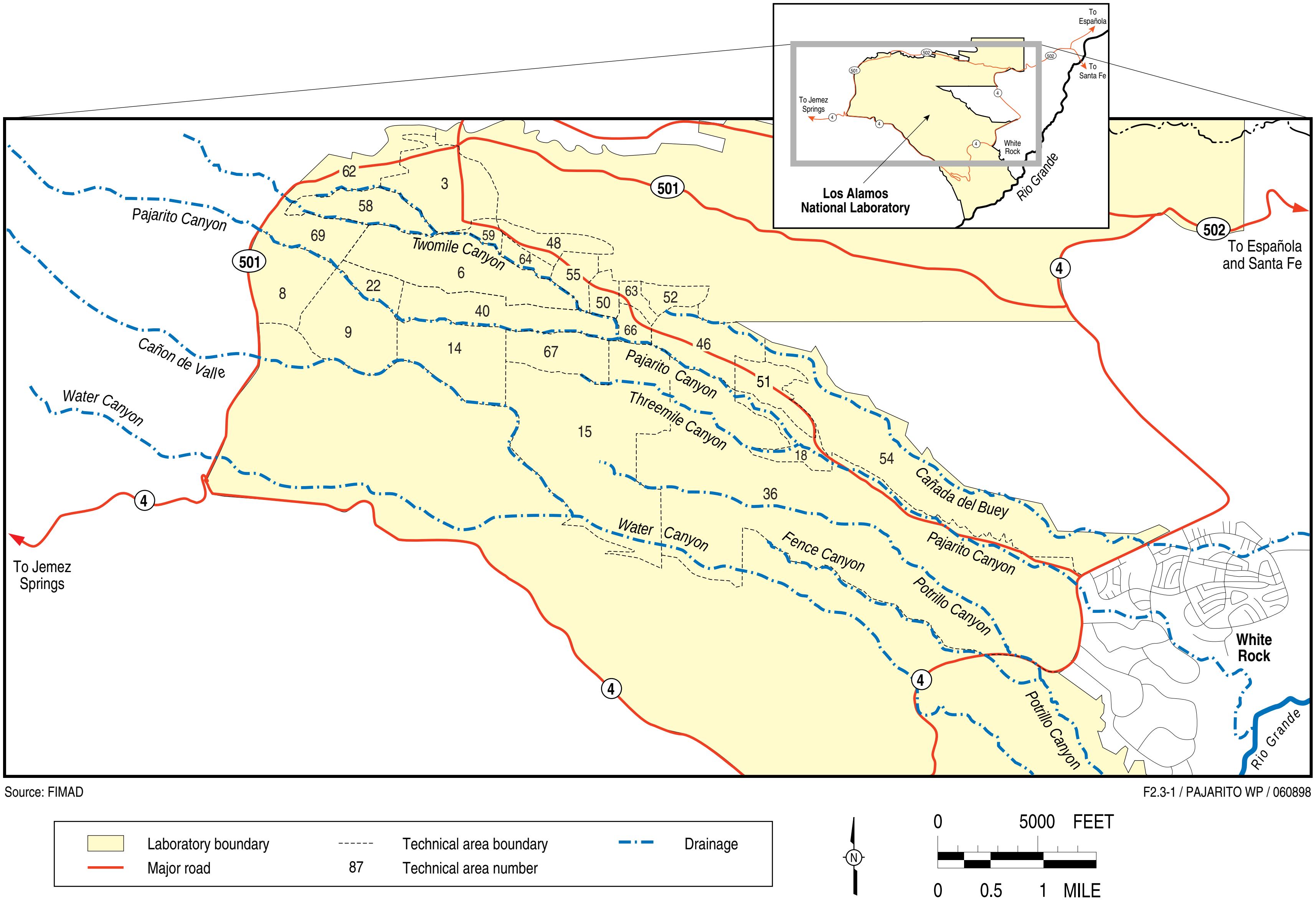


**Figure 2.3-1. Laboratory technical areas adjacent to Pajarito Canyon and selected tributaries.**

### 2.3.1 Technical Areas 8, 9, and 69 and Former Technical Area 23

*TA-8, -9, and -69 contain some of the earliest Manhattan Project sites built at the Laboratory. The developed areas of TA-8 and TA-9 (which includes former TA-23) lie on a broad mesa that is bounded on the north by Pajarito Canyon, on the south by Cañon de Valle, and on the west by state road NM501 and the Jemez Mountains. The mesa is drained via three tributaries to Pajarito Canyon. TA-69 is located on Twomile Mesa across Pajarito Canyon to the north of TA-8 and TA-9. Twomile Canyon bounds Twomile Mesa on the north (LANL 1993, 20949, p. 2-1).*

*TA-8, which is known as Anchor West, was the site of the original Anchor Ranch homestead, the Manhattan Project Gun-Firing Site (referred to as Old Anchor West) as well as MDA Q and other postwar facilities. The area is also known as GT Site, named for one of the workers, Gerald Tinney. In 1943 a gun-firing site was established west of Anchor Ranch Road (Hawkins et al. 1983, 57519, pp. 111, 500–501). Structures at the site included buried concrete bunkers and four wooden structures used for office space, storage space, and a carpenter's shop. South of the control bunkers, two gun mounts were installed and two sand butts were emplaced to catch experimental projectiles. The projectiles were made of various combinations of steel, tungsten carbide, boron carbide, lead, copper, and depleted uranium (DU). The standard practice was to recover the projectiles for detailed examination. However, occasionally the projectile and/or the target would fracture, reportedly scattering fragments over distances of up to 75 yd (67.5 m) (Jones 1993, 14994). In 1945 prototypes of the Little Boy weapon were tested at the Gun-Firing Site. In these tests DU was used in place of the enriched uranium contained in the actual weapon. Occasionally testing was performed using small quantities of polonium and beryllium; however, there are no indications that any of these materials escaped the targets (Jones 1993, 14994). The Gun-Firing Site was abandoned in 1946, and the naval guns and various other items were buried in a pit on site at Anchor West, which is now known as MDA Q. The wooden structures were removed at various times between 1949 and 1968. In 1992 the only remaining relics were the now abandoned concrete bunkers, the concrete pads that supported the gun mounts, and two piles of sand that mark the locations of the sand butts. In 1949 and 1950 modern TA-8 was established north and west of the Gun-Firing Site with the construction of office buildings, utility buildings, magazines, sewer lines, septic tanks, electric utilities and other support facilities. These new buildings were used primarily for x-ray work and, among other uses, contained photographic-processing laboratories (LANL 1993, 20949, p. 2-3).*

*TA-9 is located east of Anchor Ranch Road and encompasses three Manhattan Project sites known as Old Anchor East, the Far Detonation Point (also known as Far Point), and Nu Site. Nu Site was also known as TA-23 before its incorporation into TA-9 in 1950. TA-9 also contains MDA M and the postwar site known as New Anchor East. Old Anchor East was established in 1943 to house explosives production, development, and test experiments, and x-ray work. There were eight major structures along with associated sewer lines, septic tanks, manholes, and electric and steam heating utilities. Old Anchor East was returned to the Atomic Energy Commission in 1957; the permission to decommission the site was given in 1959, and the buildings and substructures were removed between 1960 and 1965 (LASL 1957, 14913; Bodler 1959, 14932; Wingfield and Courtright 1960, 14920; Wingfield 1960, 915; Sizer 1961, 14964). Buildings known to contain radioactive contaminants were removed and disposed of at Mesita Del Buey (TA-54). Soil testing indicated no explosives remained after decommissioning activities were completed (LANL 1993, 20949, p. 2-12). In 1992 only broken concrete bricks, bits of plumbing pipe, some burn pits, and some of the manholes remained at Old Anchor East.*

*Far Point at TA-9, which consisted of a pair of shelters each buried in a mound, was established in 1944 to conduct various explosives detonation experiments. These explosives tests were conducted in the open, west of the mounds. Far Point was abandoned in the late 1940s because the structural integrity of the control rooms had deteriorated due to repeated shock loading; the site was decommissioned in 1965*

*(Jones 1993, 14994). MDA M, which was used from 1948 to approximately 1965 as a surface dump for construction debris and other solid wastes, is located in a clearing about 1200 ft (360 m) north-northeast of Far Point. Materials such as metal and wood objects, chemical and high explosives (HE), laboratory appliances and fixtures, metal and glass containers, and construction and demolition debris were disposed of at the site. During a site visit to MDA M in the spring of 1992, rusted metal cans ranging in size from 12 oz to 5 gal. (0.36 to 19 L), and a white fibrous substance believed to be asbestos was visible on the ground in this area (LANL 1993, 20949, p. 5-73). MDA M has since been the subject of remedial action and is discussed later in this section.*

*Nu Site was established during 1943 and 1944 and was used for explosives testing. The site contained one firing point and four small structures. During and after the war tests of up to 135 lb of HE were conducted regularly. Postwar activities, in particular, resulted in contamination with HE, beryllium, radionuclides, and heavy metals such as uranium-238, mercury, cadmium, and lead. The site was decommissioned during 1949 and 1950 in preparation for the construction of New Anchor East; at that time it was incorporated into TA-9 for administrative purposes (LANL 1990, 7511).*

*Construction of New Anchor East began in 1950, immediately after construction was completed at TA-8. Approximately 30 new structures were erected, together with associated settling tanks, septic tanks, drain lines, manholes, and other support structures. Generally, the site, which is still active, has been used for developing, producing, conducting compatibility studies of, and testing explosives.*

*TA-69 was created in 1989 and incorporates a number of small structures at the intersection of Anchor Ranch Road and Twomile Mesa Road as well as structures on what was the northwest section of TA-6. Before 1989 the structures now in TA-69 were designated with either TA-0 or TA-6 numbers. The structures include a guard station, two trailers used for office space, an inactive incinerator building, and other miscellaneous buildings (LANL 1993, 20949, p. 2-5). The incinerator (TA-69-3) was built in 1959 to destroy classified documents. For security purposes the ashes from the burned documents were wetted down behind the incinerator building in a small pond (Jones 1992, 14936).*

*PRSs located within the Pajarito Canyon watershed at TA-8, -9, -23, and -69 have been addressed in the RFI Work Plan for Operable Unit 1157 (LANL 1993, 20949). Of the 116 PRSs identified, 58 were recommended for no further action (NFA), and 21 were recommended for deferred action in the work plan. Most of the remaining PRSs were investigated and subsequently recommended for NFA in the RFI Report for Potential Release Sites at TA-8 and TA-9 (LANL 1996, 54586) and in the RFI Report for Potential Release Sites at TAs -6, -8, -22, and -40 (LANL 1997, 56664). Investigated PRSs were combined into nine aggregates. Table 2.3.1-1 contains a summary of these groups with respect to the PRSs located within the Pajarito Canyon watershed and the associated chemicals of potential concern (COPCs).*

*PRSs 8-004(d), 9-005(a), 9-005(d), 9-009, 8-009(d), 8-009(e), 9-001(a), 9-001(b), 9-003(g), 9-003(h), 9-003(l), 9-001(d), and C-8-010 were recommended for NFA in the RFI Report for Potential Release Sites at TA-8 and TA-9 (LANL 1996, 54586). PRS 8-002 was recommended for NFA in the RFI Report for Potential Release Sites at TAs -6, -8, -22, and -40 (LANL 1997, 56664). PRSs that have been the subject of remedial action are discussed below.*

*An expedited cleanup (EC) was conducted at PRS 8-003(a) during August and September 1995 as described in the Expedited Cleanup Plan for Solid Waste Management Unit 8-003(a) (LANL 1995, 46092). PRS 8-003(a) was an underground septic tank located south of the Abandoned Bunker Site in TA-8-3 that served buildings TA-8-1 and TA-8-3. Both buildings were built in 1943 within a controlled area of the Laboratory. The septic tank was connected to the sanitary sewage piping systems and may have received wastes associated with a variety of activities conducted in the buildings that involved the use of photographic-processing chemicals, radioactive materials, explosives, and solvents. The Phase I* *investigation revealed the presence of chloroform, trichloroethane, and trichloroethene at levels that exceeded their respective screening action levels (SALs). The soil overburden, lid, and hazardous contents of the tank were removed. The tank was pressure washed and pumped. Confirmatory samples indicated that established cleanup goals had been met. The site was restored by backfilling the tank with sand and closing the excavation with the removed overburden material.*

**TABLE 2.3.1-1**

**PRSs IN TA-8, -9, AND -69 WITHIN THE PAJARITO CANYON WATERSHED AND COPCs**

| Aggregate | PRS(s) | Description | Drainage Basin | COPCs |
|---|---|---|---|---|
| 1 | 8-004(d), 8-009(c–f) | Active TA-8: drains and outfalls | "Starmer Gulch" | PCBs, silver, chromium, pentachlorophenol, TPH, VOCs, SVOCs, nitrite, nitrate, strontium-90, gross-alpha, gross-beta |
| 2 | 8-002, 8-006(a) | TA-8 Gun-Firing Site and MDA Q | "Starmer Gulch" | Copper, lead, beryllium, gross-alpha, gross-beta |
| 3 | 8-003(a), 8-005, 8-009(a) | TA-8 Abandoned Bunker Site: septic system, storage vessel, and outfall | "Starmer Gulch" | TNT, RDX, HMX, PETN, tetryl, 2,4-dinitrotoluene, 1,3,5-trinitrobenzene, explosive D, acetone, benzene, carbon tetrachloride, chloroform, methyl ethyl ketone, toluene, barium, beryllium, cadmium, chromium, cyanide, lead, mercury, nitrate, silver, gross-alpha, gross-beta |
| 4 | 9-009, 9-010(a–b), 9-011(b-c) | Active TA-9: lagoon and sand filters, and storage areas | "Arroyo de LaDelfe" | TNT, RDX, HMX, PETN, tetryl, 2, 4-dinitrotoluene, 1,3,5-trinitrobenzene, explosive D, VOCs, SVOCs, strontium-90 |
| 5 | 9-001(d), 9-003(a–b), 9-003(d–e), 9-003(g,h,i), 9-005(a and d), 9-006, 9-008(b), 9-012, 9-016 | TA-9 Decommissioned Area: firing site, settling tanks, waste water sumps, septic systems, oxidation pond, waste pit, and storage tank | "Starmer Gulch" | TNT, RDX, HMX, PETN, tetryl, 2,4-dinitrotoluene, 1,3,5-trinitrobenzene, explosive D, acetone, benzene, carbon tetrachloride, chloroform, methyl ethyl ketone, toluene, barium, beryllium, cadmium, chromium, lead, mercury, nitrate, strontium-90, gross-alpha, gross-beta |
| 6 | 9-001(a–c), 9-002, 9-014 | TA-9 and TA-69 Decommissioned Firing Sites: firing sites, recovery pit, and burn pit | "Arroyo de LaDelfe" | TNT, RDX, HMX, PETN, tetryl, 2,4-dinitrotoluene, 2,6-dinitrotoluene, 1,3,5-trinitrobenzene, explosive D, antimony, barium, beryllium, cadmium, chromium, lead, mercury, nitrate, silver, gross-alpha, gross-beta |
| 7 | 9-013 | MDA M (surface disposal area) | "Starmer Gulch" and Pajarito Canyon | Asbestos, TNT, RDX, HMX, PETN, 2,4-dinitrotoluene, tetryl, 1,3,5-trinitrobenzene, explosive D, VOCs, SVOCs, metals, organochlorine pesticides, PCBs, calcium sodium, magnesium, potassium, iron, uranium, chloride, fluoride, carbonate, bicarbonate, nitrate, sulfate, gross-alpha, gross-beta |
| 8 | 69-001 | TA-69: incinerator ash pond | Twomile Canyon | Antimony, cadmium, chromium, lead, silver, copper |
| 9 | C-8-010, C-9-001 | AOCs: drum storage site and stained soil | "Starmer Gulch" | VOCs, SVOCs, TPH |

Source and Pajarito Canyon tributary nomenclature: LANL 1993, 20949

*PRS 8-005 was the subject of a voluntary corrective action (VCA) as described in the Voluntary Corrective Action Completion Report for Potential Release Site 8-005 (LANL 1996, 54328). PRS 8-005, a 4-ft by 4-ft (1.2-m by 1.2-m) metal vessel, was an abandoned oven used in the 1950s for crystal growth experiments. The vessel was located on the ground outside the west end of building TA-8-2, a machine shop and storage building. Group J-16 used the vessel to conduct crystal-growth experiments in the now-abandoned bunker buildings. Crystal growth residue from photographic equipment crystal experiments at building TA-8-1 (located next to TA-8-2) was contained in this storage vessel. Other chemicals used were terphenyl, alpha naphthyl oxazole, styrene, ethyl chloroform, and thallous iodide. The inside of the vessel was contaminated with naphthalene and asbestos. The Johnson Controls Asbestos Abatement team confirmed the presence of asbestos in the form of a gasket and strap on the vessel (LANL 1995, 49326). There were no visible signs of stained ground around the vessel. VCA activities were initiated in September 1994 and included the removal and disposal of one $ft^3$ (0.03 $m^3$) of solid naphthalene from the vessel and the asbestos strap and gasket. Then the vessel was transported to the Laboratory's salvage yard where it was inspected and found to contain no cracks or holes. In October 1994 the site was inspected, and a site reconnaissance survey was conducted with radiation and organic chemical field instruments at the location of the vessel; no elevated readings were detected. On July 26, 1995, one confirmatory soil sample was collected from the former location of the vessel. The VCA report states that the sampling data were reviewed and no contaminants were found; therefore, PRS 8-005 was recommended for NFA (LANL 1996, 54328).*

*VCAs were conducted at PRSs 9-010(a and b) as described in the Voluntary Corrective Action Completion Report for Potential Release Sites 09-010(a) 09-010(b) (LANL 1996, 53777). PRS 9-010(a) is a three-sided waste container storage structure located at the northwest corner of building TA-9-48. The structure was 11.5 ft (3.45 m) wide, 2.5 ft (0.75 m) deep, and 6.5 ft (1.95 m) tall and was sheathed in corrugated metal except for an exposed north side. It was constructed of four steel pipe posts anchored in concrete with a steel-grid floor suspended above ground. The structure, which was built in 1961, had been used to store HE-contaminated solid wastes from the HE machining building before it was picked up for disposal. Machining operations resulted in HE chips and chunks and organic solvent-contaminated Kimwipes tissues. A VCA was proposed to remove the metal structure because it was obsolete and no longer in use. Data from the Phase I investigation indicated that the COPCs were below SALs in the upper 12 in. (0.3 m) of soil; therefore, no soil excavation or confirmatory sampling was proposed as part of the VCA. VCA activities were conducted in July 1995 and consisted of the removal of the structure and field screening of its components for radiation, organic vapor, and HE compounds. Subsequently the structure was transported to the Los Alamos County landfill for disposal. Holes in the ground caused by the removal of the structure's anchor pipes were filled with gravel. PRS 9-010(a) was recommended for NFA in the VCA report (LANL 1996, 53777).*

*PRS 9-010(b) is a structure nearly identical to PRS 9-010(a) except for the presence of a secondary containment pan below the floor of the structure that was absent at PRS 9-010(a). PRS 9-101(b) is located at the southwest corner of building TA-9-45. The structure was built in 1961 to store organic solvents, such as methyl sulfoxide, m-pyrol, acetone, and propanol. Before the VCA was implemented, the solvents were stored in grounded 55-gal. drums or 5-gal. cans housed within the shed. The purpose of the VCA was to remove the metal structure because the storage function could be accomplished more effectively elsewhere at TA-9. Data from the Phase I investigation indicated that the COPCs were below SALs in the upper 12 in. (0.3 m) of soil; therefore, no soil excavation or confirmatory sampling was proposed as part of the VCA. VCA activities were conducted in July 1995 and consisted of the removal of the structure and field screening of its components for radiation, organic vapor, and HE compounds. Subsequently the structural debris was transported to the Los Alamos County landfill for disposal. The* *deputy group leader for the site arranged for the disposition of the secondary containment tray and the removal and disposition of the chemicals stored in the shelter. Holes in the ground caused by the removal of the structure's anchor pipes were filled with gravel. PRS 9-010(b) was recommended for NFA in the VCA report (LANL 1996, 53777).*

*An EC was performed at PRS 9-013 (MDA M) as described in the Expedited Cleanup Plan for Solid Waste Management Unit 9-013 (LANL 1995, 47257). Preliminary results from the Phase I RFI sampling indicated the presence of heavy metals, organic compounds, and radioactive contamination above soil SALs. Additionally, asbestos was also visually confirmed to be present at several locations at the site. Phase I of the EC included the removal of debris and soil located within the top 5 ft (1.5 m) of the surface over the 3.2-acre (12,545-m$^2$) site, the installation of runoff diversion structures at the site, and the collection of confirmatory samples. The cleanup resulted in the disposal of approximately 5460 yds$^3$ (4150 m$^3$) of radioactive, chemical, asbestos, hazardous, and sanitary waste streams. The proposed Phase II of the EC is planned to consist of the evaluation of the confirmatory sampling results to determine if the cleanup action levels established based on the Phase I RFI data are still appropriate, followed by additional site excavation and subsequent round(s) of confirmatory sample collection. Phase I of the EC was conducted between November 1995 and March 1996. Completion of the Phase II activities and the final EC report is pending.*

*VCAs were conducted at PRSs C-9-001 and 69-001 as described in the Voluntary Corrective Action Completion Report for Potential Release Sites C-9-001 69-001 (LANL 1996, 54334). PRS C-9-001 was a stained soil area beneath a drainage pipe located at the southeast corner of building TA-09-31, which had been used for chemical storage. The drainage pipe, now plugged, was a discharge point from spill containment trays in the building. The stained area measured approximately 2 ft by 3 ft (0.6 m by 0.9 m). The source area was a chemical storage area that may have contained organic compounds and solvents. The time during which the drainage pipe may have operated is not known; however, the structures in the area were built in the early 1940s and were in use until the 1950s. Data collected during the Phase I investigation conducted in 1994 identified benzo[a]pyrene as a contaminant of concern at the site. VCA activities were conducted in September 1995 and consisted of the excavation of approximately two 55-gal. drums (0.54 yd$^3$) of soil and the collection of confirmatory samples (which did not detect the presence of benzo[a]pyrene). Then the excavation was backfilled and recontoured, and the site was reseeded with native grasses.*

*PRS 69-001 is a dry, unlined pond located northeast of the Twomile Mesa incinerator building (TA-69-3), which is located at the intersection of Anchor Ranch Road and Twomile Mesa Road. The incinerator building houses two inactive incinerators that were used to destroy large quantities of classified documents and viewgraphs from 1959 until the late 1970s. The ash and all of the noncombustible materials removed from the incinerator were transferred to the pond. The ash from the secondary combustion chamber was periodically flushed directly into the pond. The berm that once contained the pond has been breached by erosion at the northeast end; therefore, no standing water remains in the pond. Data collected during the Phase I investigation conducted in 1994 identified the presence of barium and lead at levels exceeding soil SALs and the presence of antimony, cadmium, copper, manganese, and nickel at levels exceeding upper tolerance limit (UTL) background levels, which identified the site as a candidate for VCA (LANL 1996, 54334). After the pond was excavated, visual observations and subsequent field screening identified a much larger area and depth of contamination than originally anticipated: approximately 30 ft by 160 ft (9 m by 48 m). Soil within the defined area of contamination was excavated below the visible ash layers to a total depth of approximately 24 in. (0.6 m). Soil samples for* *field screening collected from the perimeter of and downgradient from the excavation indicated that the area of contamination extends to the northeast of the excavation into the forest and canyon below the pond. The location of samples and the data associated with the screening samples were not included in the VCA report. The cleanup was terminated because (1) the increase in the size of the project (four times the original waste volume estimate), (2) equipment access problems due to grade and the presence of trees, and (3) the lack of authorization to cut trees taller than 10 ft (3 m). The cleanup was halted before entering the channel at the bottom of the northern berm and before disturbing any soils within 50 ft (15 m) of the rim or within the adjacent Twomile Canyon. Approximately 265 yds$^3$ (200 m$^3$) of contaminated soil were excavated before the project was terminated. Data from nine confirmatory samples collected within the boundaries of the excavation show that the contaminants of concern are below their respective cleanup levels. Site restoration included placement of log silt dams in the excavation and recontouring the berms. If no further sampling and cleanup efforts are required, the excavated area is planned to be backfilled, recontoured, and reseeded. The Voluntary Corrective Action Completion Report for Potential Release Sites C-9-001 69-001 concluded that the primary source of contamination had been removed. However, the report also acknowledged that the current efforts may be viewed as an interim measure and that additional actions may be required before the PRS is approved for NFA (LANL 1996, 54334).*

*The PRSs that directly impact drainages are outfalls that enter shallow channels to Pajarito Canyon and its tributaries and potentially MDA M. To a lesser extent, contaminants from mesa-top PRSs may be transported into the canyons via sheet wash runoff associated with storm events. Pajarito Canyon, Twomile Canyon, and Cañon de Valle appear to sustain reaches of perennial flow, at least in some years (LANL 1993, 20949, p. 6-139). Joints and faults may provide additional pathways for infiltration and release of contaminants into the shallow subsurface.*

*The RFI for MDA M (PRS 9-013 in OU 1157) included the collection of water samples from three springs located downslope from the disposal area (Homestead Spring, Charlie's Spring, and Starmer Spring) and from Pajarito Creek. Sediment samples and surface water runoff samples were also collected from down gradient locations near the disposal area, where local runoff could have transported waste constituents (LANL 1993, 20949, p. 6-136). A summary of the results of the sampling is included in Sections 3.4 and 3.6 of this work plan.*

### 2.3.2 Technical Areas 6, 7, 22, and 40

*TA-6, -7, -22, and -40 are located on Twomile Mesa, which is bound to the north by Twomile Canyon and to the south by Pajarito Canyon. Early in the Manhattan Project, two methods for assembling fissionable material to produce a weapon were identified: gun assembly and implosion. Early efforts emphasized the development of a gun design. However, when measurements of the nuclear properties of plutonium showed that reactor-produced plutonium could not produce a nuclear explosion in a gun assembly, efforts rapidly shifted to produce an implosion weapon. TA-6 (Twomile Mesa South), TA-7 (Gomez Ranch Site), TA-22 (Trap Door Site), and TA-40 (Detonator Firing Site) were all related to the Manhattan Project development of the implosion weapon, which involved implosion tests, plutonium recovery from the tests, and detonator and firing system development and fabrication.*

*During 1944 construction to support the project was initially concentrated at TA-6 with the construction of control buildings for test firing, a chemistry laboratory, and a carpenter shop. In 1944 and 1945 several new buildings were constructed to consolidate the detonator work. In 1945 significant construction at*

*TA-6 resulted in 25 new structures, which included three firing chambers (TA-6-7, -8, and -9), a laboratory (TA-6-6), and one explosives pressing shop (TA-6-5) (LANL 1993, 26068). Detonator process work involved the use of pentaerythritol tetranitrate (PETN); hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX); and octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine (HMX). The total amount of PETN used in detonator processing has been estimated to be less than 585 lb (263 kg), with total losses estimated at less than 1.5 lb (0.7 kg) (Meyers 1993, 15072). A 20-year study showed that PETN decomposes slowly in soil (DuBois and Baytos 1991, 6994); therefore, few decomposition products are expected. The decomposition rate for PETN, expressed as its half-life, is 92 years. The half-lives of RDX, HMX, and 2,4,6-trinitrotoluene (TNT) are 36 years, 39 years, and 1 year, respectively (DuBois and Baytos 1991, 6994).*

*In 1946 and 1947 Norris Bradbury, the Laboratory director, ordered that pits be dug on Twomile Mesa to bury classified objects (Bradbury 1946, 15076; Bradbury 1947, 15077). It was expected that in a few years the objects could be recovered and declassified (North 1974, 15083). These pits are now part of MDA F. Interviews and archival sources suggest that most of the material disposed of at MDA F was buried to protect classification and that explosives were probably not buried there. However, records are incomplete, and the possibility cannot be discounted that other hazardous materials, such as solvents and other chemicals, were placed in the pits (Roy F. Weston, Inc., 1988, 20268). In the spring of 1945 shaped explosive charges called lenses were being produced in large numbers at S-Site (TA-16) for the Trinity test and the implosion weapon. The charges were called lenses because they focused the force of the explosives to provide an implosion. About 100 of these lenses were defective and were destroyed by detonation on Twomile Mesa, probably in the area now known as MDA F (Van Vessem 1992, 15073).*

*Test firing continued at TA-6 until 1952 when operations were moved to TA-40 (Creamer 1993, 15267). Explosives development and laser, chemical laboratory, and photographic operations continued at TA-6 until 1976 (Schott 1993, 21496). Several small operations, including a carpenter shop, a cable fabrication shop, and silk screening continued at TA-6 until the 1980s (Schott 1993, 21496). Several structures are still in place but are no longer used. Ten magazines and other buildings were removed or destroyed by burning.*

*Late in 1944 four additional buildings were constructed on the southern edge of Twomile Mesa to assemble the conventional explosives for the Fat Man Weapon. This area (TA-22) is located on the north rim of Pajarito Canyon. In 1948 the buildings were remodeled into office, laboratory, and fabrication space to replace those activities at TA-6, and new magazines and utility buildings were built. In the early 1980s a new Detonation Systems Laboratory was constructed north of the old buildings at TA-22. By 1985 only the new Detonation Systems Laboratory building was occupied, and the older buildings were demolished or abandoned (Creamer 1993, 15267).*

*TA-40 was built in 1950 to replace the detonator firing chambers at TA-6 (Creamer 1993, 15267). TA-40 contains six firing sites that have been used since 1950 for explosives testing related to research and development of detonators and other small explosives assemblies. TA-40 includes an office building, an inert assembly building, six firing chambers, five shot preparation buildings, eight magazines, and utility buildings. One of the firing chambers, TA-40-9, was upgraded in the 1980s to house a two-stage gas gun. The Laboratory's first contained test-firing site was completed in 1992 at chamber TA-40-8 (LANL 1993, 26068).*

*TA-6 now includes former TA-7; both sites are inactive. TA-22 and TA-40 are presently active. PRSs located within the Pajarito Canyon watershed at TA-6, -7, -22, and -40 have been addressed in the RFI*

*Work Plan for Operable Unit 1111 (LANL 1993, 26068). Of the 62 PRSs identified, 11 PRSs were proposed for VCA in the work plan. Most of the remaining PRSs were investigated and subsequently recommended for NFA in the RFI Report for Potential Release Sites 22-012 22-015(a, b, d, e) (LANL 1997, 56749) and in the RFI Report for Potential Release Sites at TAs -6, -8, -22, and -40 (LANL 1997, 56664). The PRSs were combined into 10 aggregates based on site or source similarities. Table 2.3.2-1 lists the COPCs associated with each PRS aggregate.*

**TABLE 2.3.2-1**

**TWOMILE MESA PRSs AND COPCs**

| Aggregate | PRS(s) | Description | Drainage Basin | COPCs |
|---|---|---|---|---|
| 1 | 6-005, 6-007(a–e) | MDA F | Southwest fork of Twomile Canyon | HMX, PETN, RDX, TNT, barium, uranium, cesium-137, strontium-90 |
| 2 | 22-015(c) | Plating and etching outfall and runoff area | Pajarito Canyon | Benzene, perchloroethylene, trichloroethylene, chromium IV, copper, silver, zinc, cyanide, fluoride, nitrite, nitrate, phosphate, sulfate, sodium carbonate, sodium hydroxide, sodium thiosulfate |
| 3 | 22-012, 22-014(a and b), 22-015(a, b, d, e), 40-005 | Sump and dry well systems and adjacent wash pad | Southwest fork of Twomile Canyon and Pajarito Canyon | HMX, PETN, RDX, TNT, acetone, trichloroethylene, aluminum, barium, calcium, chromium IV, iron, magnesium, fluoride, nitrite, nitrate, phosphate |
| 4 | 6-003(a, c, d, e, f, g), 6-008, C-6-019, 7-001(a–d) | Inactive firing sites | Southwest fork of Twomile Canyon | HMX, PETN, RDX, TNT, acetone, carbon tetrachloride, barium, cobalt, copper, uranium, cesium-137 |
| 5 | 6-007(f–g), 40-010 | Surface disposal areas | Southwest fork of Twomile Canyon | HMX, PETN, RDX, TNT, barium, uranium, cesium-137, strontium-90 |
| 6 | 6-001(a and b), 22-010(a and b), 22-016, 40-001(b and c) | Septic systems | Southwest fork of Twomile Canyon and Pajarito Canyon | HMX, PETN, RDX, TNT, acetone, carbon tetrachloride, barium, iron, magnesium, silver, fluoride, nitrite, nitrate, phosphate, sulfate |
| 7 | 40-006(a–c), 40-009, TA-40-4, -9, -12 | Active firing sites | Pajarito Canyon | HMX, HNS, nitroguanidine, PETN, RDX, TATB, TNT, barium, copper, lead, thallium |
| 8 | 6-002, C-6-001, C-6-003, C-6-005, C-6-018, C-6-021 | Former structure sites | Southwest fork of Twomile Canyon | HMX, PETN, RDX, TNT, barium |
| 9 | 6-006, 40-004 | Former container storage areas | Southwest fork of Twomile Canyon and Pajarito Canyon | PCBs |
| 10 | 40-007(a–e) | Storage areas | Southwest fork of Twomile Canyon and Pajarito Canyon | HMX, HNS, nitroguanidine, PETN, TATB, TNT |

Source: LANL 1993, 26068

*PRSs 22-012 and 22-015(a, b, d, and e) were recommended for NFA in the RFI Report for Potential Release Sites 22-012 22-015(a, b, d, e) (LANL 1997, 56749). PRSs 7-001(a through d), 6-003(a, c, f, and g), 6-008, C-6-019, 6-001(a and b), 22-016, 22-010(a and b), 40-005, 22-014(a and b), and 6-007(g) were* *recommended for NFA in the RFI Report for Potential Release Sites at TAs -6, -8, -22, and -40 (LANL 1997, 56664). PRSs that have been the subject of remedial action are discussed below.*

*PRS 6-007(f) was the subject of a VCA conducted in August 1995 as described in the Voluntary Corrective Action Completion Report for Potential Release Site 06-007(f) (LANL 1996, 54330). PRS 6-007(f) was a surface disposal area located outside a security fence approximately 150 ft (45 m) north of building TA-6-3. The PRS periodically received miscellaneous solid wastes. Facilities at TA-6 have included chemistry laboratories, machine shops, mechanical assembly, darkrooms, and areas for explosive storage, loading, and test firing. Data from the Phase I investigation conducted in July 1994 indicated that surface soils at the site contained levels of lead and cesium-137 that exceeded SALs. Scrap metal and other debris were also scattered about the site. The cleanup consisted of excavating an area that measured approximately 20 ft by 30 ft (6 m by 9 m). During the excavation, a number of Manhattan Project era artifacts were unearthed, including laboratory equipment and glassware, inactive detonators, and chunks of metals such as copper and lead. Phase I RFI sampling identified localized contamination at two discrete locations: one with near-surface cesium-137 contamination and one with lead contamination. These two discrete areas were excavated, and the contaminated soil was managed separately. The remaining soil was heavily contaminated with ash, metal, and glass debris. The site also contained fragments of large metal casings, which are referred to as "jumbinos." After they were field screened for radioactivity and HE contamination, the artifacts and jumbinos were released to the Bradbury Science Museum. Approximately 19 yd$^3$ (14.4 m$^3$) of wastes were generated during the cleanup activities; a summary of wastes by type and volumes is presented in Table 2.3.2-2. Confirmatory samples were collected from three locations within the rectangular area of the PRS. The samples showed that cesium-137 and lead are present in the remaining soils at less than an order of magnitude below their respective cleanup levels (LANL 1996, 54330). PRS 6-007(f) was subsequently recommended for NFA in the VCA report.*

**TABLE 2.3.2-2**

**WASTES GENERATED DURING VCA ACTIVITIES AT PRS 6-007(f)**

| Volume | Potential Waste Type | Waste Classification (MDA) |
|---|---|---|
| *0.27 yd$^3$ (0.21 m$^3$)* | *Cesium-137-contaminated soil* | *Radioactive solid waste (TA-54, MDA G)* |
| *0.27 yd$^3$ (0.21 m$^3$)* | *Lead-contaminated soil* | *Radioactive solid waste (TA-54, MDA G)* |
| *13 yd$^3$ (9.9 m$^3$)* | *Ash-contaminated soil* | *Radioactive solid waste (TA-54, MDA G)* |
| *2.5 yd$^3$ (1.9 m$^3$)* | *Metal debris* | *Hazardous waste (TA-54, MDA L)* |
| *0.27 yd$^3$ (0.21 m$^3$)* | *Glass* | *Municipal (Los Alamos County landfill)* |
| *0.81 yd$^3$ (0.62 m$^3$)* | *Miscellaneous metals (primarily lead and copper)* | *Hazardous waste (TA-54, MDA L)* |
| *0.27 yd$^3$ (0.21 m$^3$)* | *Personal protective equipment* | *Radioactive solid waste (TA-54, MDA G)* |

Source: LANL 1996, 54330

*An EC was conducted at PRS 22-015(c) during September 1995, as described in the Expedited Cleanup Plan for Solid Waste Management Unit 22-015(c) (LANL 1995, 47257). PRS 22-015(c) is the site of a former outfall and the related runoff area originating from a floor drainage system in building TA-22-52, a plating a circuit etching shop that operated from approximately 1953 to 1984. Floor drains within the shop reportedly received spills from plating baths and rinse tank overflow. Plating liquids used in the shop are believed to have contained cadmium, copper, gold, nickel, platinum, rhodium, silver, and zinc. The shop* *was located near the southern edge of Twomile Mesa just north of Pajarito Canyon. The site included a drainage channel leading to a former effluent and storm water collection pond located near the edge of the mesa, an overflow drainage channel from the pond area that flowed downhill to an old wagon road, and two channels that flowed across the road and discharged into Pajarito Canyon. Contaminants of concern identified during the Phase I investigation include arsenic, chromium, copper, lead, nickel, silver, cesium-137, and strontium-90. The contaminated area was remediated by excavation. Confirmatory sample data indicated that no constituents were detected above the established cleanup levels. The site was restored by backfilling, regrading, reseeding, and placing a straw cover over the area. Completion of the final EC report is pending.*

*Non-RFI remediation activities were conducted as a requirement for site closure at the TA-40 scrap detonation site (SDS), as discussed in the Closure Certification Report for the Technical Area 40 Scrap Detonation Site (LANL 1995, 57521). The SDS includes a detonation area, a burn pit, and three small burn areas. It is located on a south-facing mesa-rim shelf that overlooks Pajarito Canyon. No portion of the SDS is identified as a PRS. The SDS operated as a RCRA interim status hazardous waste thermal treatment unit for open burning and open detonation of explosive scrap until April 1985. A final closure plan (FCP) (July 1991, as amended January 1992), which was approved by the New Mexico Environment Department (NMED), outlined a sampling strategy to characterize the site and presented the specific closure requirements for the SDS. Characterization samples were collected in January and May 1992. Review of the analytical results identified two small surface areas (one approximately 4 ft by 4 ft [1.2 m by 1.2 m] and one approximately 6 ft by 6 ft [1.8 m by 1.8 m]) that required remediation. These two sites are referred to as the Burn Cage Area (BCA) and the Burn Area East (BAE). Lead and antimony were identified as contaminants of concern at the BCA; lead was identified as a contaminant of concern at the BAE. Soils from the BCA and BCE were excavated during September and October 1994. During excavation of the BAE, an additional area estimated to be 15 ft by 15 ft (4.5 m by 4.5 m) was discovered immediately north of and partially overlapping the BAE. The additional contaminated soil at the BAE was excavated during December 1994. Analysis of verification samples from the BCA and BAE excavations demonstrated that remediation of the areas successfully removed contaminants to concentrations below the cleanup levels specified in the FCP and the amendment to the FCP. During the final phase of cleanup, additional contaminated material was discovered west of the expanded BAE excavation. The additional contaminated material was associated with one end of the burn pit, the remediation of which was beyond the scope of activities outlined in the amendment to the FCP. The SDS closure report proposed the burn pit to be addressed for corrective action as part of ER Project activities associated with OU 1111 (LANL 1995, 57521).*

### 2.3.3 Technical Area 3

*TA-3, the location of the main administration building and research laboratories at the Laboratory, is a large area located between Los Alamos Canyon to the north and Twomile Canyon to the south. TA-3 was originally built as a firing site before 1945; it was decommissioned and cleared in 1949. Operational facilities were shifted to TA-3 from the Los Alamos townsite beginning in 1950. Construction during the early 1950s resulted in the Van de Graaff accelerator building, laboratory, and support structures; the Communications Building; the Chemistry and Metallurgy Research (CMR) Building; the Physics Building; the general and chemical warehouses; the cryogenics laboratory; the Administration Building; and the Sigma Building. Construction of new buildings continued through the 1960s and 1970s as office buildings, shops, storage areas, an addition to the wastewater treatment plant, a cement batch plant, and numerous transportable containers filled areas between the initial buildings. Construction continued with the*

*Oppenheimer Study Center in 1977, an annex to the Administration Building in 1981, and a computer laboratory and several centers for various scientific activities in the 1990s. The western and southwestern portions of TA-3, primarily located south and west of Pajarito Road, are located north of the north fork of Twomile Canyon. This area is almost completely developed with buildings, roads, large paved parking lots, and landscaped unpaved areas (LANL 1993, 51977).*

*PRSs located within the Pajarito Canyon watershed at TA-3 have been addressed in the RFI Work Plan for Operable Unit 1114 (LANL 1993, 51977) and the addendum to the work plan (LANL 1995, 51981). The NMED issued a notice of deficiency (NOD) for the work plan and the addendum to the work plan; the NODs and the Laboratory's responses are presented in the Notice of Deficiency Response for OU 1114 (LANL 1995, 45976), and the Response to the Notice of Deficiency for the RFI Work Plan for Operable Unit 1114, Addendum 1 (LANL 1996, 54088). Most TA-3 PRSs were recommended for NFA in the work plan. PRSs 3-002(c); 3-003(a and b); 3-012(b); 3-013(f); 3-014(a through z, $a_2$, $b_2$, $c_2$); 3-015; 3-033; 3-042; 3-045(b and c); 3-052(f); and 3-053 were investigated and subsequently recommended for NFA in the RFI Report for 53 Potential Release Sites in TA-3, TA-59, TA-60, TA-61 (LANL 1996, 52930). PRSs that were the subject of additional investigation or remedial action are summarized below. Investigations at some PRSs are currently in progress.*

*PRS 3-010(a), a former vacuum pump repair shop, was used from 1950 to 1957 to dispose of used vacuum pump oil from the pump repair area in building TA-3-30. Contaminants in the oil included radionuclides and metals, particularly mercury. The disposal site was approximately 40 ft (12 m) long by 15 ft (4.5 m) wide and was located on a moderately steep hillside on the western margin of TA-3. A surface water drainage, which flows southward into the north fork of Twomile Canyon, transects the lower quarter of the site (LANL 1995, 55638).*

*The preliminary Phase I RFI conducted in 1992 identified the presence of lead, mercury, total petroleum hydrocarbons (TPH), cesium, plutonium, and tritium at the site. Subsequently, PRS 3-010(a) was the subject of a Phase I VCA and Phase II activities. After the 1992 sampling event, cleanup levels of 20 parts per million (ppm) mercury and 100 ppm TPH in soil were established by agreement between the Laboratory and the NMED. In 1993 Phase I activities involved soil sampling on a grid basis to determine the horizontal and vertical extent of mercury and TPH contamination in the soil and to determine if water quality standards were being exceeded in runoff from the site. Analytical results of the grid samples were used to guide VCA activities, which consisted of removing the soils from within the contamination area. The depth of the 40-ft (12-m) by 15-ft (4.5-m) excavation area ranged from approximately 1 to 15 ft (0.3 to 4.5 m). The activities were conducted as a VCA because radionuclides (specifically tritium, plutonium-238, and plutonium-239,240 present in concentrations above background levels) presented concern with respect to waste disposal requirements. After the third lift of soil was removed, verification samples revealed the presence of volatile organic compounds (VOCs) (1,1-dichloroethene, 1,2-dichloroethane, and trichloroethene) other than the benzene, toluene, ethylbenzene, and xylene (BTEX) constituents originally suspected to be present at the site. Because the extent of VOC contamination was not known and the presence of VOCs created mixed waste problems, the VCA could not be completed as a final remedy for the site. By the time VCA activities were terminated, approximately 130 to 140 $yd^3$ (99 to 106 $m^3$) of material had been removed from the excavation. A screening assessment was performed to identify the constituents remaining at the site after implementation of the VCA and to determine which constituents would be considered in the risk assessment. The screening assessment considered data from surface soil and surface water samples collected during the Phase I investigation and the verification data collected at the conclusion of the VCA. No COPCs were retained from the storm water runoff data assessment. However, the following contaminants of concern were retained for soil to be carried forward* *to the Phase II evaluation: benzene, chloroform, 1,2-dichloroethane, 1,2-dichloroethene, and cis-1,3-dichloropropene (RFI 3-010[a] LANL 1995, 55638).*

*A Phase II sampling and analysis plan (SAP) implemented in 1994 was designed to determine the nature and extent of VOC, TPH, and tritium contamination (LANL 1994, 47298). Before the onset of Phase II activities, the bottom of the VCA excavation was capped with a 2-ft-thick (0.6-m-thick) hydraulic barrier layer of bentonite-amended crushed tuff, and the excavation was backfilled to the surface to prevent future moisture infiltration at the site. The Phase II characterization activity consisted of a soil-vapor probe survey that was conducted to obtain data that would guide the selection of borehole locations. Seven boreholes were drilled during the field investigation; soil samples were collected from six boreholes for site characterization, and the seventh borehole was used to provide geologic and hydrologic characterization information at the site. Subsurface soil samples collected from boreholes B1 through B6 were analyzed for VOCs, TPH, and tritium. Eight organic compounds including 1,1-dichloroethane, 1,2-dichloroethane, 1,1-dichloroethene, Freon-113, 1,1,1-trichlrorethane, trichloroethene, TPH, and tritium were detected in the soil samples. Two solvents, 1,2-dichloroethane and 1,1-dichloroethene were retained as COPCs for the purpose of risk assessment. Water was encountered in three of the boreholes. One borehole was completed as a monitoring well (03-MW-1 [B-1]). This well encountered water at approximately 23 ft (6.9 m) below ground surface. The well was drilled to a depth of 29 ft (8.7 m) and completed as a 2-in.-diameter (5.08-cm-diameter) stainless steel monitoring well. Solvents were also detected in the groundwater samples. The results of the borehole investigations are further described in Sections 3.5 and 3.6 of this work plan.*

*The VCA was successful in removing the source term of the solvents and reducing concentrations of lead and mercury in the soil to concentrations below concern. PRS 3-010(a) was subsequently recommended for NFA in the RFI report (LANL 1995, 55638). The NMED issued an NOD for the RFI report which, in addition to requests for supplemental information, expressed concerns that the extent of contaminants associated with the solvent plume had not been adequately determined as suggested by the seep and borehole water analytical data. The Laboratory's response indicated that the Phase II data support the assertion that the source term of the plume had been mitigated, and the data for VOCs in soil remaining at the site indicate that human health risk posed by the plume is low. The NOD and the Laboratory's response to the NOD are presented in the Response to the Notice of Deficiency for the RFI Report for Solid Waste Management Units 3-010(a) (LANL 1996, 54084).*

*In August 1995 a VCA was conducted at PRS 3-003(p) as described in the Voluntary Corrective Action Completion Report for Potential Release Sites 03-003(p), 03-047(d), and 03-051(c) (LANL 1996, 53780). PRS 3-003(p) is an unpaved island of soil within the asphalt-paved parking lot east of building TA-03-142. The island is triangular with sides measuring approximately 15 ft by 15 ft by 23 ft (4.5 m by 4.5 m by 6.9 m). Before the area was resurfaced in 1994 as a parking lot, the PRS had been a storage area for drums and miscellaneous equipment, including electrical capacitors and transformers that may have contained insulating oils with polychlorinated biphenyls (PCBs). VCA activities included the removal of approximately 10 $yd^3$ (7.6 $m^3$) of soil at the site to depths ranging from 3 to 8 in. (7.6 to 20.3 cm). After the determination that confirmatory sample results met the established cleanup goals, the site was backfilled and reseeded with native grasses.*

*PRS 3-022 was the subject of a VCA conducted during August and September 1995 as described in the Voluntary Corrective Action Completion Report for Potential Release Site 3-022 (LANL 1996, 53795). PRS 3-022 is a former secondary containment system that housed non-PCB dielectric oil tanks and was part of an aboveground mineral oil storage and pumping system that supported the operation of a Marx generator in building TA-3-316. The COPC identified for this site was TPH, and the cleanup level was* *calculated to be 2600 ppm. The containment system was constructed of reinforced concrete walls with a sand bottom and a Hypalon liner over the sand. The storage tanks that were located within the containment system and the associated pumps, electrical supply, and aboveground piping were removed in early 1995. Stains present on the concrete walls above the liner suggested that the electrical pump system had been leaking. VCA activities included the removal of the containment structure components, 30 yd$^3$ (22.8 m$^3$) of sand from the bed of the structure, and an additional 180 yd$^3$ (136.8 m$^3$) of tuff surrounding the removed containment structure. After cleanup levels were met, the site was backfilled, regraded, contoured, and reseeded.*

### 2.3.4 Technical Area 59

*TA-59 currently houses the occupational health and environmental surveillance groups at the Laboratory. Over the years groups at TA-59 included industrial hygiene, environmental surveillance, epidemiology, health, environmental chemistry, and meteorology. TA-59 is located on the north rim of Twomile Canyon. The site is terraced; the main laboratory-office complex and several support buildings are located on the mesa near the canyon rim, and a large office building and several transportable structures are located on a large bench approximately 20 ft (6 m) below the canyon rim. Paved roads and parking areas serve both levels, and the remainder of TA-59 consists of pine forest on the steep north wall of Twomile Canyon.*

*Four PRSs located within the Pajarito Canyon watershed at TA-59 have been addressed in the RFI Work Plan for Operable Unit 1114 (LANL 1993, 51977) and the addendum to the work plan (LANL 1995, 51981). PRSs 59-001 (a septic system), 59-002 (a container storage area), and 59-003 (a sump) were recommended for NFA in the work plan. PRS 59-004, an outfall potentially receiving VOCs, semivolatile organic compounds (SVOCs), radionuclides, and photographic chemicals, was investigated and subsequently recommended for NFA in the RFI Report for 53 Potential Release Sites in TA-3, TA-59, TA-60, TA-61 (LANL 1996, 52930).*

### 2.3.5 Technical Area 64

*TA-64, the Laboratory's Central Guard Site, contains the central administrative building for the protective guard force and infrastructure support structures, including two water towers, a pumping station, and a storage area. TA-64 is a small area located on the north rim of Twomile Canyon east of TA-59. The one building and adjacent parking area, which were constructed in 1987, are located on a leveled bench approximately 20 ft (6 m) below the mesa top. Water towers are located on the mesa above the buildings. The forested north wall of Twomile Canyon comprises the southern portion of TA-64.*

*The RFI Work Plan for Operable Unit 1114 (LANL 1993, 51977) and the addendum to the work plan (LANL 1995, 51981) identified one PRS at TA-64, PRS 64-001 (a storage area), which was recommended for NFA in the work plan.*

### 2.3.6 Technical Area 48

*TA-48, the Radiochemistry Site, is located northeast of TA-64 and north of Pajarito Road; it is situated on a mesa between Mortandad Canyon to the north and Twomile Canyon to the south. TA-48 is the site of former and current operational structures that were built to house radiochemistry and nuclear medicine research. Initial activities at TA-48 largely involved the study of samples from nuclear bomb tests conducted at the Nevada Test Site, but activities subsequently evolved to include other types of studies related to weapons testing, research on long-term placement of radioactive materials in waste disposal sites, basic research in geochemistry and radiochemistry, and the production of radioisotopes for nuclear* *medicine (LANL 1992, 7666). The radiochemistry building was constructed in 1957; stack emissions are believed to have begun at approximately that time.*

*The air exhaust system at TA-48 (PRS 48-001), as described in the RFI Work Plan for Operable Unit 1129 (LANL 1992, 7666), is the primary source of possible contaminants from this site into Pajarito Canyon. Most hoods in the radiochemistry laboratory housed in building TA-48-1 are equipped with a water spray that removes some of the vapors from acids used to process high-level alpha and beta/gamma emitters. Approximately one-third to one-half of the vapors from the acids used (such as perchloric, hydrochloric, hydrofluoric, and nitric) is vented to the atmosphere. The soil surrounding TA-48-1 was suspected of being contaminated by deposition from the exhaust (DOE 1987, 52975; LANL 1992, 7666). Most PRSs at TA-48 are located in the Mortandad Canyon drainage, and the outfalls at TA-48 flow into the Mortandad Canyon drainage.*

*The Phase I RFI for PRSs at TA-48 was completed in 1994 according to the RFI Work Plan for Operable Unit 1129 (LANL 1992, 7666) and was reported in the RFI Report for Potential Release Sites 48-001, 48-002(e), 48-003, 48-005, 48-007(a), 48-007(b), 48-007(c), 48-007(d), 48-007(f), 48-010 (LANL 1995, 50295). Based on the characterization data, no hazardous constituents or inorganic or organic COPCs were identified in concentrations above risk-based levels at PRS 48-001. Therefore, the PRS was recommended for NFA (LANL 1995, 50295). An NOD for the TA-48 RFI report was received from the NMED in March 1996 (NMED 1996, 53810). Most concerns were related to analytical procedures and data quality. A response to the NOD (LANL 1996, 54448) and a supplemental SAP (LANL 1997, 55326) were prepared to support a resampling event for several PRSs at TA-48. Supplemental samples were collected and analyzed in early 1997; the results will be presented in a future RFI report.*

### 2.3.7 Technical Area 55

*TA-55 was established in 1973 for the operation of the Plutonium Processing Facility. Operations include fabrication of plutonium metal components, plutonium processing, and basic research on TRU materials. The main structure at TA-55 is the Plutonium Building (TA-55-4), which serves as the primary site for plutonium processing, fabrication, and research. TA-55 is located on an unnamed mesa between Mortandad Canyon to the north and Twomile Canyon to the south.*

*The RFI Work Plan for Operable Unit 1129 (LANL 1992, 7666) identified one PRS at TA-55 located within the Pajarito Canyon watershed. PRS 55-011(d) is an outfall that discharges storm water from the south side of TA-55-4 to Twomile Canyon. PRS 55-011(d) was recommended for NFA in the work plan.*

### 2.3.8 Former Technical Area 12

*Former TA-12, known as L-Site, is located on Pajarito Mesa, which is bounded by Pajarito Canyon to the north and Threemile Canyon to the south. TA-12 has been decommissioned and presently is located within the boundaries of TA-67 and TA-15 (LANL 1990, 7511).*

*L-Site was constructed in 1944 for the Explosives Division (X Division). Original structures at the site included a trim building (C-12-001), control chamber (C-12-002), generator building (C-12-004), magazine (C-12-003), firing pit (12-001[b]), a junction box (C-12-005), and a road-block. The principal structure was the below ground, steel-lined firing pit, PRS 12-001(a). The pit was used from 1946 to the mid-1950s. One test in the structure involved a 154-lb (70-kg) sphere of uranium; other materials used included explosives, lead, and uranium-238 (DOE 1987, 52975). The burn site (PRS 12-002) was used once to dispose of 0.5 lb (0.23 kg) of explosives by burning (LANL 1994, 34755).*

*An open section on the mesa east of the pit was used for several months as a firing site for explosive charges (12-001[b]). A 70-kg (154-lb) charge was once detonated at this firing site. The site was abandoned by X Division in April 1946 (LASL 1947, 7006). By 1951 the explosives testing group GMX-2 occupied TA-12. The site was one of three for the 7N Program, in which 600 shots per month were fired (LANL 1994, 34755). PRSs associated with L-Site lie within the present boundaries of TA-67.*

*In 1950 the Biomedical Group (H-4) constructed a bermed radiation test bunker at the far east end of L-Site and conducted animal irradiation experiments using a 1000-Ci sealed radioactive source of lanthanum-140 in transient equilibrium with barium-140. Traces of strontium-90 were still detectable in 1966 when a radiological survey tested a telephone pole, a plastic tube, and a container for radioactive materials (Blackwell 1966, 5012). The control bunker (PRS 12-004[a]), although decrepit, is still in place (LANL 1994, 34755). PRS 12-004(b) is an aluminum pipe of uncertain history that is present at the site. PRSs 12-004(a and b) lie within the present boundaries of TA-15.*

*L-Site was abandoned in 1953. A radiological survey conducted in 1959 indicated that all buildings were free of radioactive contamination (Blackwell 1959, 5396). A 1959 survey of vacated Laboratory structures indicated that the bermed area was contaminated with HE, although the presence of undetonated HE was unlikely. Most of the structures were decontaminated and decommissioned (D&D) and burned in 1960.*

*PRSs located within the Pajarito Canyon watershed at TA-12 have been addressed in the RFI Work Plan for Operable Unit 1085 (LANL 1994, 34755). Of the 12 PRSs identified, 3 were recommended for NFA in the work plan. PRSs proposed for investigation were combined into two aggregates. Table 2.3.8-1 contains a summary of these aggregates and the associated COPCs.*

**TABLE 2.3.8-1**

**TA-12 PRSs AND COPCs**

| Aggregate | PRSs | Description | Drainage Basin | COPCs |
|---|---|---|---|---|
| *1* | *12-001(a and b), C-12-001, C-12-005* | *Decommissioned Firing Site: steel pit, trim building, control building, magazine, generator building, junction box* | *Pajarito Canyon and Threemile Canyon* | *RDX, TNT, uranium, metals, PAHs, SVOCs* |
| *2* | *12-004(a and b)* | *Source experiment and aluminum pipe* | *Threemile Canyon* | *RDX, TNT, gross beta, gross gamma, lanthanum-140, barium-140, strontium-90, metals, SVOCs* |

Source: LANL 1994, 34755

*PRSs C-12-001 through C-12-005 and 12-004(a and b) were investigated and subsequently recommended for NFA in the RFI Report for Potential Release Sites at TA-14 and TA-12/67 (LANL 1996, 54086). The NMED issued an NOD for the RFI report requesting additional information for PRSs C-12-004 and 12-004(a and b). The Laboratory clarified information presented in the RFI report but proposed that no additional sampling was necessary to support the NFA recommendation. The NOD and the Laboratory's response are presented in the Response to the NOD for TAs -12, -14, and -67, for RFI Report (Former Operable Unit 1085 (LANL 1996, 55045). PRSs 12-001(a and b) were the subject of remedial actions and are discussed below.*

*PRSs 12-001(a and b) are components of a decommissioned firing site. PRS 12-001(a) consists of a belowground, steel-lined firing pit and an aboveground cover, which was used for recovery shots, including uranium, from 1945 to 1953 when it was abandoned. Data obtained during the Phase I investigation revealed the presence of arsenic in soil from within the pit at levels exceeding the SAL. A multiple chemical evaluation from the same soil sample indicated that barium, chromium, copper, nickel, thallium, and total uranium were also chemicals of concern. Soil samples collected from the outside perimeter of the pit did not contain constituents above SALs, thereby indicating that contamination was limited to soil within the pit. A VCA was determined to be appropriate based on the analytical results, and the fact that the site may be preserved as a historical site. VCA activities were conducted in June 1996 and consisted of the removal of approximately 75 gal. (0.28 $m^3$) of soil that was characterized as low-level (radioactive) waste (LLW) based on analysis of the excavated soil. No site restoration was necessary. The VCA activities are described in the Voluntary Corrective Action Completion Report for Potential Release Site 12-001(a) (LANL 1996, 55073).*

*PRS 12-001(b) is an open firing pit approximately 21 ft (6.3 m) long by 17 ft (5.1 m) wide by 3 ft (0.9 m) deep located 175 ft (52.5 m) east of PRS 12-001(a). Shots using uranium, lead, and HE were conducted at the firing site, which was abandoned during the 1950s. Soil samples were collected from soil within and around the firing pit during the Phase I investigation; elevated levels of DU were found in samples collected from soil within the pit. Visible HE and shrapnel were observed scattered in an area defined approximately by a 150-ft (45-m) radius around the firing pit. The contaminant of concern identified at the site is DU. PRS 12-001(b) was initially recommended for VCA in the work plan; a formal Voluntary Corrective Action Plan was submitted to the NMED in May 1997 (LANL 1997, 55675). Activities proposed in the VCA plan include the removal of the top few inches of surface soil from the open firing pit and the removal of the pieces of HE and shrapnel from the surrounding area. Field screening and an on-site mobile survey system were proposed to guide excavation and fragment removal. Confirmatory samples were planned to be collected to determine when established cleanup levels (698 mg/kg [279 pCi/L] uranium based on an exposure of 30 mrem/yr) have been met. Based on the Phase I sampling results, the maximum detected concentration of uranium was 469 mg/kg (188 pCi/L), which did not exceed the calculated cleanup level for this site. However, because the open firing pit was sampled at only one location, as part of the VCA the area is planned to be thoroughly screened to ensure the removal of soil exceeding this standard. After remediation has been confirmed, the plan proposes site restoration activities during which the excavated areas are planned to be returned to the original grade and revegetated. Implementation of the planned VCA activities at PRS 12-001(b) is pending (LANL 1997, 55675).*

### 2.3.9 Technical Area 15

*TA-15, known as R-Site, is located on Threemile Mesa between Threemile Canyon to the north and Cañon de Valle and Water Canyon to the south. Potrillo Canyon intersects the main portion of Threemile Mesa, dividing the mesa into two fingers. PRSs within the Pajarito Canyon watershed are located primarily north of Potrillo Canyon on the northern finger mesa, which is known as Mesita del Potrillo (LANL 1993, 20946). Access to TA-15 and to Water Canyon and Potrillo Canyon is controlled by M Division, which maintains control of keys to gates accessing the canyon (LANL 1993, 20946).*

*TA-15, which originated as a firing site area in 1944, contains a complex of firing sites and related support structures. The sites located within the Pajarito Canyon watershed include office complex R-40; Firing Points C, E-F, R-44, and R-45; and Ector site.*

*Area R-40 contains office buildings that have supported TA-15 operations since the early 1950s. PRSs associated with R-40 include outfalls and a septic tank. PRS 15-010(b) is a septic tank that served one of the first operational buildings at TA-15. The tank was used in the drainline from building TA-15-8 to an* *outfall at the edge of Threemile Canyon. Because HE compounds were machined in the building with water cooling, HE compounds may have been discharged to the tank and from the outfall. PRS 15-014(h) consists of three outfalls that discharge to a tributary of Threemile Canyon. Two of the outfalls are presently NPDES permitted and the third was proposed for NFA in the RFI Work Plan for Operable Unit 1086 (LANL 1993, 20946). The two permitted outfalls (EPA 04A 013 and EPA 04A 102) currently discharge noncontact cooling water and roof and floor drain effluent. However, they may have discharged photographic laboratory wastes containing silver and organic compounds before permitting and are therefore the subject of investigation.*

*Firing Points C and E-F were in use by 1945. Firing Points C and E-F are not used today, and most of the structures associated with these firing sites have been decommissioned and dismantled. The hazardous materials used in these explosion tests, such as uranium, beryllium, and lead, have largely been left in place at the firing sites where the materials were deposited by the explosion or pushed aside to clean the area. Other materials that may have been deposited include aluminum, boron, cadmium, gold, mercury, steel, and tritium, although in very small amounts. Many types of HE have been used at these sites that have left some inorganic residues, but no unexploded HE has been found in analyses of firing site soil samples. Firing Point C was in use from 1945 until 1948 and was decommissioned in 1967. PRSs investigated at Firing Point C include concrete slabs that were used as firing platforms (PRSs 15-004[a and d]) and a container storage area (PRS 15-005[c]) (LANL 1993, 20946).*

*Firing Point E-F (PRS 15-004[f]) was used the most heavily and contains the largest quantities of hazardous materials. The site was established for tests using up to 2500 lb (1125 kg) of explosives and was used extensively through 1973. Between 1947 and 1957 an estimated 43,000 kg (94,600 lb) of natural uranium metal was expended on E-F site. After 1957 approximately 20,000 kg (44,000 lb) of DU was expended (Venable 1990, 5628). Additionally, approximately 320 kg (704 lb) of beryllium and estimated quantities of lead and mercury have been expended at E-F site over the period of use. Shrapnel and/or pieces of uranium may have been scattered up to approximately 3500 ft (1050 m) from the firing point during very large explosions. However, most of the debris is probably concentrated within 1000 ft (300 m) of the firing point. Firing Points E and F were originally two distinct depressions in the soil. As tests were conducted, the soil was either regraded to level the disturbed earth or new gravel was brought in to fill depressions. No major effort has been carried out to remove or remediate dispersed hazardous materials that may be present at E-F site. After each explosion, debris from the test as well as noticeable pieces of uranium metals were picked up in an effort to prepare the area for the next test. On some occasions, a bulldozer was used to regrade the area after an explosion (Robbins 1954, 6166); the rubble was added to mounds on each side of the firing site. However, no effort was made to remediate the area; chunks of uranium metal presently lay scattered about the site that are slowly oxidizing to yellow uranium oxides. The site was last used in 1981. The area investigated at Firing Point E-F covers approximately 60 acres (24 hectares). Table 2.3.9-1 lists a summary inventory of metals expended at E-F site over its lifetime (LANL 1993, 20946).*

**TABLE 2.3.9-1**

**AMOUNTS OF TOXIC METALS USED AT FIRING POINT E-F**

| Analyte | Estimated Amount (kg) |
|---|---|
| *Uranium* | *63,000* |
| *Beryllium* | *320* |
| *Lead* | *100* |
| *Mercury* | *<100* |

Source: LANL 1993, 20946

*Firing Points R-44 and R-45 were established in the 1950s and have since been used for various explosive tests; R-45 is used for smaller tests, and R-44 is used for larger tests. Firing Point R-44 is located near the head of Threemile Canyon and is the third most extensively used firing site at TA-15. The site was built in 1951 and was used extensively from 1956 to 1978 for diagnostic tests of weapons components. During this period approximately 7000 kg (15,000 lb) of uranium (largely DU), 350 kg (770 lb) of beryllium, and 15 kg (33 lb) of lead were expended at R-44 (LANL 1993, 20946). Since approximately the mid-1980s this site has been used only for small experiments. The last experiment was conducted in 1992. Firing Point R-45 is located at the head of Threemile Canyon and is the least used of the active firing sites at TA-15. The area was originally built in 1951 and has been used only for small quantities of explosives. R-45 still retains active status, and the associated PRSs at this site were either proposed for NFA or proposed for deferred investigation in the RFI Work Plan for Operable Unit 1086 until the site is decommissioned (LANL 1993, 20946).*

*Ector Site has been used from the mid-1980s to the present for dynamic radiography of explosion-driven weapons components. The use of this site has not been extensive; therefore, the potential for significant contamination by beryllium, lead, and uranium is considered small. PRSs located at Ector Site include the firing site (15-006[b]) and septic system (PRS 15-009[h]). Both PRSs are currently active and were proposed for deferred investigation in the RFI Work Plan for Operable Unit 1086 until the site is decommissioned (LANL 1993, 20946).*

*PRSs located within the Pajarito Canyon watershed at TA-15 have been addressed in the RFI Work Plan for Operable Unit 1086 (LANL 1993, 20946). Of the 22 PRSs identified, 8 were recommended for NFA, and 4 are located at active sites that have been proposed for deferred investigation until the sites are decommissioned. Table 2.3.9-2 contains a summary of the investigated and deferred PRSs at TA-15 and the associated COPCs.*

**TABLE 2.3.9-2**

**TA-15 PRSs AND COPCs**

| Site | PRS(s) | Description | Investigation Status | COPCs |
|---|---|---|---|---|
| *C* | *15-004(a), 15-004(d), 15-005(c)* | *Firing platforms, container storage area* | *Phase I conducted* | *Uranium, beryllium, lead, HE* |
| *E-F* | *15-004(f)* | *Firing site* | *Phase I conducted* | *Uranium, beryllium, lead, HE* |
| *R-40* | *15-014(h), 15-010(b)* | *Outfalls, septic system* | *Phase I conducted* | *Silver, VOCs, SVOCs, HE* |
| *R-44* | *15-006(c), 15-009(c)* | *Firing site, septic system* | *Deferred* | *Uranium, beryllium, lead* |
| | *15-008(b)* | *Surface disposal area* | *Phase I conducted* | *Uranium, beryllium, lead, HE* |
| *R-45* | *15-006(d), 15-008(g)* | *Firing site and sandbags* | *Phase I conducted* | *Uranium, beryllium, lead* |
| | *15-009(b)* | *Septic system* | *Deferred* | *Uranium, beryllium, lead* |
| *Ector* | *15-006(b), 15-009(h)* | *Firing site, septic system* | *Deferred* | *Uranium, beryllium, lead* |

Source: LANL 1993, 20946

*PRSs 15-004(a and d) were investigated and subsequently recommended for NFA. PRSs 15-004(f) and 15-008(b) were recommended for VCA in the RFI Report for Potential Release Sites 15-004(a–d, f), 15-007(b), 15-008(a, b), 15-009(e, j), 15-012(b), C-15-004 (LANL 1995, 50294). The NMED issued an NOD for the RFI report expressing specific concerns regarding the quality of data with respect to low surrogate analyte percent recoveries and exceeded holding times, which were used to support the* *conclusions and recommendations presented in the report. The Laboratory's response states that the analytical data in question for PRSs 14-004(a and d) represent only a percentage of the data set and that adequate data of sufficient quality are available to support the recommendation of NFA for these PRSs. The Laboratory's response with respect to PRSs 15-004(f) and 15-008(b) states that because these sites have been recommended for VCA based on other contaminants of concern identified at the sites, resampling is planned to be conducted at these sites in accordance with the respective VCA plans when cleanup is completed. The NOD and the Laboratory's response are presented in the Response to the NOD for the RFI Report for PRSs in TA-15 (Former OU 1086) (LANL 1997, 56921).*

*PRSs 15-005(c), 15-014(h), 15-010(b), 15-006(d), and 15-008(g) were investigated and subsequently recommended for NFA. PRS 15-006(c) was recommended for EC in the RFI Report for Potential Release Sites at TA-15 15-001, 15-002, 15-004(g,h), 15-005(b,c), 15-006(c,d), 15-007(a), 15-008(c,g), 15-009(a, f, i, k), 15-010(a–c), 15-011(a–c), 15-012(a), 15-014(a, b, d, e, $g_1$), C-15-001, C-15-005, C-15-006, C-15-007, C-15-010, and C-15-011 (LANL 1996, 54977). PRSs that are the subject of remedial actions are discussed below.*

*PRS 15-006(c) is Firing Point R-44. Cleanup of PRS 15-006(c) is being proposed for the future. An interim action (IA) has been conducted at the site as described in the Interim Action Plan for Potential Release Site 15-006(c), which planned for the removal of visible DU and lead on the ground surface while the plan for the final remedy is being prepared and submitted for approval (LANL 1996, 54620). The IA consisted of visually locating and removing DU and lead shot. The materials were removed by hand or by sieving and were segregated for disposal or recycling. The lead was surveyed for radioactivity before being released for recycling. No confirmatory monitoring or sampling was conducted; these activities are planned to be performed after the final remedy.*

*PRS No 15-008(b) is a surface disposal area associated with Firing Point R-44. The disposal area comprises a shelf of soil and debris that was created on the north side of the firing site when remnants and debris from tests were pushed into a tributary of Threemile Canyon. Data from surface and near-surface soil samples collected during the Phase I investigation indicate the presence of antimony, copper, lead, and uranium present at levels exceeding SALs at multiple locations throughout the disposal area. In addition, arsenic and beryllium were detected at concentrations exceeding background levels. Background levels are used as screening values for these constituents because no SALs are available. The RFI report recommends that an EC be performed at the site and states that supplemental sampling has been proposed and conducted in accordance with a SAP developed for Firing Point R-44 and Firing Point R-45. The results of the additional proposed sampling are to be evaluated in conjunction with the data presented in the existing RFI report and submitted with an assessment and formal recommendation for the site in a future RFI report (LANL 1995, 50294).*

*PRS 15-004(f) is Firing Point E-F, which has been the most extensively used firing site at the Laboratory in terms of both length of continuous use and quantities of uranium expended. The site is approximately 250,000 $ft^2$ (22,500 $m^2$) or 5.7 acres. Previous investigations at the site have measured uranium concentrations in soil ranging from less that 200 mg/kg to 4500 mg/kg (Hanson and Miera 1976, 5556; Hanson and Miera 1977, 5701; Miera et al. 1980, 57517). Future cleanup of PRS 15-004(f) is proposed that will include the subsurface removal of uranium and DU. An IA has been conducted at the site as described in the Interim Action Plan for PRSs 15-004(f) and 15-008(a), which planned for the removal of visible uranium and DU at the ground surface while the plan for the final remedy is being prepared and submitted for approval (LANL 1996, 55835). The IA consisted of visually locating uranium and DU and removing identified pieces from the site. Radiological surveys were conducted to locate and verify the presence of uranium. The materials were removed using hand tools or sampling spoons. No confirmatory monitoring or sampling was conducted; these activities are planned to be performed after the final remedy.*

*PRS 15-008(a) is a surface disposal area associated with E-F site. However, this disposal area is located south of the firing site along the north wall of Potrillo Canyon and therefore is not considered a potential source of contaminants in Threemile Canyon. The IA activities and methodologies employed at PRS 15-004(f) were also performed at PRS 15-008(a). The cleanup completion report for PRSs 15-004(f) and 15-008(a) is pending. A summary of environmental studies conducted at the site is presented in Section 3.9 of this work plan.*

#### 2.3.10 Technical Area 18

*TA-18, known as Pajarito Site, is located at the confluence of Pajarito Canyon and Threemile Canyon. The site was the location of a former guest ranch, the Pajarito Club, which was built by Ashley Pond in 1914 and later abandoned. One of the log buildings was moved to Los Alamos townsite and is now a historic site next to Fuller Lodge; an earlier log homestead remains at TA-18. The site was first developed in August 1943 during the Manhattan Project by Group P-5, the Radioactivity Group, to study rates of spontaneous fission from samples of radioactive materials. Figure A-1 in Appendix A of this work plan shows the location of TA-18.*

*In 1944 Group G-3 took over the site (named Pajarito Canyon Laboratory), enlarged it, and used it as a proving ground to study implosions. Three firing sites were constructed: a small firing site in Pajarito Canyon for experiments involving small explosive charges of a few pounds (approximately 1 to 2 kg); a second site, called medium firing site, in Threemile Canyon for charges of several hundred pounds (a few hundred kilograms); and a third site, located approximately a mile (1.6 km) east of TA-18, for testing charges of up to 2 tons (1800 kg). Each site consisted of one or more firing locations and aboveground bunkers reinforced with steel plates, referred to as "battleships." The third site, known as Far Point, was east of TA-18 and was later incorporated into Gamma Site, which was later redesignated TA-27 (LANL 1993, 15310, p. 2-4).*

*Explosives testing by G Division ended in late 1945. In April 1946 the site was transferred to Group M-12, the Critical Assemblies Group. Since that time TA-18's history has revolved around critical assembly work.*

*In 1946 a fatal incident involved a hands-on criticality experiment. This incident followed a similar fatality in 1945 and caused an immediate shutdown of manual criticality operations, which indicated the urgent need for remotely controlled operation of such experiments. Remotely controlled criticality experiment structures, called kivas, were constructed after the accident. Kiva 1 (TA-18-23) was built in 1947 at the former small firing site in Pajarito Canyon at the western part of TA-18. The 0.25 mi. (0.4 km) separation from the new control room in the east end of building TA-18-1 provided a safe working distance from which to operate critical assemblies. In 1951 the workload expansion required the addition of an office building (TA-18-30) and a second Kiva (TA-18-32), which was located south of the central TA-18 area in lower Threemile Canyon. Buildings TA-18-28, -31, and -37 were constructed between 1949 and 1951. The third remotely controlled structure, Kiva 3 (TA-18-116), was added in 1960 near the confluence of Threemile Canyon and Pajarito Canyon (LANL 1993, 15310, p. 2-4).*

*From 1955 to 1972 fission reactor mockup studies for the Rover Program, a nuclear rocket propulsion program, were conducted at TA-18 using the remotely controlled kivas. Reactor mockups consisted of various geometries and used materials such as deuterium oxide, uranium carbide, enriched uranium, graphite, niobium, and zirconium hydride (Paxton 1978, 5716, p. 23).*

*Termination of the Rover Program in 1973 resulted in a major downsizing and reorganization of TA-18 personnel. The work shifted to mockups of a plasma-core power reactor, which used fuel elements and beryllium (components left over from the Rover Program), enriched uranium foils, and uranium* *hexafluoride gas. Criticality work involving reactor safety and, later, nuclear detection technologies continued under various other groups.*

*During the 1970s and 1980s buildings TA-18-186, -187, -188, -189, -227, -256, -257, and -258 were added. TA-18's facilities and expertise in critical assemblies have made it the center of training in criticality safety for the DOE and other institutions. TA-18 presently continues its long history in nuclear criticality research, nuclear weapons safeguards and security, and treaty verification technology as the LACEF.*

*PRSs located at TA-18 and in lower Pajarito Canyon east of TA-18 have been addressed in the RFI Work Plan for Operable Unit 1093 (LANL 1993, 15310). PRSs within TA-18 and TA-27 share many common site characteristics and therefore were grouped together into five aggregates: liquid waste management systems; an underground storage tank; surface contamination from abandoned firing sites and structures, and storm sewer outfalls; and buried materials, including a disposal area, and a bazooka impact area. TA-27 is presently located within the boundaries of TA-36; the operation history of TA-27 is presented with the discussion of TA-36 in Section 2.3.11.*

*Aggregate A included the liquid waste management systems associated with TA-18. Liquid waste discharged to the liquid waste management systems included sanitary sewage, wash water from industrial drains and sinks in kivas and laboratories, and photographic chemical wastes. A summary of COPCs associated with the liquid waste system is presented in Table 2.3.10-1.*

**TABLE 2.3.10-1**

**TA-18 AGGREGATE A – LIQUID WASTE MANAGEMENT SYSTEMS**

| PRS | Description | Structure No. | Operational Status | Period Used | COPCs |
|---|---|---|---|---|---|
| *18-001(a)* | *Sewage lagoons* | *TA-36-135* | *Inactive* | *1969–1992* | *Uranium, plutonium, solvents* |
| *18-001(b)* | *Sanitary sewer line* | *N/A* | *Inactive** | *1969–1992* | *Uranium, plutonium, solvents* |
| *18-001(c)* | *Sump* | *N/A* | *Active* | *1969–present* | *No data* |
| *18-003(a)* | *Settling pit* | *TA-18-105* | *Active* | *1946–present* | *Uranium, plutonium* |
| *18-003(b)* | *Septic tank* | *TA-18-39* | *Active* | *1947–present* | *Uranium, plutonium* |
| *18-003(c)* | *Septic tank* | *TA-18-42* | *Active* | *1952–present* | *Uranium, plutonium* |
| *18-003(d)* | *Septic tank* | *TA-18-120* | *Active* | *1960–present* | *Uranium, plutonium, oil* |
| *18-003(e)* | *Septic tank* | *TA-18-40* | *Inactive* | *1952–?* | *Beryllium, uranium, plutonium, silver* |
| *18-003(f)* | *Septic tank* | *TA-18-41* | *Inactive* | *1952–?* | *Beryllium, uranium, silver* |
| *18-003(g)* | *Septic tank* | *TA-18-43* | *Inactive* | *1944–?* | *Beryllium, uranium, plutonium, silver* |
| *18-003(h)* | *Septic tank* | *TA-18-152* | *Inactive* | *?–?* | *Beryllium, uranium, solvents, oil* |
| *18-004(a)* | *Industrial drain line* | *N/A* | *Inactive* | *1950–1977* | *Uranium, solvents* |
| *18-004(b)* | *Collection tanks* | *TA-18-38* | *Inactive* | *1950–1977* | *Uranium, solvents* |
| *18-012(a)* | *Outfall* | *N/A* | *Active* | *?–present* | *Beryllium, uranium, silver* |
| *18-012(b)* | *Outfall* | *N/A* | *Active* | *?–present* | *Beryllium, uranium, solvents* |
| *18-012(c)* | *Sumps and drain lines* | *N/A* | *Active* | *1966–present* | *Beryllium, uranium, solvents* |

** The portion of the sanitary sewer line east of TA-18, to and including the lagoons, was taken out of service in the fall of 1992. The portion of the line inside TA-18 is still active and discharges to the new sanitary waste treatment plant at TA-46.*

Source: LANL 1993, 15310

*Aggregate B at TA-18 consisted of a 1000-gal. (3800-L) steel underground storage tank located north of building TA-18-40, which was used to store fuel for diesel-operating generators. A summary of Aggregate B and associated COPCs are provided in Table 2.3.10-2.*

**TABLE 2.3.10-2**

**TA-18 AGGREGATE B – UNDERGROUND STORAGE TANK**

| PRS | Description | Structure No. | Operational Status | Period Used | COPC |
|---|---|---|---|---|---|
| *18-008* | *Underground storage tank* | *TA-36-104* | *Inactive* | *1950?–1966* | *Diesel fuel* |

Source: LANL 1993, 15310

*Aggregate C consisted of areas potentially containing surface contaminants from explosive testing of devices or from possible solid discharge of radioactive or hazardous materials from buildings. A summary of Aggregate C and associated COPCs are provided in Table 2.3.10-3.*

**TABLE 2.3.10-3**

**TA-18 AGGREGATE C – FIRING SITES, MAGAZINE, AND GENERATOR SITE**

| PRS | Description | Structure No. | Operational Status | Period Used | COPCs |
|---|---|---|---|---|---|
| *18-002(a)* | *Firing site* | *TA-18-2, -3* | *Inactive* | *1944–1945* | *Uranium, thorium, HE residuals, lead, beryllium* |
| *18-002(b)* | *Firing site* | *TA-18-4, -5* | *Inactive* | *1944–1945* | *Uranium, thorium, HE residuals, lead, beryllium* |
| *18-002(c)* | *Drop tower* | *N/A* | *Inactive* | *1944–1945* | *HE residuals, lead, beryllium* |
| *18-005(a)* | *Magazine site* | *TA-18-15* | *Inactive* | *1945–1977* | *Uranium, beryllium oxide* |
| *18-011* | *Contaminated soil* | *TA-18-22* | *Inactive* | *1946–1950* | *Mercury* |
| *27-002* | *Firing sites* | *N/A* | *Inactive* | *1945–1947* | *Uranium, thorium, HE and residuals, lead, beryllium* |

Source: LANL 1993, 15310

*Aggregate D consisted of all discharge points for storm sewers that drain roofs and paved areas in TA-18. One of these, PRS 18-010(f), also provides a discharge point for floor drains in Kiva 2. A summary of Aggregate D and associated COPCs are provided in Table 2.3.10-4.*

*Aggregate E consisted of a burial trench, a bazooka impact area, and possibly a buried military tank (based on anecdotal evidence). A summary of Aggregate E and associated COPCs are provided in Table 2.3.10-5.*

**TABLE 2.3.10-4**

**TA-18 AGGREGATE D – STORM SEWER OUTFALLS**

| PRS | Description | Structure No. | Operational Status | Period Used | COPCs |
|---|---|---|---|---|---|
| *18-010(b)* | *Storm sewer outfall* | *N/A* | *Active* | *?–present* | *Uranium, lead, solvents* |
| *18-010(c)* | *Storm sewer outfall* | *N/A* | *Active* | *?–present* | *Uranium, lead, solvents* |
| *18-010(d)* | *Storm sewer outfall* | *N/A* | *Active* | *?–present* | *Uranium, lead, solvents* |
| *18-010(e)* | *Storm sewer outfall* | *N/A* | *Active* | *?–present* | *Uranium, lead, solvents* |
| *18-010(f)* | *Storm sewer outfall* | *N/A* | *Active* | *?–present* | *Uranium, lead, solvents* |

Source: LANL 1993, 15310

**TABLE 2.3.10-5**

**TA-18 AGGREGATE E – MATERIAL DISPOSAL AREAS AND BAZOOKA IMPACT AREA**

| PRS | Description | Structure No. | Operational Status | Period Used | COPCs |
|---|---|---|---|---|---|
| *18-007* | *Buried military tank* | *N/A* | *Inactive* | *~1949* | *Unknown* |
| *27-001* | *Burial trench* | *N/A* | *Inactive* | *~1945* | *Uranium, munitions* |
| *27-003* | *Bazooka impact area* | *N/A* | *Inactive* | *~1944–1947* | *Munitions* |

Source: LANL 1993, 15310

*The 31 PRSs summarized above were proposed for investigation as described in the RFI Work Plan for Operable Unit 1093 (LANL 1993, 15310). In addition, 11 areas of concern (AOCs) and 1 PRS (PRS 18-012[d]) were recommended for NFA in the work plan. One PRS (PRS 18-006) was proposed for deferred investigation until the site is subjected to D&D. Six PRSs, including Aggregate E in its entirety, were investigated in 1993 and subsequently proposed for NFA in the RFI Report for Operable Unit 1093, Potential Release Sites 18-001abc; 18-007, 27-001, 27-003 (LANL 1995, 54615). The remaining 24 PRSs were addressed in the RFI Report for Potential Release Sites 18-002(a–c), 18-003(a–h), 18-004(a,b), 18-005(a), 18-008, 18-010(b–f), 18-012(a–c), 18-013, 27-002, PCO Wells, LACEF Monitoring Wells, Wetlands (LANL 1995, 55527) and in the addendum to the RFI report (LANL 1996, 54919). PRSs 18-003(a through e and g) were proposed for EC or IA in the addendum to the RFI report (LANL 1996, 54919). Those activities are summarized below. The remaining PRSs were investigated and subsequently proposed for NFA in the RFI report and the addendum to the RFI report (LANL 1995, 55527; LANL 1996, 54919).*

*PRSs 18-001(a and b) consist of the area's former sanitary sewage lagoons and sanitary sewer line. The proposal for NFA for these PRSs was to be contingent upon completion of VCA and EC activities described in the RFI Report for Operable Unit 1093, Potential Release Sites 18-001abc; 18-007, 27-001, 27-003 (LANL 1995, 54615). The VCA and EC activities included removal of all above-grade portions of the lagoon and sewer line manhole system and stabilization of the below-grade structures, which were left in place. Stabilization activities included filling the structures (below-grade portion of the lagoons and sewer line manholes) with clean soil to restore original grade and seeding the regraded areas. The VCA and EC activities were conducted during August and September 1995 and are described in the Voluntary*

*Corrective Action Completion Report for Potential Release Site 18-001(a)* (LANL 1996, 54324) and the *Expedited Cleanup Completion Report for Potential Release Site 18-001(b)* (LANL 1996, 54841).

An IA was performed at five septic systems comprising PRSs 18-003(a, b, c, d, and g) during May and June 1996. The activities at some of the sites were originally proposed in the RFI report as ECs (LANL 1995, 55527); however, the activities were implemented and reported as IAs. IA activities consisted of removing the contents of each tank, pressure rinsing the interior of each tank, and disposing of the contents of the tanks and the associated decontamination water. The IA was performed to remove the potential for future release of radioactive and hazardous contaminants in the tanks to the environment. An especially important environment associated with these septic tanks is a shallow groundwater body that periodically fluctuates due to seasonal variability of water table elevations and potentially transfers water into or out of the septic tanks. The IA activities as described in the *Interim Action Plan for Potential Release Sites 18-003(a–d, g)* (LANL 1996, 54470) and the *Interim Action Completion Report for Potential Release Sites 18-003(a–d, g)* (LANL 1996, 55044).

In addition, groundwater contamination was addressed at PRS 18-003(d), which served Kiva 3, in the *Corrective Action Report for TA-18* (LANL 1996, 55120). As part of the RFI at PRS 18-003(d), surface samples were collected above the drainfield, subsurface samples were collected adjacent to the septic tank and within the drainfield, and groundwater samples were collected from two temporary wells located near the outer edge of the drainfield. The analytical results of these samples indicated the presence of 1,2-dichloroethane at the site, which is believed to be associated with waste disposal at the septic tank. Corrective actions were proposed to provide additional evidence of the source of the 1,2-dichlorethane and to define extent, which included the installation of five additional monitoring wells and additional subsurface soil samples to be collected during installation of the wells. The plan also included quarterly sampling of the wells for up to two years. The corrective action plan activities were initiated in the fall of 1996, and the investigation is currently in progress. Five additional monitoring wells were drilled in the drainfield area, and samples of alluvial groundwater are being collected quarterly. An interim report summarizes the monitoring well installation and the initial results of two quarters of sampling (LANL 1997, 57015). A description of the preliminary results of this RFI is in Sections 3.5 and 3.8 of this work plan.

PRS 18-003(e), a septic tank, was the subject of an EC conducted in August 1995 as described in the *Expedited Cleanup Plan for Solid Waste Management Unit 18-003(e)* (LANL 1995, 52976) and the *Expedited Cleanup Report for Potential Release Site 18-003(e)* (LANL 1996, 54488). Hazardous wastes were removed from the tank, the tank was decontaminated and backfilled with cement, and the site was revegetated. No corrective action was required in the soils or the drainfield (LANL 1995, 55527, p. 4-43).

Although proposed for deferred investigation in the *RFI Work Plan for Operable Unit 1093* (LANL 1993, 15310, p. 1-10), PRS 18-006 was the subject of a VCA that was conducted during the fall of 1997. PRS 18-006 is a decommissioned uranium solution pipe that stored uranyl sulfate liquid fuel used by the Kinglet reactor in association with the LACEF from 1970 to 1974. Site activities included the excavation, removal, and disposal of the uranium solution pipe, followed by backfilling of the excavation trench. Although residual liquid collected from within the abandoned line in support of the VCA activities was found to contain uranium-234 (109 pCi/L) and uranium-235 (3 pCi/L) and exhibit corrosivity characteristics (pH=12.8), the data from confirmatory samples collected from the soil surrounding the fuel pipe do not indicate that a release has occurred. The VCA activities are described in the *Voluntary Corrective Action Plan for Potential Release Site 18-006* (LANL 1997, 56355) and the *Voluntary Corrective Action Completion Report for Potential Release Site 18-006* (LANL 1997, 56609).

*Since 1990 18 shallow alluvial groundwater-monitoring wells have been installed at TA-18. Appendix D of this work plan contains summary information about these wells, including well status, location, water level data, and stratigraphic information. Figure A-1 in Appendix A shows the locations of the wells. The results of sampling these wells are discussed in Sections 3.7 and 3.8.*

*Groundwater monitoring was conducted at the LACEF and PCO wells, and surface water and sediment sampling was performed in wetland areas near TA-18 as part of the Phase I investigation. The results of the sampling were reported in the RFI Report for Potential Release Sites 18-002(a–c), 18-003(a–h), 18-004(a,b), 18-005(a), 18-008, 18-010(b–f), 18-012(a–c), 18-013, 27-002, PCO Wells, LACEF Monitoring Wells, Wetlands (LANL 1995, 55527) and the addendum to the RFI report (LANL 1996, 54919). A description of the LACEF and PCO wells and the results of the groundwater monitoring are discussed in Sections 3.7 and 3.8 of this work plan.*

*Non-RFI investigations were conducted to characterize petroleum releases associated with two underground storage tanks (USTs) at TA-18. UST TA-18-PL30, located east of building TA-18-189, was taken out of service and removed in September 1993. The investigation at this site included the collection of samples from soil beneath and surrounding the former tank, followed by excavation of contaminated soil to a TPH cleanup level of 100 µg/g (LANL 1993, 33314). In addition, monitoring wells 18-MW-5 and 18-MW-6 were installed in March 1994 in accordance with New Mexico UST Regulations to monitor for potential impacts to the shallow alluvial groundwater associated with a release from the UST (LANL 1994, 47113). The results of the investigation are discussed in Sections 3.7 and 3.8 of this work plan.*

### 2.3.11 Technical Area 36 and Former Technical Area 27

*The original designation of TA-27 was Far Point, which served as a firing site formerly associated with TA-18. The Far Point at TA-27 is not to be confused with the Far Detonation Point at TA-9 (also known as Far Point) as described in Section 2.3.1. Far Point (TA-27) was established during the Manhattan Project in 1944 for full-scale tests of implosion weapons designs that required larger charges of HE than could be fired at TA-18's other two firing sites. In late 1945 the site was upgraded with several structures from TA-18 and became known as Gamma Site, later redesignated TA-27. Structures associated with TA-27 include two small concrete control bunkers covered by earthen berms, a boardwalk, a series of instrumented manholes, and five round firing pits. The Far Point firing pits were located within Pajarito Canyon south of Mesita del Buey and approximately 0.8 mi (1.3 km) east of the present location of TA-18.*

*Shots fired at Gamma Site contained up to 2 tons (1800 kg) of HE and used materials such as beryllium, DU, and thorium. In 1946 a bullet sensitivity test was conducted at Firing Pit 1 in which a 0.50-caliber machine gun was fired at a block of Composition B explosive. The block underwent a low-order explosion (the shot did not detonate completely) scattering undetonated HE up to 250 yards (225 m) (LANL 1990, 7511).*

*The 1945 Gamma Site upgrade included improving the access road from TA-18 with a layer of gravel. The entire site was abandoned and fenced off in early 1947. Gravel for road material was excavated from lower Pajarito Canyon between 1949 and 1962 along the length of Pajarito Canyon east of TA-18 and within TA-27.*

*The area of Gamma Site was reopened in March 1960 to begin construction of a road to White Rock. The gravel road from TA-18 was moved north, bisecting the old firing site. The road was widened, paved, and opened to the public as Pajarito Road on July 11, 1962. An incident involving unexploded Army ordnance from a hillside north of TA-27 occurred at that time. Civilians entered the area before it was refenced and* *removed a dud bazooka round, which later exploded amid a group of children who were playing with it in Los Alamos (Brawley et al. 1962, 5607).*

*During the 1960s all structures, concrete foundations, and other debris were removed at Gamma Site, and the ground surface was leveled. In 1969 the sanitary sewage lagoons and sewer line from TA-18 were built, which was the last major site activity. The lagoons and sewer line were the subject of VCA and EC activities performed in 1995, as discussed in Section 2.3.10. The sites of all former structures have been located in relation to present-day Pajarito Road. Firing Pits 4 and 5 were north of the road; all other structures were south of the road. Only Firing Pit 4 has any surface expression; the other firing pits are buried (the material within and around former Firing Pit 5 may have been removed during excavations for road gravel).*

*No Laboratory operations have taken place at this former site since 1947. Former TA-27 presently is located within the fragment impact circle of Firing Site 12 at TA-36 and is potentially affected by operations there.*

*PRSs located within the Pajarito Canyon watershed at TA-27 have been addressed in the RFI Work Plan for Operable Unit 1093 (LANL 1993, 15310). PRSs within TA-18 and TA-27 share many common site characteristics and therefore were grouped together into five aggregates. A description and summary of each aggregate is presented with the discussion for the investigation of TA-18 in Section 2.3.10.*

*TA-36, also called Kappa Site, is primarily used as firing sites and contains a 900-m (990-yd) fragment impact circle that includes former TA-27 and part of TA-54 located north of TA-36. TA-36 is bound to the north by the south rim of Pajarito Canyon, and portions of the area lie west and south of TA-18. Although operations at TA-36 are primarily located within the Potrillo Canyon watershed, the northwest portion of TA-36 is transected by a segment of Threemile Canyon west of TA-18 that is within the Pajarito Canyon watershed. Operations at TA-36 commenced in 1950. Structures at TA-36 comprise the group office and sanitary facilities; four firing sites: Eenie, Meenie, Minie, and Lower Slobbovia (36-004[a through d]); and a storage magazine at Moe (36-004[f]). In 1983 the boundary of TA-36 was changed to incorporate I-J Site (PRS 36-004[e]). I-J Site, formerly part of TA-15, was established in the late 1940s and was used for firing explosive shots up to 500 lb (225 kg) (LANL 1993, 15313). The explosives used included boracitol, baratol, TNT, Composition B, cyclotol, 9404, and nitromethane. All five firing sites at TA-36 are currently active. Fragments from decades of firing at TA-36 and/or former TA-27 can still be found throughout the area. For example, in July 1992 a crew inspecting a power line route east of former TA-27 near building TA-36-136 found fragments of aluminum with minor radioactivity from uranium (LANL 1992, 12542).*

*PRSs located at TA-36 have been addressed in the RFI Work Plan for Operable Unit 1193 (LANL 1993, 15313). Of the 24 PRSs identified at OU 1193, 8 were proposed for deferred investigation, 10 were proposed for NFA, and 6 were proposed for Phase I investigation. Of the 6 PRSs proposed for investigation, 4 are located within the Pajarito Canyon watershed. PRS 36-002 is a sump that was constructed to receive the drainage from two sinks in building TA-36-48, the Controlled Environment Building. Activities performed within the building included shot assembly, temperature controlled experiments, preparation and polishing of DU, and metal plating. PRS 36-003(a) is a septic system that discharges into Threemile Canyon and was constructed to handle sanitary wastes from office/laboratory building TA-36-1. PRS 36-004(e) is the active I-J Site, which consists of two active firing points, I and J; two control buildings; a dirt bunker; a covered work area; and an old chamber for enclosed firing (Schlapper 1991, 22533). PRS C-36-003 is an NPDES-permitted outfall (Permit No. EPA 06A106) that serves building TA-36-1 and may have discharged photographic processing chemicals. A summary of TA-36 PRSs within the Pajarito Canyon watershed and associated COPCs is provided in Table 2.3.11-1.*

**TABLE 2.3.11-1**

**TA-36 PRSs AND COPCs**

| PRS | Description | Structure No(s) | Operational Status | Period Used | COPCs |
|---|---|---|---|---|---|
| *36-002* | *Sump* | *TA-36-49* | *Inactive* | *1965–?* | *Uranium, metals, VOCs, SVOCs, HE* |
| *36-003(a)* | *Septic system* | *TA-36-17, TA-36-38* | *Inactive* | *1949–1991* | *Metals, cyanides, VOCs, SVOCs* |
| *36-004(e)* | *I-J Site* | *N/A* | *Active* | *~1948–present* | *Uranium, plutonium, metals, VOCs, SVOCs, HE* |
| *C-36-003* | *Photographic outfall* | *N/A* | *Inactive* | *1950–?* | *Metals, cyanides, SVOCs* |

Source: LANL 1993, 15313; LANL 1995, 53985

*PRS 36-002 is a sump designed to receive the drainage from sinks located in building TA-36-48. TA-36-48 was used for shot assembly and temperature-controlled experiments. DU was also cut, lapped, and polished in the building. PRS 36-002 was investigated and subsequently recommended for NFA in the RFI Report for Operable Unit 1130 Potential Release Site 36-002 (LANL 1995, 48942).*

*PRS 36-003(a), a septic system, was investigated and subsequently recommended for EC in the RFI Report for Potential Release Sites 36-003(a), 36-003(b), 36-005, C-36-003 (LANL 1995, 53985). Data from the Phase I investigation revealed the presence of barium, cadmium, chromium, manganese, mercury, silver, vanadium, and zinc in the sludge within the septic tank at levels significantly exceeding SALs. Mercury was detected in one subsurface soil sample (0 to 24 in. [0 to .06 m] depth) collected from the drainfield at a level of two times its SAL. The presence of metals in the sludge indicates that the tank contents meet the definition of a RCRA hazardous D-listed waste. The EC activities involved excavating to access the tank, removing the tank contents, three cycles of pressure rinsing the tank followed by removal of the rinse liquids, filling the tank with concrete, and backfilling the excavation to restore original grade. Subsurface confirmatory soil samples were collected along the sides of the tank at levels below the pipe ports and the bottom of the tank. All analyzed constituents in the subsurface samples are present at levels below background UTL values, which suggests that the contaminants in the sludge were contained by the septic tank. The EC activities are detailed in the Expedited Cleanup Plan for Solid Waste Management Unit 36-003(a) (LANL 1995, 52975) and the Expedited Cleanup Completion Report for Potential Release Site 36-003(a) (LANL 1996, 54484).*

*PRS 36-004(e), the I-J Firing Site, was the subject of an IA as described in the Interim Action Plan for Potential Release Sites 36-004(e), 15-008(f), and C-36-003(e) (LANL 1997, 55986). I-J Site is situated on a mesa top located between the south tributary of Threemile Canyon to the north and Potrillo Canyon to the south. Associated with the I and J firing points are several sand mounds (PRS 15-008[f]) and an embankment (PRS C-36-006[e]). Numerous erosion gullies have been created by storm water runoff around the firing area. Most of this storm water runoff exits the site and flows into Potrillo Canyon; however, the firing site is located near the head of a drainage that flows to the south tributary of Threemile Canyon. The IA consisted of visually locating and removing DU fragments and explosives debris and putting storm water runoff controls in place. Although most of the radioactive materials were collected and removed under the IA, storm water controls are proposed to further reduce the potential for off-site transport of contaminants. These controls consist of flow diversion along the mesa top, covering the mounds and installing diversion devices to discourage flow in the immediate area of the mounds, installing diversion devices around the firing points and the projectile testing site, and installing a silt fence* *or check dam downslope of the primary drainage pathway into Potrillo Canyon. No monitoring or confirmatory sampling is proposed as part of the IA plan; these activities may be part of the final remedy and are to be deferred until the site is decommissioned. Implementation of the IA plan was proposed to take place during the summer of 1997; the IA completion report is pending.*

*PRS C-36-003 was investigated and subsequently recommended for Phase II investigation in the RFI Report for Potential Release Sites 36-003(a), 36-003(b), 36-005, C-36-003 (LANL 1995, 53985). The outfall served as a point of discharge for spent photographic-processing fluids into Threemile Canyon. The Phase I investigation included the collected of seven surface samples (0 to 6 in. [0 to 15.2 cm] depth) in the drainage channel below the outfall. Chromium, copper, lead, mercury, nickel, and zinc were detected at levels above background UTL levels. Silver, dibenz(a,h)anthracene, and indeno[1,2,3-cd]pyrene were detected at levels exceeding SALs. Additionally, the presence of mixed aroclors (for example, PCBs) was detected. Development of the Phase II SAP is currently in progress, and the Phase I data are to be assessed with the Phase II data to develop conclusions and recommendations in a future RFI report.*

### 2.3.12 Technical Area 54

*TA-54 is located on Mesita del Buey, which is bounded by Cañada del Buey to the north and lower Pajarito Canyon to the south. TA-54 contains four MDAs (G, H, J, and L); the nondestructive testing (NDT) program, which supports verification and certification of TRU waste to be transported to the Waste Isolation Pilot Plant; and supporting offices. Security fences enclose the four MDAs. PRSs associated with MDAs G, H, and J are located within the Pajarito Canyon watershed; PRSs associated with MDA L and the NDT program are located in the Cañada del Buey watershed and therefore are not considered potential sources for the purpose of the Pajarito Canyon investigation. PRSs located within the Pajarito Canyon watershed at TA-54 have been addressed in the RFI Work Plan for Operable Unit 1148 (LANL 1992, 7669).*

#### 2.3.12.1 MDA G

*MDA G is the LLW disposal area for the Laboratory and has been in use since 1957. MDA G is also used to store low-level and TRU mixed waste and will continue to store such wastes in support of the newly constructed area at TA-54 West for NDT of TRU waste. The south side of Mesita del Buey at MDA G is deeply incised by multiple drainages that flow into adjacent Pajarito Canyon, which is approximately 130 ft (40 m) below the mesa at this location (LANL 1992, 7669).*

*MDA G is a 65-acre (260,000-$m^2$) site containing several waste storage domes, a liquid waste sump, a septic tank leach field, a solid waste compactor, four TRU waste storage pads, 34 disposal pits, 174 shafts, and 4 subsurface TRU waste trenches (LANL 1997, 55873). In earlier years the site received a variety of waste types including some liquid hazardous and mixed wastes. Pits vary in size but, in general, are 200 ft (60 m) by 60 ft (18 m) and are approximately 60 ft (18 m) deep. Three pits are currently receiving LLW, and one is receiving asbestos wastes; the remainder of the pits have been closed, capped with a layer of crushed tuff. Shafts are typically 6 ft (1.8 m) in diameter and 60 ft (18 m) deep and receive wastes that require special packaging (for example, tritium), special handling (for example, highly activated metals), or segregation (for example, PCB-contaminated solid waste). Many shafts are currently receiving waste. The TRU trenches are between 200 and 300 ft (60 and 90 m) long, 13 ft (4 m) wide, and 6 ft (1.8 m) deep. All of these trenches have been closed and are covered with crushed tuff. The history of disposal practices at MDA G and old photographs from Laboratory archives* *are contained in History and Environmental Setting of LASL Near-Surface Land Disposal Facilities for Radioactive Waste (Areas A, B, C, D, E, F, G, and T) (Rogers 1977, 5707; Rogers 1977, 5708).*

*MDA G contains 24 PRSs; each PRS is composed of groups of disposal pits or shafts. Because of their proximity to each other and the common method of disposal, all PRSs were treated as a single aggregate for the purpose of characterization (LANL 1996, 54462). Definitions of individual PRSs by pit and shaft numbers are provided in the RFI Work Plan for Operable Unit 1148 (LANL 1992, 7669).*

*Documented historical releases that have occurred at MDA G are limited. Three fires occurred at MDA G between 1960 and 1976. One fire that occurred on September 16, 1960, in Pit 1 burned most of the exposed waste before the fire was discovered. Another fire was reported in Pit 3 on November 21, 1964, which resulted in burned boxes and detectable alpha activity in the smoke. On April 14, 1976, a flame several feet high was observed in Pit 24 for several seconds, but no contamination from the burning waste was detectable (Rogers 1977, 5707; Rogers 1977, 5708).*

*A drum ruptured while workers were attempting to recover a pump from a pit, and consequently three trucks and three dumpsters were contaminated. Because of this incident, a request for a decontamination (truck washing) pit was made, and Pit 19 was excavated in April 1971. Pit 19 first began receiving waste under its new definition as a decontamination pit on November 21, 1975 (Rogers 1977, 5707; Rogers 1977, 5708). Because of limited archival information, the extent of releases at the decontamination pit, PRS 54-013(b), is unknown.*

*During a visual site inspection, stains were reported on soil at PRS 54-015(a), which is a drum storage area where TRU drums are stored before being sprayed with a corrosion inhibitor (LANL 1992, 7669).*

*Surface contamination by plutonium-238 and plutonium-239,240 has been reported around the disposal pits (PRSs 54-017 and 54-018) and around the disposal shafts (PRSs 54-019 and 54-020). This surface contamination may have resulted from fires caused by mixing incompatible wastes or from releases from vehicles hauling wastes to the pits and shafts (LANL 1990, 7511).*

*The proposed RFI characterization strategy for the MDAs includes the analysis of samples from several transport pathways, including surface water, sediment, air, and subsurface vapor. Because of the size, number, complexity, and purpose of the MDAs, potential releases are being investigated in stages, which are each based on the individual transport pathways. The investigations focus on the MDAs as a whole rather than individual disposal units, such as pits and shafts (LANL 1992, 7669).*

*MDA G and the surrounding mesa and canyons are monitored by Laboratory environmental surveillance groups for chemical releases by way of surface water runoff, sediment transport, air pathways, and soil vapor in the subsurface (LANL 1996, 54462). Supplemental MDA G environmental surveillance sampling has been conducted annually since 1993 by ESH-19 personnel to provide data for existing radioactive (and other constituent) contamination in surface soils, sediments, and surface-water runoff. The data have been used to augment environmental surveillance sampling and to provide data for the RFI at TA-54. Reports are currently available for the results of surveillance conducted for 1993 through 1995 (Conrad et al. 1995, 52014; Conrad et al. 1996, 55621; and Childs and Conrad 1997, 57518).*

*A series of RFI status reports have been planned to address potential contaminants at the MDAs with respect to the identified transport pathways. To date, the RFI Report for Channel Sediment Pathways from MDAs G, H, J, and L, TA-54 (LANL 1996, 54462) and the RFI Status Report for Tritium in Surface*

*Soils at MDA G, TA-54 (LANL 1997, 55873) have been completed; the status reports for tritium in the air and surface water pathways at MDA G are currently in progress. The distributions of other radionuclides, metals, and organic compounds are planned to be reported in other upcoming status reports (LANL 1997, 55873). The channel sediment pathway report focused on the transport of mesa-top sediments into the adjacent canyons. Topographic maps and aerial photographs were examined and direct field observations were made, and 14 drainage channels associated with MDA G were selected for sediment and runoff sampling (LANL 1996, 54462). The results of the channel sediment pathway report are described in Sections 3.4 and 3.7 of this work plan.*

*Tritium activity in surface soils and sediments has been evaluated as described in the RFI Status Report for Tritium in Surface Soils at MDA G, TA-54 (LANL 1997, 55873). The data presented in the status report were compiled from data collected by the routine Environmental Surveillance Program from 1993 to 1996, because the surveillance data satisfy the requirements of the RFI Work Plan for Operable Unit 1148 (LANL 1992, 7669). The data were not collected specifically for the RFI work plan or for RCRA purposes. The RFI report did not propose additional surface soil sampling at MDA G for RFI purposes. After the MDA G series status reports have been completed, a multipathway assessment is planned to be incorporated into a final report. Recommendations regarding any additional site investigations or other RFI-related activities are planned to be deferred to the final evaluation report. Routine environmental surveillance activities will continue to be conducted at MDA G by the Laboratory Environmental Surveillance Program (LANL 1997, 55873).*

*A performance assessment (PA) and composite analysis (CA) were conducted for MDA G in 1997. The purpose of the PA was to determine if LLW has been (and will continue to be) disposed of at MDA G in a manner that will not result in radiation doses to members of the public that exceed performance objectives specified by the DOE. In a complementary fashion, the CA was used to evaluate options for ensuring that exposures from all waste disposed of at MDA G will not impart doses to future members of the public in excess of specified limits. Together, the PA and CA are designed to provide a comprehensive evaluation of the potential radiological exposures to future members of the public from past, present, and future disposals at MDA M. Doses were projected beyond 1000 years after facility closure, which is assumed to occur in 2044. The projected doses for all considered pathways were found to be well below applicable performance objectives (Hollis et al. 1997, 57523).*

#### 2.3.12.2 MDA H

*MDA H comprises PRS 54-004. MDA H is a 0.3-acre (1200-$m^3$) inactive site containing nine shafts where classified waste was deposited from 1960 until 1986. The shafts are 6 ft (1.8 m) in diameter and 60 ft (18 m) deep. Disposed waste materials common to all nine shafts include weapon components, classified documents and paper, aluminum, plastic, stainless steel, rubber, graphite, weapon mock-ups (models), DU scraps, classified shapes, film, prints and slides, classified objects contaminated with HE, and graphite nuclear reactor fuel elements. Examples of additional wastes that were disposed of in one or more of the shafts include phenolin, Styrofoam plastic foam, titanium, beryllium, lithium, copper, tungsten, magnesium shapes and scraps, radioactive sources, detonators, solid radioactive waste, expended mortar shells, machine gun barrels, tritium- and plutonium-contaminated shapes and records, and lead coil assemblies.*

*Eight of the nine shafts at MDA H are sealed; one shaft received waste as late as 1986, but no additional waste disposal at MDA H is planned. Shaft 9 is the only unit at MDA H that received hazardous waste after 1980, making it subject to RCRA interim status closure provisions and New Mexico State jurisdiction. The original closure plan for Shaft 9 was submitted in November 1986. The eight sealed shafts* *collectively contain approximately 13,600 ft$^3$ (408 m$^3$) of classified waste; Shaft 9 received approximately 990 ft$^3$ (30 m$^3$) of waste by the time disposal ceased in 1986 (LANL 1992, 7669).*

*Tritium apparently migrated from the shafts at MDA H in the 1960s and early 1970s. A study to evaluate the activity of tritium in tuff was conducted coincident with the drilling of additional shafts at MDA H in 1969. Moisture samples of tuff collected from the 40-ft (12-m) depth in a shaft contained elevated tritium activity (2.0 x $10^9$ pCi/L). Air samples collected from shafts at MDA H also contained elevated tritium activities approximately 1.6 to 4.4 million times the DOE derived concentration guide of 1.0 x $10^2$ (Aeby 1969, 1799). These results led to further investigations, which were conducted in 1969 and 1973. The subsequent tritium investigations show that tritium has been released from shafts to the surrounding tuff, where it may be migrating via a vapor phase contaminant plume. Tritium activity in flora at MDA H indicates that tritium is reaching the surface or near-surface where it is absorbed by plants and can be released to the atmosphere through evapotranspiration (Krueger 1992, 2245).*

*A sediment transport investigation has been conducted at MDA H (LANL 1996, 54462). The objective and methodology of the investigation were the same as described for MDA G in Section 2.3.9.1. MDA H has one significant drainage channel capable of carrying surface runoff into Pajarito Canyon to the south. Eight sediment samples were collected from the drainage and analyzed for PCBs, inorganic chemicals, and radionuclides. Lead was detected in three samples at levels exceeding background but below the SAL. The SAL comparisons and the multiple chemical evaluation suggested that unacceptable risk from inorganic chemicals is unlikely and no COPCs were retained from the screening assessment. Therefore, the RFI report recommended no further evaluation or remediation of the drainage channel adjacent to MDA H (LANL 1996, 54462).*

*Future monitoring of runoff and sediment from MDA H, which drains into Pajarito Canyon, was deferred to the Environmental Surveillance Program. Future investigations of contaminant transport at MDA H via the air and surface water pathways are pending (LANL 1996, 54462).*

#### 2.3.12.3 MDA J

*MDA J is a 2.7-acre (10,800-m$^2$) fenced, active disposal area for disposal of administratively controlled waste, for surface storage of nonfriable asbestos, and for land-farming (aeration) of petroleum-contaminated soils. Examples of administratively controlled wastes are classified items such as safes with secured locks, objects with classified shapes, scrap equipment, treated sand from barium sand treatment operations at MDA L, and empty containers. Historically MDA J received wastes that were potentially contaminated with trace quantities of nonreactive HE residues. Other wastes buried in early operations include discarded equipment, asbestos, and small amounts of hazardous waste (LANL 1992, 7669). Waste disposal began at MDA J in 1961. Subsurface disposal units at MDA J consist of six pits and four shafts, collectively identified as PRS 54-005. Three of the pits and two of the shafts are active; others are closed and covered with crushed tuff (LANL 1996, 54462).*

*A sediment investigation has been conducted at MDA J as presented in the RFI Report for Channel Sediment Pathways from MDAs G, H, J, and L, TA-54 (LANL 1996, 54462). The objective and methodology of the investigation were the same as described for MDA G in Section 2.3.9.1. MDA J consists of one PRS and has one significant channel carrying surface runoff into Cañada del Buey to the north. Although disposal units associated with MDA J are located in the Pajarito Canyon watershed, the channel sediment pathway drains into Cañada del Buey and therefore is not considered a potential contaminant source for the purpose of the Pajarito Canyon investigation. Future investigations of contaminant transport via the air and surface water pathways are to be used to determine the impact of MDA J, if any, to Pajarito Canyon.*

**REFERENCES FOR CHAPTER 2**

*The following list includes all the references cited in this chapter. The parenthetical information following each reference provides the author, publication date, and ER identification (ER ID) number. This information is also included in the citations in the text and can be used to locate the documents.*

*ER ID numbers are assigned by the Laboratory's ER Project to track all material associated with Laboratory PRSs. These numbers can be used to locate copies of the documents at the ER Project's Records-Processing Facility and, where applicable, within the ER Project reference library. The references cited in this work plan can be found in the volumes of the reference library titled Reference Set for Canyons.*

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## 3.0 ENVIRONMENTAL SETTING

*This chapter describes the environmental setting of Pajarito Canyon, including Twomile Canyon and Threemile Canyon, which are the main tributaries to Pajarito Canyon. The regional environmental setting of the Laboratory is presented in Chapter 3 of the Core Document for Canyons Investigations (hereafter referred to as the "core document") (LANL 1997, 55622) and in Chapter 2 of the Installation Work Plan for Environmental Restoration Program (IWP) (LANL 1996, 55574). This chapter summarizes existing information relevant to the characterization of the Pajarito Canyon system. This chapter also identifies additional information needed to expand the conceptual understanding of the environmental processes that occur within the system and to assess the magnitude and importance of potential exposure pathways within the system.*

*This chapter provides the technical basis for the conceptual model, which is described in Chapter 4 of this work plan. Chapter 2, Chapter 3, and Chapter 4 are then used to develop the specific field sampling plans presented in Chapter 7 of this work plan.*

*Since 1985 several boreholes have been drilled in Pajarito Canyon and either completed for some purpose, left open and uncompleted, or abandoned. These boreholes and completions have been designated by letters and numbers. The first two or three letters or numbers designate the canyon or mesa or technical area (TA) (for example, PC = Pajarito Canyon, 18 = TA-18), and the last letter or letters designate the function, as follows.*

*O* — *Observation well; completed with screen or perforated casing in alluvium; intended for water level measurement and water sample collection; installed by personnel from the Laboratory Water Quality and Hydrology group (ESH-18) for environmental surveillance monitoring*

*MW* — *Monitoring well; completed with screen or perforated casing in alluvium; intended for measuring water levels and collecting water samples; most have been installed by the Laboratory Environmental Restoration (ER) Project for groundwater monitoring*

*OI* — *Observation intermediate well; completed in a deeper, intermediate perched groundwater zone or potential intermediate groundwater zone*

*M* — *Moisture access tube; borehole cased with 2-in.- (5.08-cm-) diameter plastic pipe with a plug at the bottom to keep water out of the pipe, intended for logging in situ moisture measurements with a neutron moisture/density probe*

*C/CH* — *Core hole; not completed as a well; usually plugged and abandoned*

*WB* — *Water-balance; well completed in alluvium intended primarily for water level measurement but may be useable to collect water samples*

*Each letter is typically followed by a number, which normally indicates the downstream sequence of well installation. Any letters after the numbers indicate multiple installations at approximately the same location in the canyon, usually as transects or replacement wells.*

*Other well designations include the following water supply wells that are designated by the location of the well field.*

*LA* — *Los Alamos Canyon*

*PC* — *Pajarito Canyon*

*2MC Twomile Canyon*

*3MC Threemile Canyon*

*PM Pajarito Mesa*

*G Guaje Canyon*

*O Otowi*

*Test wells, typically drilled to the regional aquifer (to monitor water levels and collect samples) are designated TW or DT (deep test); SHB as a sole designator means seismic hazard borehole, not completed as a well; EGH means exploratory geothermal hole, also not completed. In addition, a special set of boreholes, originally designated TH for test hole (herein referred to as PCTH-5 and PCTH-6 for the Pajarito Canyon test holes), were drilled as water exploration test holes through the Bandelier Tuff (Purtymun 1995, 45344, p. 211). The letter and number/letter designations for these installations also are used as locations on various maps provided in this work plan.*

*Within this work plan, the term "well" refers to a completed borehole with the capability to contain water, specifically the water supply, test, observation, Pajarito test, and water-balance wells. Uncompleted core holes are referred to as "boreholes," whereas the "moisture access tubes" are referred to as such. A comprehensive compilation and description of boreholes and completions installed by the Laboratory before circa 1993 are provided by Purtymun (1995, 45344).*

*Environmental surveillance sediment sampling locations are designated as Pajarito at state road NM4, or Pajarito at state road NM501, which indicates the location near a major highway. Other sediment sample locations designated by the ER Project are designated by the technical area designation and a unique ER Project site identification (ID) number, such as 18-2001 (see Figure A-2 in Appendix A of this work plan).*

*The New Mexico Environment Department (NMED) Department of Energy (DOE) Oversight Bureau describes collection sites by the canyon name abbreviation and the distance in miles as measured from the Rio Grande. For example, surface water gaging station PA-8.9 is located in upper Pajarito Canyon 8.9 mi (14.24 km) west of the Rio Grande, and surface water collection site PA-0.01 is located in lower Pajarito Canyon 0.01 mi (0.016 km) west of the Rio Grande.*

## 3.1 Location, Topography, and Surface Drainage

### 3.1.1 Pajarito Canyon

*Pajarito Canyon has a large drainage area (13.6 mi$^2$) (35.2 km$^2$) that heads on the flanks of the Sierra de Los Valles at an elevation of 10,441 ft (3183 m) at Pajarito Mountain. The canyon is a long east/southeast-trending canyon that extends from the Sierra de Los Valles to the Rio Grande for a distance of approximately 13 mi (20.8 km). The canyon contains a stream that is discontinuously perennial in the uppermost and lowermost reaches and mostly ephemeral and/or intermittent throughout the canyon. The largest tributaries within the Pajarito Canyon watershed are Twomile Canyon and Threemile Canyon.*

*For discussion purposes, the Pajarito Canyon system is divided into upper, middle, lower, and lower off-site sections, as described below:*

*The* **upper canyons** *are those portions of the canyons that extend from the head waters to near TA-3 and TA-6, before the canyons become deeply incised into the Tshirege Member of the Bandelier Tuff.*

*The* **middle canyons** *are the deep narrow portions of the canyons that extend from near TA-3 and TA-6 to TA-18 and the confluence of Threemile Canyon.*

*The* **lower canyon** *is the wider portion of the canyon that extends from near TA-18 to the Laboratory boundary at state road NM4. This portion of the canyon contains the largest volume of alluvial material and probably most of the alluvial groundwater.*

*The* **lower off-site canyon** *is the remaining portion of the canyon that extends from the Laboratory boundary to the Rio Grande.*

*In this work plan Pajarito Canyon is further segregated into subdrainage basins so that each one can be properly addressed. Figure A-1 in Appendix A of this work plan shows the informal designations of the tributaries of Pajarito Canyon. The south fork of Pajarito Canyon extends from TA-9 westward onto the National Forest and is mostly a mountainside drainage. The lower part of the south fork of Pajarito Canyon that forms a canyon has been informally referred to as "Starmer Gulch" (LANL 1993, 20949, p. 6-139). Two other small tributaries to Pajarito Canyon are located at TA-9, which is known as Anchor East Site. In this work plan these tributaries are referred to informally as north Anchor East basin and south Anchor East basin. The lower portion of north Anchor East basin forms a canyon that has previously been referred to informally as "Arroyo de LaDelfe" (LANL 1993, 20949, p. 6-139).*

*In this work plan Twomile Canyon is further segregated informally into the north fork of Twomile Canyon, the main fork of Twomile Canyon, the southwest fork of Twomile Canyon, and the southeast fork of Twomile Canyon so that each of these tributaries may be individually addressed.*

*Similarly, Threemile Canyon is further segregated informally into the south fork of Threemile Canyon, the middle fork of Threemile Canyon, and the west fork of Threemile Canyon.*

*The Pajarito Canyon watershed extends from the rim of the Valles Caldera east-southeast for approximately 3 mi (4.8 km) on National Forest land, 8 mi (12.8 km) on Laboratory property, and 2.7 mi (4.5 km) on private land and Los Alamos County land to the confluence with the Rio Grande at an elevation of 5430 ft (1630 m). The drainage area of Pajarito Canyon and its tributaries on Laboratory property is 11.36 mi$^2$ (29.4 km$^2$) (McLin 1992, 12014, p. 13). Figure A-1 shows the area of the Pajarito Canyon watershed in gray shading.*

*The canyon transects the central part of the Laboratory and encompasses portions of many different technical areas, including TA-3, -6, -7, -8, -9, -12 (former), -14, -15, -18, -22, -23, -27 (former), -36, -40, -48, -51, -54, -55, -58, -59, -64, -67, and -69. The canyon system borders TA-3, -59, -55, and -54 on the south. The watershed is widest at state road NM501 along the western border of the Laboratory where the combined width of upper Twomile Canyon, Pajarito Canyon, and the south fork of Pajarito Canyon is approximately 1.5 mi (2.4 km). South of TA-55 Pajarito Canyon is between 700 and 800 ft (approximately 200 to 240 m) wide and approximately 200 ft (61 m) deep. The upper portions of the canyons are incised approximately 100 to 200 ft (30.5 to 61 m) into the Tshirege Member of the Bandelier Tuff.*

*Downstream of the confluence of Threemile Canyon at TA-18, the watershed narrows to less than 1500 ft (450 m) wide. The watershed in this reach from TA-18 to state road NM4 is confined to Pajarito Canyon and is relatively narrow compared with the upper reaches of Pajarito Canyon. Lower Pajarito Canyon contains a relatively wide, flat canyon floor upon which lower Pajarito Road is constructed. Sand and gravel aggregate materials have been extracted from the alluvium in this part of the canyon, and several old gravel pits remain as depressions and sometimes contain wetlands (see Figure A-1).*

*Pajarito Canyon contains an interrupted stream fed by several perennial springs in the upper portion of the canyon. Perennial flow from PC Spring in the upper reaches of the canyon is followed by an intermittent reach that extends 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 western Laboratory 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 at times may extend as far as the confluence with Threemile Canyon.*

*Both Twomile Canyon and Threemile Canyon contain ephemeral and/or intermittent streams. Seasonal springs in Twomile Canyon and perennial springs in Threemile Canyon support short reaches of ephemeral and perennial flow, respectively. East of the confluence with Threemile Canyon, Pajarito Canyon is ephemeral across Laboratory property to a point approximately 0.4 mi (0.64 km) upstream from the confluence with the Rio Grande. Pajarito Springs (Springs 4A and 4AA) are located at this point and support perennial flow to the confluence with the Rio Grande. In most years snowmelt runoff extends onto Laboratory property downstream to near the confluence with Threemile Canyon. Local runoff and streamflow from seasonal rainstorms occasionally extend downstream as far as the Rio Grande.*

#### 3.1.1.1 South Fork of Pajarito Canyon ("Starmer Gulch")

*The south fork of Pajarito Canyon, the lower portion of which has been informally referred to as "Starmer Gulch," is a tributary to upper Pajarito Canyon at TA-8 and TA-9 (see Figure A-1). The south fork of Pajarito Canyon parallels the south side of Pajarito Canyon for approximately 2.4 mi (3.8 km) and has a drainage area of approximately 0.15 mi$^2$ (0.4 km$^2$). Several springs discharge to the lower portion ("Starmer Gulch") including Starmer, upper Starmer, Brian, Charlie's, Garvey, Josie, and Perkins. In this work plan the informal name "Starmer Gulch" is used when relating previously printed information about this tributary; however, planned investigations discussed in Chapter 7 refer to the tributary as the south fork of Pajarito Canyon.*

*A small tributary to the south fork of Pajarito Canyon drains most of TA-8, which is known as Anchor West Site. In this work plan this small tributary to the south fork of Pajarito Canyon is referred to informally as "Anchor West basin."*

#### 3.1.1.2 North Anchor East Basin ("Arroyo de LaDelfe")

*A small tributary to Pajarito Canyon drains the northern portion of TA-9 (Anchor East Site). In this work plan this small tributary is referred to informally as "north Anchor East basin" (see Figure A-1). The lower portion of Anchor East basin forms a small canyon that has previously been referred to informally as "Arroyo de LaDelfe." The north Anchor East basin is approximately 0.8 mi (1.3 km) long. Bulldog Spring and Kieling Spring discharge into the lower portion of north Anchor East basin ("Arroyo de LaDelfe"), and several National Pollutant Discharge Elimination System (NPDES) outfalls have discharged into this tributary canyon.*

#### 3.1.1.3 South Anchor East Basin

*A small tributary to Pajarito Canyon drains the southern portion of TA-9 (Anchor East Site). In this work plan this small tributary is referred to informally as "south Anchor East basin." This basin is approximately 1 mi (0.6 km) long and has a maximum width of approximately 1500 ft (450 m). This small tributary has not been formally named.*

### 3.1.2 Twomile Canyon

*The Twomile Canyon drainage basin is north of Pajarito Canyon and parallels upper Pajarito Canyon for approximately 5 mi (8 km). Twomile Canyon heads on the flanks of the Sierra de Los Valles at an elevation of approximately 9800 ft (2988 m), which is approximately 1 mi (1.6 km) east and 600 ft (180 m) lower than the head of adjacent Pajarito Canyon. Twomile Canyon joins Pajarito Canyon at TA-66 and contains a total area of 3.13 $mi^2$ (8.1 $km^2$), comprising approximately 23% of the area of the Pajarito Canyon watershed.*

*Twomile Canyon consists of several tributaries herein referred to as the north fork of Twomile Canyon, the main fork of Twomile Canyon, the southwest fork of Twomile Canyon, and the southeast fork of Twomile Canyon (see Figure A-1). The north fork of Twomile Canyon is the largest tributary canyon (0.62 $mi^2$ [1.6 $km^2$]); it forms the western border of TA-3 and is south of upper Los Alamos Canyon west of TA-3. Twomile Canyon also forms the south border of TA-59, -48, and -55.*

*Springs located within the Twomile Canyon watershed include Anderson, Hanlon, SM-30, and TW-1.72 (see Figure A-1).*

### 3.1.3 Threemile Canyon

*Threemile Canyon joins Pajarito Canyon at TA-18 and is the second largest tributary to Pajarito Canyon after Twomile Canyon. Threemile Canyon parallels Pajarito Canyon on the south and extends for a distance of approximately 3.3 mi (5.28 km). Threemile Canyon heads at TA-14 and includes portions of TA-67, -15, -36, and -18. Threemile Canyon has several unnamed tributaries; herein the largest is referred to informally as the south fork of Threemile Canyon, which has a total drainage area of approximately 1.67 $mi^2$ (4.3 $km^2$) (see Figure A-1). Other tributaries to Threemile Canyon are herein informally referred to as the middle fork of Threemile Canyon and the west fork of Threemile Canyon.*

*Springs that discharge to Threemile Canyon include Threemile -A and -B Springs and TA-18 Spring.*

## 3.2 Climate

*The climate of the Pajarito Plateau and the vicinity of Pajarito Canyon is described in the core document (LANL 1997, 55622, p. 3-1) and is briefly discussed in this section. The Laboratory has two meteorological stations in or adjacent to Pajarito Canyon located at TA-6 and TA-54 that provide site-specific meteorological data for the canyon (for example, Environmental Surveillance and Compliance Programs 1997, 56684). The locations of the meteorological stations are shown in Figure A-1. See Section 3.8 for a discussion of site-specific meteorological monitoring in Pajarito Canyon.*

*Climate influences sediment formation and transport, and the transport of contaminants in surface and subsurface environments. The speed, frequency, direction, and stability of winds influence the airborne transport of contaminants; the form, frequency, intensity, and evaporation potential of precipitation influences surface water runoff and infiltration within the canyon.*

*Los Alamos County has a semiarid, temperate, mountain climate, which is summarized in the core document (LANL 1997, 55622, p. 3-1) and Chapter 2 of the IWP (LANL 1996, 55574). Detailed data compilations and extensive statistical summaries including projected probabilities are provided by Bowen (1990, 6899).*

*Past investigations of the hydrology of the Pajarito Plateau have mentioned evapotranspiration (ET) as a process for removing shallow alluvial groundwater (for example, Baltz et al. 1963, 8402, p. 82; Purtymun*

*1974, 5476, p. 4; Purtymun et al. 1983, 6407, p. 3). Site-specific ET data for Pajarito Canyon are not available. However estimates for nearby watersheds are available for comparison. Some studies for Mortandad Canyon indicate approximately 20% of the input to the stream channel is ultimately lost to ET (Purtymun 1974, 5476, p. 7). A study of the Los Alamos Canyon system indicated that approximately 75 to 85% of the total input to the watershed is lost to ET (Gray 1997, 58208, p. 68). Annual summaries are presented in the environmental surveillance reports.*

## 3.3 Geology

*Discussions of the regional geologic setting of the Pajarito Plateau are presented in Griggs (1964, 8795); the IWP (LANL 1996, 55574); the Hydrogeologic Workplan (LANL 1996, 55430); and, most recently, the core document (LANL 1997, 55622, p. 3-6). The following discussion uses the core document as the point of departure and provides detail that is specific to the Pajarito Canyon system. Unless otherwise noted, locations of wells and boreholes mentioned herein are shown in Figure A-1. Some locations are beyond the extent of Figure A-1; these wells and boreholes can be found in maps and figures in the core document (LANL 1997, 55622) and/or the Hydrogeologic Workplan (LANL 1996, 55430).*

*The surface distribution of bedrock geologic units in the Pajarito Canyon area is shown on geologic maps that have been prepared by Griggs (1964, 8795); Smith et al. (1970, 9752); Purtymun and Kennedy (1971, 4798); Vaniman and Wohletz (1990, 21589); Rogers (1995, 54419); Dethier (1997, 49843); and others. The subsurface geology has been investigated by a number of deep boreholes including those for wells PM-2 located in Pajarito Canyon; test holes PCTH-5 and -6 and SHB-4 (Gardner et al. 1993, 12582, p. 16) also located in Pajarito Canyon; PM-4 located on Mesita del Buey north of Pajarito Canyon; PM-5 located north of Pajarito Canyon; and H-19, SHB-1, -2, and -3, and EGH-LA-1 (Purtymun 1995, 45344, p. 225). Numerous shallow boreholes on the floor of Pajarito Canyon have penetrated alluvium and upper bedrock units. Additionally, numerous boreholes on Mesita del Buey at TA-54, especially around Material Disposal Area (MDA) L, have penetrated down to or into lower stratigraphic units including basaltic rocks of the Puye Formation. A list of the wells pertinent to Pajarito Canyon is included in Appendix C of this work plan.*

### 3.3.1 Stratigraphy

*The principal bedrock units in the Pajarito Canyon area consist of the following, in ascending order.*

- *Santa Fe Group: 4 to 21 Ma (ages from Manley 1979, 11714)*
- *Puye Formation: 1.7 to 4 Ma (Turbeville et al. 1989, 21587; Spell et al. 1990, 21586) and interstratified volcanic rocks including the Tschicoma Formation on the west (2.53 to 6.7 Ma) (Gardner and Goff 1984, 44021; WoldeGabriel et al. 1996, 54427) and basalts of the Cerros del Rio volcanic field on the east (2 to 3 Ma) (Gardner and Goff 1984, 44021)*
- *Otowi Member of the Bandelier Tuff: (ca 1.61 Ma, Izett and Obradovich 1994, 48817)*
- *tephras and volcaniclastic sediments of the Cerro Toledo interval (Broxton and Reneau 1995, 49726, p. 11)*
- *Tshirege Member of the Bandelier Tuff: ca 1.22 Ma (age from Izett and Obradovich 1994, 48817; Spell et al. 1990, 21586)*

*The bedrock stratigraphy is illustrated in Figure 3.3.1-1, and a brief description of the principal bedrock units is given below. The stratigraphy is based on the site-wide three-dimensional stratigraphic model, which contains detailed stratigraphic mapping for the sedimentary deposits and has been supplemented for this work plan by additional detail on the volcanic units. Stratigraphic information for pertinent wells in the Pajarito Canyon area is provided in Table C-5 in Appendix C. Stratigraphic information from the site-wide three-dimensional model pertinent to Pajarito Canyon is provided in Appendix D.*

### 3.3.1.1 Santa Fe Group

*In the general area of Pajarito Canyon, the Santa Fe Group was penetrated by water supply wells PM-2, PM-3, PM-4, and PM-5 and by borehole EGH-LA-1. Based on borehole lithological and geophysical logs, Purtymun (1995, 45344, p. 4) informally divided the Santa Fe Group into three formations, which include (in ascending order) the Tesuque Formation, the Chamita Formation, and a coarse-grained upper facies (the "Chaquehui Formation").*

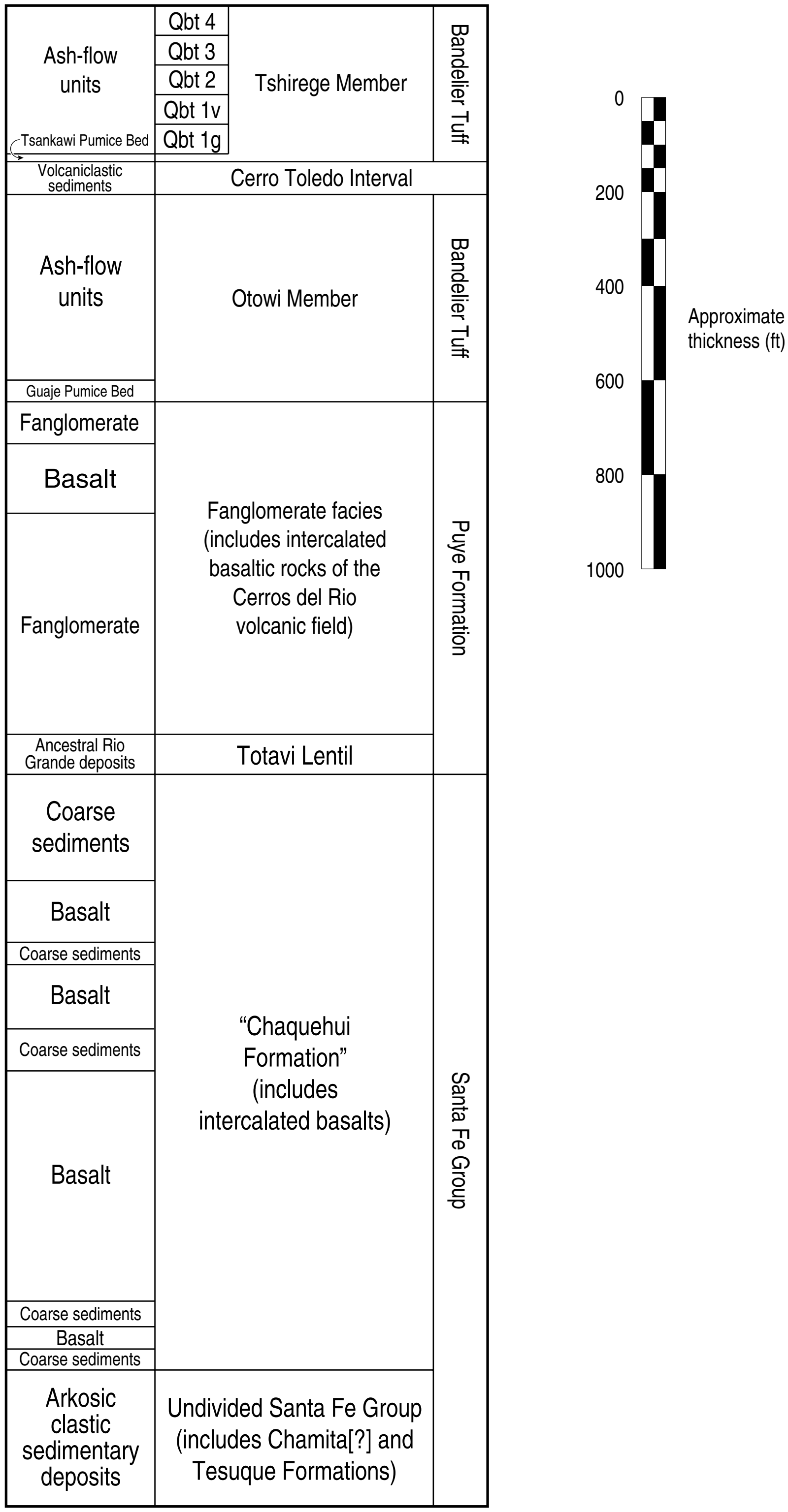
*The Santa Fe Group was deposited in a late Miocene trough 3 to 4 mi (4.8 to 6.4 km) wide and 7 to 8 mi (11 to 13 km) long that extended northeastward beneath the Pajarito Plateau (see Figure 2-4 in the Hydrogeologic Workplan [LANL 1996, 55430]). This trough is filled with up to 1500 ft (approximately 450 m) of gravels, cobbles, and boulders derived from the Jemez volcanic field and with volcanic, metamorphic, and sedimentary rocks derived from highlands to the north and east. The trough is partly coincident with low-gravity anomalies that Ferguson et al. (1995, 56018) interpreted as a sediment-filled graben on the western side of the Española basin of the Rio Grande rift. The eastern side of this trough crosses Pajarito Canyon near state road NM4. The western margin of the trough is not well constrained but may be located in the western portion of the Laboratory.*

#### 3.3.1.1.1 Tesuque Formation

*In PM-2 (located in Pajarito Canyon) and PM-4 (located to the north on Mesita del Buey) the Tesuque Formation primarily consists of poorly-consolidated, light pinkish brown, silty sandstone, siltstone, and claystone (Cooper et al. 1965, 8582, p. 59). The sandstones are predominately fine- to medium-grained, and the sand grains are subrounded to well rounded. The Tesuque Formation also contains interbedded gravel and conglomerate beds and basalt flows in boreholes for wells that are located in the Pajarito Canyon area.*

#### 3.3.1.1.2 Chamita Formation

*The Chamita Formation is similar in appearance to the Tesuque Formation but reportedly contains a larger proportion of volcanic and granitic clasts in its gravel layers (Galusha and Blick 1971, 21526, p. 71) and Paleozoic limestone cobbles in its conglomerate layers (Dethier and Manley 1985, 21506). The Chamita Formation contains lithologically distinct quartzitic gravels (Galusha and Blick 1971, 21526, p. 71). Upper layers of the Chamita Formation may contain cobbles of Jemez volcanic rocks, primarily andesites and dacites. However, because of similarities of appearance, obvious time overlaps, and interfingering relations, differentiation of the Chamita Formation from the coarse-grained upper facies of the Santa Fe Group is often difficult, particularly in borehole investigations. The Chamita Formation was reported to be 100 ft (30 m) thick in PM-2, 80 ft (24 m) thick in PM-5, and absent in PM-3 (Purtymun 1995, 45344, pp. 275–277).*




Source: Baltz et al. 1963, 8402; Purtymun 1995, 45344; LANL 1996, 55430

F3.3.1-1 / PAJARITO CANYON WP / 071098

**Figure 3.3.1-1. Generalized stratigraphy of bedrock geologic units in the Pajarito Canyon area.**

#### 3.3.1.1.3 Coarse-Grained Upper Facies of the Santa Fe Group

*Purtymun (1995, 45344, p. 6) called a distinctive group of coarse-grained sediments at the top of the Santa Fe Group the "Chaquehui Formation." The name "Chaquehui Formation" as related to Santa Fe Group sediments is a potentially confusing designation because the type section of the Chaquehui Formation in Chaquehui Canyon is much younger than the coarse-grained upper facies of the Santa Fe Group identified in boreholes on the Pajarito Plateau. In PM-3 the upper facies consists of medium- to coarse-grained sandstone, conglomerate, and siltstone (Purtymun 1967, 11829, p. 9). Because of the high permeability characteristics of this facies, it is an important aquifer for the development of high-yield, low-drawdown municipal and industrial water supply wells on the Pajarito Plateau.*

*The deep boreholes in the lower Pajarito Canyon area encountered basaltic lava flows that are interbedded with the sedimentary deposits of the upper Santa Fe Group. These basalts range in thickness from 30 to 480 ft (9.1 to 146 m). They are generally described as dark gray and dense, but red vesicular zones are also present (Cooper et al. 1965, 8582, p. 60; Purtymun 1967, 11829, p. 9; Purtymun 1995, 45344, p. 263).*

### 3.3.1.2 Puye Formation, Tschicoma Formation, and Cerros Del Rio Basalts

*The Puye Formation is mostly a fanglomerate deposit generally consisting of poorly sorted boulders, cobbles, and coarse sands. At PM-3 the clasts are composed of dacite, rhyolite, and fragments of basalt and pumice (Purtymun 1967, 11829, p. 8). At TW-8 the fanglomerate consists predominately of fine- to coarse-grained sands and interbedded clay, silt, and gravel (Baltz et al. 1963, 8402, Figure 4). The lower part of the fanglomerate includes more than 95 ft (29 m) of light tan to light gray tuff and tuffaceous sand.*

*The lower part of the Puye Formation includes coarse sand and boulder deposits interpreted to represent an axial facies deposit of the ancestral Rio Grande as described by Manley (1976, 57673) and Dethier (1997, 49843). The axial facies deposit was previously (informally) called the "Totavi Lentil" of Griggs (1964, 8795). At PM-3 this deposit is composed of gravel and boulders of dacite, rhyolite, and quartzite (Purtymun 1967, 11829, p. 9). The thickness of the axial facies deposit varies from 40 ft (12 m) at PM-4 to 70 ft (21 m) at PM-2 and PM-5 (Purtymun 1995, 45344, pp. 275–277). The axial facies deposit interfingers with the fanglomerates of the Puye Formation and basaltic rocks of the Cerros del Rio volcanic field in White Rock Canyon.*

*At PM-2 and PM-4 a sequence of brown and gray basaltic lava flows split the Puye Formation into the main lower part and a thin upper part (Purtymun 1995, 45344, pp. 275–277) (see Figure A-3 in Appendix A of this work plan). Similar basalts were penetrated in the Puye Formation by other deep boreholes in the area. These basalts are present beneath the Guaje Pumice Bed at PM-2 and PM-4, although variable thickness of fanglomerate facies may be present above the basalts. The basalts are stratigraphically equivalent to the basaltic rocks of the Cerros del Rio volcanic field and probably represent an extension of that volcanic field beneath the Pajarito Plateau.*

*Dacitic volcanic rocks, presumably representing the distal edge of a Tschicoma Formation lava flow, were encountered beneath the Bandelier Formation in borehole SHB-1 (located west of TA-55). The dacite flow appears to occupy a similar stratigraphic position within the Puye Formation as do the basalts. Similar dacite flows may underlie the upper and middle sections of Pajarito Canyon. Several deep boreholes drilled to 750 ft (225 m) at TA-46 did not encounter either the dacite or the basalt flows in the upper Puye Formation (Purtymun 1995, 45344, p. 209) (see Figure A-1). This may indicate that the volcanic flows in the Puye Formation do not extend laterally beneath the entire Pajarito Plateau.*

*The top of the regional aquifer beneath the Pajarito Plateau is usually encountered within the fanglomerate of the Puye Formation and the associated interbedded basalts. The regional aquifer was initially encountered at 823 ft (251 m) in PM-2 and at 1060 ft (323 m) in PM-4. No intermediate perched zones were identified in the Puye Formation during the drilling of these wells. Additional information about the regional aquifer is presented in Section 3.7.4.*

#### 3.3.1.3 Otowi Member of the Bandelier Tuff

*The Otowi Member is a nonwelded, poorly-consolidated ignimbrite sheet composed of stacked ash-flow units composed of pumice lapilli supported by a matrix of ash and crystal fragments. The Otowi Member varies in reported thickness from 184 ft (56 m) in SHB-1 to 465 ft (142 m) in EGH-LA-1. The deposits of the Otowi Member beneath middle Mortandad Canyon (near TW-8 and EGH-LA-1) are among the thickest on the Pajarito Plateau from deposition in a pre-Bandelier Formation paleovalley (see Figure 5 in Broxton and Reneau [1996, 55429, p. 330]). The paleovalley containing the thick Otowi Member sediments continues southward across lower Pajarito Canyon.*

*The Otowi Member does not outcrop in the Pajarito Canyon watershed area but is known to exist in the subsurface from drill hole data. The Otowi Member is 305 ft (92 m) thick at PM-2, approximately 155 ft (47 m) thick at PCTH-6, and approximately 55 ft (17 m) thick at PCTH-5. The Otowi Member thins eastward against a north-trending basaltic highland that crosses Pajarito Canyon near state road NM4. The Otowi Member is absent in the lower off-site Pajarito Canyon where it either was not deposited or was removed by erosion before the Tshirege Member was deposited. See Appendix C and Figure A-2 for stratigraphic information from test holes and wells.*

*The basal part of the Otowi Member includes the Guaje Pumice Bed, which is a sequence of well-stratified pumice-fall and ash-fall deposits. The Guaje Pumice Bed is typically 30 to 35 ft (9.1 to 10.7 m) thick beneath the Pajarito Plateau (27 ft [8 m] at PM-2); however, beneath lower Pajarito Canyon the Guaje Pumice Bed thins from west to east and is 27 ft (8.2 m) thick in PM-2, 20 ft (6 m) thick in PCTH-6, and 11 ft (3.3 m) thick in PCTH-5 (Purtymun 1995, 45344, pp. 223 and 275).*

#### 3.3.1.4 Tephras and Volcaniclastic Sediments of the Cerro Toledo Interval

*Tephras and volcaniclastic sediments of the Cerro Toledo interval is an informal name given to a complex sequence of epiclastic sediments and tephras of mixed provenance (Broxton and Reneau 1995, 49726, p. 11). This unit includes well-stratified tuffaceous sandstones and siltstones, primary ash-fall and pumice-fall deposits, and dacite-rich gravel and boulder deposits. The Cerro Toledo deposits, which vary in thickness from 0 to more than 100 ft (30 m), were likely deposited episodically with unevenly distributed local deposits. Some sediments were deposited in drainage channels developed on top of the Otowi Member before deposition of the Tshirege Member and other blanket-type sediments may have been deposited across the plateau including on paleotopographic drainage divides. Erosion and possible redeposition of the Cerro Toledo interval sediments may have occurred in places before deposition of the Tshirege Qbt 1 unit, which may have contributed to locally variable thickness. The Cerro Toledo interval is approximately 140 ft (43 m) thick in SHB-1 (Gardner et al. 1993, 12582, p. 9) and approximately 80 ft (24 m) thick in borehole 35-2028 located in Ten Site Canyon to the north (LANL 1996, 54422, p. 2-3).*

*The Cerro Toledo interval does not outcrop in the Pajarito Canyon watershed area and was not previously identified in any boreholes drilled for wells in Pajarito Canyon. However, numerous boreholes drilled at TA-54 on Mesita del Buey encountered Cerro Toledo interval sediments, providing adequate documentation of its presence in lower Pajarito Canyon. During preparation of this work plan, borehole logs were reinterpreted to identify probable Cerro Toledo deposits beneath Pajarito Canyon based on* *results of drilling at TA-54 and the expected thickness of the Tshirege Qbt 1g unit and the Tsankawi Pumice Bed in lower Pajarito Canyon.*

#### 3.3.1.5 Tshirege Member of the Bandelier Tuff

*The Tshirege Member is a multiple-flow ignimbrite sheet that underlies the alluvium on the floor of upper and middle Pajarito Canyon and forms the prominent cliffs and mesas adjacent to the canyon. The Tshirege Member includes a number of subunits that can be recognized based on differences in physical and weathering properties. This work plan follows the nomenclature of Broxton and Reneau (1995, 49726, p. 8), which was adopted for use as a standard by the ER Project. Both Purtymun and Kennedy (1971, 4798) and Rogers (1995, 54419) applied different systems of stratigraphic nomenclature to subunits of the Tshirege Member. Correlations among these different systems of nomenclature are shown in Figure 3-8 of the core document (LANL 1997, 55622, p. 3-19).*

*Within the Pajarito Canyon system, the following subunits of the Tshirege Member are present.*

- *The Tsankawi Pumice Bed (Qbtt) is the basal pumice fallout deposit of the Tshirege Member. This pumice bed is typically 1 to 3 ft (0.30 to 0.91 m) thick in this part of the Laboratory. It is composed of equant angular to subangular clast-supported pumice lapilli up to 6 cm (2.4 in.) in diameter. It is not exposed (or not well exposed) at the surface in the Pajarito Canyon watershed area.*

- *Qbt 1g is the lowermost unit in the thick ignimbrite sheet that makes up most of the Tshirege Member. Qbt 1g is a porous, nonwelded, poorly-sorted, vitric ignimbrite. It is poorly-indurated but nonetheless forms steep cliffs because a resistant bench near the top of the unit forms a protective cap over the softer underlying tuffs. Qbt 1g underlies the broad canyon floor in lower Pajarito Canyon and outcrops as lower parts of cliff walls in portions of the middle sections of Pajarito Canyon.*

- *Qbt 1v is a series of cliff- and slope-forming outcrops composed of porous, nonwelded, devitrified ignimbrite. (All units above Qbt 1g are vapor-phase-altered and devitrified.) The base of the unit is a thin, horizontal zone of preferential weathering that marks the abrupt transition from vitric tuffs below to devitrified tuffs above; this feature forms a mappable marker horizon on canyon walls in portions of middle Pajarito Canyon. The lower part of Qbt 1v is a resistant orange brown colonnade tuff that forms a distinctive low cliff characterized by columnar jointing. The colonnade tuff is overlain by a distinctive white band of slope-forming tuffs. Qbt 1v is exposed in canyon walls in middle and lower Pajarito Canyon and is present beneath the canyon floor west of the confluence with Twomile Canyon.*

- *Qbt 2 forms a distinctive, medium brown, vertical cliff-forming unit that stands out in marked contrast to the slope-forming, lighter-colored tuffs above and below. This unit is devitrified, relatively highly welded, and underlies the canyon floor in the steep, narrow parts of upper Pajarito Canyon. Qbt 2 forms a resistant caprock on mesa tops surrounding lower Pajarito Canyon and is the caprock at Mesita del Buey.*

- *Qbt 3 is a nonwelded to partially welded, devitrified ignimbrite. The basal part of Qbt 3 consists of a soft, nonwelded tuff that forms a broad gently sloping bench on top of Qbt 2 in canyon wall exposures and on the broad canyon floor in upper Pajarito Canyon. The upper part of Qbt 3 is a partially welded tuff that forms the caprock of mesas adjacent to middle Pajarito Canyon. This unit* *is more densely welded to the west and locally contains apparent horizontal bedding and/or fracturing where springs discharge.*

- *Qbt 4 is a partially- to densely-welded ignimbrite characterized by small, sparse pumices and numerous intercalated surge deposits. This unit is exposed on mesa tops west of TA-55 and TA-67 in the Pajarito Canyon area. Some of the most densely welded areas occur on the western margin of the Laboratory.*

#### 3.3.1.6 Alluvium

*Alluvium of Pleistocene and Holocene age rests unconformably on the Bandelier Tuff in Pajarito Canyon between state road NM501 and state road NM4 (Devaurs and Purtymun 1985, 7415, p. 11). The alluvium may overlie the Cerro Toledo interval in lower Pajarito Canyon near PCO-3. East of state road NM4 through White Rock the stream channel is often located directly on basalts of the Cerros del Rio volcanic field, with relatively minor alluvium being present (see Figure A-2). The alluvium includes sediment derived from the Tschicoma Formation and the Tshirege Member of the Bandelier Tuff, which forms the steep walls of the canyon. The alluvium also contains sediment derived from eolian sources and fallout pumice deposits. In the upper canyon, the alluvium is thin and consists of boulders, cobbles, and pebbles of tuff and dacitic rocks intermixed with sand, silt, and clay. The sand consists mainly of fine- to coarse-grained crystals of quartz and sanidine.*

*In middle and lower Pajarito Canyon, the alluvium is generally composed of finer-grained materials, including sand, silt, and clay (for example, Devaurs 1985, 7416; LANL 1995, 55527, p. 4-179). The alluvium is relatively thin in the upper and middle part of the canyon but widens and thickens downstream from the confluence of Twomile Canyon. Volcanic boulders have been reported near the base of the alluvium in boreholes drilled at TA-18 (LANL 1997, 56356, pp. 432–512). These are probably boulders of Tschicoma Formation lavas that have been transported down the canyon from the Sierra de los Valles.*

*Figure 3.3.1-2a and Figure 3.3.1-2b are preliminary isopach maps of the alluvium in lower Pajarito Canyon. The data points were derived from information provided from previous boreholes drilled in the canyon (for example, Purtymun 1995, 45344, p. 113) and from the relatively recent installation of monitoring wells (LATA 1991, 12464, p. 3-1; LANL 1995, 55527, p. 4-179; LANL 1997, 56356, pp. 432–512).*

*The thickest part of the alluvium may be near TA-18, although no data exist on the thickness of the alluvium in Pajarito Canyon west of TA-18. The alluvium is approximately 35 to 40 ft thick at TA-18, 11 ft thick at PCO-1, 9 ft thick at PCO-2, and 12 ft thick at PCO-3. The alluvium in Threemile Canyon at monitoring well 18-MW-8 is probably approximately 10 to 15 ft (3 to 4.5 m) thick based on re-evaluation of the lithologic descriptions. The alluvium is widest in the lower part of the canyon south of TA-54. Eastward from TA-18 the alluvium thins until the stream channel rests directly on basalt bedrock east of state road NM4. The location of the base of the alluvium may be difficult to determine in the lower canyon where the Cerro Toledo interval subcrops beneath the alluvium.*

*Figure A-2 shows the longitudinal cross section along the axis of the Pajarito Canyon drainage channel and the main tributary canyons, including Threemile Canyon, Twomile Canyon, and the south fork of Pajarito Canyon. The figure contains information from selected boreholes in Pajarito Canyon and information from deep boreholes near the canyon, which are projected into the line of cross section.*

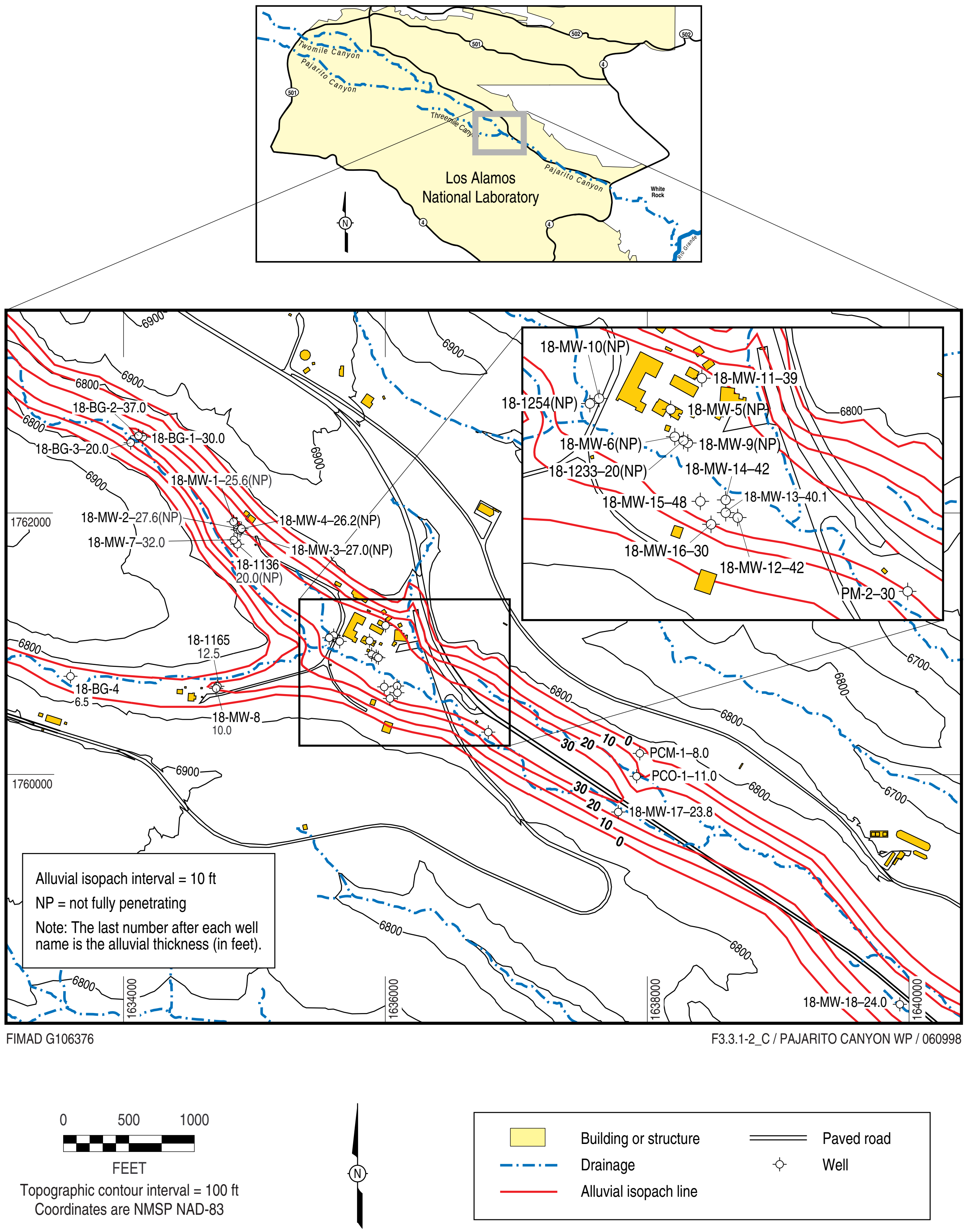
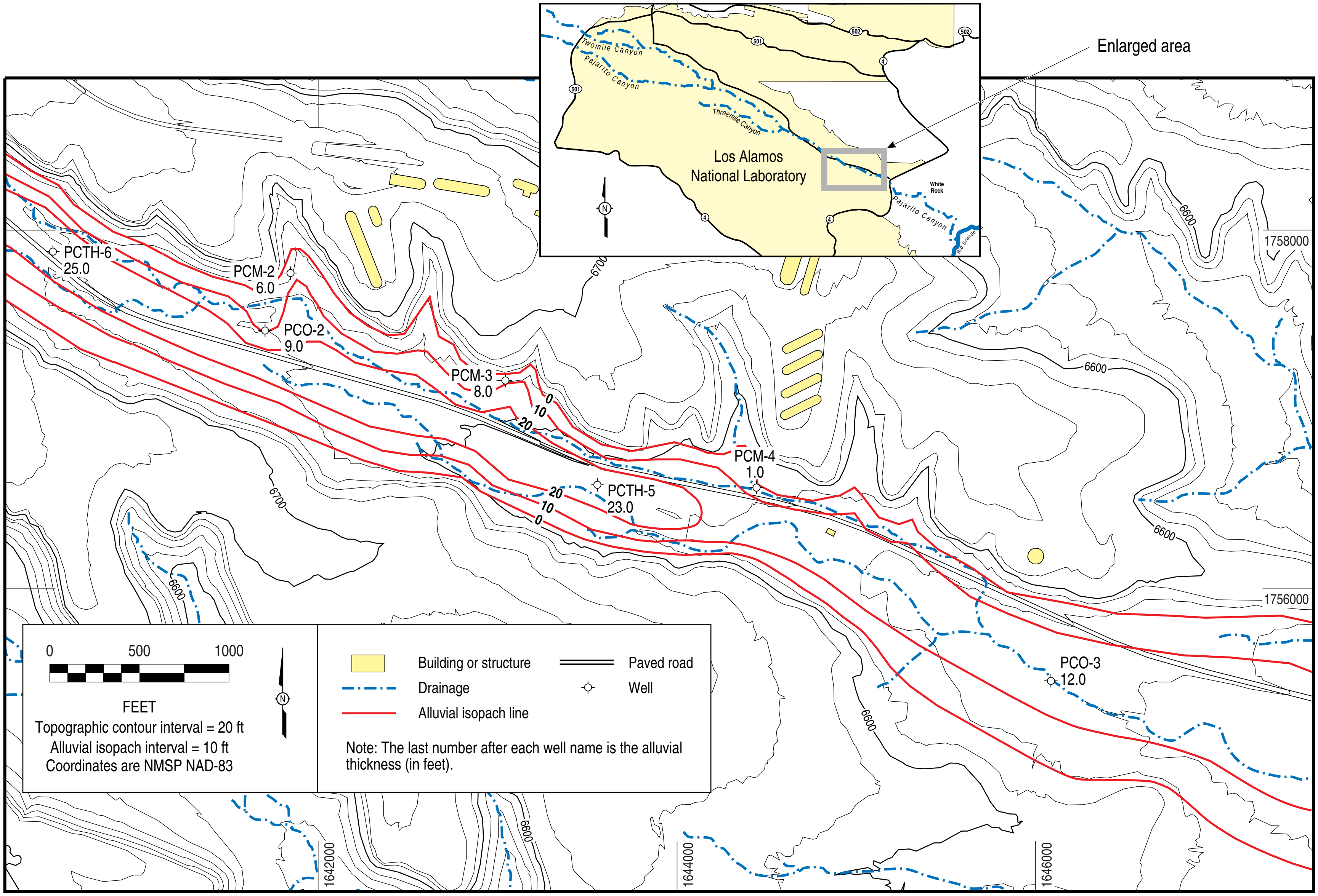



**Figure 3.3.1-2a. Preliminary isopach map of alluvium in upper Pajarito Canyon.**




Source: FIMAD G106377

F3.3.1-2b_C / PAJARITO CANYON WP / 060998

**Figure 3.3.1-2b. Preliminary isopach map of alluvium in lower Pajarito Canyon.**

*Figure A-3 shows multiple cross sections of the alluvium perpendicular to the axis of the channel in lower Pajarito Canyon. The cross sections are generally located where alluvial monitoring wells have been drilled, and the construction information from these monitoring wells is shown on the cross sections. Ten transverse cross sections across lower Pajarito Canyon are shown on this figure, all of which are at the same reference elevation to illustrate the change in shape, elevation, and dimensions of the alluvium and approximate prealluvium incision throughout the lower part of the canyon. The vertical scale exaggeration shown is 10 times the horizontal scale so that changes in the channel gradient are obvious on the cross section. Additional subsurface and canyon-wall stratigraphic information (see Appendix D) is shown on the cross sections. Additional detail was added for the volcanic deposits by reference to the original drilling lithological logs that are summarized in Table C-6 in Appendix C.*

*The tuff underlying the alluvium is variably weathered, and it is often difficult to distinguish the fine-grained alluvium above the tuff from the tuff that has weathered in place. The weathered tuff ranges from a few feet thick up to approximately 20 ft (6.1 m). In the lower canyon, the Cerro Toledo interval is inferred to subcrop beneath the alluvium in the area between PCTH-5 and PCO-3. Distinguishing tuffs and sediments of the Cerro Toledo interval from alluvium in borehole cuttings may be difficult; therefore, identification of this unit in the Pajarito Canyon area has not been previously documented.*

### 3.3.2 Geomorphology

*Pajarito Canyon has several geomorphically distinct sections between the headwaters on the flank of the Sierra de los Valles and the mouth at the Rio Grande, which vary in their potential for sediment deposition and subsequent remobilization. The major longitudinal variations in morphology are largely controlled by the bedrock geology.*

*The upper portions of Pajarito Canyon and Twomile Canyon are relatively steep and narrow where the stream incises through Tschicoma volcanics and Tshirege units Qbt 3 and Qbt 4. In sections of Twomile Canyon and Threemile Canyon, local variations in stream gradient and resultant variations in the potential for sediment storage occur relative to stratigraphic variations in the tuff. Relatively flat sections of the canyon floors may occur upstream of resistant units in the tuff, particularly west of where the initial channel begins incising through unit Qbt 2, which provides opportunities for sediment storage. In some areas the narrow canyon floor is partially filled with boulders derived from adjacent Qbt 2 and Qbt 3 cliffs, which creates steep reaches with relatively little potential for sediment storage.*

*The canyon floor begins widening and the channel gradient decreases where the channel reaches the nonwelded tuff of Tshirege unit Qbt 1g near TA-18, which provides greater opportunity for sediment deposition and long-term sediment storage. The Pajarito Canyon channel gradient decreases from an average of approximately 0.06 m/m (6%) on Forest Service land west of state road NM501 to a minimum of approximately 0.014 m/m (1.4%) in lower Pajarito Canyon near state road NM4. The alluvium is dominated by sand and may thicken downstream from the confluence with Twomile Canyon to the vicinity of TA-18 where it is approximately 10.6 m (35 ft) thick. The combination of decreasing channel gradient; widening canyon floor; a thick section of permeable, sandy alluvium; and the presence of abandoned borrow pits in lower Pajarito Canyon contribute to enhancing surface water infiltration and sediment deposition.*

*The greatest amount of sediment deposition probably occurs in middle and lower Pajarito Canyon between stream gage E245 and PCO-1. The elevation of the stream channel in Pajarito Canyon northwest of TA-18 is slightly higher than in the adjoining Threemile Canyon west of TA-18 (see Figures A-2 and A-3), which indicates a slightly higher channel gradient in Pajarito Canyon immediately west of TA-18 than in Threemile Canyon. At state road NM4, the alluvium pinches out where basalt is exposed in the canyon floor 3.2 km (2 mi) west of the Rio Grande.*

*In lower off-site Pajarito Canyon, downstream from state road NM4 through White Rock, the stream channel is steeper (approximately 0.02 to 0.03 m/m [2 to 3%]) and is contained within a narrow, shallow canyon through basalt where there is relatively little sediment stored. On the east side of White Rock, at the west edge of White Rock Canyon, the channel drops over basalt cliffs and onto a series of massive landslide complexes. In White Rock Canyon the channel first traverses a bouldery alluvial fan deposited on the west side of a large slump block with a slope of approximately 0.06 m/m (6%). The channel steepens past Pajarito Springs (Spring 4A and Spring 4AA) as it is diverted southward around the southern end of the slump block. Finally, the channel traverses a second bouldery alluvial fan before draining into the Rio Grande.*

### 3.3.3 Geological Structure

*See Appendix D for a compilation of the site-wide geologic model of the geologic units in the Pajarito Canyon area. Generalized stratigraphic information for sites in and near Pajarito Canyon and its tributaries is shown on accompanying cross sections (see Figures A-2 and A-3), and stratigraphic information from boreholes in the Pajarito Canyon area are summarized in Table C-6 (see Appendix C).*

*A generalized structure contour map of the base of the Tshirege Qbt 1v unit is shown in Figure 3.3.3-1. This map suggests that subunits of the Tshirege Member dip gently southeastward in the Pajarito Canyon area. The southeastward dip of these tuffs is probably the primary initial dip, mainly resulting from the burial of a southeast-dipping paleotopographic surface and thinning of subunits away from the volcanic source to the west.*

*The paleotopography of the pre-Tshirege surface may strongly influence the direction of possible groundwater flow in the Cerro Toledo interval beneath Pajarito Canyon. Available data from test wells and borehole drilling on the Pajarito Plateau, especially at TA-54, help define this paleotopographic surface; however, few data points exist in the TA-18 area. The existing data indicate that a Cerro Toledo-age drainage system likely heads on the flanks of the Sierra de los Valles in the area of the headwaters of Los Alamos Canyon. The channel system appears to trend to the southeast and crosses obliquely beneath Pajarito Canyon near TA-18 and continues southeastward to south of the White Rock basalt high (Broxton and Reneau 1996, 55429, p. 331). Dacite boulders in the Cerro Toledo interval are exposed in lower Water Canyon east of state road NM4, which indicates the presence of a large channel system within the Cerro Toledo interval. Similar volcanic boulders in the Cerro Toledo interval have also been encountered in boreholes SHB-1 and 35-2028.*

*Paleotopography of the pre-Otowi surface may also influence the direction of flow of potential perched groundwater in the Pajarito Canyon area. A significant zone of intermediate perched zone groundwater occurs in the Guaje Pumice Bed approximately 300 ft (91 m) beneath Los Alamos Canyon. This intermediate perched zone groundwater contains elevated concentrations of tritium (Broxton et al. 1995, 50121, p. 97), which are declining over time, suggesting the passage of a tritiated groundwater plume (Longmire et al. 1996, 54168, p. 476). Although this perched groundwater has been found only in the area beneath Los Alamos Canyon, structure contour maps (Broxton and Reneau 1996, 55429, p. 329; Davis et al. 1996, 55446, p. 54) suggest that the gradient of the perching layer changes from eastward to southward near TA-21 and that water confined to this zone probably will move down gradient along the axis of a large pre-Otowi paleodrainage toward the south, beneath Pajarito Canyon. The location of the axis of this paleodrainage cannot be constrained precisely, but the available data suggest that it crosses beneath Pajarito Canyon near TA-18 and water supply well PM-2. Groundwater infiltrating to and potentially perching in the Guaje Pumice Bed from Pajarito Canyon would tend to migrate toward the axis of this paleodrainage and then flow toward the south or southwest.*

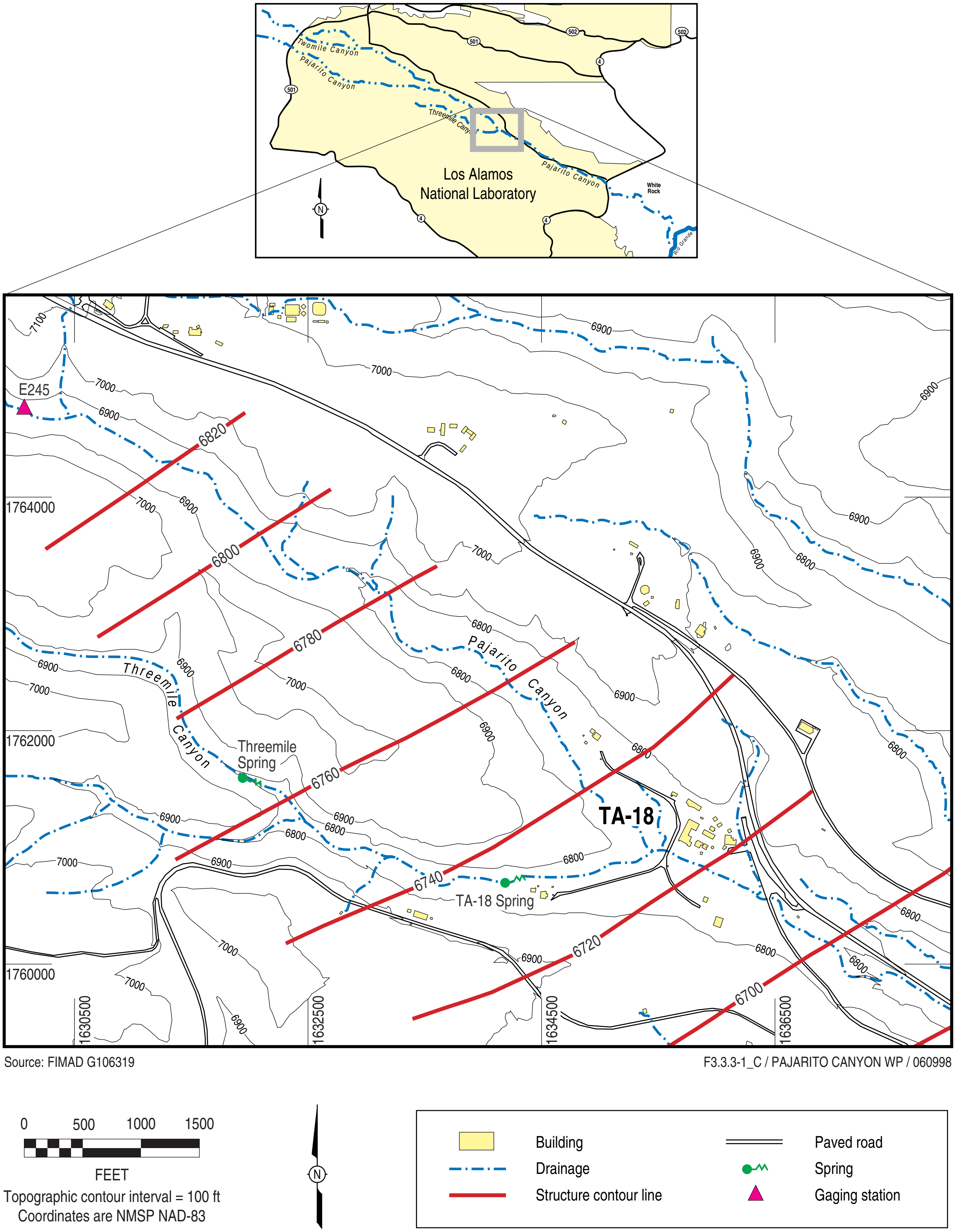



**Figure 3.3.3-1. Preliminary structure contour map of the base of Qbt 1v near TA-18.**

*Faults and fractures may play a role as infiltration pathways if they become saturated, particularly in the canyon floor. The Pajarito fault, which is located west of the Laboratory boundary and extends roughly parallel to state road NM501, crosses Pajarito Canyon where the total vertical displacement is near its maximum 160 m (525 ft) (Olig et al. 1996, 57574). Small displacement faults are present on Laboratory property east of state road NM501 (for example, Reneau et al. 1995, 58031, p. 55; Vaniman and Chipera 1995, 58032, p. 72). Stream loss in upper Pajarito Canyon occurs across the Pajarito fault zone (Stearns 1948, 11871, p. 11; Dale 1998, 57286, p. 7) and may partially reemerge along contacts between flow units down-dip of the fault.*

### 3.3.4 Geological Data Requirements

*The following data are needed in the geologic investigations of the Pajarito Canyon system to resolve uncertainties in the conceptual model for the canyon, particularly those that relate to potential contaminant pathways.*

- *Characterization of the geologic nature and distribution of possible perching layers for intermediate-depth groundwater is important for defining potential groundwater zones. Additional hydrologic information at the interfaces between the Cerro Toledo interval, Otowi Member, Guaje Pumice Bed, and the basalts would be especially important.*

- *The geologic nature of possible saturated zones in the Tshirege Member of the Bandelier Tuff and the relationship with springs in Threemile Canyon and near the western Laboratory boundary*

- *Refinement of the location of the axis and down gradient direction for pre-Tshirege and pre-Otowi paleodrainages*

- *Evaluation of the geometry and distribution of geologic units below Pajarito Canyon, especially near the axes of the paleodrainages and the discontinuous volcanic flows, if present, between the Tschicoma Formation and Cerros del Rio basalts that overlie the regional aquifer*

## 3.4 Surface Sediments

### 3.4.1 Natural Background Conditions

*Sediments in the Pajarito Canyon system are primarily derived from erosion of the Bandelier Tuff, Tschicoma Formation dacites, and soils that have developed in the watershed; the latter include components of wind-blown sediment and fallout pumice. The natural background chemistry of the sediments reflects both the source materials and particle size distribution of resultant deposits. No background data are available from sediments in Pajarito Canyon, but background data have been obtained from geologically similar settings in Ancho Canyon and Indio Canyon (Reneau et al. 1996, 56047), which are also similar to background data collected from upper Guaje Canyon, Los Alamos Canyon, and Pueblo Canyon by the canyons investigation team in 1996 (Ryti et al. 1998, 58093). Because background sediment data obtained from upper Los Alamos Canyon are similar in provenance to sediments in upper Pajarito Canyon, these background data are used in Section 3.4.3 to provide the basis for evaluating the nature of contamination in Pajarito Canyon sediments. Background values reported for sediment, soil, and Bandelier Tuff units equate to the 95% upper tolerance limit for each analyte reported, which represent the upper range of the background concentrations (Ryti et al. 1998, 58093, p. 1).*

### 3.4.2 Historic Channel Changes

*Changes are known to have occurred in the Pajarito Canyon channel since the time of homesteader activity on the Pajarito Plateau. In 1914 a homesteader built a small earth and rock-fill dam in upper Pajarito Canyon to divert water via a wooden flume to a pond near the homestead site that later became the Anchor Ranch. In 1943 the Laboratory raised the height of the dam to approximately 6 ft (1.8 m) and installed steel piping to the pond (Hoard 1993, 57491, p. 82). In 1952 this dam was 6 ft (1.8 m) high and 16 ft (4.8 m) long and was located where the canyon intersects the Pajarito fault, west of the Laboratory boundary. Some of the flow from Pajarito Canyon was diverted for use at the Los Alamos town site (Black and Veatch 1946, 57905, p. 5; Stearns 1948, 11871, p. 11; Griggs 1964, 8795, p. 90), but the water was primarily used at local Laboratory technical areas for fire control. The diversion system was abandoned in 1960 and only the remains of the dam are now present in the canyon (Hoard 1993, 57491, p. 82).*

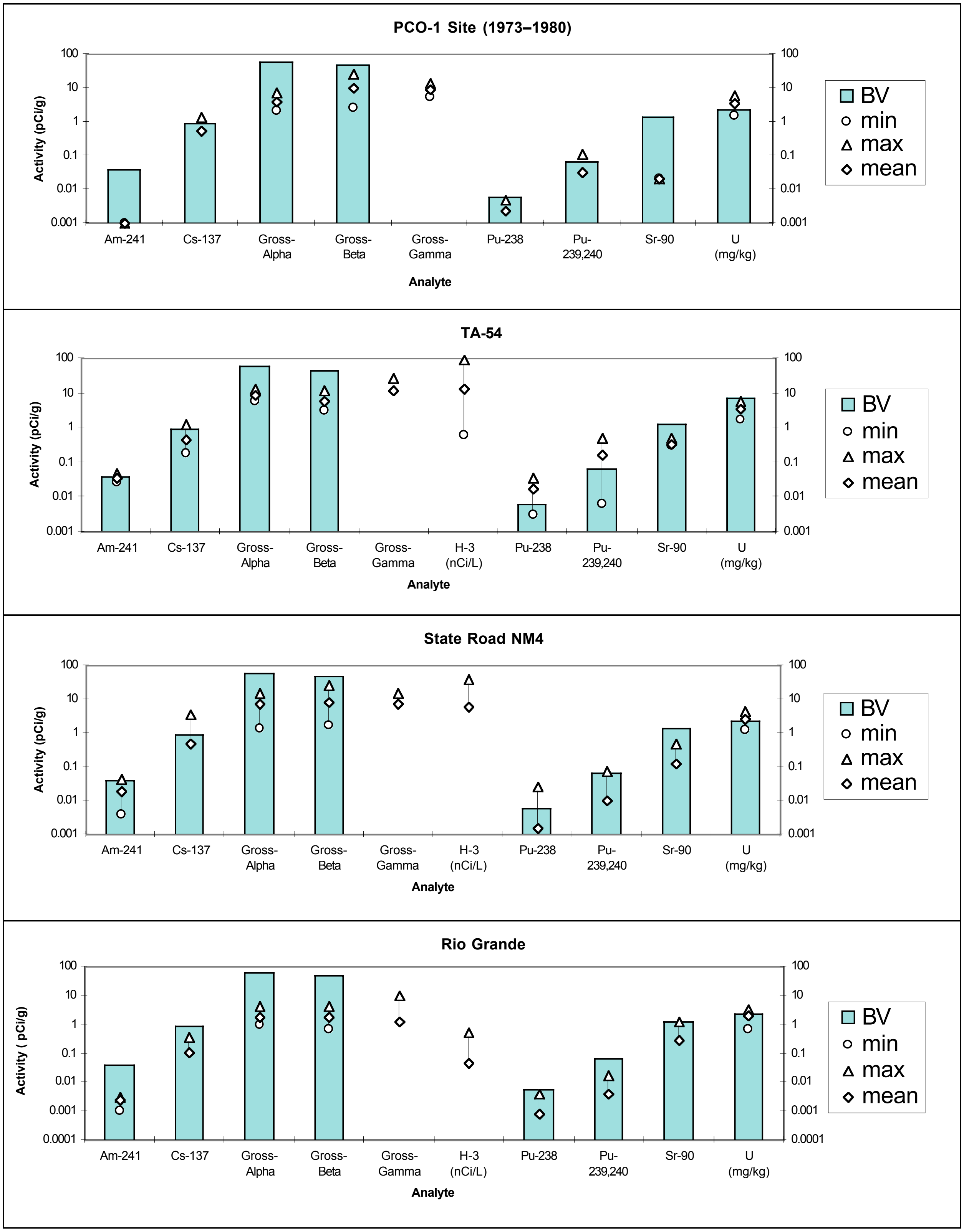
*The most significant channel changes have been the result of quarrying sand and gravel materials from lower Pajarito Canyon east of TA-18 in the late 1940s, 1950s, and 1960s. Up to 15 ft (4.5 m) of alluvial material was removed in large areas throughout the lower canyon (Black and Veatch 1950, 57575, p. 3). Major channel changes were imposed with the excavation of the borrow pits and by diversion of the channel during construction of TA-18 and Pajarito Road. Since the gravel pits were excavated, recent sediment transport down Pajarito Canyon has not been sufficient to fill any of the pits with recent sediment deposits, although some deposition undoubtedly has occurred. From TA-18 eastward for approximately 0.6 mi (1 km) the stream channel has been diverted to the south side of the canyon to allow placement of structures and Pajarito Road.*

*Although these and other channel changes have been only partially defined, they potentially affect the horizontal and vertical distribution of possible contaminants in the alluvium. Other channel changes potentially include both aggradation that has locally raised the level of the streambed and degradation that has locally caused incision of streambeds. Areas of the Laboratory that have been impacted by post-1942 aggradation and degradation in the Pajarito Canyon system have not yet been defined.*

### 3.4.3 Contaminants in Pajarito Canyon Sediments

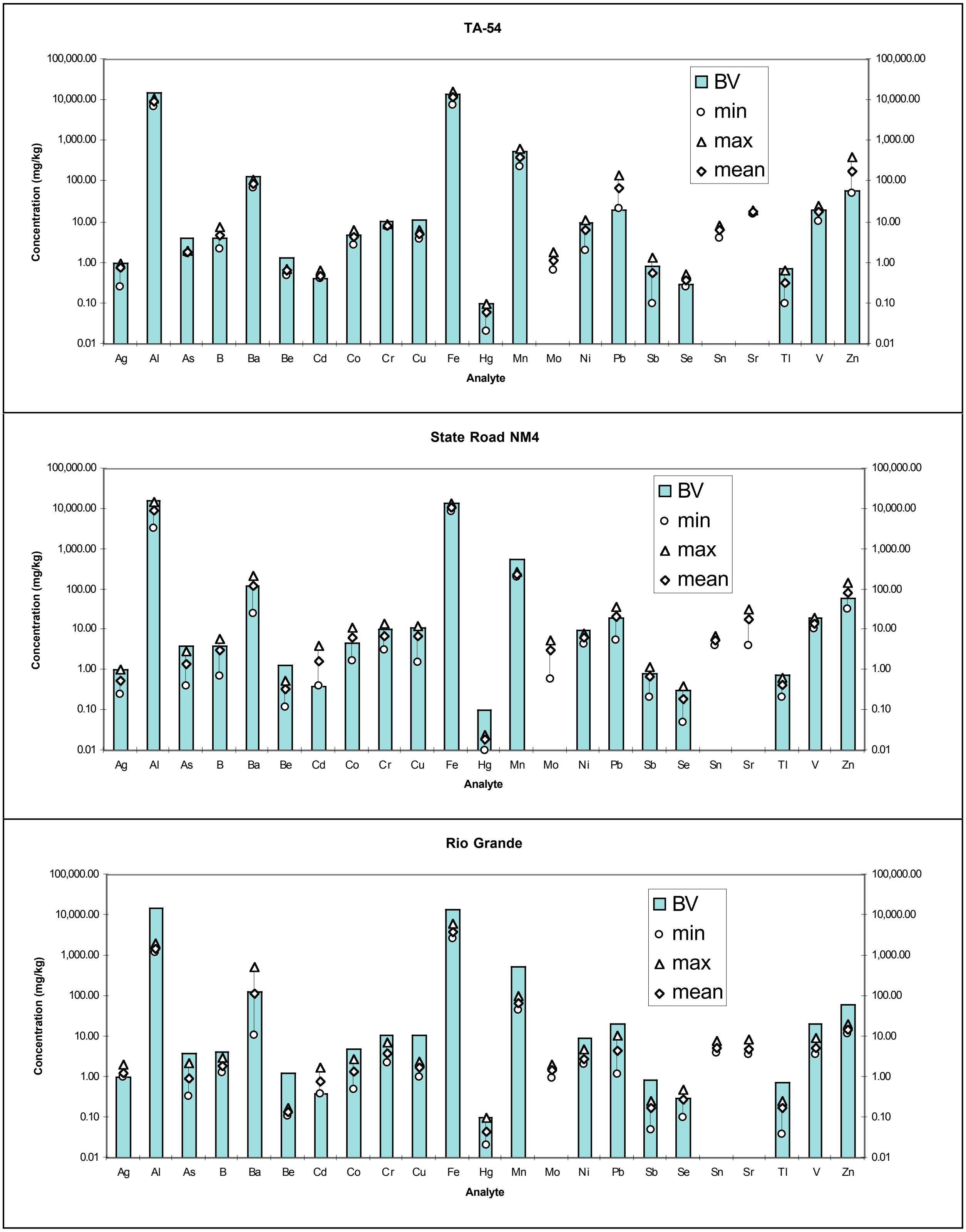
#### 3.4.3.1 Routine Environmental Surveillance of Active Channel Sediments

*Since 1977 the Laboratory has collected surficial sediment samples annually from various locations along the active channel of Pajarito Canyon. At present, the active channel is sampled at two locations on Laboratory property and one location on Los Alamos County land. In addition, samples are collected annually from six ephemeral channels that drain MDA G at TA-54. These sediment samples are typically analyzed for radioactive constituents and trace metals. Results are reported in the annual surveillance reports (for example, Environmental Surveillance and Compliance Programs 1997, 56684). The sediment sampling locations in Pajarito Canyon are listed in Table 3.4.3-1 and shown in Figure A-1. A summary of the analytical results for radionuclides is shown in Figure 3.4.3-1; a summary of the metals results is shown in Figure 3.4.3-2.*




Source: Environmental surveillance reports; background values from Ryti et al. 1998, 58093

**Figure 3.4.3-1. Summary of radiological data from environmental surveillance sediment sampling.**




Source: Environmental surveillance reports 1974–1997; background values from Ryti et al. 1998, 58093

**Figure 3.4.3-2. Summary of metals data from environmental surveillance sediment sampling.**

**TABLE 3.4.3-1**

**ROUTINE ENVIRONMENTAL SURVEILLANCE SEDIMENT SAMPLING LOCATIONS**

| Location | Comment |
|---|---|
| **Pajarito Canyon on Laboratory Property *** | |
| *Pajarito Canyon Site* | *Active channel sediment site near PCO-1 (1973–1980 only)* |
| *Station G-1* | *Ephemeral tributary channel from MDA G* |
| *Station G-2* | *Ephemeral tributary channel from MDA G* |
| *Station G-3* | *Ephemeral tributary channel from MDA G* |
| *Station G-4* | *Ephemeral tributary channel from MDA G* |
| *Station G-5* | *Ephemeral tributary channel from MDA G* |
| *Station G-6* | *Ephemeral tributary channel from MDA G* |
| *At state road NM4* | *Active channel sediment site at gaging station E250* |
| **Pajarito Canyon on Los Alamos County Land** | |
| *Pajarito at Rio Grande* | *Pajarito Canyon just upstream from the Rio Grande* |
| **See Figure A-1 in Appendix A of this work plan for locations.* | |

Source: Environmental surveillance reports 1973–1997

### 3.4.3.1.1 Pajarito Canyon at PCO-1

*In 1973, 1978, 1979, and 1980, active channel sediment samples were collected from Pajarito Canyon near PCO-1 (Pajarito Canyon site). These samples were analyzed for radionuclide activity including americium-241; cesium-137; plutonium-238; plutonium 239,240; strontium-90; and total uranium (Schiager and Apt 1974, 5467; ESG 1979, 5819; ESG 1980, 5961). A summary of the results of the analyses is shown in Figure 3.4.3-1. The activities for most radionuclides were within background values for canyon sediments (Ryti et al. 1998, 58093). However, some samples contained cesium-137 and plutonium-239,240 activities up to 1.5 times background values and total uranium concentrations (using SW-846 method 3050 [nitric acid digestion]) up to 2.5 times background values. Analyses for metals were not reported for these samples.*

### 3.4.3.1.2 Pajarito Canyon at State Road NM4

*Sediment samples collected from the active stream channel at the state road NM4 collection site (Pajarito Canyon at state road NM4) have been analyzed for radionuclide constituents annually since 1976. Before annual sampling, sediment samples were collected from this site in 1973 and analyzed for radionuclides. Figure 3.4.3-2 summarizes the results of the environmental surveillance sampling at this site. Generally, all radionuclide activities have been measured below background values. One result for cesium-137 in 1973 was 3.8 times background value, and one result for plutonium-238 in 1995 was 4.2 times background value. These results have not been substantiated by subsequent sampling, but they indicate the potential for contaminated sediments near the eastern Laboratory boundary.*

*The sediment samples collected at state road NM4 were analyzed for metal constituents in 1990, 1994, and 1996. The results of the analyses are shown in Figure 3.4.3-2. Metals and trace elements including barium, boron, cadmium, chromium, cobalt, lead, and zinc have been measured in concentrations greater than background values. The metals observed at more than two times background values include* *cadmium, cobalt, and zinc. Barium concentrations range from 25 to 220 mg/kg (the background value is 127 mg/kg).*

*Sediment samples collected from the Pajarito Canyon stream channel at state road NM4 were analyzed for high-explosives (HE) compounds in 1996. The results of the analyses were below detection levels for all constituents analyzed (Environmental Surveillance Program 1996, 55333).*

#### 3.4.3.1.3 Pajarito Canyon at the Rio Grande

*Since 1977 sediment samples have been collected most years from Pajarito Canyon above the confluence with the Rio Grande. The samples were analyzed for radionuclides; they were also analyzed for metals from 1991 through 1995 only. The summary of the results are shown in Figure 3.4.3-1 and Figure 3.4.3-2.*

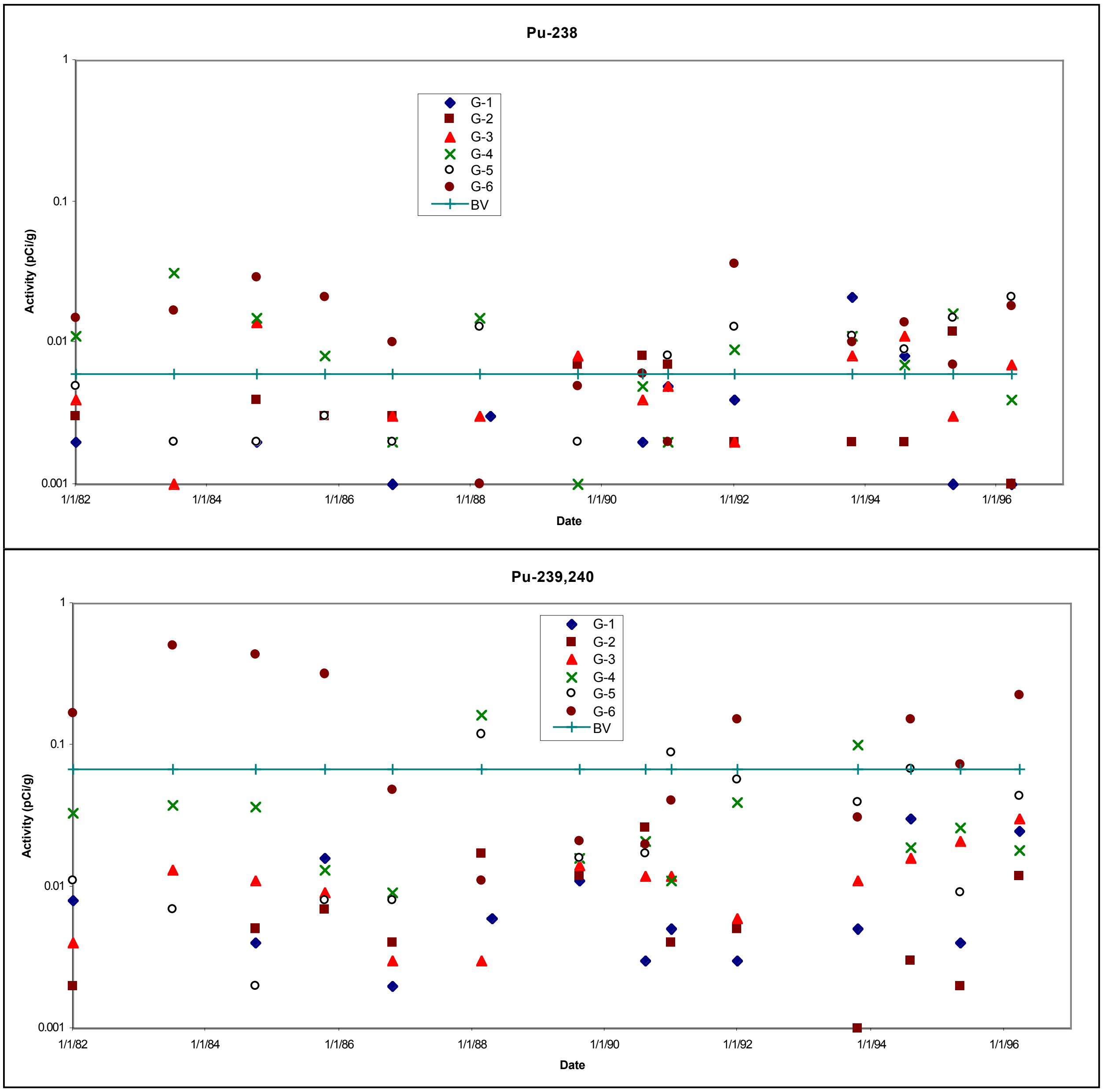
*The results of the surveillance sampling for sediments in lower Pajarito Canyon at the Rio Grande show that radionuclides are within background values. The metals analyses show that, on average, the concentrations of cadmium are approximately two times background values; measured concentrations of barium, cadmium, selenium, and silver occasionally have been observed above background values (Environmental Protection Group 1992, 7004; Environmental Protection Group 1993, 23249; Environmental Protection Group 1994, 45363; Environmental Protection Group 1995, 50285). However, Laboratory background values for sediments may not be applicable for metals comparison at this site because sediments derived from bedrock units (for example, basalt) exposed in White Rock Canyon typically contain higher metal contents than the sediments derived from the Bandelier Tuff.*

#### 3.4.3.1.4 Sediment Sampling Adjacent to TA-54

*In 1982 nine sediment sampling stations were established by ESH-18 outside the perimeter fence at MDA G to monitor possible transport of radionuclides by surface runoff from the active waste storage and disposal area. Six of the sampling stations (G-1 through G-6) are on the south side of Mesita del Buey within the Pajarito Canyon watershed area; they provide information about possible contaminant migration in sediments and runoff from TA-54. The sample locations are at the foot of the mesa in active channels that drain MDA G. These samples have been collected and analyzed for radionuclides annually (except 1987) since 1982. The samples were analyzed for metals in 1993, 1994, and 1996.*

*A summary of the results of the sampling for radionuclides is shown in Figure 3.4.3-1. Most radionuclides are below background values except for plutonium-238 and plutonium-239,240, which average 2.8 and 2.5 times background values, respectively, for all samples collected. Figure 3.4.3-3 shows the results of the annual sediment sampling for plutonium-238 and plutonium-239,240. The highest activity is typically from station G-6, which is located at the east end of TA-54 (see Figure A-1), although sampling stations G-4 and G-5 also exhibit activities above background values. These data indicate that plutonium isotopes have been transported from MDA G in suspended or bed sediments into channels that drain the area. The contamination is reported to be "residual" contamination from the mesa that resulted from earlier handling of wastes at MDA G and not related to the buried wastes in the pits and shafts (Environmental Protection Group 1994, 45363 p. IV-41).*

*Sediment samples collected in Pajarito Canyon at the base of Mesita del Buey were analyzed for metals in 1993, 1994, and 1996. The results of all samples collected show that average concentrations of four metals have been measured above background values, including cadmium (1.2 times background value), lead (3.5 times background value), selenium (1.3 times background value), and zinc (2.9 times background value).*




Source: Environmental surveillance reports 1984–1997

**Figure 3.4.3-3. Plutonium activity in sediments adjacent to TA-54.**

*In 1995 and 1996 the sediment samples were analyzed for organic compounds including HE compounds. The results of the analyses for all HE compounds were below detection limits. The only organic compound detected in the samples was di-n-butyl phthalate, which was detected in each sample at concentrations below 870 μg/kg.*

### 3.4.3.2 Supplemental Environmental Surveillance Sampling at TA-54

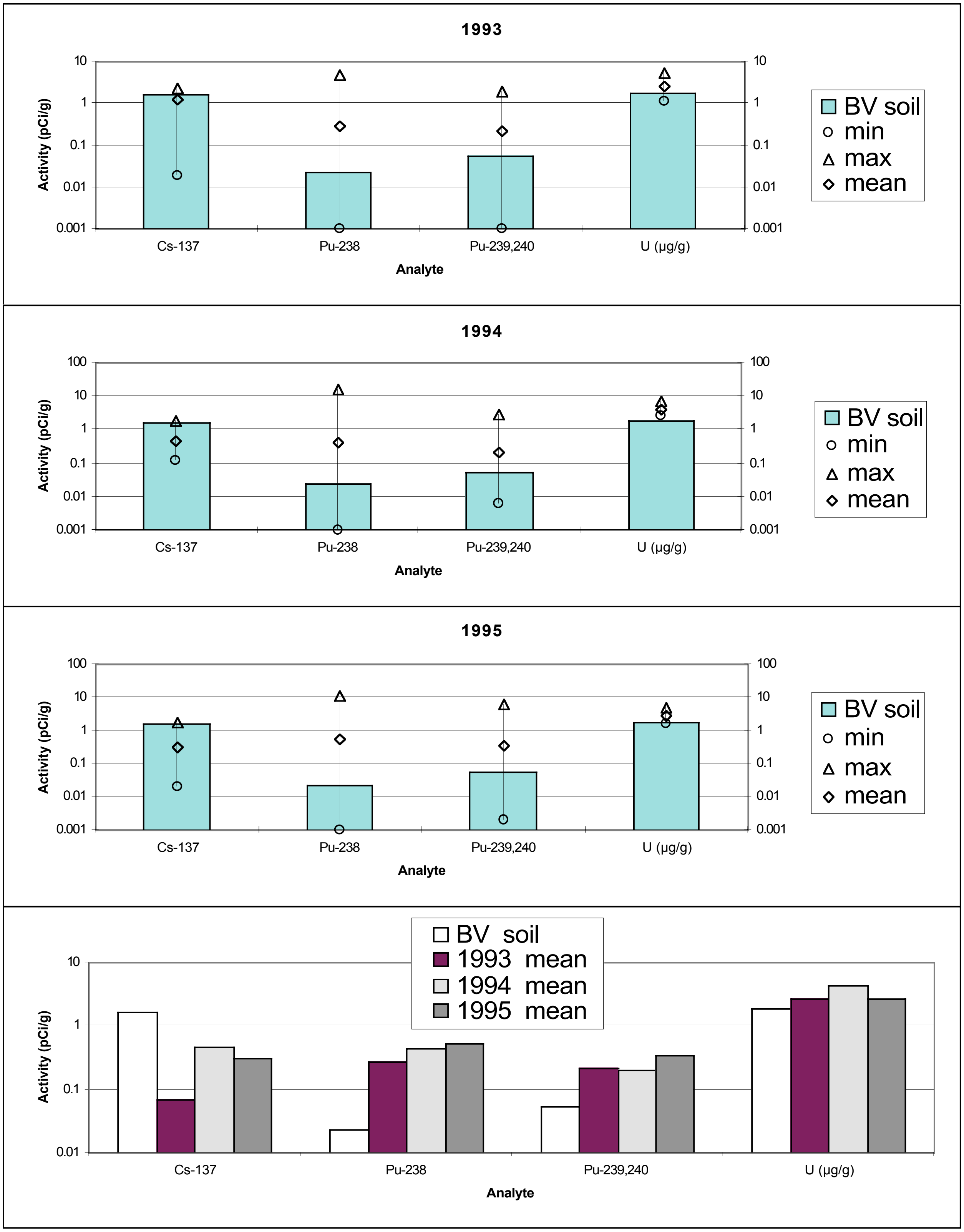
*In addition to the data presented annually in the environmental surveillance reports, a supplemental environmental surveillance investigation was initiated at TA-54 in 1993. The investigation was designed to monitor potential contaminant migration from MDA G via the surface sediment transport pathway. In 1993, 1994, and 1995, soil and sediment samples were collected from the perimeter of MDA G to supplement existing environmental surveillance of the TA-54 area (Conrad et al. 1995, 52014; Conrad et al. 1996, 55621; Childs and Conrad 1997, 57518). The resulting data were used subsequently in status reports as part of the Resource Conservation and Recovery Act facility investigation (RFI) for Operable Unit (OU) 1148 (LANL 1996, 54462; LANL 1997, 55873).*

*The sediment investigation established an extensive perimeter sampling network that is limited to the mesa-top perimeter outside the fence at MDA G, the hillsides directly below MDA G, and one major drainage within the disposal area itself. Generally, these soil/sediment locations are upgradient from the channel sediment samples collected for routine environmental surveillance (the MDA G sample sites G-1 through G-6, which are shown in Figure A-1). A summary of the results of the samples collected and analyzed in 1993, 1994, and 1995 is shown in Figure 3.4.3-4.*

*In 1993 83 soil/sediment samples collected from the perimeter of MDA G were analyzed for the radionuclides tritium, total uranium, isotopic plutonium, americium-241, and cesium-137, and for the metals barium, lead, and mercury using x-ray fluorescence (XRF) methods. Elevated levels of tritium (as high as 117,200 pCi/L) were found in samples along the eastern half of the north side of MDA G, which drains into Cañada del Buey. To the east and south of the transuranic (TRU) pads, which are located at the east end of MDA G, the samples contained slight increases (3000 to 5000 pCi/L) above baseline tritium levels (100 to 1000 pCi/L for MDA G soils). A summary of the results of the sampling for selected radionuclides is shown in Figure 3.4.3-4 (Conrad et al. 1995, 52014).*

*In 1994 108 samples were collected that on average contained slightly higher plutonium-238 activity and uranium concentrations compared with data collected in 1993. A summary of the results obtained in 1994 is shown in Figure 3.4.3-4. The maximum tritium activity in 1994 was 1,715,560 pCi/L collected from the north side of MDA G. plutonium-238 activities ranged from 0.001 to 16.68 pCi/g; the average activity was 0.435 pCi/g. Measured activities of plutonium-239,240 and cesium-137 were similar with the values obtained in 1993. plutonium-239,240 activities ranged from 0.006 to 2.77 pCi/g; the average activity was 0.203 pCi/g. The cesium-137 activities ranged from 0.12 to 1.89 pCi/g. The mean activity of americium-241 was 0.059 pCi/g. The average uranium concentration observed in the samples was 4.3 μg/g.*

*In 1994 the metals analyte list was expanded to include arsenic, beryllium, cadmium, chromium, nickel, selenium, and silver, and the analytical methods for metals were expanded to include inductively coupled plasma and atomic absorption techniques in addition to the XRF technique. Metals analyses were performed on 21 perimeter samples; the results showed that samples were within baseline concentrations. Baseline concentrations were determined from sample sites located in an undisturbed area west of active operations at MDA G. The undisturbed area was sampled as part of a program to determine baseline concentrations for future disposal operations in the proposed MDA G expansion area (Conrad et al. 1996, 55621).*




Source: Conrad et al. 1995, 52014; Conrad et al. 1996, 55621; Childs and Conrad 1997, 57518

**Figure 3.4.3-4. Summary of data from supplemental environmental surveillance sampling at TA-54.**

*The results of the 1995 surveillance sampling are also shown in Figure 3.4.3-4. The results show lower tritium concentrations in soil compared with the 1994 data. The elevated levels of tritium (as high as 105,000 pCi/L) found in the perimeter soil samples were substantially lower than those found during the corresponding sampling accomplished in 1994 but similar to tritium levels in soils collected during 1993. The average plutonium-238 activity was 0.539 pCi/g, and the average plutonium-239,240 activity was 0.343 pCi/g. Activity of cesium-137 values ranged from 0.02 to 1.76 pCi/g, which is consistent with the results obtained in 1993 and 1994. The mean activity of americium-241 was 0.202 pCi/g. The average uranium concentration was 2.67μg/g, which is consistent with the 1993 data. Metals were analyzed in six perimeter soil samples, and all samples were found to be within the baseline concentrations established during the expansion area baseline study.*

*The results of the supplemental environmental surveillance investigation performed at TA-54 from 1993 through 1995 were that low levels of radionuclides are present in MDA G perimeter surface soils and sediments. Small amounts of radioactivity are leaving the confines of MDA G via the surface sediment transport pathway (Conrad et al. 1995, 52014; Conrad et al. 1996, 55621; Childs and Conrad 1997, 57518). Additional discussion of the results of the supplemental soil/sediment sampling can be found in Section 3.4.3.3.3.*

### 3.4.3.3 RFI Sediment Sampling and Analysis in Pajarito Canyon

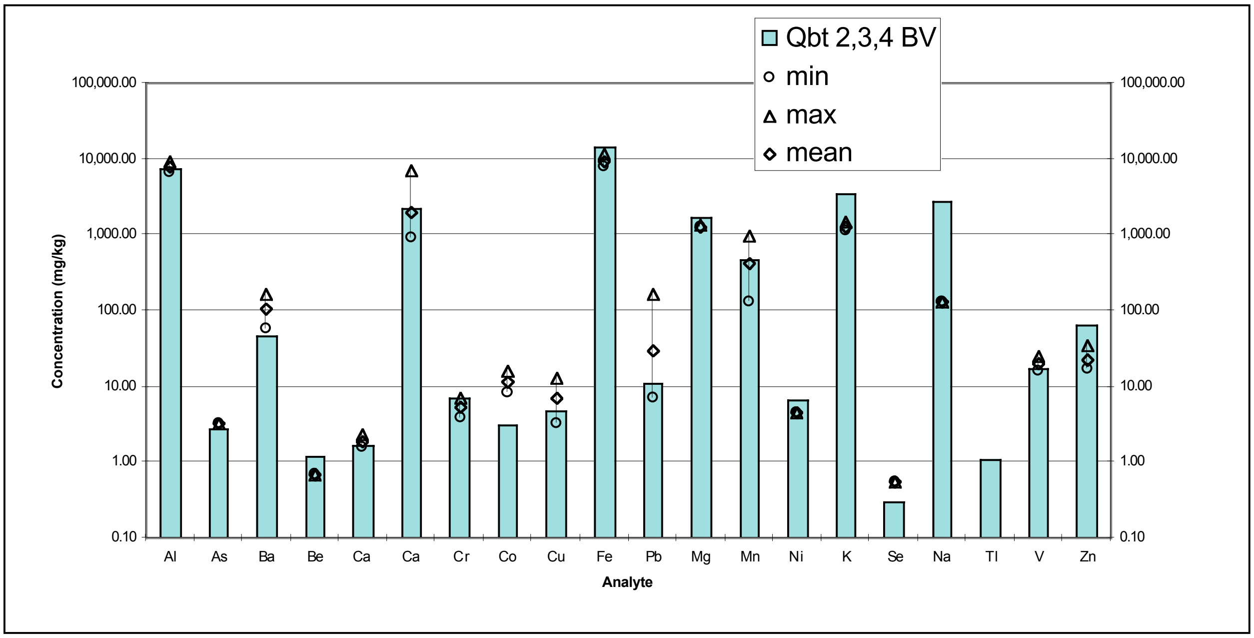
*This section (for sediments) and the following sections (for surface water and groundwater) describe the currently available results of the RFIs. Chapter 2 of this work plan discusses the history of the investigations within the Pajarito Canyon watershed.*

#### 3.4.3.3.1 MDA M

*The RFI of MDA M (Potential Release Site [PRS] 9-013, see Figure A-1) included the collection of surface sediment samples from the hillside down gradient of the disposal area where local runoff could have transported waste constituents. The samples were analyzed for metals, volatile organic compounds (VOCs), semivolatile organic compounds (SVOCs), polychlorinated biphenyls (PCBs), pesticides, and HE compounds (LANL 1993, 20949, p. 6-120). The results of the sediment sampling for metals are shown in Figure 3.4.3-5. Metals and trace elements detected above background values include arsenic, barium, cadmium, cobalt, copper, lead, selenium, and vanadium. The results of analyses for VOCs, SVOCs, PCBs, pesticides, and HE compounds were below method detection limits (LANL 1995, 47257).*

#### 3.4.3.3.2 TA-18

*Sediment sampling was performed in Pajarito Canyon and Threemile Canyon near TA-18 as part of the RFI for OU 1093 (LANL 1993, 15310, p. 4-19). Sediment samples were collected in two wetlands (WL) areas (WL-1 and WL-3) located upgradient of TA-18 in Threemile Canyon to provide data to represent TA-18 site-specific baseline conditions. Sediment samples were also collected from five wetland areas (WL-4, -5, -6, -7, and -8) east of TA-18 in lower Pajarito Canyon. The samples were collected from depth intervals of 0.5 to 1.5 ft (0.15 to 0.5m) to represent older sediments that could have resulted from historical laboratory operations. The samples were analyzed for metals, VOCs, SVOCs, HE compounds, total uranium, isotopic plutonium, and isotopic thorium (LANL 1995, 55527, p. 4-186; LANL 1996, 54919, p. 4-79).*



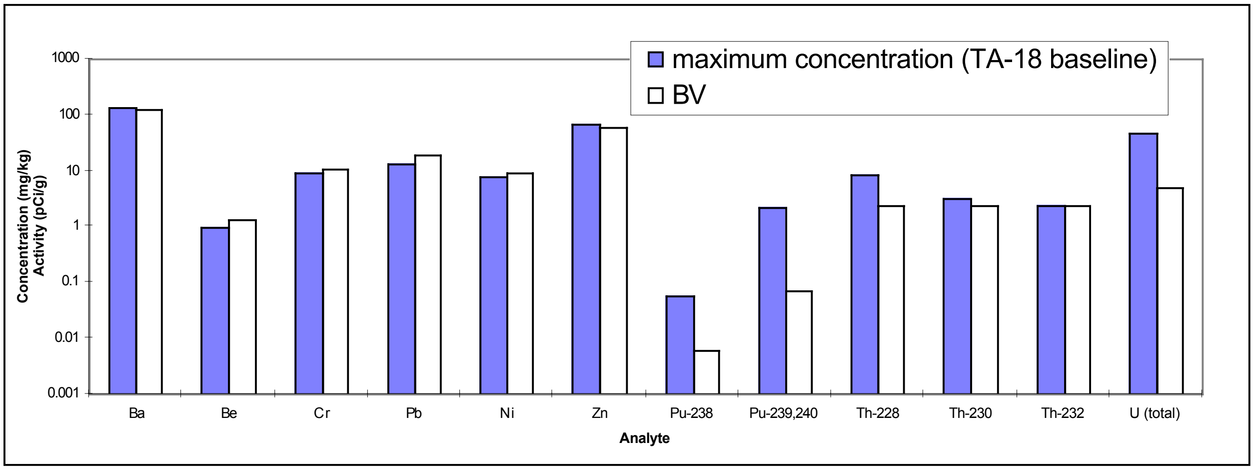

Source: LANL 1995, 47257; background values from Ryti et al. 1998, 58093

**Figure 3.4.3-5. Summary of sediment sampling near MDA M.**

*The results of the wetland sediment samples collected in Threemile Canyon are shown in Figure 3.4.3-6a. The maximum concentrations obtained for the analytes were used as site-specific baseline values in the RFI report (LANL 1995, 55527, p. 4-186). However, comparisons with site-wide background sediment values are shown in Figure 3.4.3-6a (Ryti et al. 1998, 58093). Maximum concentrations obtained for barium; zinc; plutonium-238; plutonium-239,240; thorium-228; thorium-230; and total uranium in sediments in Threemile Canyon were above background values. The only radionuclide detected in wetland sediments in concentrations greater than the screening action level (SAL) value was thorium-228. However, thorium-228 was not retained as a chemical of potential concern (COPC) because it does not pose an unacceptable health risk associated with a nonintrusive industrial exposure scenario (LANL 1996, 54919, p. 4-83). No organic compounds were detected in wetland sediment samples in Threemile Canyon (LANL 1995, 55527, p. 4-198).*

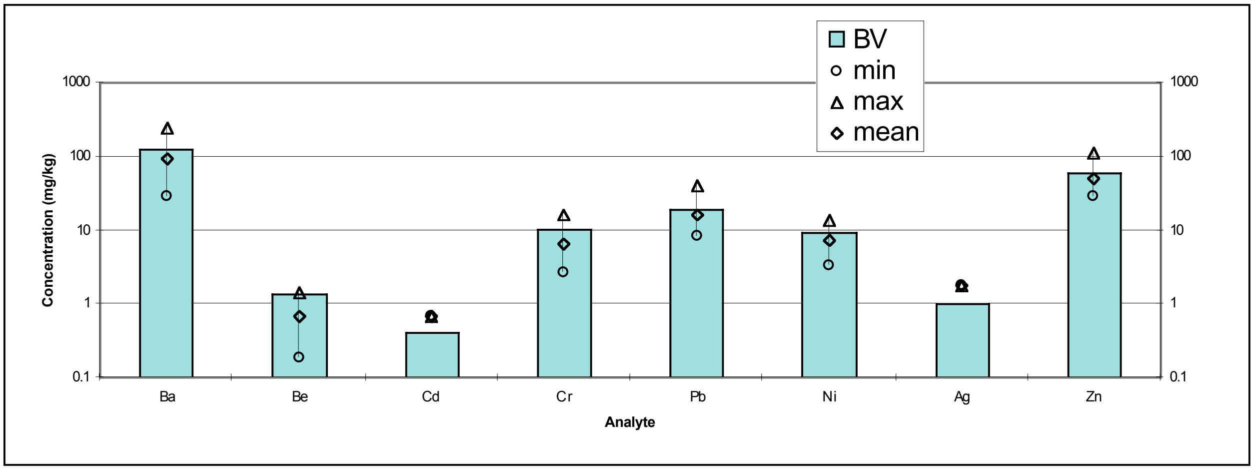
*The results of all wetland sediment sample analyses for metals that were detected above method detection limits are shown in Figure 3.4.3-6b. The average values of metals detected are within background ranges for all metals except one sample that contained cadmium and one sample that contained silver above method detection limits.*

*Figure 3.4.3-6c shows the results of the RFI sediment sampling for metals and radionuclides in wetlands in lower Pajarito Canyon east of TA-18 compared with site-wide sediment background values. The metals barium, beryllium, chromium, lead, nickel, silver, uranium, and zinc were detected in sediment samples in the wetlands downstream from TA-18 at concentrations that exceed sediment background values but in concentrations less than respective SAL values (LANL 1995, 55527, p. 4-193; LANL 1997, 56356, p. 38). The concentration of barium appears to increase in successive wetland areas downstream from TA-18. However, other metal concentrations do not show this trend. One sample from WL-5 contained 0.02 pCi/g plutonium-238, which is above the site-wide background value for sediment.*



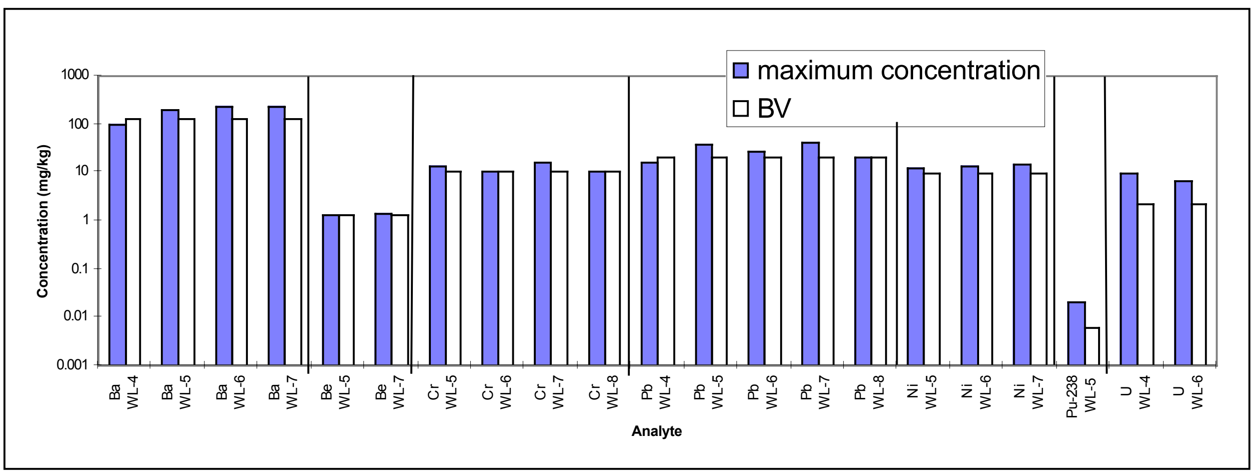

Source: LANL 1995, 55527; background values from Ryti et al. 1998, 58093

**Figure 3.4.3-6a. Results of sediment sampling of wetlands in Threemile Canyon west of TA-18.**




Source: LANL 1995, 55527; LANL 1997, 56356

**Figure 3.4.3-6b. Summary of metals results in all wetlands sediments near TA-18.**




Source: LANL 1995, 55527; LANL 1997, 56356

**Figure 3.4.3-6c. Results of sediment sampling for metals in the wetlands east of TA-18.**

*Organic compounds detected in sediments from the wetlands downstream from TA-18 that exceeded the site-specific baseline levels or that did not have background values include acetone, 2-butanone, and methylene chloride. According to the RFI report, the presence of these constituents could be the result of analytical laboratory contamination, although these compounds were not detected in the associated laboratory blank samples (LANL 1995, 55527, p. 4-193).*

#### 3.4.3.3.3 TA-54

*Channel sediment sampling was performed along the perimeter of MDA G in support of the RFI for TA-54 (see Section 3.4.3.2). An RFI report for the channel sediment pathway was prepared that focused on the transport of mesa-top sediments into the adjacent canyons (LANL 1996, 54462). Topographic maps and aerial photographs were examined, and direct field observations were made. Fourteen drainage channels associated with MDA G were selected for channel sediment sampling. Drainage basins were determined for each of the channels to estimate the area and relative contribution of sediments and water to each channel. The channels were examined from their origin on top of the mesa down to the point where they merged with larger drainage channels of Cañada del Buey to the north or Pajarito Canyon to the south. Depositional areas were identified, and seven to ten sample locations were selected in each channel. Deposits of coarse sediment and of fine sands, silts, and clays were selected for measurement. Sampling locations were also selected in depositional areas of channels that did not extend to the master stream, but where runoff infiltrates into the alluvium resulting in deposition of its sediment load (LANL 1996, 54462).*

*The results of the channel sediment sampling showed that several radionuclides were present. Some of those radionuclides have no background values; others were present at activities above their background values. Those radionuclides include americium-241; cesium-137; cobalt-60; plutonium-238; plutonium-239,240; polonium-210; strontium-90; technetium-99; tritium; uranium-235; and yttrium-90, which are all present at levels below their respective SAL values. These results are consistent with environmental surveillance data obtained since 1987 (ESG 1988, 6877; ESG 1989, 6894; Environmental Protection Group 1990, 6995; Environmental Protection Group 1992, 7004; Environmental Protection Group 1993, 23249; Environmental Protection Group 1994, 45636; Conrad et al. 1995, 52014). Several of the sediment samples contained concentrations of some inorganic constituents (including barium in one channel, copper and chromium in two channels, and lead in six channels) above background values but below SAL values. The results of the SAL comparisons and the multiple chemical evaluation show that unacceptable risk from radionuclides and inorganics is unlikely. Therefore, no COPCs were retained from the screening assessment; the RFI report recommended no further evaluation or remediation of the channels draining MDA G (LANL 1996, 54462).*

*Tritium activity in surface soil/sediments was evaluated in another RFI status report for MDA G (LANL 1997, 55873). All the data presented in the status report were compiled from the supplemental environmental surveillance data collected from 1993 to 1996, pursuant to the RFI work plan for OU 1148 (LANL 1992, 7669) (see Section 3.4.3.3). For the evaluation of tritium in surface soil/sediments, MDA G was divided into nine sectors. Sediment samples were collected from approximately 310 locations within the nine sectors and from 53 locations within the proposed MDA G expansion area. The expansion area is located west of the current disposal area at MDA G and has been proposed for development to provide additional storage and disposal capabilities. Samples were collected from within the expansion area to provide local background values, or baseline data, for comparison with data collected from the MDA G sectors.*

*Comparison of the results with the baseline data collected from the expansion area indicates that tritium concentrations throughout MDA G are greater than local background values. Three locations at MDA G, in particular, have tritium concentrations in surface soils that are much greater than background values. These locations are*

- *along the southern border of MDA G adjacent to the active tritium disposal shafts (sector 4);*
- *just west of the TRU pads near a set of inactive tritium disposal shafts (sector 6); and*
- *near the TRU pads, in particular at TRU Pad 2 (sector 9) (LANL 1997, 55873).*

*However, comparison of the tritium data with the SAL value (260 pCi/g) indicated that only one sample at MDA G exhibited a tritium concentration exceeding the SAL value; all other tritium values were less than the SAL value. One measurement of 2191 pCi/g tritium was elevated compared with other soil samples collected throughout MDA G. The next highest concentration observed in the samples was approximately 100 pCi/g. The RFI report did not propose additional soil/sediment sampling at MDA G for RFI purposes. Routine environmental surveillance activities will continue at MDA G (LANL 1997, 55873).*

### 3.4.4 Surface Sediment Data and Requirements for Understanding Surface Sediments and Associated Contaminants

*The following bullets summarize the significant information about surface sediments provided in Section 3.4.*

- *Little information about contaminants in the stream channel sediments is known in upper Pajarito Canyon. Sediment sampling adjacent to MDA M at TA-22 shows elevated concentrations of arsenic, barium, cadmium, cobalt, copper, lead, and vanadium compared with Laboratory site-wide background values.*
- *The stream channel in lower Pajarito Canyon has been highly disturbed by diversion of the stream channel and excavation of sand and gravel pits. The locations of sediment and contaminant deposition have not been adequately described or documented.*
- *Sediment sampling in wetlands in Threemile Canyon shows that barium; zinc; plutonium-238; plutonium-239,240; thorium-228; thorium-230; and total uranium are above background values.*
- *Sediments in wetlands downstream of TA-18 contain barium, beryllium, chromium, lead, nickel, silver, and zinc in concentrations above background values.*
- *Supplemental environmental surveillance of sediments along the perimeter of MDA G shows that the activity of plutonium isotopes exceeds soil background values.*
- *Routine environmental surveillance sampling of sediments at the downstream Laboratory boundary at state road NM4 shows near background values for most radionuclides. However, trace elements and metals including barium, boron, cadmium, chromium, cobalt, lead, and zinc have been measured in concentrations greater than background values in Pajarito Canyon at state road NM4. The metals observed at more than two times background values include cadmium, cobalt, and zinc. At the Rio Grande site, only cadmium is observed above background sediment values, which may be the result of greater cadmium contents in basalts at that location.*

*The following additional data are required for the evaluation of contaminants within the sediments of the Pajarito Canyon system.*

- *The full suite of contaminants that are present within the sediments at or above background values will be determined.*
- *The locations of significant contaminant sources will be determined.*
- *The average concentrations, the range of concentrations, and approximate inventories of contaminants contained with different geomorphic units and different sediment facies will be investigated, particularly for those contaminants that may be shown to be risk drivers.*
- *The horizontal and vertical distribution of contaminated sediments that have been deposited by flood events, including the nature and effects of historic channel changes, will be investigated. For example, channel bed aggradation and/or degradation, lateral migration and diversion of the active channel, and abandonment of inactive channels will be investigated at key locations within Pajarito Canyon.*

*See Section 7.2 of this work plan for a complete description of the sediment sampling and analysis plan.*

## 3.5 Previous Subsurface Sediment and Bedrock Investigations

*This section summarizes the results of previous borehole drilling in and adjacent to Pajarito Canyon. The locations of boreholes are shown in Figure A-1. Information about the boreholes is summarized in Appendix C, and additional information is shown in Figure A-2.*

### 3.5.1 Historic Boreholes

*The first holes drilled in lower Pajarito Canyon were test holes drilled by cable tool in search of water supplies for the Laboratory. Test holes 5 and 6 (PCTH-5 and -6) were drilled in March 1950 to a depth of approximately 300 ft (90 m). The holes were drilled after water was obtained from a large 15-ft- (4.5-m-) deep pit in the alluvium in 1949. However, when the holes were drilled in 1950, significant water supplies were not found in the alluvium or in deeper units (Black and Veatch 1950, 57575, p. 2; Purtymun 1995, 45344, p. 223). A summary of the information obtained from these holes is in Appendix C, and the locations of these test holes are shown in Figure A-1. The stratigraphic information obtained from these holes is shown graphically in Figure A-2.*

*In 1965 water supply well PM-2 was drilled to a depth of 2600 ft (780 m) into the Santa Fe Group sediments. Basalt in the Puye Formation was encountered beneath the Bandelier Tuff at a depth of 432 ft (130 m). The Santa Fe Group was encountered at 1410 ft (423 m). The well was completed in the regional aquifer as a municipal and industrial supply well. The screened interval is from 1004 to 2280 ft (301 to 684 m) (Purtymun 1995, 45344, p. 276). Additional information about this well can be found in Section 3.7.4.*

*In 1971 boreholes were drilled at TA-46 for construction of cryogenic separation columns for stable isotopes. The holes were drilled to a depth of 747 ft (224 m) using mud rotary techniques and were cased with 13-3/8-in.- (34-cm-) diameter casing. The holes penetrated to the top of the Puye Conglomerate and reportedly did not encounter water (Purtymun 1995, 45344, p. 209).*

*In 1984 subsurface engineering test holes at TA-18 were drilled in support of construction of three guard towers. Three test holes were drilled through the alluvium and into the tuff. Test hole 1, drilled near Kiva 2 in Threemile Canyon to a depth of 28 ft (8.4 m), encountered 14 ft (4.2 m) of alluvium. Perched groundwater was encountered in the alluvium from 9 to 14 ft (2.7 to 4.2 m), and extremely wet tuff was present beneath the alluvium. Test hole 2, drilled in lower Threemile Canyon near the confluence with Pajarito Canyon to a depth of 23 ft (7 m), encountered 12 ft (3.6 m) of alluvium. Alluvial groundwater was present from 8 to 12 ft (2.4 to 3.6 m) in this hole. The alluvium in holes 1 and 2 was mainly sand from erosion and weathering of the Tshirege Member in the Threemile Canyon watershed. Test hole 3, drilled near Kiva 1 in Pajarito Canyon to a depth of 32 ft (9.6 m), encountered 18 ft (5.4 m) of alluvium and perched alluvial groundwater from 13 to 18 ft (4 to 5.4 m). The alluvium in this hole contained volcanic rock fragments and volcanic gravels and cobbles from erosion of the volcanic rocks that form the flanks of the Sierra Valles. The cobbles were contained in a matrix of sand, silt, and clay from erosion and weathering of the Tshirege Member (Purtymun 1994, 58233, p. 162-1). The information obtained from the holes is shown in Figure A-3.*

*In 1990 four monitoring wells were drilled near Kiva 1 at TA-18. These wells were drilled to monitor possible contaminants in the groundwater associated with operations at the Los Alamos Critical Experiments Facility (LACEF) and hence have been referred to as the LACEF wells. In this work plan these wells are referred to as 18-MW-1 through 18-MW-4. Each well is approximately 25 ft (7.5 m) deep. Subsurface sediment and alluvial groundwater samples were collected in 1990 when the wells were drilled. The borehole sediment samples were analyzed for isotopic uranium, cesium, and strontium. The results of the analyses were below detection limits for cesium-137 and uranium-235. The maximum activity of strontium-90 was 0.48 pCi/g from borehole 18-MW-3. The maximum activity of uranium-234 was 0.17 pCi/g, and the maximum activity of uranium-238 was 0.16 pCi/g, both from borehole 18-MW-3 (LATA 1991, 12464, p. 4-3). These wells were subsequently sampled as part of the RFI for OU 1093 at TA-18 (LANL 1995, 55527, p. 4-179). The results of the RFI sampling of the alluvial groundwater from these wells are discussed in Section 3.7.2.5.*

*A seismic hazard borehole, SHB-4, was drilled at TA-18 in the winter of 1991 to 1992. This borehole was drilled to a depth of 200 ft (60 m) into the Otowi Member of the Bandelier Tuff. Samples were not collected for analyses, but core samples are archived at the Laboratory Sample Management Office. This borehole encountered damp bedrock from 32 to 125 ft (9.8 to 38 m) and potentially saturated conditions from 125 to 145 ft (38 to 44 m) (Gardner et al. 1993, 12582).*

### 3.5.2 RFI Boreholes at TA-3

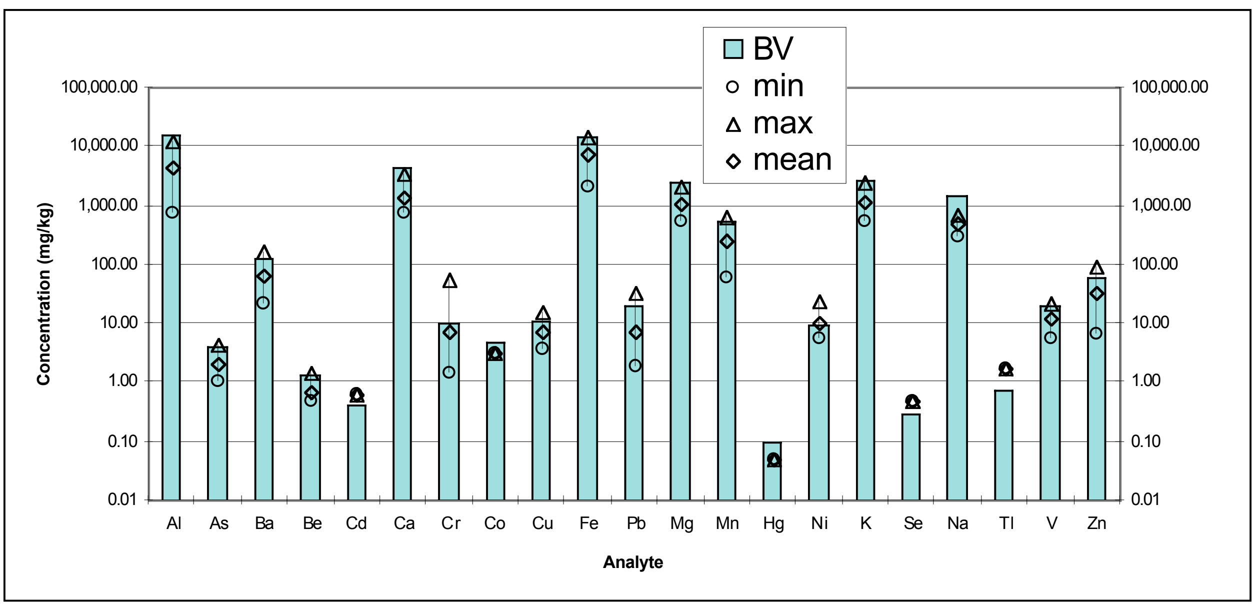
*After initiating a voluntary corrective action (VCA) at PRS 3-010(a) at TA-3, a Phase II RFI sampling and analysis plan (SAP) was implemented in 1994. The SAP was designed to determine the nature and extent of VOC, total petroleum hydrocarbons (TPH), and tritium at PRS 3-010(a) (LANL 1994, 47298). Seven boreholes were drilled; samples were collected from six boreholes for site characterization purposes, and the seventh borehole was used to provide geologic and hydrologic characterization information at the site. Subsurface soil samples were collected from every 5 ft (1.5 m) in boreholes B2 through B6 up to a depth of 30 ft (9 m) (LANL 1994, 47298).*

*Soil samples collected from boreholes B1 through B6 were analyzed for VOCs, TPH, and tritium. Eight compounds [1,1-dichloroethane; 1,2-dichloroethane; 1,1-dichloroethene; Freon-113; 1,1,1-trichlorethane (TCA); trichloroethene; TPH; and tritium) were detected in the soil samples. Two solvents (1,2-dichloroethane and 1,1-dichloroethene) were retained as potential contaminants of concern. The conclusion of the investigation was that the VCA was successful in removing the source term of the* *solvents and reducing concentrations of lead and mercury in the soil to concentrations below concern. PRS 3-010(a) was subsequently recommended for no further action in the RFI report (LANL 1995, 55638).*

### 3.5.3 RFI Boreholes at TA-18

*In 1993 and 1994 numerous boreholes were drilled at TA-18 to sample subsurface sediments as part of the RFI for OU 1093, which encompasses TA-18 and former TA-27 in lower Pajarito Canyon (LANL 1995, 55527). Additionally, in the summary of 1994, a total of 18 monitoring wells were drilled in the TA-18 area. These include monitoring wells 18-BG-1, 18-MW-5 through 18-MW-11, 18-MW-17, and 18-MW-18; and temporary wells 18-1063, -1066, -1136, -1165, -1195, -1196, -1233, and -1254. Three of the boreholes were drilled as "baseline" holes (18-BG-1, 18-1063, and 18-1066). These baseline holes are approximately 1500 ft (450 m) northwest of Kiva 1 upstream in Pajarito Canyon from TA-18. Another two wells, 18-MW-17 and 18-MW-18, were drilled east of TA-18 in lower Pajarito Canyon. Subsurface sediment samples and alluvial groundwater samples were collected from the boreholes (LANL 1995, 55527; LANL 1997, 56356). The results of the analyses of the groundwater from the wells are discussed in Section 3.7.2.5.*

*A summary of the metals results of the core samples collected from these boreholes is shown in Figure 3.5.3-1. The concentration of most metals are within background sediment levels; however, barium, chromium, copper, lead, nickel, and zinc were detected in concentrations above background values at several sites at TA-18. Barium was detected above background value at the depth of 10 ft (3 m) in RFI borehole 18-1275 at PRS 18-003(g). Chromium and nickel were detected above background values in the three baseline boreholes drilled west of TA-18, at depths ranging from 15 to 37 ft (4.5 to 11 m). Chromium, lead, and nickel were also detected above background values at depths ranging from 5 to 21 ft (1.5 to 6.3 m) at PRSs 18-003(f) and 18-003(g), a septic drainfield and a septic tank, respectively. Zinc was detected above background value at depths ranging from 5 to 7 ft (1.5 to 2.1 m) at PRS 18-013, a waste holding tank near Kiva 1 (LANL 1995, 55527).*




Source: LANL 1995, 55527

**Figure 3.5.3-1. Summary of metals results in borehole core samples at TA-18.**

*Also at PRS 18-013, the following organic compounds were detected at a depth of 4.8 ft (1.4 m): anthracene, benz[a]anthracene, benzo[a]pyrene (0.74 mg/kg), benzo[b]fluoranthene, bis(2-ethylhexyl)phthalate, chrysene, fluoranthene, phenanthrene, and pyrene. Additionally, trichlorofluoromethane was detected in three samples up to a depth of 9 ft (2.7 m) in borehole 18-1254 at PRS 18-003(f), a septic system near building TA-18-30. All organic compound detects, except one sample containing benzo[a]pyrene, were below SAL values.*

*HE compounds were detected in alluvial sediments at a depth of 5 ft (1.5 m) in a borehole (18-1079) at PRS 18-002(b), a firing site located near Kiva 2. The following HE compounds were detected above method detection limits: amino-2,6-dinitrotoluene [4-] (0.1 mg/kg); hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX) (0.856 mg/kg); and trinitrotoluene [2,4,6-] (0.867 mg/kg). HE compounds were not detected in other borehole core samples, and all detects of HE compounds in the borehole core samples were below SAL values.*

*Organic solvents were detected during the RFI at TA-18 in subsurface soil and groundwater samples adjacent to a septic system attached to Kiva 3 (LANL 1996, 55120, p. 1). Therefore, in December 1996 an additional five monitoring wells were drilled in the septic drainfield area north of Kiva 3 at PRS 18-003(d), according to the voluntary corrective action plan (LANL 1996, 56554). These wells were drilled to depths ranging from 37 to 48 ft (11 to 14.4 m). Subsurface sediment was collected from core samples and analyzed for metals, VOCs, SVOC, HE compounds, and radionuclides (LANL 1997, 57015, p. 3-1). The results of the analyses showed that metals and radionuclides were measured below background values. Two subsurface sediment samples contained the organic compounds acetone and methylene chloride but at concentrations below SAL values (LANL 1997, 57015, p. 5-8).*

*Radionuclides detected above method detection limits in borehole core samples collected at TA-18 were within SAL values and were generally within background values for canyon sediment samples. The maximum activities of radionuclides detected were 0.079 pCi/g americium-241; 0.956 pCi/g cesium-137; <0.03 pCi/g plutonium-238; and <0.01 pCi/g plutonium-239,240 (LANL 1996, 54919, Appendix D).*

### 3.5.4 Boreholes, Shafts, Pits, and Subsurface Sampling at TA-54

*Migration of tritium in the MDA G shaft disposal area was first detected in 1970. Tuff samples were collected from approximately 15 shafts and analyzed for moisture content and tritium content in moisture. The moisture content averaged 1.2% by volume, and the tritium content in moisture activity ranged from 0 to 1180 pCi/ml. Monitoring during the 1970s revealed that tritium at concentrations of 100 pCi/ml had moved a distance of approximately 105 ft (32 m) west along the contact between two ash-flow units. The areal distribution of the concentrations and the low moisture content of the tuff indicate that the tritium was being distributed through the pore space of the tuff by diffusion in water vapor. The tritium concentration data indicated the presence of a lens-shaped plume, shortened to the east and elongated to the west. The 100 pCi/ml contour line was extrapolated beneath the shafts to a depth of approximately 97 ft (29 m) below the surface of the mesa (Rogers 1977, 5708).*

*Recorded tritium concentrations around Pit 1 at MDA G were three orders of magnitude greater than the average measured background values of 0 to 20 pCi/ml for both solid and near-surface tuff. The significant concentration gradient toward the surface indicates that tritium was diffusion toward and perhaps out of the ground surface (Rogers 1977, 5708; Purtymun et al. 1978, 5728).*

*In 1985 18 test holes were cored or augered at TA-54 to characterize the vadose zone in and around the chemical disposal pits and shafts at MDA L and the radioactive waste disposal pits and shafts at MDA G. The holes ranged in depth from 60 to 145 ft (18 to 44 m) and were used for pore moisture measurements,* *core pore-gas sampling, psychrometer tests, in situ permeability tests, and neutron probe moisture access holes in an effort to investigate the hydrologic properties of the tuff. Core samples were analyzed for organic and inorganic constituents and radionuclides. Seven additional holes were cored in 1986 for core and pore-gas sampling, and 10 more holes were cored between 1988 and 1990 to monitor vapors in the tuff (Purtymun 1995, 45344, p. 185). The results of the investigations were presented by Kearl et al. (1986, 8414).*

*From 1985 to 1990 a total of 27 boreholes were drilled at TA-54 to characterize the vadose zone beneath the chemical disposal pits and shafts at MDA L. The holes ranged in depth from 120 to approximately 300 ft (36 to 90 m). In 1988 several holes were drilled to the basalts at the top of the Puye Formation. The basalts were encountered at depths ranging from 198 to 298 ft (59 to 89 m) (Purtymun 1995, 45344, p. 185). The results of the drilling showed that an organic vapor plume is present beneath MDA L that extends to the depth of the basalt. The RFI for OU 1148 continued characterization of the vadose zone beneath MDA L. A total of 21 organic compounds have been identified in the plume; the most concentrated compound is TCA (LANL 1996, 53791).*

*In 1985 seven shallow boreholes were drilled in Pajarito Canyon to determine if tritium and other contaminants from TA-54 had migrated southward into sediments, bedrock, or alluvial groundwater. The results of the drilling showed that no tritium or other contaminants were present in Pajarito Canyon (Devaurs and Purtymun 1985, 7415, p. 12; Devaurs 1985, 7416). Three of the holes were completed as monitoring wells (PCO-1, -2, and -3), and four were completed as moisture access tubes (PCM-1, -2, -3, and -4.) These boreholes and wells are more fully described in Section 3.7.2.*

## 3.6 Surface Water Hydrology

*The water that flows through Pajarito Canyon is used by wildlife and plants and potentially by humans; therefore, it constitutes a transport pathway to potential receptors. The results of past investigations of surface water (described in this section) and groundwater (described in Section 3.7) 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 possible transport through the unsaturated and saturated zones within the canyon system.*

*Surface water flow provides one of the primary mechanisms for redistributing and transporting contaminants that may be present in the Pajarito Canyon system.*

*Relevant aspects of surface water hydrology include the following:*

- *areas, pathways, and rates of surface water runoff, wastewater discharges, and sediment deposition;*
- *rates of contaminant dissolution and desorption, transport, and sedimentation;*
- *relationships between infiltration, runoff, evaporation and transpiration, and wastewater discharges;*
- *presence and effectiveness of adsorptive media in the sediments in retarding infiltration of water-borne contaminants; and*
- *where contaminants are present, fate of surface water that infiltrates into the alluvium.*

*The general hydrology of the canyon systems is discussed in Section 2.4.2 of the IWP (LANL 1996, 55574) and Section 3.5 of the core document (LANL 1997, 55622). The discussion in this section elaborates on surface water as a potential contaminant transport pathway in the Pajarito Canyon system.*

### 3.6.1 Pajarito Canyon Stream Channel System and Streamflow

*The geomorphology of the stream channel characteristics of Pajarito Canyon and its tributaries are described in Section 3.1.*

*Pajarito Canyon surface water originates on the flanks of the Sierra de los Valles west of the Pajarito Plateau. The drainage basin area from the headwaters in the canyon to the eastern Laboratory boundary is approximately 10.6 $mi^2$ (27.6 $km^2$). Streamflow in three reaches of the canyon system (on the mountain flank below PC Spring, in the western portion of the plateau, and near the Rio Grande) is fed by springs and is perennial. Figure A-1 shows the locations of perennial streamflow in the Pajarito Canyon watershed; other reaches of the canyon are ephemeral.*

*From 1914 to 1960 surface water in upper Pajarito Canyon was diverted initially for homestead use and later for fire control and use by the Los Alamos townsite (see Section 2.1.2). In 1947 the flow of water diverted from upper Pajarito Canyon west of state road NM501 averaged 33.2 gallons per minute (gpm) (126.2 liters per minute [L/m]) (0.07 cubic feet per second [cfs]). This was the amount of flow collected from upper Pajarito Canyon after stream loss across the Pajarito fault (Stearns 1948, 11871). In 1952 minimum streamflow in upper Pajarito Canyon west of the Laboratory boundary was 35,000 gallons per day (gpd) (133,00 liters per day [L/d]) (0.05 cfs) and was as high as 180,000 gpd (684,000 L/d) (0.28 cfs) during spring snowmelt runoff (Griggs 1964, 8795, p. 90).*

*The streamflow is ephemeral across the central and eastern Pajarito Plateau where the canyon passes through TA-18 to the Rio Grande. Storm water runoff drains into the canyon from the flanks of the mountains and surrounding mesas. During peak flow events, streamflow in Pajarito Canyon may occasionally reach the Rio Grande. A significant volume of surface flow recharges the shallow alluvial groundwater body in the canyon, and the remainder is lost through infiltration into subsurface units and through evapotranspiration (Purtymun and Kennedy 1971, 4798, p. 8; LATA 1991, 12464, p. 2-7).*

*Borrow pits in lower Pajarito Canyon east of TA-18 were excavated deep enough to occasionally intersect the perched alluvial water, depending on the seasonal variability of the water levels. The borrow pits frequently contain ponded water from local storm water runoff, Laboratory discharges, or streamflow into the pits. Semipermanent wetlands have developed in the abandoned pits. The surface of the water in these depressions probably coincides with the alluvial water table (LANL 1997, 55120, p. 6).*

*In Pajarito Canyon, Twomile Canyon, and Threemile Canyon the 100-year floodplain occupies an area along the canyon floor more or less centered on the stream channel (McLin 1992, 0825). Therefore, PRSs near or adjacent to the stream channel are within the 100-year floodplain. Most of the structures at TA-18 and their associated PRSs are above the 100-year floodplain.*

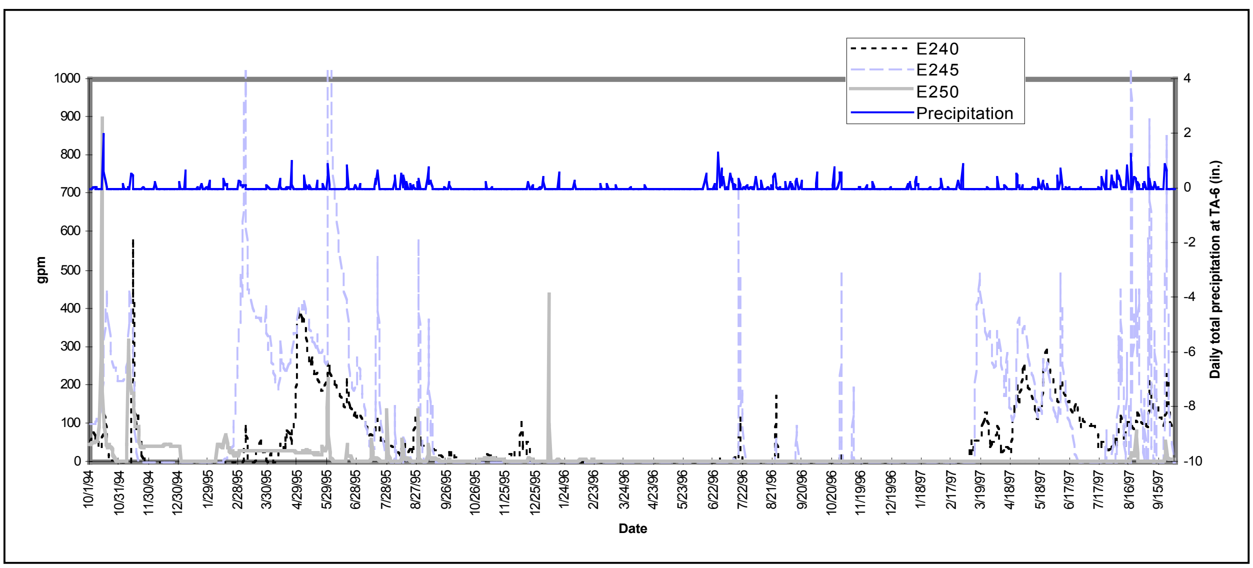
*Table 2.2.1-2 in Section 2.2.1 lists the NPDES-permitted outfalls into Pajarito Canyon and its tributaries and summarizes the current status and source of each outfall and its discharge point. Figure A-1 shows the locations of NPDES-permitted outfalls in the Pajarito Canyon watershed and shows the locations of the wetlands in lower Threemile Canyon and Pajarito Canyon. During the past few years, most of the outfalls in the watershed have been deleted from the NPDES permit. The outfalls that remain active discharge small volumes to the watershed, usually less than approximately 1 to 2 gpm. Potentially one of the largest volumes of discharge to Pajarito Canyon may be from occasional purging of PM-2. Some years this well is operated only during the summer months, which requires several days of pumping 1000 to 1500 gpm (3800 to 5700 L/m) to clean out the well bore. At times this may be one of the primary sources of surface water in lower Pajarito Canyon.*

*Some outfalls may support short reaches that occasionally flow for a short distance when the outfall is active. Some outfalls may also have created small cattail areas. Intermittent flow from outfalls in the upper part of the canyons, such as upper Twomile Canyon and Threemile Canyon, apparently may infiltrate into alluvial sediments and may reemerge downstream as springs such as the TW-1.72 or Threemile Spring. Flow from the outfalls, especially occasional high-volume discharges from well PM-2, probably helps support the small body of alluvial groundwater in lower Pajarito Canyon. Since 1995 many of the NPDES outfalls were redirected to the sanitary waste treatment system or otherwise eliminated, which has resulted in a decreased volume of discharge into Pajarito Canyon. The volume of flow in the stream channel in lower Pajarito Canyon probably has decreased since redirection of the outfalls, concurrent with a lowering of the alluvial groundwater levels in the lower part of the canyon (see Section 3.7.2).*

*In lower Pajarito Canyon, downstream of TA-18 and the Threemile Canyon confluence, the Pajarito Canyon channel becomes wider and contains ephemeral wetland areas in the abandoned borrow pits. Ephemeral streamflow through this part of the canyon is supported primarily by local runoff and streamflow from up canyon. Occasional storm events and snowmelt runoff may create continuous flow throughout the canyon to the Rio Grande.*

*Three stream gaging stations were constructed in Pajarito Canyon in 1993 to measure streamflow volumes. Figure A-1 shows the locations of the stream gages.*

*Gaging station E240 (08313240) is located in upper Pajarito Canyon approximately 200 ft (61 m) west (upstream) of state road NM501 at an elevation of 7760 ft (2366 m). The gage is located downstream of the Pajarito fault zone. This gage was installed in October 1993 to measure flow volume in the upper part of the Pajarito Canyon watershed that crosses from National Forest land onto Laboratory property. The drainage area at this gage is 1.90 $mi^2$ (4.9 $km^2$). The daily flow volume recorded at this gaging station for the period October 1, 1994, through September 30, 1997, is shown in Figure 3.6.1-1 (Shaull et al. 1996, 56019; Shaull et al. 1996, 56020; Shaull et al. 1998, 57581). During this period the average daily flow volume measured was 45.7 gpm (0.1 cfs), and the maximum daily flow volume was 580 gpm (1.3 cfs).*




Source: Shaull et al. 1996, 56019; Shaull et al. 1996, 56020; Shaull et al. 1998, 57581

**Figure 3.6.1-1. Mean daily discharge at stream gaging stations in Pajarito Canyon.**

*The major contribution to streamflow at gage E240 during the period of record is from snowmelt runoff that began in March and April 1995 and 1997, with peak flow occurring at the end of April. The streamflow continued, probably as spring-fed runoff through the summer of 1995 and 1997. Low precipitation and snowpack amounts during the winter of 1995 to 1996 appear to have resulted in almost no spring runoff in 1996. Streamflow in Pajarito Canyon was not recorded in 1996 until summer rains caused occasional streamflow measurements. Perennial streamflow from PC Spring typically extends to within a few hundred feet upstream of the E240 gage, where the flow apparently largely infiltrates into the Pajarito fault zone. Continuous flow at this gage was recorded from approximately April 1, 1995, to December 20, 1995, and from March 1, 1997, to September 30, 1997.*

*Gaging station E245 (08313245) is located in middle Pajarito Canyon approximately 1.5 mi (2.4 km) upstream from TA-18 and the confluence with Threemile Canyon and approximately 0.7 mi (1.1 km) below the confluence with Twomile Canyon. This gage was installed in November 1993 to measure flow in central Pajarito Canyon below the confluence with Twomile Canyon. The drainage area above this stream gage is 7.84 mi$^2$ (20.4 km$^2$), and the gage is at an elevation of 6865 ft (2093 m). The daily flow volume recorded at this gaging station for the period October 1, 1994, through September 30, 1997, is shown in Figure 3.6.1-1 (Shaull et al. 1996, 56019; Shaull et al. 1996, 56020; Shaull et al. 1998, 57581). Streamflow volumes at this location are generally greater than at the upper gaging station because of the larger drainage area. During the period of record, the average daily flow volume recorded was 95 gpm (0.21 cfs), and the maximum daily flow volume was 1700 gpm (3.8 cfs). Spring snowmelt runoff volume is greater at this location than the upper gaging station, and the peak snowmelt runoff event occurs sooner in the year because of the lower elevation of this gage. Flow at this gage also results from seasonal rainstorms, after which some of the highest streamflow volumes in Pajarito Canyon have been recorded. Continuous flow was recorded at this location from approximately March 1, 1995, to September 15, 1995, and from March 15, 1997, to approximately June 20, 1997. Flow volumes recorded during the latter part of 1997 were highly variable and resulted directly from precipitation events.*

*Gaging station E250 (08313250) is located in lower Pajarito Canyon approximately 0.25 mi (0.4 km) upstream from the eastern Laboratory boundary and state road NM4. This gage was installed in November 1993 to measure flow from the lower portion of Pajarito Canyon before it crosses the Laboratory boundary. The drainage area above this stream gage is 10.9 mi$^2$ (28.2 km$^2$), and the gage is at an elevation of 6550 ft (1997 m). The daily flow volume recorded at this gaging station for the period October 1, 1994, through September 30, 1997, is shown in Figure 3.6.1-1 (Shaull et al. 1996, 56019; Shaull et al. 1996, 56020; Shaull et al. 1998, 57581). Flow at this gage was recorded continuously or intermittently from October 1, 1994, until approximately the end of 1995. Almost no flow was measured through 1995 until late August 1997. During the period of record, the average daily flow volume recorded was 11 gpm (0.02 cfs), and the maximum daily flow volume was 898 gpm (2 cfs).*

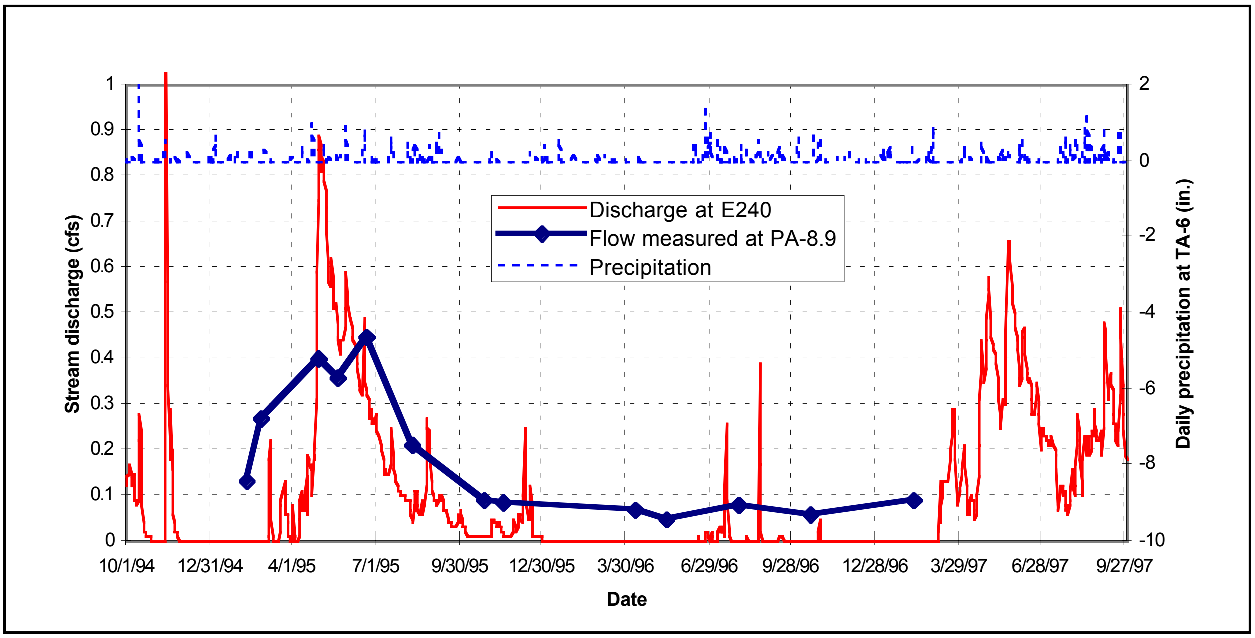
*The flow at this gage may depend on the amount of storage in the alluvial groundwater in lower Pajarito Canyon. When the alluvium in the lower part of Pajarito Canyon is saturated, additional inflow into the lower canyon from precipitation and/or Laboratory discharges may cause steady flow at gaging station E250 (as was measured in the fall of 1994). However, after the relatively dry winter of 1995 to 1996, the alluvium in the lower part of the canyon may have become unsaturated and very little flow was recorded in 1996 and 1997, even after significant precipitation events.*

*During the period of stream gage records, the average annual flow at E245 was 6.7 million ft$^3$ (0.2 million m$^3$) per year and at E250 was 0.77 million ft$^3$ (0.02 million m$^3$) per year. This represents a net stream loss of approximately 6 million ft$^3$ (0.18 million m$^3$) per year between these two gaging stations. Stream loss is* *primarily caused by infiltration of surface water into the alluvium, which is enhanced in wetland areas created in abandoned gravel pits in the lower canyon.*

*A direct reading stream gage (flume) was recently installed in lower Threemile Canyon west of Kiva 2 at TA-18 (Gould 1997, 56015). However, systematic readings from this flume have not been obtained. A new stream gage may be installed in lower Pajarito Canyon downstream from TA-18 and near well PM-2 (LANL 1997, 56356, p. A5).*

*ESH-18 personnel collect surface water and runoff samples for environmental monitoring. Runoff samples are collected at one station in Pajarito Canyon (at state road NM4), and surface water is collected at two locations. Surface water samples are collected annually from the stream channel near monitoring well PCO-1 and in lower off-site Pajarito Canyon upstream from the Rio Grande. The surface water flow in the lower reaches of Pajarito Canyon upstream from the Rio Grande are primarily the result of spring flow from Pajarito Springs, which are called Spring 4A and Spring 4AA in the environmental surveillance reports. The results of the sampling and analyses are discussed in Section 3.6.6.*

*In 1995 personnel from the NMED DOE Oversight Bureau established a temporary surface water gaging station in Pajarito Canyon downstream from the confluence of the south fork of Pajarito Canyon and upstream of the confluence with north Anchor East basin. The station is called PA-8.9, referring to the distance in Pajarito Canyon upstream from the Rio Grande (Dale 1998, 57286, p. 6). The location of the stream gage is shown in Figure A-1. Periodic flow measurements obtained at this stream gage during a two-year period are shown in Figure 3.6.1-2. Flow measurements obtained at gaging station E240, which is located west of the Laboratory boundary in upper Pajarito Canyon, and daily precipitation totals are also shown in Figure 3.6.1-2.*




Source: Dale 1998, 57286, p. 12

**Figure 3.6.1-2. Streamflow measurements at gaging stations PA-8.9 and E240.**

*During the period of this investigation, the stream in Pajarito Canyon directly upstream from Homestead Spring was observed to be dry when the flow measurements were made at PA-8.9. In upper Pajarito Canyon the stream exhibits potentially perennial flow in a limited reach west of the Laboratory boundary below PC Spring. However, significant stream loss appears to occur at the intersection of Pajarito Canyon with the Pajarito fault approximately 0.25 mi (0.4 km) west of state road NM501 (Stearns 1948, 11871, p. 11; Dale 1998, 57286, p. 7).*

*Streamflow below Homestead Spring in Pajarito Canyon is supplemented by flow from springs in the south fork of Pajarito Canyon. The hydrograph of streamflow at PA-8.9 is generally similar to that for E240, although streamflow is not continuous between the two stations. Except during the snowmelt runoff period from April to June in 1995, the flow rate measurements at PA-8.9 exceeded the flow rates recorded at E240 for the discrete times evaluated. The lack of resolution in the PA-8.9 data precludes a definitive correlation between the two stations, but the data suggest that in the absence of significant snowmelt runoff, the streamflow reaches present in upper Pajarito Canyon are predominantly fed by spring discharges.*

*During a one-year period from December 1996 to November 1997, the United States Fish and Wildlife Service conducted an investigation of the streamflow in Pajarito Canyon downstream of the confluence with the south fork of Pajarito Canyon. A continuous reading water-quality monitor was installed in the stream channel. Measurements for date, time, temperature, pH, specific conductance, and dissolved oxygen were recorded hourly during the one-year period. Short gaps in the record were experienced when the monitor was washed out by flooding, but the data indicate that the stream flowed continuously from December 1996 to November 1997 (Dale 1998, 57286, p. 9).*

*The preliminary investigations conducted into the streamflow in upper Pajarito Canyon concluded that*

- *potentially perennial surface-water conditions occur in the reaches of upper Pajarito Canyon and*
- *the magnitude and extent of streamflow appears to vary seasonally in response to precipitation (and snowmelt) conditions (Dale 1998, 57286, p. 18).*

*In November 1995 personnel from the NMED DOE Oversight Bureau measured streamflow volumes in selected reaches of Twomile Canyon, upper Pajarito Canyon, the south fork of Pajarito Canyon, and north Anchor East basin. The streamflow measured in Pajarito Canyon below Homestead Spring was 4.9 gpm (18.6 L/m); the streamflow in the lower part of the south fork of Pajarito Canyon was 22.6 gpm (85.9 L/m); the streamflow in lower north Anchor East basin was 15.5 gpm (59 L/m). The combined flow in Pajarito Canyon below the confluence with the south fork of Pajarito Canyon was 38.5 gpm (146 L/m). Twomile Canyon downstream from Anderson Spring and Hanlon Spring was measured at 3.4 gpm (12.9 L/m) (Dale et al. 1996, 57014, p. 63; Dale 1998, 57286, p. 9).*

### 3.6.2 Springs in Pajarito Canyon

*Numerous springs, both perennial and ephemeral, are present in Pajarito Canyon. An early inventory of springs on the Pajarito Plateau listed two perennial springs in Pajarito Canyon: PC Spring near the head of the canyon and Pajarito Springs in White Rock Canyon (John et al. 1966, 8796, p. 118), which are called Spring 4A and Spring 4AA in the environmental surveillance reports. A more complete listing of springs in the canyon was prepared by Dale and Yanicak (1996, 57753). A list of the known springs and seeps located in Pajarito Canyon is shown in Table 3.6.2-1.*

**TABLE 3.6.2-1**

**SPRINGS IN PAJARITO CANYON**

| Name | Location | Type | Elev (ft) | Formation | Source | Rock Source |
|---|---|---|---|---|---|---|
| Anderson | Twomile Canyon | Perennial | 7440 | Qbt | Dale et al. 1996, 57014 | Tshirege Member |
| Bryan | "Starmer Gulch"[a] | Seep? | 7406 | | Dale et al. 1996, 57014 | Tshirege Member |
| Bulldog | "Arroyo de LaDelfe"[b] | Perennial | 7390 | Qbt | Dale et al. 1996, 57014 | Tshirege Member |
| Charlie's | "Starmer Gulch" | Perennial | 7480 | Qbt | Dale et al. 1996, 57014 | Tshirege Member |
| Garvey | "Starmer Gulch" | Seasonal | 7465 | Qbt | Dale et al. 1996, 57014 | Tshirege Member |
| Hanlon | Twomile Canyon | Seasonal | 7460 | Qbt | Dale et al. 1996, 57014 | Tshirege Member |
| Homestead | Pajarito Canyon | Perennial | 7450 | Qbt | Dale et al. 1996, 57014 | Tshirege Member |
| Josie | "Starmer Gulch" | Seasonal | 7380 | Qbt | Dale et al. 1996, 57014 | Tshirege Member |
| Kieling | "Arroyo de LaDelfe" | Seasonal | 7400 | Qbt | Dale et al. 1996, 57014 | Tshirege Member |
| PC | Upper Pajarito Canyon | Perennial | 8650 | Qal, Qv | John et al. 1966, 8796 | Tshirege Member |
| Perkins | "Starmer Gulch" | Seasonal | 7460 | Qbt | Dale et al. 1996, 57014 | Tshirege Member |
| SM-30 | North Twomile Canyon | Seasonal | 7420 | Qal, Qbt | Dale et al. 1996, 57014 | Tshirege Member |
| SM-30A | North Twomile Canyon | Seasonal | 7410 | Qal, Qbt | Dale et al. 1996, 57014 | Tshirege Member |
| Spring 4 | White Rock Canyon | Perennial | 5420 | Tpt | John et al. 1966, 8796 | Fault Block in Puye Formation |
| Pajarito Springs (4A) | Lower Pajarito Canyon | Perennial | 5640 | Tpt | John et al. 1966, 8796 | Puye Formation at Rotational Fault |
| Pajarito Springs (4AA) | Lower Pajarito Canyon | Perennial | 5630 | Tpt | Dale et al. 1996, 57014 | Puye Formation at Rotational Fault |
| Starmer | "Starmer Gulch" | Perennial | 7460 | Qbt | Dale et al. 1996, 57014 | Tshirege Member |
| TA-18 | Threemile Canyon | Perennial | 6760 | Qbt | Dale et al. 1996, 57014 | Tshirege Member |
| Threemile A | Threemile Canyon | Seasonal | 6795 | Qal, Qbt | Dale et al. 1996, 57014 | Tshirege Member |
| Threemile B | Threemile Canyon | Seasonal, located near "A" | 6795 | Qal, Qbt | Dale et al. 1996, 57014 | Tshirege Member |
| TW-1.72 | Twomile Canyon | Unknown | 7460 | Qbt | Dale et al. 1996, 57014 | Tshirege Member |
| Upper Starmer | "Starmer Gulch" | Seasonal | 7490 | Qbt | Dale et al. 1996, 57014 | Tshirege Member |

a. Located in the lower part of the south fork of Pajarito Canyon

b. Located in the lower part of the north Anchor East basin

PC Spring is located in upper Pajarito Canyon on National Forest land approximately 1.6 mi (2.6 km) west (upstream) of the Laboratory boundary at an elevation of approximately 8660 ft (2640 m). On July 9, 1948, the spring flow volume was estimated to be 25 gpm from seeps issuing from a contact in volcanic rocks to the alluvium and colluvium in the floor of the canyon (Stearns 1948, 11871, p. 11; John et al. 1966, 8796, p. 120). Griggs (1964, 8795, p 91) reported that the spring "emerges from alluvium and talus in the floor of the canyon." During a sampling event on May 22, 1991, the stream below the spring was reported to be flowing approximately 32 gpm (120 L/m) (Blake et al. 1995, 49931, p. 8).

*Numerous springs and seeps discharge to Pajarito Canyon and its tributaries near the western Laboratory boundary. These springs are shown in Figure A-1 and may be the result of surface water infiltrating into the Pajarito fault zone west of the Laboratory boundary. Surface water flows diminish across this fault in upper Pajarito Canyon, which indicates that infiltrating water moves downward along the Pajarito fault (Dale 1998, 57286, p. 7). Some of this water may become perched locally along bedding planes such as surge beds in the upper units of the Tshirege Member. The perched groundwater may move laterally down-dip for a distance east of the fault where the water either infiltrates deeper or emerges as springs along the bedding planes (Griggs 1964, 8795, p. 89). Rogers (1995, 54419, sheet 2) indicated the presence of several small normal faults on Laboratory property in the area east of the Pajarito fault that, if present, may also provide conduits for the spring discharge. Several of the springs in this area are reported to be perennial, including Homestead Spring, which discharges to Pajarito Canyon, Starmer Spring and Charlie's Spring, which discharge to the south fork of Pajarito Canyon, Bulldog Spring, which discharges to north Anchor East basin, and Anderson Spring, which discharges to Twomile Canyon (Dale and Yanicak 1996, 57753, p. 78).*

*Anderson Spring was measured to be flowing 0.5 gpm (2 L/m) in November 1995. In Pajarito Canyon below the confluence with the south fork of Pajarito Canyon, combined surface water flow from springs was measured at location PA-8.9, as described in Section 3.5 (Dale et al. 1996, 57014).*

*The springs in upper Pajarito Canyon and the south fork of Pajarito Canyon were investigated as part of the RFI for OU 1157, because of the proximity to MDA M and other PRSs at TA-22 (LANL 1993, 20949, p. 6-138). Homestead Spring is located north of MDA M in Pajarito Canyon and is sometimes referred to as TA-22 Spring. This spring was observed to flow at an estimated rate of 5 gpm (19 L/m) in March 1992 and approximately 2 gpm (7.6 L/m) in September 1992. The stream channel upstream of Homestead Spring was dry in September 1992. The water from Homestead Spring discharges from the side of the canyon and appears to come from a shallow perched-water zone in the Tshirege Member (LANL 1993, 20949, p. 6-139).*

*Charlie's Spring and Starmer Spring are located south of MDA M in "Starmer Gulch." Charlie's Spring discharges from the north side of the south fork of Pajarito Canyon beneath MDA M and was observed to flow at a rate of approximately 1 gpm (3.8 L/m) in September 1992. Starmer Spring discharges from the south side of the south fork of Pajarito Canyon approximately 30 ft (9 m) downstream from Charlie's Spring and was observed flowing at approximately 4 gpm (15 L/m) in September 1992. Starmer Spring is similar in elevation to Homestead Spring; these springs may originate from the same perched zone (LANL 1993, 20949, p. 6-139).*

*Most of the active TA-8 outfalls (Table 2.3.6-1) discharge to upstream tributaries of the south fork of Pajarito Canyon and are potential supplemental sources for the springs in the south fork of Pajarito Canyon. The stream channel upstream of the springs in the south fork of Pajarito Canyon was dry in September 1992; however, the vegetation near the springs indicated that the springs may be perennial. The source of the springs is unknown; however, possibilities include a perched zone west of the Laboratory boundary (possibly from the Pajarito fault zone), potential local infiltration from mesa tops, or recharge from the saturated alluvium present on the floors of Pajarito Canyon and its tributaries (LANL 1993, 20949, p. 6-139).*

*Two primary springs discharge into Threemile Canyon: Threemile Spring and TA-18 Spring. Threemile Spring is located approximately 0.5 mi (0.8 km) west of Kiva 2 at TA-18. This spring appears to discharge from alluvium on the floor of the stream channel. In November 1995 this spring was measured to be flowing 7.6 gpm (29 L/m). A nearby smaller spring downstream from Threemile Spring, called Threemile B*

*Spring, appears to be emergent flow from the alluvium associated with flow from Threemile Spring. Threemile Spring is ephemeral in nature. TA-18 spring is located approximately 150 ft (45 m) west of Kiva 2 at TA-18 and discharges from backfill material on the north side of the canyon. TA-18 Spring is reported to be perennial; in November 1995 this spring was measured to be flowing 1.6 gpm (6 L/m) (Dale et al. 1996, 57014). The curious nature of the discharge location of TA-18 Spring from backfill material has prompted suggestions that a pipe from upstream in Threemile Canyon may be the source of TA-18 Spring. Although recent observations suggest that TA-18 Spring may be perennial, the Pajarito Club, a recreational hunting ranch established in 1914, closed shortly thereafter because of "drying of the spring and the advent of World War I" (Foxx and Tierney 1994, 5950).*

*The springs in Threemile Canyon may originate from underflow in the alluvium in Threemile Canyon or from a possible perched zone in the colonnade tuff at the base of unit Qbt 1v. In this area the Tshirege units are dipping to the southeast (see Appendix D). Construction of stratigraphic cross sections along the strike of the bedrock units through these springs (see Figure A-3) suggests that a plausible source of the water to these springs may be the infiltration of alluvial groundwater into the bedrock in middle Pajarito Canyon near stream gage E245. Geochemical data collected from the surface water in Pajarito Canyon and the springs in Threemile Canyon, as discussed in Section 3.6.6, may provide additional insight for the source of the springs in Threemile Canyon.*

*Pajarito Springs (Spring 4A) is located in lower Pajarito Canyon at an elevation of approximately 5640 ft (1720 m), above the confluence with the Rio Grande, which is at an elevation of 5420 ft (1650 m). This spring reportedly flows from gravel beds of the Totavi Lentil near the base of the Puye Formation (John et al. 1966, 8796, p. 119). However, because the spring is located along a rotational slump fault in White Rock Canyon, it is difficult to determine from which strata the spring actually discharges. During the 1960s this spring was equipped with a water-stage recorder to monitor the spring flow. At that time the spring flow measurement was 122 gpm (464 L/m). The water-stage recorder was installed to determine if well development and pumping from the regional aquifer on the Pajarito Plateau affected the spring flow. No effects from pumping of the wells were observed at Pajarito Springs (Spring 4A) (John et al. 1966, 8796, p. 118). Since then, Pajarito Springs (Spring 4A) has been routinely sampled by ESH-18. The results of the sampling are discussed in Section 3.6.6.*

*The temperature of the water at Pajarito Springs (Spring 4A) ranges from 20.2° to 20.6° C, which is similar to the temperature measured in regional aquifer wells on the Pajarito Plateau. The temperature at Spring 4A is slightly warmer than water from Springs 4, 4B, and 4C, which discharge directly into the Rio Grande and which normally range in temperature from 10° to 16° C. The higher temperature of Spring 4A may indicate that this spring discharges directly from the regional aquifer, whereas Spring 4 may be the result of water seeping through the slump block material from Spring 4A (Blake et al. 1995, 49931, p. 27). Alternatively, it has also been suggested that Spring 4A may be recharged from surface water from upstream within Pajarito Canyon (Dale et al. 1996, 57014, p. 15); however, this would not explain the higher temperature or low tritium values reported for Spring 4A (Blake et al. 1995, 49931, p. 28) (see Section 3.6.6.3).*

*Reference to springs and seeps in Pajarito Canyon were made by Foxx and Tierney (1984, 5950, p. 35); however, the locations of the springs and seeps mentioned were not defined. When describing Pajarito Canyon, Foxx and Tierney state*

> *At about 7100 ft, just where it [the canyon] broadens into a wide valley, permanent springs have been bull-dozed into ponds, and a small check dam has been built down-grade across a seep,*

> *which, in the 3 years we have worked in the area, has never been dry. The seeps here may have been perennial since prehistoric times as evidenced by the nearby, exceptionally large, pueblo ruin of Tsirege [sic].*

*The reference to bulldozed ponds may be the abandoned borrow pits that are present in lower Pajarito Canyon, and the seeps mentioned near the Tshirege Ruins may be alluvial groundwater that intersects the bottom of the borrow pits.*

### 3.6.3 Surface Water Runoff

#### 3.6.3.1 Normal Seasonal Runoff

*Surface water runoff into the canyon system varies with the amount of seasonal precipitation in the watershed. Spring flow, snowmelt, and storm water runoff from the upper canyon at the western Laboratory boundary are monitored by streamflow past gaging station E240. Gaging station E245 measures runoff and streamflow in Pajarito Canyon below the Twomile Canyon confluence, and gaging station E250 measures runoff at the eastern Laboratory boundary. Records at these gages begin on October 1, 1994. Three years of flow records are shown in Figure 3.6.1-1. During the period of record, the average annual flow at E245 was 6.7 million $ft^3$ (0.20 million $m^3$) per year and at E250 was 0.77 million $ft^3$ (0.02 million $m^3$) per year.*

*For the 1997 water year (October 1, 1996, through September 30, 1997) a total of 7.07 million $ft^3$ (0.21 million $m^3$ ) of water passed gaging station E245 above TA-18. During this most recent water year, only approximately 70,000 $ft^3$ (2100 $m^3$) of water passed gaging station E250 at the eastern Laboratory boundary.*

#### 3.6.3.2 Storm Water and Snowmelt Runoff Investigations

*Personnel from ESH-18 periodically monitor runoff from storm water and snowmelt. The results are reported annually in environmental surveillance reports (for example, Environmental Surveillance and Compliance Programs 1997, 56684) and in surface water data reports (for example, Shaull et al. 1996, 56020).*

*A special survey of spring snowmelt runoff (draft) for the Laboratory was prepared for the water years 1993 and 1994 (AATA 1995, 57752). Results showed that surface flows in the canyon depend primarily on the snowmelt runoff. Runoff volumes depend on the amount of snowpack available on the flanks of the Sierra Valles and the seasonal temperatures. Surface flow from snowmelt runoff is variable and related to differences in daytime and nighttime temperatures. Runoff rates in Pajarito Canyon during peak snowmelt conditions in 1993 (May 3 through 7) and 1994 (May 23 and 24) were measured at the upstream gaging station (E240) and the downstream gaging station (E250). In 1993 snowmelt flow at E240 was 0.9 cfs (6.7 gallons per second [gps]) and at E250 was 0.02 cfs (0.15 gps). In 1994 snowmelt runoff at E240 was 0.003 cfs (0.022 gps), and runoff was not observed at E250 because of reduced snowpack (AATA 1995, 57752). Water quality parameters associated with the snowmelt runoff investigation are discussed in Section 3.6.6.*

### 3.6.4 Flooding Potential

*Flow and floodplain estimates for the Los Alamos region were developed by McLin (1992, 12014) using computer-based models (HEC 1 and 2) developed by the United States Army Corps of Engineers*

*Hydrologic Engineering Center. The models 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 the canyons and on different Laboratory areas and structures. Precipitation totals and floodplain elevations were projected for 2-, 5-, 10-, 25-, 50-, and 100-year storms (LANL 1995, 50124).*

*The theoretically estimated 24-hour runoff for a probability of 0.02 ("2-year recurrence interval") 6-hour storm for Pajarito Canyon at the Laboratory boundary at state road NM4 is 6 acre-feet (7400 $m^3$) (McLin 1992, 12014). The estimated 24-hour runoff for a 50-year recurrence 6-hour storm for Pajarito Canyon at this location is 169 acre-feet (208,400 $m^3$). This 50-year event corresponds to a calculated 6-hour precipitation total of 1.84 in. (over the entire watershed area), creating a peak flow of 372 cfs at the eastern Laboratory boundary.*

*Since installation of the stream gages in 1994, the peak 5-minute flow recorded at each stream gage has been 1.9 cfs at E240, 30 cfs at E245, and 4.6 cfs at E250 (Shaull et al. 1996, 56019; Shaull et al. 1996, 56020; Shaull et al. 1998, 57581). The maximum flow recorded at the Laboratory boundary for the period of record is approximately 1% of the calculated 50-year, 6-hour precipitation event; however, the period of record is not sufficient to represent a 50-year event.*

*The highest five 24-hour precipitation events recorded at Los Alamos are shown in Table 3.6.4-1 (Bowen 1990, 6899, Table 1.1). Because of the nature of thunderstorms on the Pajarito Plateau and the extreme variation in elevation difference in the Pajarito watershed area, it is unlikely that the entire Pajarito Canyon watershed has received the maximum amounts of precipitation that have been recorded during any specific event. Since 1911 the average annual maximum precipitation in a 24-hour period is approximately 1.5 in. (Bowen et al. 1990, 6899).*

**TABLE 3.6.4-1**

**HIGHEST 24-HOUR PRECIPITATION EVENTS RECORDED AT LOS ALAMOS**

| Rank | 24-Hour Precipitation (in.) | Date |
|---|---|---|
| *1* | *3.48* | *October 5, 1911* |
| *2* | *2.51* | *June 10, 1913* |
| *3* | *2.47* | *July 31, 1968* |
| *4* | *2.45* | *January 27, 1916* |
| *5* | *2.26* | *August 1, 1951* |
| **Maximum Annual Average** | *1.5* | *1911 to 1996* |

Source: Bowen 1990, 6899

### 3.6.5 Infiltration

*Surface water enters the canyon from springs, runoff, discharges from NPDES outfalls, and discharges from a basement sump (alluvial groundwater) at TA-18. Most of the surface water normally infiltrates into the alluvium and recharges a body of perched alluvial groundwater in the middle and lower canyon. As the groundwater moves through the alluvium, a significant portion is probably lost to ET, and the remainder seeps into the underlying tuff and/or the Cerro Toledo interval and basalt or continues to flow down gradient.*

*The extent of seepage into suballuvial units in Pajarito Canyon is not known. In the past holes such as PCTH -5 and -6, and PCM-1 through PCM-4, which were drilled into the suballuvial units in lower Pajarito Canyon, encountered dry rock beneath the alluvium (Devaurs and Purtymun 1985, 7415 p. 12; Purtymun 1995, 45344, p. 113, pp. 215–216). However, boreholes drilled at TA-18, such as geotechnical boreholes drilled in 1984 (18-TH-1, -2, and -3) and borehole SHB-4, drilled in 1992 (see Appendix C), encountered damp to moist bedrock beneath the alluvium. Borehole SHB-4 encountered damp bedrock from 32 to 125 ft (9.8 to 38 m) and potentially saturated conditions from 125 to 145 ft (38 to 44 m) (Gardner et al. 1993, 12582, p. 16). The occurrence of moist bedrock beneath the alluvium indicates the possibility of seepage into deeper units.*

*From October 1, 1994, through September 30, 1996, the average annual flow recorded at gaging station E245 was 6.7 million ft$^3$ (0.2 million m$^3$) per year and at gaging station E250 was 0.77 million ft$^3$ (0.02 million m$^3$) per year. This represents an average net stream loss of approximately 6 million ft$^3$ (0.18 million m$^3$) per year between these two gaging stations. Some of this stream loss is attributable to evaporation, but most is probably caused by infiltration into the alluvium. Some of this stream loss may infiltrate into the adjacent tuff and provide a source of recharge to possible perched intermediate zones. It does not reappear as downstream flow or in the lower alluvial basin.*

*Infiltration through mesa tops is very slow. At the surface of the mesa tops, evapotranspiration consumes approximately 90% of precipitation, which leaves little water for runoff or infiltration. The mean annual calculated percolation of water beneath the surface on mesa tops is approximately 1 mm (0.04 in.) per year. Infiltration beneath canyon floors is higher and has been calculated to be approximately 4.4 mm (0.18 in.) per year beneath Cañada del Buey and between 20 and 100 mm (0.8 and 4 in.) per year beneath Pajarito Canyon (LANL 1998, 57576).*

*Streamflow from PC Spring may largely infiltrate into the Pajarito fault zone providing recharge to subsurface units. Isotopic data (see Table 3.6.6-4) indicate that the water emerging from PC Spring is "old" water and is not from recent snowmelt. If this is confirmed, then this infiltration is an added input to the subsurface water balance in the watershed.*

### 3.6.6 Surface Water Quality and Contaminant Data

#### 3.6.6.1 Results of Environmental Surveillance Sampling of Surface Waters

*ESH-18 personnel annually collect surface water samples from the Pajarito Canyon stream near monitoring well PCO-1 and in lower Pajarito Canyon upstream from the confluence with the Rio Grande (for example, Environmental Surveillance and Compliance Programs 1997, 56684). In 1967, 1971, and 1972 surface water samples were also collected from an abandoned borrow pit downstream from TA-18 (Purtymun 1975, 11787). Additionally, storm water runoff samples are periodically collected from the stream channel at state road NM501, near PCO-1, and at state road NM4 after significant runoff events. Most of the storm water runoff samples have been collected at state road NM4 at the eastern Laboratory boundary. The following discussion of the results of environmental surveillance sampling is primarily about data presented annually in the environmental surveillance reports (for example, Environmental Surveillance and Compliance Programs 1997, 56684).*

#### 3.6.6.1.1 Surface Water Quality

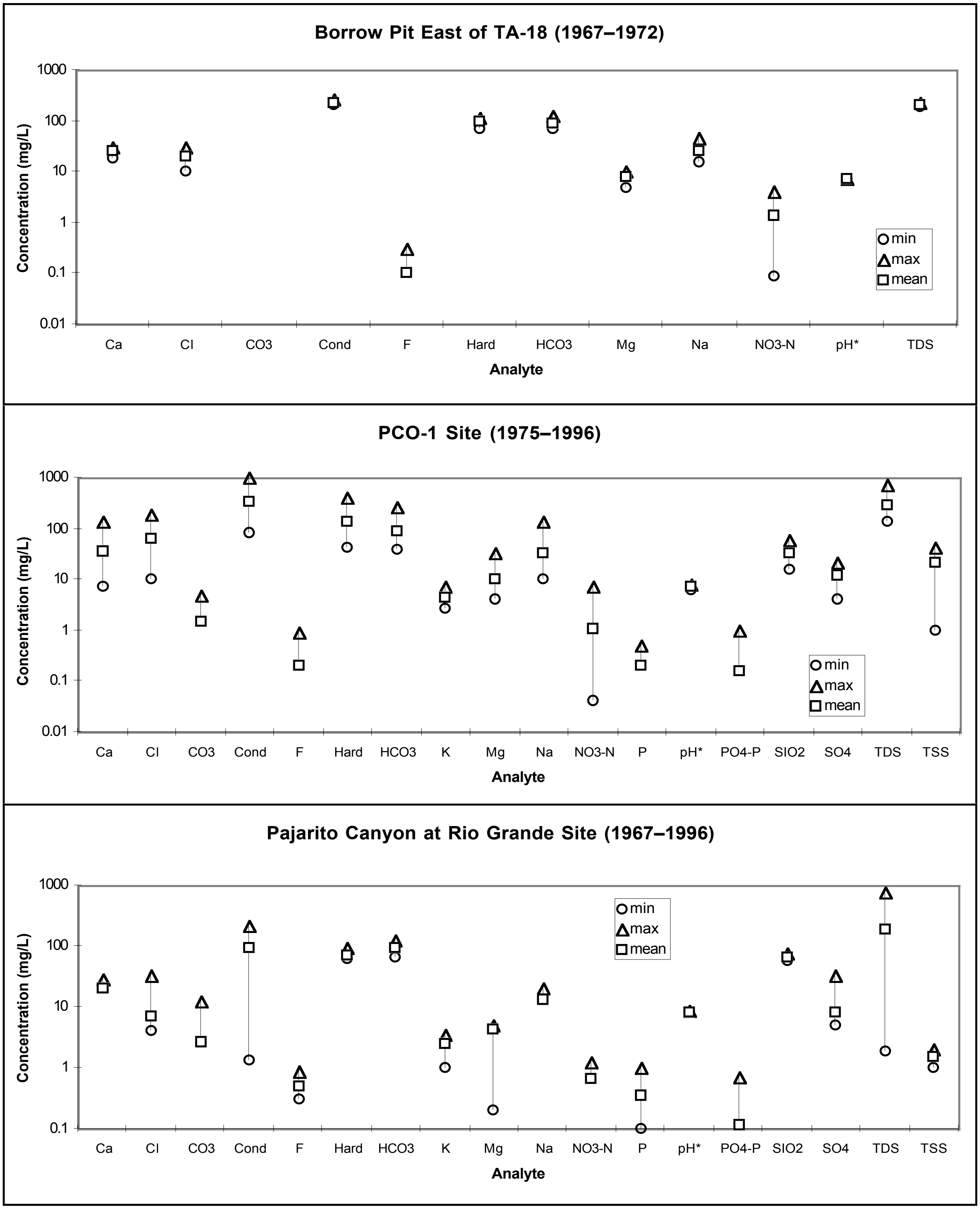
**General Water Quality**

*A summary of the results of surface water sampling in Pajarito Canyon for general water quality parameters at each collection site is shown in Figure 3.6.6-1. This figure shows the minimum, maximum, and mean concentrations of analytes sampled for the years for which results are available at each site. Surface water collected from a borrow pit east of TA-18 and the PCO-1 site show a range in nitrate (as nitrogen) varying from 4 up to 7 mg/L. Most cations and anions vary approximately an order of magnitude at the PCO-1 site, which reflects both sampling techniques and seasonal variations in water quality parameters, likely caused by lesser or greater dilution effects depending on runoff magnitudes. No significant trends in the annual variation of surface water quality data at the PCO-1 site are obvious, due in part to the annual sampling being conducted at different times of the year and different sampling techniques (samples were not filtered before analysis).*

*The surface water samples collected from the lower Pajarito Canyon at the Rio Grande site are primarily from the discharge from Pajarito Springs (Spring 4A and Spring 4AA) and normally represent perennial groundwater/surface water flow from the springs. However, runoff from Pajarito Canyon occasionally extends to the Rio Grande; therefore, surface water samples collected during times of storm water runoff may typically contain elevated constituents when compared with surface water discharged from Pajarito Springs (Spring 4A and Spring 4AA). The occurrence of runoff from the upper part of the canyon extending to the Rio Grande is not documented when samples are collected at this site. A relatively wide range in concentration values for specific conductance, magnesium, phosphate (as phosphorus), and total dissolved solids (TDS) (Figure 3.6.6-1) suggests that surface water samples from the Pajarito Canyon at the Rio Grande site reflect different sources for the surface water.*

*A comparison of the mean surface water quality data at each collection site in Pajarito Canyon is shown in Figure 3.6.6-2. The mean concentrations obtained from sampling Pajarito Springs (Spring 4A) are also shown on the figure for comparison with the results from the Pajarito Canyon at the Rio Grande site (see Section 3.7.4 for spring water discussion). The mean concentrations of calcium, chloride, specific conductance, sodium, nitrate (as nitrogen), sulfate, and TDS are highest at the PCO-1 site east of TA-18. The mean concentrations of calcium, chloride, potassium, magnesium, sodium, nitrate (as nitrogen), phosphate (as phosphorus), and sulfate are lowest at the Rio Grande site; however, the surface water at this location usually represents flow from Spring 4A. The concentrations of most constituents measured at Spring 4A are similar to those measured at the Pajarito Canyon at the Rio Grande site. The geochemistry of the surface water in lower Pajarito Canyon at the Rio Grande supports the observation that the surface water at this site is primarily from Spring 4A.*

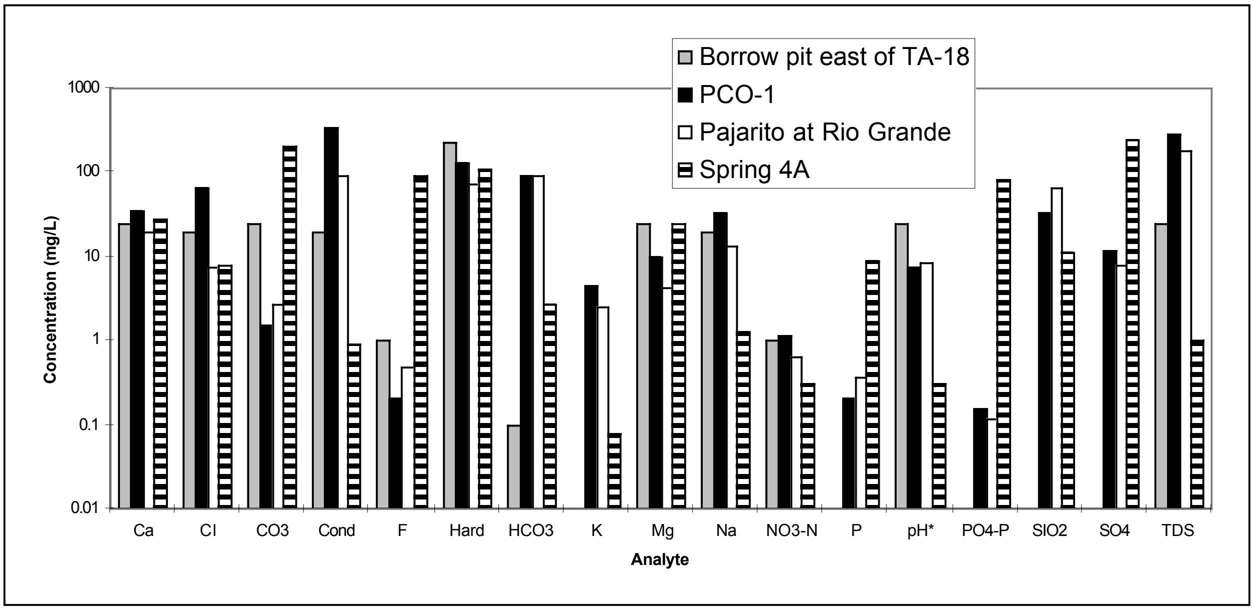
*In samples collected from the borrow pit east of TA-18 from 1967 to 1972, the concentration of nitrate (as nitrogen) in surface water ranged from 0.1 to 4 mg/L. The highest nitrate concentration measured at the PCO-1 site was 7 mg/L in 1983. The chloride concentration has ranged from 10 to 194 mg/L and sodium from 10 to 130, which probably results from the use of road salt on Pajarito Road. Highest concentrations of sodium and chloride are typically observed at sampling events conducted during spring runoff periods, although samples are not routinely collected during this time, and the data are insufficient to determine seasonal trends. The concentrations observed in the surface water are within New Mexico Water Quality Control Commission (NMWQCC) standards for streams in New Mexico (New Mexico Water Quality Control Commission 1995, 50265).*




**pH is measured in standard units.*

Source: Environmental surveillance reports, Purtymun 1975, 11787

**Figure 3.6.6-1. Summary of environmental surveillance sampling in Pajarito Canyon for general water quality parameters.**




**pH is measured in standard units.*

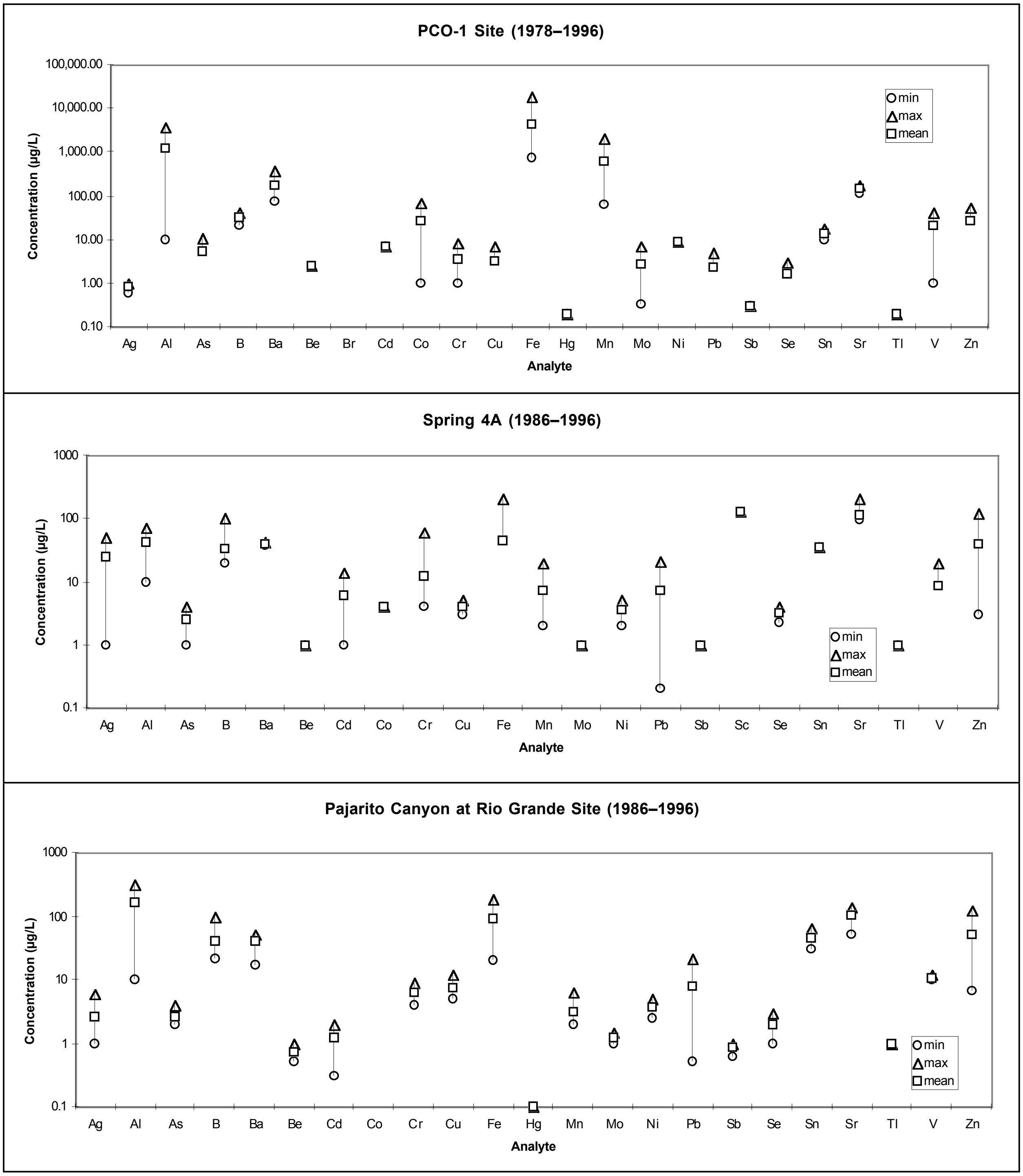
Source: Environmental surveillance reports 1971–1997; Purtymun 1975, 11787

**Figure 3.6.6-2. Comparison of mean surface water and spring water quality.**

### Metals

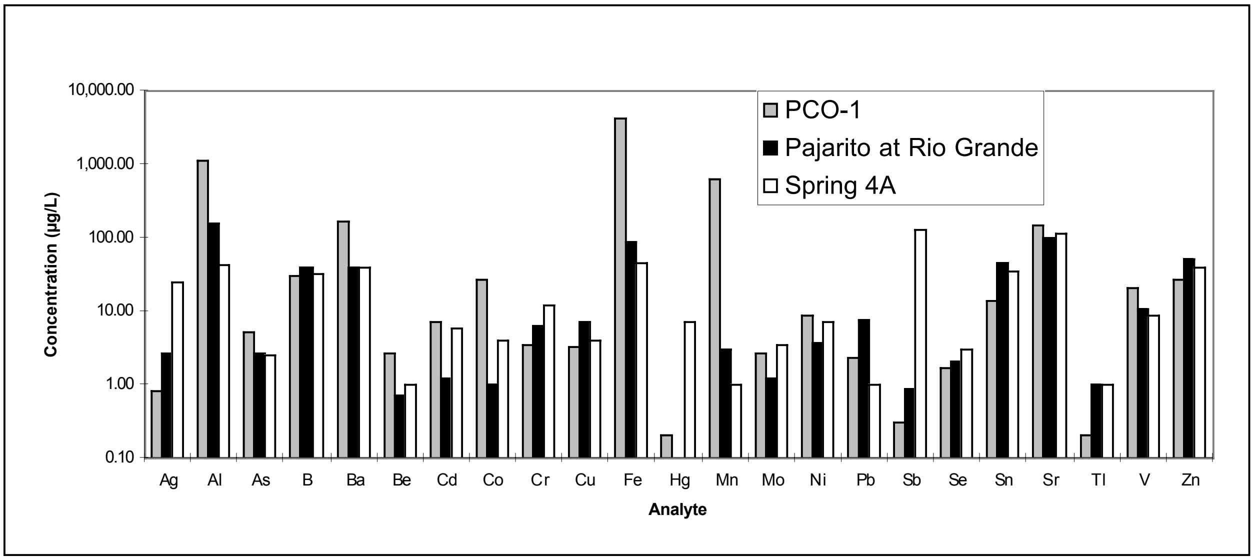
*The summary of results of surface water sampling for metal constituents at sites near PCO-1, the Pajarito Canyon at the Rio Grande site, and Pajarito Springs (Spring 4A) are shown in Figure 3.6.6-3. The minimum, maximum, and mean concentrations for each analyte are shown in the figure. The concentrations of metals in the surface water at the Rio Grande site and the spring water are similar because the source of the surface water at the Rio Grande site is Pajarito Springs (Spring 4A). Significantly higher concentrations of aluminum, iron, and manganese are observed at the PCO-1 site, possibly the result of the analyses of nonfiltered samples, which contain suspended solids.*

*Comparison of the mean metals concentrations at these sites is shown in Figure 3.6.6-4. The mean concentrations of aluminum, arsenic, barium, beryllium, cadmium, cobalt, iron, manganese, mercury, molybdenum, nickel, strontium, and vanadium are higher at the PCO-1 site, whereas mean concentrations of antimony, chromium, copper, lead, selenium, silver, thallium, tin, and zinc are higher in the surface water at the Rio Grande site and at Spring 4A. The range of concentrations of most metals, especially cadmium, lead, silver, and zinc (see Figure 3.6.6-3), are greater at the Rio Grande site and Spring 4A. Several metals, including cadmium, chromium, cobalt, silver, and especially antimony are present in higher concentrations in the Spring 4A water than in the Pajarito Canyon surface water below the springs. A chemical change in the spring water may occur as a result of exposure to the atmosphere, such as the loss of $P_{CO2}$ (the partial pressure of carbon dioxide) that increases the pH of the water and the solubility of the oxyanions such as chromium ($CrO_4^{2-}$) and antimony ($Sb(OH)_6^-$). The analyses of unfiltered water samples, such as these, will typically show a wide range of metal concentrations due to varying mineralogy of suspended materials, which may not be the result of contaminant loading.*




Source: Environmental surveillance reports

**Figure 3.6.6-3. Summary of environmental surveillance sampling of Pajarito Canyon surface water for metal constituents.**




Source: Environmental surveillance reports 1979–1997

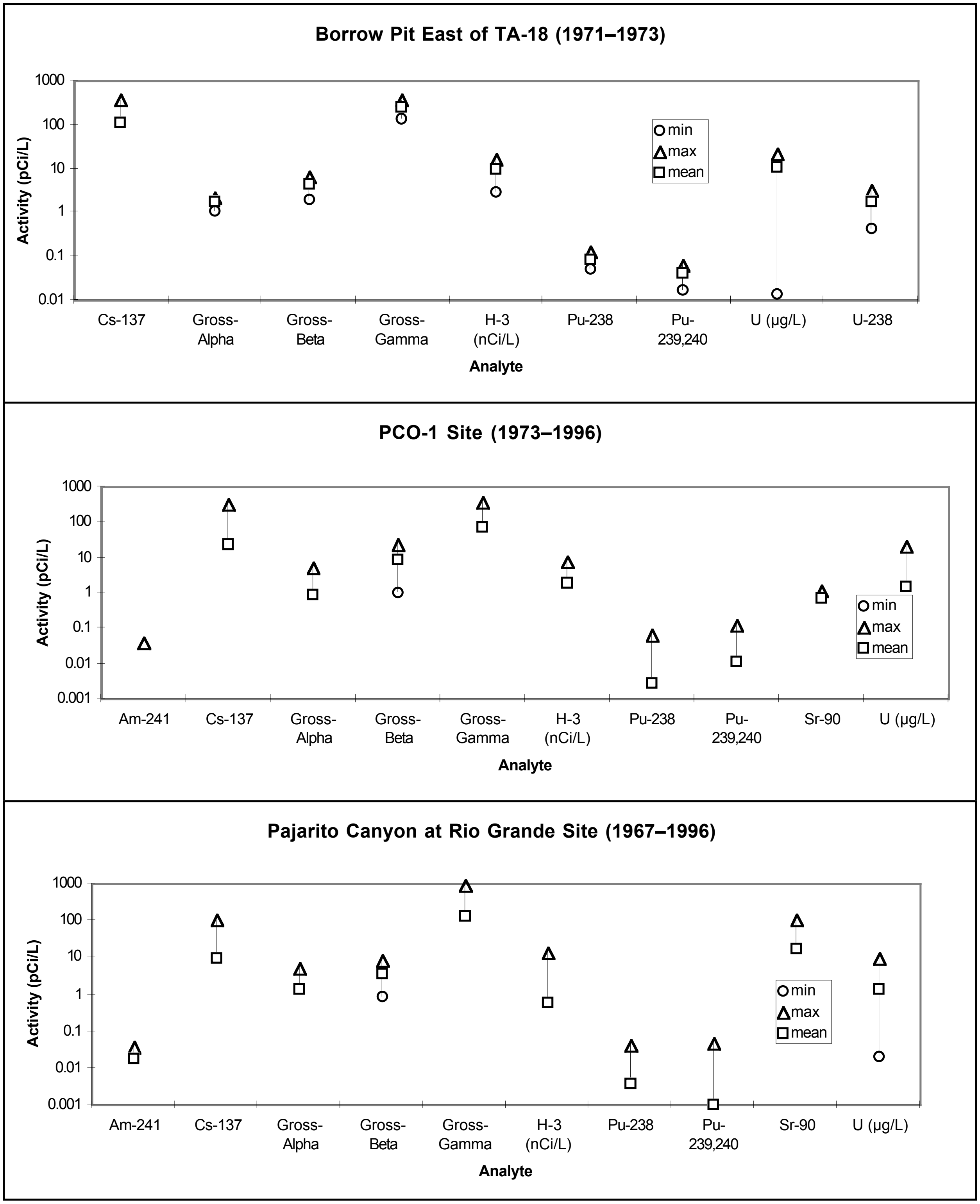
**Figure 3.6.6-4. Comparison of mean metals concentrations in surface and spring water.**

### Radionuclides

*The summary of the results of surface water sampling for radionuclides is shown in Figure 3.6.6-5, and the comparison of the mean values obtained at each surface water site and Pajarito Springs (Spring 4A) are shown in Figure 3.6.6-6. The highest observed activity of tritium (15.8 nCi/L) was collected in 1973 downstream from the effluent from the sewage treatment ponds east of TA-18 (Purtymun 1975, 11787). In 1974 and 1975 tritium activity at the PCO-1 site was more than 5 nCi/L and was as high as 7.7 nCi/L. Since 1987 tritium activity in the surface water has been less than 0.6 nCi/L, which is the approximate detection limit using the liquid scintillation method. The data show that tritium is not present in the surface water at significantly elevated levels (the Environmental Protection Agency [EPA] drinking water standard is 20 nCi/L).*

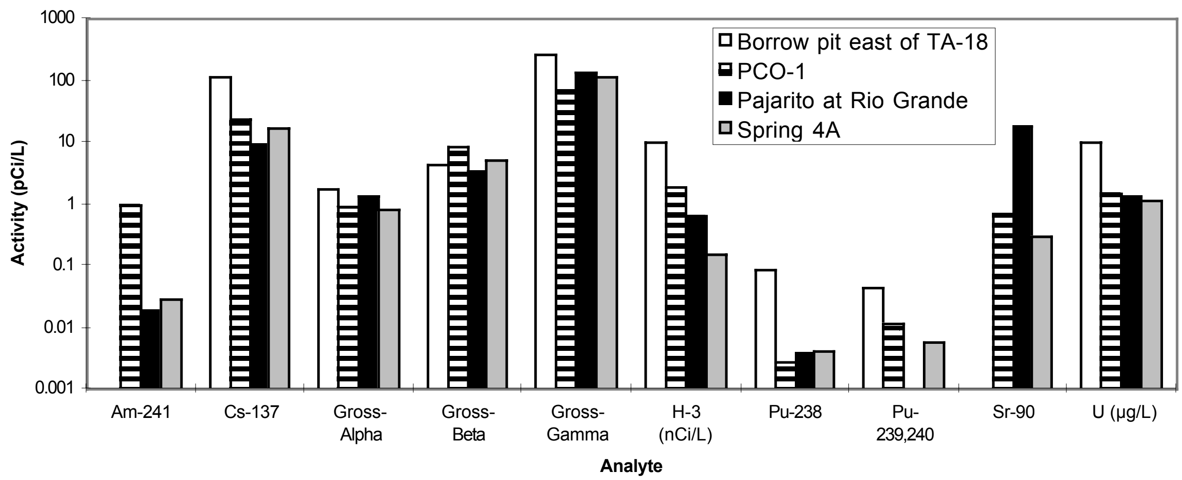
*The site that typically contains the lowest mean activity of tritium (measured by typical liquid scintillation methods) is the Pajarito Canyon at the Rio Grande site (typically <0.6 nCi/L). However, surface water at this site contained 13 nCi/L tritium in 1987, possibly the result of runoff from the upstream portion of the canyon, although subsequent sampling at this site has not indicated elevated values. Most surface water at the Rio Grande site is from Spring 4A where measurements of tritium using special low-level electrolytic enrichment techniques are much lower, typically less than approximately 2 pCi/L (see Section 3.6.6.3).*

*The highest activities of plutonium-238 and plutonium-239,240 in surface water (0.13 and 0.06 pCi/L, respectively) were measured in the early 1970s downstream from the former TA-18 sewage lagoon outfall. The concentration of total uranium was also highest in lower Pajarito Canyon at this location, 20.6 µg/L in 1973. The highest uranium concentration in surface water at the PCO-1 site was 20 µg/L in 1980, although the overall mean uranium concentration at the PCO-1 site is much lower, 1.5 µg/L. The higher levels of concentrations observed in the 1970s may reflect the larger input of depleted uranium from runoff from firing sites when more hydrodynamic testing was being conducted. The average concentration of total uranium at the Rio Grande site is 1.3 µg/L. One sample collected at the Rio Grande site in 1991 contained 100 pCi/L strontium-90 with an uncertainty of 600 pCi/L; all other activities of strontium-90 at this site have been less than 2.1 pCi/L.*




Source: Environmental surveillance reports; Purtymun 1975, 11787

**Figure 3.6.6-5. Summary of environmental surveillance results for radionuclides in surface water.**




Source: Environmental surveillance reports 1971–1997; Purtymun 1975, 11787

**Figure 3.6.6-6. Comparison of mean radionuclide activities in surface and spring water.**

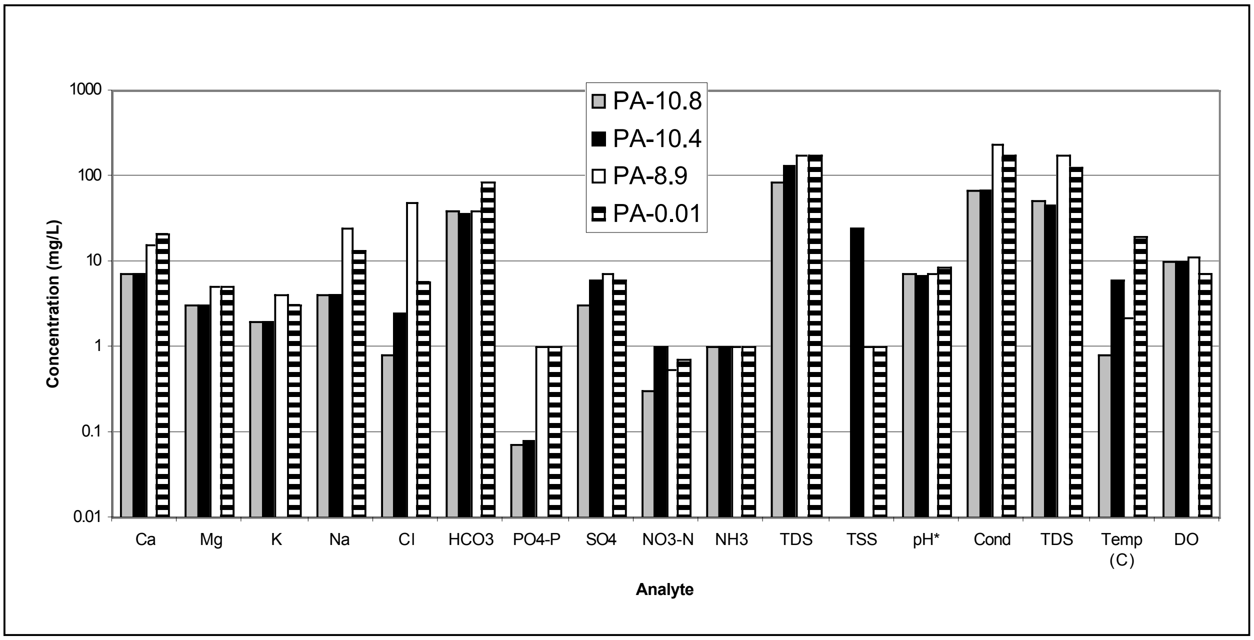
*In 1973 surface water samples were collected from a lagoon in Pajarito Acres, a private residential community east of the Laboratory boundary. The samples were analyzed for radionuclides and the results showed that the surface water contained 1.1 nCi/L tritium; 0.18 pCi/L plutonium-238; and 0.02 pCi/L plutonium-239,240 (Schiager and Apt 1974, 5467).*

**High Explosives**

*In 1996 the environmental surveillance sampling of surface water included analyses for HE compounds at the Pajarito Canyon at the Rio Grande site. The results of the sampling were below detection levels (Environmental Surveillance and Compliance Programs 1997, 56684).*

**Results of Other Surface Water Sampling**

*In 1997 personnel from the NMED DOE Oversight Bureau collected filtered surface water samples from four sites in Pajarito Canyon. The sites are labeled by the distance measured in miles from the Rio Grande. Samples were collected from sites PA-10.8 (below PC Spring), PA-10.4 (below state road NM501), PA-8.9 (below the confluence with the south fork of Pajarito Canyon), and PA-0.01 (near the Rio Grande) (Yanicak 1998, 57583, Table 7). A summary of the results is shown in Figure 3.6.6-7. The two sites in upper Pajarito Canyon (PA-10.8 and PA-10.4) contain similar concentrations of calcium, magnesium, potassium, sodium, bicarbonate, and dissolved oxygen. However, the concentrations of chloride, sulfate, nitrate (as nitrogen), TDS, and the temperature are higher at the site located near state road NM501. Contributions of road salt from the highway may contribute to the elevated constituents below the highway. Water collected at sites PA-8.9 and PA-0.01 are derived primarily from spring water and contain relatively higher concentrations of calcium, chloride, magnesium, potassium, sodium, TDS, and specific conductance. The surface water at the Rio Grande site is warmest because the water is primarily from Pajarito Springs (Spring 4A), which is a warm spring similar in temperature to the regional aquifer. The results of metals analyses of the samples were mostly below method detection limits; however, barium was detected in one sample from site PA-10.4 at 0.2 mg/L (Yanicak 1998, 57583, Table 8).*




*pH is measured in standard units.

Source: Yanicak 1998, 57583, Table 7

**Figure 3.6.6-7. Comparison of surface water quality at four sites in Pajarito Canyon.**

### 3.6.6.1.2 Storm Water Runoff Water Quality

**Environmental Surveillance Runoff Sampling**

*ESH-18 personnel regularly collect runoff samples from Pajarito Canyon at state road NM4 and have collected periodic runoff samples at other sites including Pajarito Canyon at state road NM501, the PCO-1 site, and channels draining MDA G. The results of the runoff sampling are provided in the annual environmental surveillance reports (for example, Environmental Surveillance and Compliance Programs 1997, 56684).*

*In April 1987 and May 1995 runoff samples were collected from Pajarito Canyon at state road NM501 and analyzed for selected radionuclides. The results of the sampling are shown in Table 3.6.6-1. The variability observed in the activity of plutonium isotopes may be caused by analysis of nonfiltered samples.*

**TABLE 3.6.6-1**

**RESULTS OF ENVIRONMENTAL SURVEILLANCE SAMPLING OF RUNOFF AT STATE ROAD NM501**

| Date | Cs-137 (pCi/L) | Gross-Gamma (pCi/L) | H-3 (nCi/L) | Pu-238 (pCi/L) | Pu-239,240 (pCi/L) | U (μg/L) |
|---|---|---|---|---|---|---|
| 4/29/87 | 138 | 312 | 0.7 | 0.034 | 0.006 | 1 |
| 5/25/95 | NA* | NA | NA | 0.016 | 0.011 | NA |
| *NA = not analyzed | | | | | | |

Source: ESG 1988, 6877; Environmental Surveillance Program 1996, 55333

*Runoff samples were collected from Pajarito Canyon at the PCO-1 site in 1984, 1992, 1993, and 1994 and analyzed for selected radionuclides. The results of the analyses showed that the concentration of total uranium was 0.2 μg/L (1992), cesium-137 activity ranges from 0.9 to 91.4 pCi/L, and the maximum tritium activity was 0.6 nCi/L. Activities of the plutonium isotopes were close to the method detection limits.*

*Since 1979 runoff samples have been collected in Pajarito Canyon at state road NM4 after numerous runoff events. Samples were collected after 8 runoff events in 1986, after 14 events in 1987, after 5 events in 1993, and after single events in 1979, 1983, 1985, and 1995. The samples were analyzed for radionuclides; in 1979, 1983, and 1993 the samples were also analyzed for selected water quality parameters. Table 3.6.6-2 shows the results of runoff sampling for selected water quality parameters.*

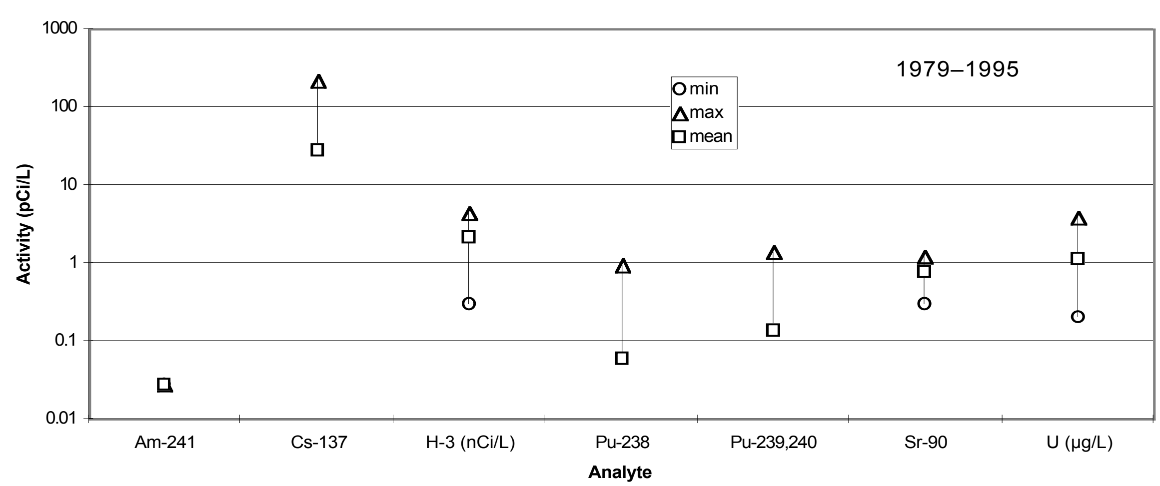
**TABLE 3.6.6-2**

**GENERAL WATER QUALITY PARAMETERS IN RUNOFF FROM PAJARITO CANYON AT STATE ROAD NM4**

| Date | Cl (mg/L) | F (mg/L) | $NO_3$-N (mg/L) | pH | $SO_4$ (mg/L) | TDS (mg/L) | TSS (mg/L) |
|---|---|---|---|---|---|---|---|
| 8/14/79 | 22.8 | 0.2 | 0 | NA | 20.6 | 178 | NA |
| 1/1/83 | 31 | 0.1 | 0.203 | 7.7 | NA | 192 | NA |
| 4/19/93 | NA | NA | NA | NA | NA | NA | 40.3 |

Source: ESG 1980, 5961; ESG 1984, 6523; Environmental Protection Group 1995, 50285

*Figure 3.6.6-8 summarizes the activities of radionuclides in runoff at the Pajarito Canyon at state road NM4 site. The activity of tritium has ranged from 0.3 to 4.4 nCi/L (June 1986), which shows a contribution from Laboratory-derived contaminants. Activities of plutonium-238 range as high as 1.0 pCi/L, and activities of plutonium-239,240 range up to 1.36 pCi/L, which suggests a source of contaminants in the runoff, possibly from MDA G. The concentration of total uranium in the runoff at this site varies from 0.2 to 3.8 μg/L.*

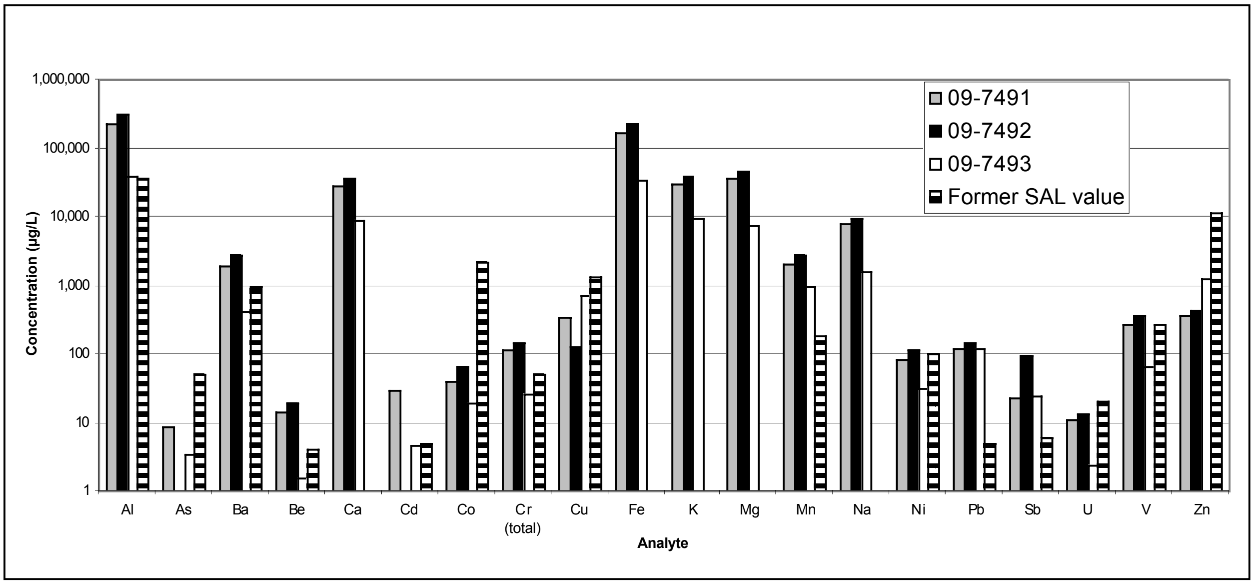



Source: Environmental surveillance reports 1979–1995

**Figure 3.6.6-8. Summary of environmental surveillance sampling of runoff for radionuclides at state road NM4.**

**Runoff Sampling at MDA M**

*Runoff samples have been collected to support the RFI for PRSs at MDA M (PRS 9-013). In May 1994 single-stage runoff samples were collected from three small rill channels draining the MDA M site. The samples were analyzed for metals, VOCs, SVOCs, pesticides, and PCBs (LANL 1995, 47257). No VOCs, SVOCs, pesticides, or PCBs were detected in the runoff samples above method detection limits. The results of metals analyses in the runoff at the three sites are shown in Figure 3.6.6-9. The former Laboratory SAL values for water samples are also shown on the figure. Metals detected significantly above former SAL values include aluminum, antimony, barium, beryllium, cadmium, chromium, lead, and manganese. However, these metals could be elevated because of the collection of turbid samples.*




Source: LANL 1995, 47257

**Figure 3.6.6-9. Results of metals analyses in runoff from MDA M.**

*On August 21, 1997, personnel from the NMED DOE Oversight Bureau collected filtered runoff samples from MDA M for analysis of selected heavy metals. The results showed that all metals were below detection limits except mercury, which was present at 0.0011 mg/L. The runoff contained approximately 5000 mg/L total suspended sediment. The suspended sediment fraction of the runoff sample was analyzed for lead. The results showed that lead was present in the suspended sediment at 37 mg/kg (Yanicak 1998, 57583, Table 13).*

**Runoff Sampling at TA-54**

*Runoff samples have been collected from the perimeter of MDA G to supplement existing environmental surveillance of the TA-54 area and as part of the RFI for OU 1148. In addition to the data presented annually in the environmental surveillance reports, a supplemental environmental surveillance study was initiated in 1993 to monitor potential contaminant migration from MDA G via the surface water pathway. In 1993 110 single-stage water samples from the perimeter of MDA G were analyzed for tritium, total uranium, isotopic plutonium, and cesium-137 (Conrad et al. 1995, 52014). The results of the analyses of the runoff samples showed that six single-stage water samples contained tritium activities greater than*

*1000 pCi/L. One of the samples contained tritium activity greater than 2000 pCi/L (maximum value 2300 pCi/L). Elevated plutonium activity was detected in the filtered sediment and water fractions of runoff samples from stations located adjacent to the TRU pads and the area's oldest disposal pits. Maximum activities measured in filtered runoff were 0.604 pCi/L plutonium-238 and 0.155 pCi/L plutonium-239,240. Maximum activities measured in the sediment fraction of the runoff samples were 26.61 pCi/g plutonium-238 and 1.25 pCi/g plutonium-239,240 (Conrad et al. 1995, 52014).*

*Beginning in 1994 the single-stage runoff samples (filtered) were submitted for tritium analysis only, and the sediment fraction of the runoff was analyzed for isotopic plutonium. The results of the 1994 sampling showed an increase in tritium concentrations in the single-stage water samples compared with data collected in 1993. Ten of the 159 single-stage water samples contained tritium activities exceeding 1000 pCi/L; the maximum tritium value in runoff (from a sample collected northeast of MDA G) was 17,200 pCi/L. The runoff containing the highest tritium activity discharges into Cañada del Buey (Conrad et al. 1996, 55621).*

*In 1995 a total of 131 single-stage runoff samples were collected, of which five contained tritium activity greater than 1000 pCi/L. Elevated plutonium activity was detected in the sediment fraction of runoff sample collected adjacent to the TRU pads and the oldest disposal pits, which is consistent with the results obtained in 1993 and 1994. Maximum activities measured in the sediment fraction were 9.46 pCi/L plutonium-238 and 2.13 pCi/g plutonium-239,240 (Childs and Conrad 1997, 57518).*

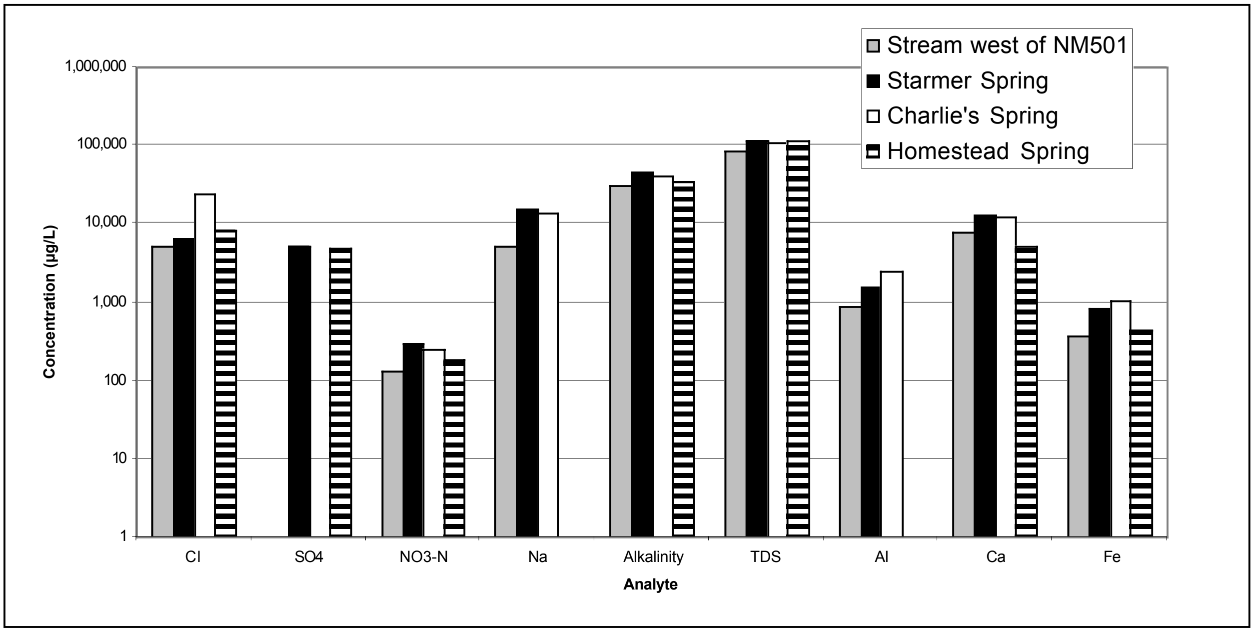
*The conclusion derived in each of the supplemental environmental surveillance reports for MDA G runoff sampling from 1993 through 1995 is that small amounts of radioactivity are leaving the confines of MDA G via the surface water runoff pathway (Conrad et al. 1995, 52014; Conrad et al. 1996, 55621; Childs and Conrad 1997, 57518).*

### 3.6.6.2 Results of RFI Sampling of Surface Waters

#### 3.6.6.2.1 RFI Sampling at MDA M

*The RFI for MDA M (PRS 9-013) included the collection of water samples from three springs and one surface water site located near the disposal area. Homestead Spring, Charlie's Spring, and Starmer Spring were sampled, and surface water was collected from a baseline surface water site in Pajarito Canyon upstream from MDA M west of state road NM501 (LANL 1993, 20949, p. 6-138; LANL 1995, 47257). The samples were analyzed for metals, VOCs, SVOCs, pesticides, PCBs, HE compounds, and radionuclides.*

*The results of the sampling showed that HE (2,4-DNT) was detected above former Laboratory SAL values at Starmer Spring (1.52 μg/L) and at the baseline surface water site in Pajarito Canyon west of state road NM501 (0.9 μg/L). Starmer Spring also contained 1.99 μg/L octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine (HMX). A summary of water quality parameters obtained at each sample site is shown in Figure 3.6.6-10. Generally, concentrations of water quality parameters are lower in the surface water collected west of state road NM501 (west of the Laboratory boundary), but all waters appear similar in constituents. Low levels of radionuclide activities were detected in the water samples, but they did not exceed former Laboratory SAL values (LANL 1995, 47257). The results of sampling other springs in the MDA M area are discussed in Section 3.6.6.3.*




Source: LANL 1995, 47257

**Figure 3.6.6-10. Summary of water quality parameters in springs and surface water near MDA M.**

*On February 7, 1997, personnel from the NMED DOE Oversight Bureau collected filtered surface water samples from Pajarito Canyon at PA-8.9, which is below the confluence with the south fork of Pajarito Canyon and downstream from MDA M (see Figure A-1). The samples were analyzed for metals, VOCs, HE compounds, and gross-alpha and -beta. The sampling results showed that all HE compounds were below detection limits (1.0 µg/L for HMX and 0.84 µg/L for RDX) and all VOCs analyzed were below detection limits (Yanicak 1998, 57583, Tables 10, 11). Of the 25 metals analyzed for (Table 8 in Yanicak 1998, 57583), only aluminum, iron, silicon, and strontium were consistently above detection limits.*

### 3.6.6.2.2 RFI Sampling at TA-3

*A small volume of water was noted emerging as a "seep" from thin alluvium and colluvium in an unnamed tributary to the north fork of Twomile canyon a few hundred feet downstream of PRS 3-010(a) during the RFI characterization of the site (LANL 1995, 55638). Springs SM-30 and SM-30A, which at the time of the RFI had not been identified, are located in this unnamed tributary downgradient of the PRS. The "seep" mentioned in the RFI report may coincide with Spring SM-30. Observations made during the RFI suggest that the "seep" may not represent discharge from a perched groundwater zone but may represent water moving through thin and discontinuous alluvium and colluvium in the channel. The water at the "seep" may originate as local runoff from the roof of building TA-3-30 and parking areas adjacent to the building. The runoff combined with infiltration of moisture through the asphalt, fill, soil, and tuff around PRS 3-010(a) may provide the source of the "seep" (LANL 1995, 55638). However, in addition to water present at the "seep," saturated groundwater conditions were observed in several boreholes drilled west of building TA-3-30 that may coincide with the groundwater supplying the "seep" (see Section 3.7.2 for more discussion of the boreholes).*

*Springs SM-30 and SM-30A are located at the north end of a group of springs that discharge from the Tshirege Member along the western Laboratory boundary (see Figure A-1). These springs may have a similar source and perching mechanism and may be related hydraulically to infiltration of surface water* *into the Pajarito fault, which approximately parallels the western Laboratory boundary (for example, Dale 1998, 57286, p. 7).*

*Samples collected from the "seep" for the RFI characterization of PRS 3-010(a) were analyzed for metals, VOCs, SVOCs, and radionuclides. The organic constituents detected in the samples are shown in Table 3.6.6-3. The spring water contained 1,1,1-trichloroethane (TCA) at concentrations ranging from 7.9 to 13 μg/L. Perched groundwater collected from the nearby boreholes also contained similar concentrations of trichloroethylene (TCE) (see Section 3.7.2.4). The detectable concentrations of organic compounds were below former SAL values.*

**TABLE 3.6.6-3**

**DETECTED CONSTITUENTS IN SPRING SM-30 AT PRS 3-010(a)**

| Location ID | Sample ID | Analyte | Result | Uncertainty | Units | SAL |
|---|---|---|---|---|---|---|
| Seep | AAB7760 | TPH | 5 | 1500 | mg/L | NA |
| | | TCA | 12 | 3.6 | μg/L | 200 |
| | | Tritium | 413 | 94 | pCi/L | 20,000 |
| Seep | AAB7764 | TCA | 13 | 3.9 | μg/L | 200 |
| | | Tritium | 458 | 95.5 | pCi/L | 20,000 |
| Seep | AAB3129 | TCA | 7.9 | 2.37 | μg/L | 200 |

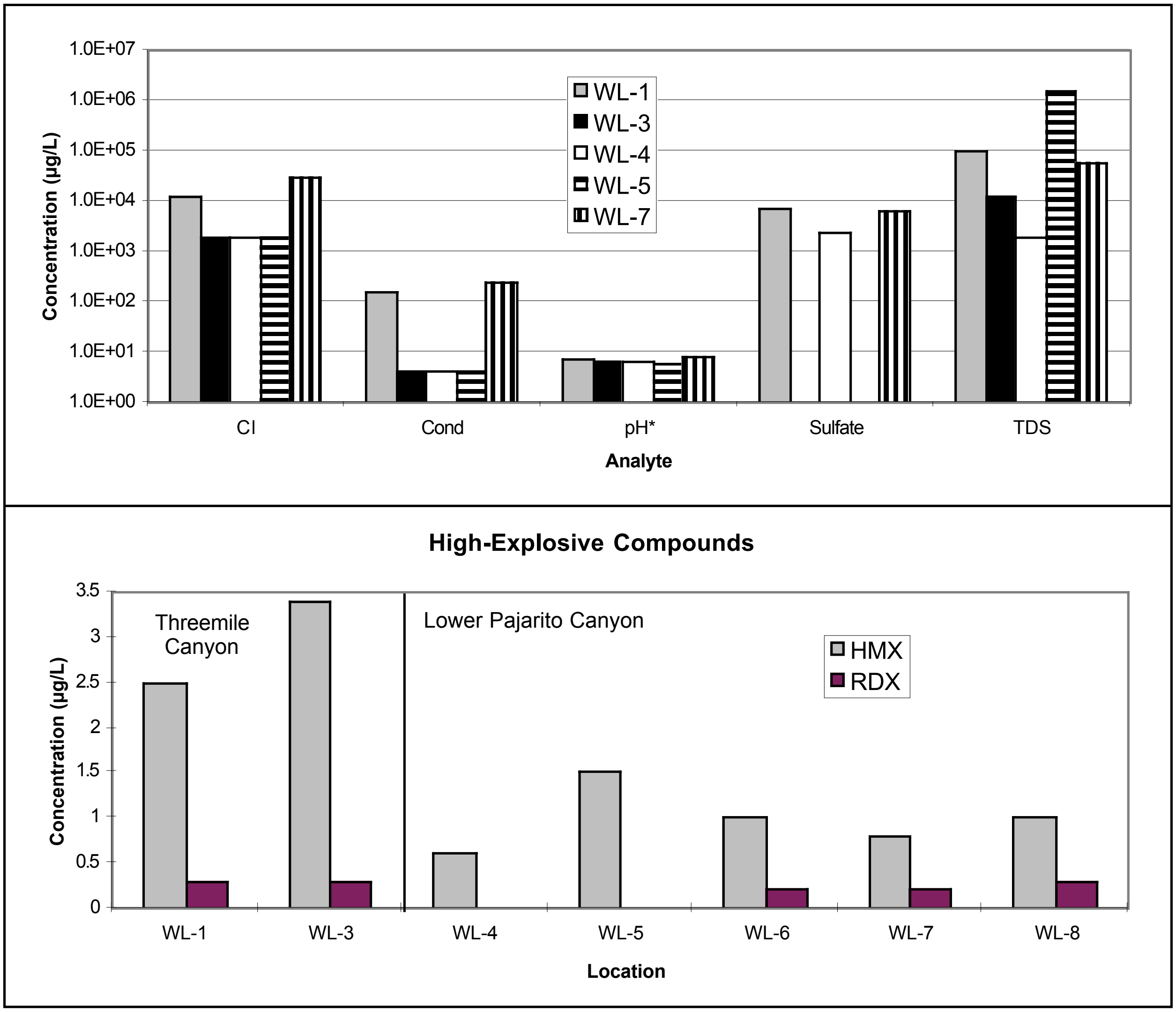
Source: LANL 1995, 55638

### 3.6.6.2.3 RFI Sampling at TA-18

*As part of the RFI for OU 1093, surface water samples were collected in natural wetlands located upgradient of TA-18 in Threemile Canyon and in wetlands formed in abandoned borrow pits in lower Pajarito Canyon east of TA-18. WL-1 and WL-3 are located in Threemile Canyon, and WL-4 through WL-8 are located in lower Pajarito Canyon downstream of TA-18 (see Figure A-1). The results of the analyses for water quality parameters are shown in Figure 3.6.6-11. The data show that no significant trends are apparent in the surface water chemistry between Threemile Canyon and lower Pajarito Canyon. Chloride concentration ranged from 12 to 29 mg/L, and specific conductance values ranged from 4 to 253 μmhos/cm; the higher values were obtained from WL-7 in lower Pajarito Canyon. TDS ranged widely from 2 to 1500 mg/L.*

*Several organic compounds were detected in surface water from the wetlands downstream from TA-18. The organic compounds included acetone, 2-butanone, and methylene chloride (LANL 1995, 55527, p. 4-193). Additionally, metals including barium, beryllium, chromium, lead, nickel, silver, and zinc were detected in surface water collected from wetlands at concentrations exceeding baseline levels but less than their respective former SAL values. Barium was detected in WL-1 at a concentration of 55 μg/L and in WL-7 at 72 μg/L.*

*The HE compounds HMX, RDX, o-nitrotoluene and tetryl (methyl-2,4,6-trinitrophenylnitramine) were detected in surface water collected from the wetlands in lower Threemile Canyon and Pajarito Canyon near TA-18. Figure 3.6.6-11 shows the results of the RFI sampling and analysis for HMX and RDX. The highest concentrations of HMX were detected in Threemile Canyon in both WL-1 and WL-3 at 2.5 and 3.4 μg/L, respectively. HMX was detected in each wetland downstream of TA-18 but at lower concentrations; the highest value was 1.5 μg/L in WL-5. RDX was detected in both Threemile Canyon and lower Pajarito Canyon in similar concentrations ranging from 0.2 to 0.3 μg/L. The source of the HE compounds in the surface water is likely from former and/or active firing sites (LANL 1995, 55527, p. 4-193; LANL 1997, 56356, p. 40).*




*pH is measured in standard units.*

Source: LANL 1995, 55227; LANL 1997, 56356

**Figure 3.6.6-11. Results of RFI sampling of surface water in wetlands near TA-18.**

*The surface water samples collected in wetlands around TA-18 were analyzed for radionuclides. Samples collected in Threemile Canyon contained up to 0.89 pCi/L thorium-228, 0.62 pCi/L thorium-230, and up to 3.7 µg/L uranium. The highest concentration of uranium detected in surface water was in Threemile Canyon. Surface water collected from wetlands in lower Pajarito Canyon east of TA-18 contained 0.56 pCi/L thorium-228, 0.38 pCi/L thorium-230, and up to 1.1 µg/L uranium. The concentrations of uranium in the surface water samples consistently decrease in downstream wetlands to a concentration of 0.16 µg/L in WL-8, which suggests chemical reduction of U(VI) to U(IV) ad/or sorption onto solid organic matter. Other radionuclides analyzed in surface water samples were not detected above method detection limits (LANL 1996, 54919, p. 4-84).*

*Supplemental RFI sampling of spring water and surface water near TA-18 was conducted in June 1997 as part of PRS investigations for OU 1093 (LANL 1997, 56356, p. 154). Surface water samples were collected at the stream gaging station in Pajarito Canyon (E245), in Threemile Canyon below Threemile Spring, and from the TA-18 Spring. The samples were analyzed for metals, SVOCs, and HE compounds. The preliminary results of the RFI sampling of surface water and springs are shown in Figure 3.6.6-12.*

*The preliminary results of the metals analysis show that the water samples from Pajarito Canyon and Threemile Canyon, including the TA-18 Spring water, are very similar in metals concentrations. The Pajarito Canyon surface water and TA-18 Spring are within method detection levels for SVOCs, but the surface water collected in Threemile Canyon below Threemile Spring contains elevated concentrations of acenaphthene; bis(2-ethylhexyl)phthalate; chloro-3-methylphenol[4-]; chlorophenol[2-]; dichlorobenzene[1,4-]; diethylphthalate; dinitrotoluene[2,4-]; nitrophenol[4-]; nitroso-di-n-propylamine[N-]; pentachlorophenol; phenol; and pyrene (Figure 3.6.6-12). One organic compound, bis(2-ethylhexyl)phthalate, was present in a concentration of 10 μg/L, which is above the former SAL value of 6 μg/L. These data are preliminary and have not been formally evaluated for risk assessment purposes.*

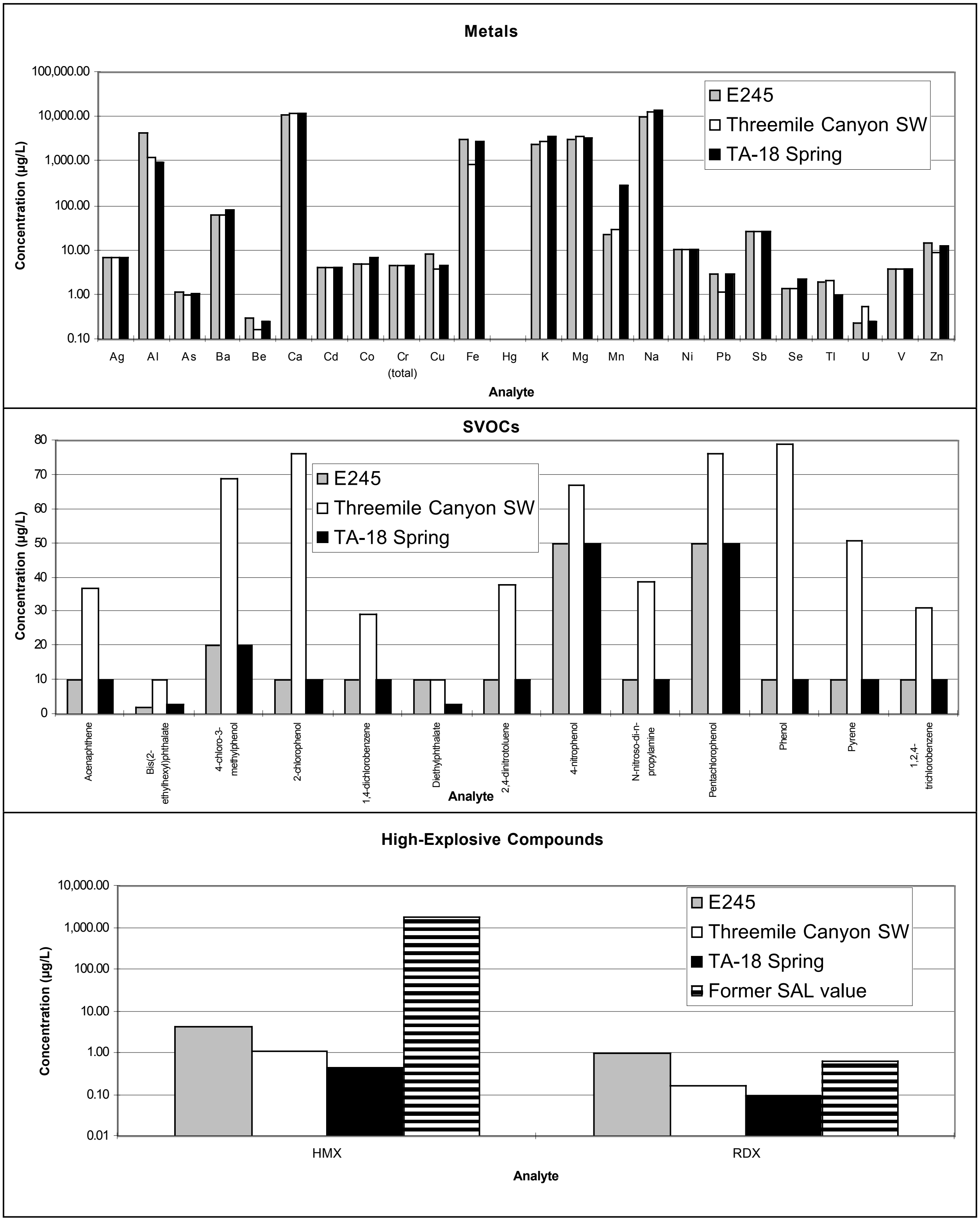
*The HE compounds HMX and RDX were detected in the surface water from each of the three sample sites (see Figure 3.6.6-12). Concentrations of HMX and RDX are highest in the Pajarito Canyon surface water at gaging station E245, which contained 4.4 μg/L HMX and 1.01 μg/L RDX. TA-18 Spring contained the lowest concentrations of HMX and RDX, but at concentrations above method detection limits. HMX concentrations were two orders of magnitude below the former SAL value, but RDX was present at 1.01 μg/L, which is above the former SAL value of 0.61 μg/L.*

*The RFI sampling data may suggest that the surface waters in middle Pajarito Canyon and Threemile Canyon have a similar source in upper or middle Pajarito Canyon that contains HE compounds. An additional source of SVOCs appears to be present in upper Threemile Canyon that affects the water quality at Threemile Spring. The RFI sampling of springs and surface water near TA-18 is scheduled to continue in 1998 (LANL 1997, 56356, p. A-3).*

*On June 23, 1995, personnel from the NMED DOE Oversight Bureau collected spring water samples from Threemile (A) and (B) Springs. The samples were analyzed for metals, organic compounds, inorganic compounds, HE compounds, and radionuclides. Threemile (B) Spring contained HMX (1100 μg/L), and RDX (77 μg/L). Additionally, Threemile (A) Spring contained 0.03 pCi/L uranium-235 and 2.55 pCi/L uranium-238, and Threemile (B) Spring contained <0.07 pCi/L uranium-235 and 0.88 pCi/L uranium-238. Threemile (B) Spring was subsequently resampled on August 18, 1995, and analyzed for HE compounds. The results showed significantly lower concentrations of HMX (1.2 μg/L) and RDX (below detection level [2 μg/L]). This sampling occurred after a significant precipitation event that may have caused dilution of contaminants in the surface water (Dale et al. 1996, 57014).*

### 3.6.6.3 Isotope Geology and Geochemistry of Springs and Surface Water in Pajarito Canyon

*In October 1993 samples were collected from surface water, groundwater, and springs in the Los Alamos area for environmental geochemical characterization and trace-level tritium analysis. Samples were collected in the Pajarito Canyon watershed area from upper Pajarito Canyon downstream of PC Spring, Homestead Spring, the north fork of Twomile Canyon (two locations), supply well PM-2, and Pajarito Springs (Spring 4A). The samples were analyzed for tritium and stable oxygen isotopes (Blake et al. 1995, 49931, p. 28). Table 3.6.6-4 summarizes the results of the sampling in Pajarito Canyon.*




Source: Preliminary data from RFI sampling in 1997

**Figure 3.6.6-12. Preliminary RFI results for surface water and springs near TA-18.**

**TABLE 3.6.6-4**

**SUMMARY OF TRACE-LEVEL TRITIUM AND STABLE ISOTOPE RESULTS FOR PAJARITO CANYON WATERS**

| Location | Temperature (°C) | Activity of Tritium Tritium Units | (pCi/L) | Max Age (years) | Min Age (years) | Recharge Elevation (ft) $\delta D$ | $\delta O_{18}$ |
|---|---|---|---|---|---|---|---|
| **October 1993 Samples (Blake et al. 1995, 49931, Table 4)** | | | | | | | |
| *Upper Pajarito Creek below PC Spring* | *10.9* | *0* | *0* | *>10,000* | *>110* | *8423* | *8387* |
| *Homestead Spring* | *7.8* | *38.1* | *121.92* | *N.A. ** | *20* | *9263* | *9095* |
| *N. Twomile Canyon* | *6.0* | *44.9* | *143.68* | *N.A.* | *23* | *6714* | *6471* |
| *N. Twomile Canyon* | *7.4* | *62.8* | *200.96* | *N.A.* | *26* | *6567* | *6038* |
| *PM-2 (1992)* | *23.3* | *0.15* | *0.48* | *>10,000* | *70* | *7570* | *7718* |
| *PM-2 (1993)* | *22.4* | *0.49* | *1.568* | *3000* | *45* | *7777* | *7501* |
| *Spring 4A (05/91)* | *22.2* | *0.09* | *0.288* | *>10,000* | *>110* | *7613* | *7059* |
| *Spring 4A (11/91)* | *<20* | *0.74* | *2.368* | *2500* | *38* | *7203* | *6924* |
| **Environmental Surveillance Sampling (Environmental Protection Group 1996, 54769)** | | | | | | | |
| *Spring 4A (10/91)* | *N.A.* | *0.75* | *2.4* | *N.A.* | *N.A.* | *N.A.* | *N.A.* |
| *Spring 4A (9/94)* | *N.A.* | *0.43* | *1.39* | *N.A.* | *N.A.* | *N.A.* | *N.A.* |
| *Pajarito SW at Rio Grande (9/28/94)* | *N.A.* | *0.61* | *1.98* | *N.A.* | *N.A.* | *N.A.* | *N.A.* |
| *Spring 4 (9/94)* | *N.A.* | *4.8* | *15.4* | *N.A.* | *N.A.* | *N.A.* | *N.A.* |
| **N.A. = not available* | | | | | | | |

Source: Blake et al. 1995, 49931, Table 4; Environmental Protection Group 1996, 54769, p. 259

*The surface water in the upper reaches of Pajarito Canyon downstream from PC Spring does not show the effects of atmospheric or Laboratory contaminants. This water appears to be from a much older and probably deeper water source that has not been in communication with recent precipitation. The surface water collected downstream of PC Spring appears to contain tritium activity comparable with the regional aquifer water from supply well PM-2. Homestead Spring and the surface water in the north fork of Twomile Canyon contain tritium activities ranging from 121 to 200 pCi/L, which is comparable to contemporary precipitation levels in the Los Alamos area (Environmental Protection Group 1995, 50285). The regional aquifer water at PM-2 contains trace levels of tritium, ranging from 0.48 to 1.57 pCi/L, which is consistent with other measurements of regional aquifer water and indicate maximum ages ranging from 3000 to more than 10,000 years.*

*The water from Pajarito Springs (Spring 4A) also contains trace levels of tritium, which is similar to water from the regional aquifer. These tritium data, together with similar temperatures of the water from regional aquifer water and Spring 4A, indicate that Spring 4A probably discharges from the regional aquifer. The source of the water at Spring 4A could be the regional aquifer beneath the Pajarito Plateau. However, it has also been suggested that the source of water in the regional aquifer in the lower Los Alamos Canyon area near the Rio Grande could possibly be from the Sangre de Cristo Range east of the Rio Grande (Blake et al. 1995, 49931, p. 27).*

*In 1991 and 1994 personnel from ESH-18 collected water from springs and streamflow in White Rock Canyon for trace-level tritium analysis. The results of the analyses for samples collected in the lower*

*Pajarito Canyon area are shown in Table 3.6.6-4. Water samples collected from Pajarito Springs (Spring 4A) and from Pajarito Canyon downstream from Spring 4A contained low levels of tritium activity, ranging from 1.39 to 2.4 pCi/L. Water collected from Spring 4, which discharges into the Rio Grande in White Rock Canyon upstream from Pajarito Canyon, contained 15.4 pCi/L tritium, which possibly shows a contribution of Los Alamos area precipitation to this spring.*

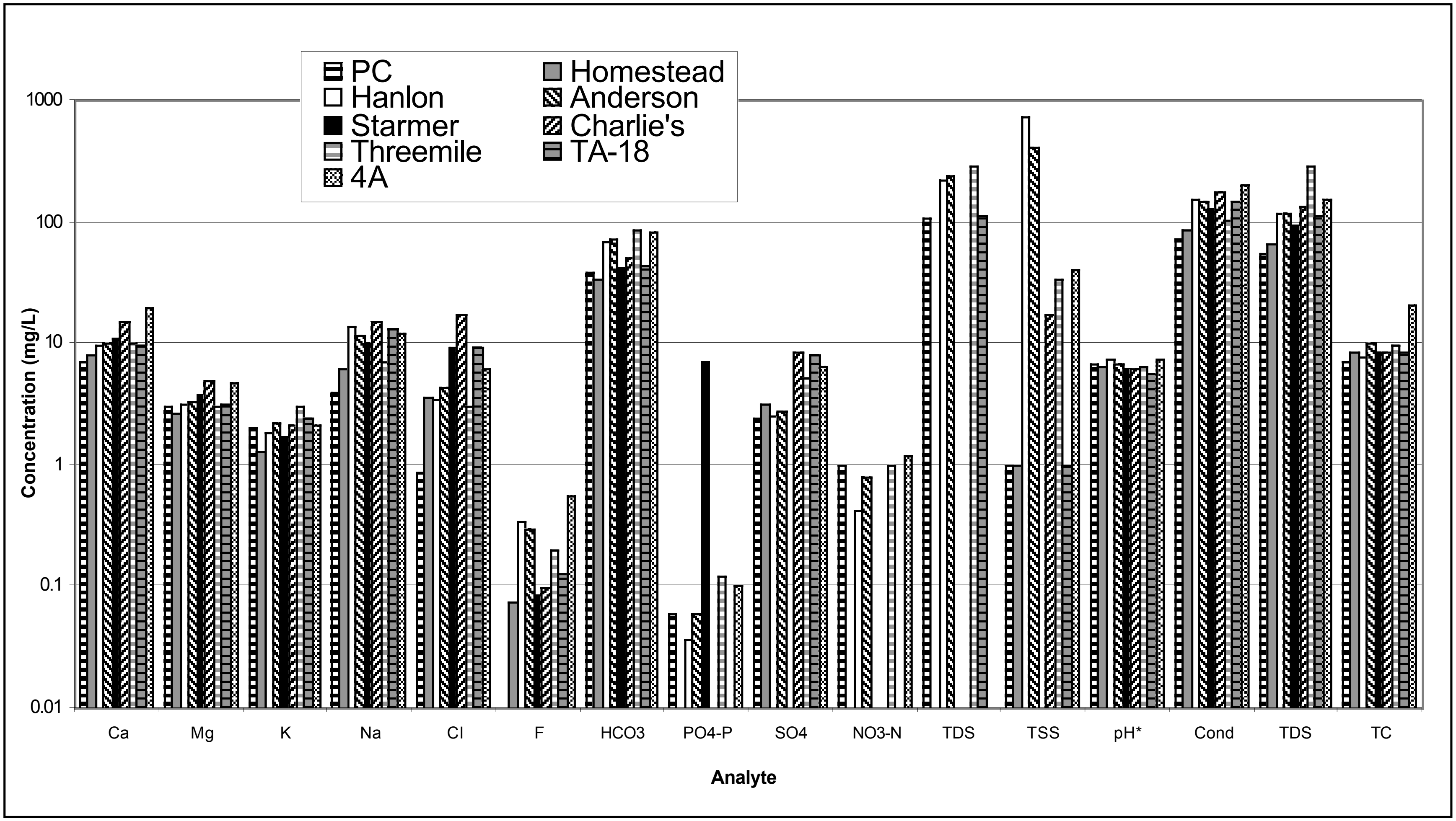
*In 1995, 1996, and 1997 personnel from the NMED DOE Oversight Bureau sampled springs on the Pajarito Plateau (including nine springs in Pajarito Canyon) for analysis of water quality parameters. The springs sampled included PC, Anderson, Charlie's, Starmer, Hanlon, Homestead, Threemile, TA-18, and Pajarito Springs (Spring 4A) (see Figure A-1). The samples (filtered and unfiltered) were analyzed for water quality parameters, and selected samples were analyzed for metals, VOCs, SVOCs, HE compounds, and radionuclides (Dale et al. 1996, 57014; Yanicak 1998, 57583).*

*Figure 3.6.6-13 shows the results of sampling springs in the Pajarito Canyon watershed for water quality parameters. PC Spring generally contains the lowest concentrations of calcium, chloride, fluoride, sodium, sulfate, TDS, and specific conductance values. The two springs in Twomile Canyon, Hanlon Spring and Anderson Spring, contain higher concentrations of bicarbonate and TDS than other springs in upper Pajarito Canyon and the south fork of Pajarito Canyon. Relative to the springs in upper Pajarito Canyon (PC Spring and Homestead Spring) and the springs in Twomile Canyon, the springs in the south fork of Pajarito Canyon (Starmer Spring and Charlie's Spring) contain higher concentrations of calcium, chloride, and magnesium. The springs in Threemile Canyon (Threemile Spring and TA-18 Spring) are similar in chemistry, but Threemile Spring contains higher bicarbonate and TDS, whereas TA-18 Spring contains slightly higher concentrations of chloride, sodium, and sulfate. The highest concentrations of calcium, magnesium, bicarbonate, specific conductance, and temperature are found at Pajarito Springs (Spring 4A), which discharges from the Puye Formation in lower Pajarito Canyon.*

*Figure 3.6.6-14 shows Stiff diagrams that were prepared for the springs sampled on the Pajarito Plateau using data from Yanicak (1998, 57583, Table 1). These diagrams are useful in graphically displaying major ion chemical compositions of each spring. Springs with identical chemical compositions probably are derived from a similar source. However, variations in major ion chemistries may result from natural chemical variations within different aquifers and/or variation in chemical composition of Laboratory discharges.*

*Background springs (those located upgradient of the Laboratory) including upper Cañon de Valle Spring, Water Canyon Gallery Spring, and PC Spring in upper Pajarito Canyon are characterized by a calcium-sodium-bicarbonate composition. However, minor amounts of magnesium, potassium, and sulfate are also naturally present. The field-measured TDS contents of the background springs are generally less than 80 mg/L or ppm. Field-measured pH values for the background springs range from 6.72 to 7.6.*

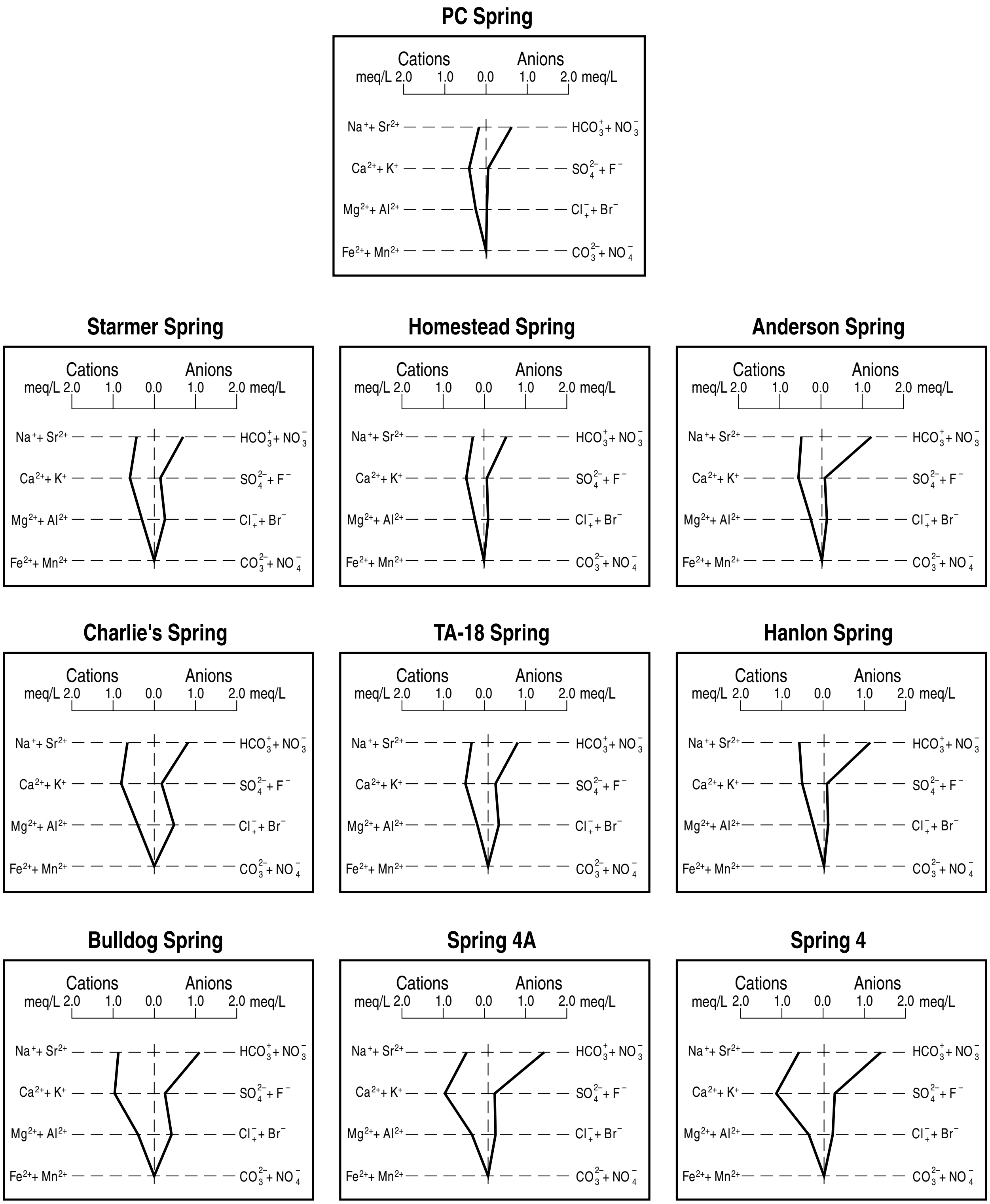
*Springs located east of the western Laboratory boundary, including Anderson, Bulldog, Burning Ground, Charlie's, Hanlon, Homestead, Martin, Starmer, and SWSC, are also characterized by calcium-sodium-bicarbonate compositions. Increasing concentrations of chloride and sulfate are present in these springs that may be derived from natural sources within the Bandelier Tuff and/or from Laboratory discharges. The field-measured TDS content of these springs is higher than the background springs, ranging from 54 to 156 mg/L. Field-measured pH values for these springs on Laboratory property range from 6.18 to 7.44.*




*pH is measured in standard units.*

Source: Dale et al. 1996, 57014; Yanicak 1998, 57583, Table 1

**Figure 3.6.6-13. Water quality parameters in Pajarito Canyon springs.**




meq = milliequivalent
Source: Yanicak 1998, 57583

F3.6.6-14 / PAJARITO CANYON WP / 052998

**Figure 3.6.6-14. Stiff diagrams of springs in Pajarito Canyon.**

*TA-18 Spring is located in lower Threemile Canyon and appears to discharge from unit Qbt 1v of the Bandelier Tuff, but discharge may be from the alluvium in Threemile Canyon. This spring is characterized by a calcium-sodium-bicarbonate composition with notable concentrations of chloride and sulfate. The field-measured pH value is 5.69, which is more acidic than the other springs investigated. This low pH could be the result of a combination of processes, such as the oxidation of $Fe^{+2}$ to $Fe^{+3}$ followed by the precipitation of ferric hydroxide when the spring emerges from the ground. The floor of the channel downstream of TA-18 Spring is strongly iron stained, which supports this hypothesis. The field-measured TDS content of the TA-18 Spring is 112 mg/L.*

*Spring 4 and Pajarito Springs (Spring 4A) discharge to lower Pajarito Canyon within White Rock Canyon, possibly from the Puye Formation through an overlying slump block. These two springs, which were sampled on April 24, 1996, are also characterized by calcium-sodium-bicarbonate compositions. Chloride and sulfate are present in samples from these springs above background values measured in springs from upper Cañon de Valle, Water Canyon Gallery, and PC Spring. The field-measured pH values for Spring 4 and Spring 4A are 6.72 and 7.39, respectively. The field-measured TDS contents of Spring 4 and Spring 4A are 162 and 151 mg/L, respectively.*

*In summary, the springs sampled by the NMED DOE Oversight Bureau personnel within Pajarito Canyon and adjacent areas have a calcium-sodium-bicarbonate composition with TDS contents generally increasing from west to east across the plateau. Chloride and sulfate concentrations increase to the east within Pajarito Canyon. This easterly direction may be the general flowpath for groundwater within the Bandelier Tuff, basalt, and Puye Formation with groundwater discharging in lower Pajarito Canyon and White Rock Canyon at Springs 4, 4A, 4B, and 4C.*

#### 3.6.7 Summary of Surface Water Hydrology Issues and Data Requirements for Understanding the Surface Water Hydrology

*The following bullets summarize the surface water hydrology of Pajarito Canyon.*

- *Two perennial reaches may occur in upper Pajarito Canyon. One reach extends downstream from PC Spring to near the Laboratory boundary, and another reach extends from Homestead Spring and Starmer Spring (in the south fork of Pajarito Canyon) downstream to near the confluence with Twomile Canyon. Another perennial reach is present in lower Pajarito Canyon from Pajarito Springs (Spring 4A) to the Rio Grande.*

- *The water from PC Spring in upper Pajarito Canyon shows no measurable tritium (see Table 3.6.6-3); therefore it is apparently from a deeper, older groundwater system, possibly similar to the regional aquifer groundwater. This water does not appear to be from recent precipitation.*

- *In upper Pajarito Canyon a significant amount of surface flow (from snowmelt, ephemeral storm water runoff, and discharge from PC Spring) is lost at the Pajarito fault zone west of the Laboratory boundary. Some of this flow loss may move through fractures and/or bedding planes in Tshirege Units 4 and 3, discharging as springs east of the fault zone. Some of the loss into the fault zone may move deeper, possibly providing some recharge to deeper perched zones (for example, as noted in SHB 3 to the south) or possibly providing some recharge to the regional aquifer.*

- *HE compounds have been detected in surface water in upper Pajarito Canyon west of the Laboratory boundary. HE compounds have also been detected in surface water in middle Pajarito*

*Canyon at streamflow gage E245 and in surface water in Threemile Canyon and in the spring water at TA-18 Spring. The surface water in Pajarito Canyon contains higher concentrations of HE compounds than surface water and springs in Threemile Canyon, and RDX has been measured in middle Pajarito Canyon above former SAL values.*

- *Surface flow across the eastern Laboratory boundary at state road NM4 is ephemeral. Flow reaches the Rio Grande occasionally as the result of high snowmelt runoff or periodic storm events. The geochemistry and temperature of surface water collected in Pajarito Canyon at the Rio Grande appears to be from Pajarito Springs (Spring 4A) and associated with discharge from the regional aquifer.*

- *The surface water collected at the Pajarito Canyon at the Rio Grande site is primarily from Pajarito Springs (Spring 4A) and is associated with the regional aquifer through geochemistry, radiochemistry, and temperature.*

*The following additional data are required to understand the surface water hydrology of Pajarito Canyon.*

- *Monitor streamflow volumes upstream and downstream of the Pajarito fault zone in upper Pajarito Canyon to determine the amount of stream loss in this area.*

- *Monitor streamflow in Pajarito Canyon below the confluence with north Anchor East basin to determine the volume of flow downstream from springs in Pajarito Canyon, the south fork of Pajarito Canyon, and north Anchor East basin.*

- *Sample surface water in upper and middle Pajarito Canyon and Threemile Canyon to determine where HE compounds are entering the surface water system; sampling biannually for a two-year period can also assess seasonal variations in water quality.*

*If contaminants are found in stream sediments, alluvial groundwater, and surface water, the following activities may help understand the surface water hydrology and distribution of contaminants in the canyon system.*

- *Monitor streamflow at several locations in Twomile Canyon for selected discrete periods to determine the contribution to streamflow and/or infiltration from springs, surface runoff, and snowmelt runoff in Twomile Canyon.*

- *Monitor streamflow at several locations in Threemile Canyon for selected discrete periods to determine the contribution to streamflow and/or infiltration from springs, surface runoff, and snowmelt runoff in Threemile Canyon.*

- *Monitor streamflow at several locations in upper Pajarito Canyon for selected discrete periods to determine the contribution to streamflow and/or infiltration from springs, surface runoff, and snowmelt runoff in upper Pajarito Canyon.*

- *Monitor streamflow immediately downstream of TA-18 facilities. The streamflow passes through a culvert beneath the access road near the eastern boundary of TA-18, which facilitates the installation of a new gaging station at this location.*

- *Quantify the surface water contribution to water balance in Pajarito Canyon.*
- *Determine the relative contribution of surface water flowing into middle Pajarito Canyon from upper Pajarito Canyon compared with surface water flow from Twomile Canyon.*

*A determination of the relative contribution of surface water flowing into middle Pajarito Canyon from upper Pajarito Canyon compared with surface water from Twomile Canyon is needed; therefore, the possibility of installing an additional gaging station in upper Pajarito Canyon upstream of the confluence with Twomile Canyon will be investigated. Most locations in the canyon are not favorable for the installation of gaging stations because of the large amount of sediment that accumulates during storm water runoff.*

## 3.7 Hydrogeology

*This section presents a summary of prior investigations of the hydrogeology of the Pajarito Canyon system and discusses the hydrogeology of the known saturated zones located in the alluvium and in the regional aquifer. At the present time, no intermediate perched zones have been identified in the Pajarito Canyon area; however, moisture and possible saturated zones encountered in boreholes near TA-18 may represent intermediate zone(s) of moisture.*

*Groundwater pathways in the Pajarito Canyon system are important because of the possibility of contaminant transport laterally or downward to zones of saturation that may be capable of contaminant transport off-site. Understanding the unsaturated zones at the upper portion of the alluvium and, most importantly, in the underlying tuff and deeper zones is an important aspect of understanding potential transport pathways.*

*Special low-detection-limit (0.67 pCi/L) measurements of tritium have confirmed the presence of recent recharge to the regional aquifer at several locations in deep wells including TW-8 in Mortandad Canyon, apparently from alluvial sources (Blake et al. 1995, 49931, p. 33; Rogers et al. 1996, 54714, Table 2). Site-specific information about contaminants at depth below Pajarito Canyon does not exist; however, similar pathways probably occur for potential contaminant transport to deeper zones. In addition, lateral contaminant transport from other canyons may occur in the subsurface.*

### 3.7.1 Shallow Unsaturated Alluvial Zone

*The shallow unsaturated alluvium is that portion of the alluvium from the surface downward to the top of the alluvial saturated zone, where present. Pajarito Canyon receives inflow from springs, precipitation, and several NPDES-permitted discharges. In the upper canyon, near TA-9 and TA-22, springs discharge into Pajarito Canyon and Twomile Canyon, and perennial flow is maintained for a distance downstream in the channel. Where perennial flow occurs, the thin alluvium probably is saturated. Alluvium in floodplains 3 to 4 ft (0.91 to 1.2 m) above the stream channel through these reaches are not saturated but probably contribute to storage.*

*In middle Pajarito Canyon the surface flow normally infiltrates into the alluvium, and the stream channel is dry except during periods of heavy precipitation and snowmelt runoff. Water levels in the alluvium at TA-18 are usually approximately 15 ft (4.6 m) below ground surface. The water levels become shallower to the east and are only approximately 1 to 2 ft (0.3 to 0.6 m) below ground surface at wells PCO-1 and PCO-2 (see Table C-5). Shallow alluvial groundwater is present in lower Threemile Canyon as evidenced by the* *presence of water in a shallow cistern west of Kiva 2 that is approximately 2 ft (0.6 m) below the surface of the ground. In this area of lower Threemile Canyon, the unsaturated alluvial zone is relatively thin.*

*During periods of precipitation and increased streamflow, the surface water front advances downstream. The surface water infiltrates into the sediments, and the alluvium becomes saturated. The unsaturated zone in the alluvium may be dissected down the center of the canyon by the infiltration of surface water.*

### 3.7.2 Alluvial Groundwater

*This section describes the wells that have been installed in Pajarito Canyon and summarizes the information that is known about the alluvial groundwater. An understanding of the bedrock stratigraphy, alluvial stratigraphy, and the relationship between water in the alluvium and water in suballuvial intermediate perched zones, if present, is needed to understand the hydrogeology of Pajarito Canyon.*

*The shallow alluvial groundwater body in Pajarito Canyon extends from approximately 1 mi (1.6 km) west of TA-18 to the eastern Laboratory boundary at state road NM4. The principal source of recharge to the shallow groundwater is probably infiltration of streamflow from the upper reaches of the canyon supplemented by infiltration of local precipitation and by NPDES discharges. Near TA-18 the canyon widens and the alluvium thickens. At this location the alluvium is primarily recharged from underflow in the alluvium from up canyon, ephemeral streamflow in the channel and spring flow from Threemile Canyon. During heavy snowmelt and summer rainstorms, the stream front occasionally extends down the canyon as far as the Rio Grande.*

*The abandoned gravel excavations in lower Pajarito Canyon provide ponding areas for surface water and are points of recharge to the alluvial groundwater. Alternately, at times of high groundwater levels, the alluvial groundwater intersects the bottom of the excavations where wetlands are formed. In the summer and fall of 1949, water for use in road construction was obtained from the alluvial groundwater via a pit in lower Pajarito Canyon that was located north of test hole PCTH-6 (see Figure A-1). The pit was approximately 100 ft (30 m) long, 35 ft (11 m) wide, and 15 ft (4.5 m) deep. Water was pumped from the pit at the rate of 50,000 to 100,000 gpd (190,000 to 3,800,000 L/d) (Black and Veatch 1950, 57575, p. 3). No other use of alluvial groundwater in Pajarito Canyon has been reported.*

*The only known groundwater discharges in Pajarito Canyon are the springs, the wetlands, a sump that collects groundwater beneath building TA-18-30, discharges to the stream channel through an outfall, and any losses from evapotranspiration (Purtymun and Kennedy 1971, 4798, p. 8; LANL 1995, 55527, p. 2-4). An unknown volume of alluvial groundwater presumably seeps downward into subsurface units through the bedrock at the base of the alluvium. The depth to the regional aquifer near TA-18 is approximately 800 ft (240 m).*

*Figure A-2 is a longitudinal cross section that shows the locations of existing wells in and near Pajarito Canyon. Five tables in Appendix C (Table C-1 through Table C-5) describe the wells, boreholes, and moisture tubes; provide location information and current status; provide construction information; provide stratigraphic information; and provide available water level measurements. Some of the stratigraphic information provided when some of the boreholes were originally drilled was found to be inconsistent with that from adjacent boreholes and with current understanding of the stratigraphy of the area. Therefore, Table C-4 contains both the original stratigraphic information, which is largely obtained from Purtymun (1995, 45344), and a revised set of stratigraphic picks based on review of lithologic descriptions and on local and regional stratigraphic information. Discussion of some of the revised stratigraphy is presented in the following sections.*

#### 3.7.2.1 Early Alluvial Groundwater Investigations

*In March 1950 two test holes were drilled with cable tools in lower Pajarito Canyon to investigate the possible development of water supplies in the canyon. These holes were drilled after shallow alluvial groundwater was pumped from a 15-ft- (4.5-m-) deep pit in the lower canyon at the rate of 50,000 to 100,000 gpd (190,000 to 3,800,000 L/d) in 1949 (Black and Veatch 1950, 57575, p. 3). Borehole PCTH-5 was drilled to a total depth of 263 ft (80 m) into basalts in the Puye Formation. This hole encountered 23 ft (7 m) of alluvium, but no water was found in the alluvium or deeper units. Borehole PCTH-6 was drilled adjacent to the 15-ft- (4.5-m-) deep pit where shallow alluvial groundwater was obtained in 1949. This hole was drilled to a total depth of 300 ft (91 m) and encountered 25 ft (7.6 m) of alluvium at the surface. A small amount of water was encountered in the alluvium at 18 ft (5.5 m). The amount of water in the alluvium was too small to measure and was described as "a slight seepage" (Black and Veatch 1950, 57575, p. 2). The information obtained from these holes was summarized by Purtymun (1995, 45344, p. 211) and is also shown in Appendix C. The locations of these test holes are shown in Figure A-1, and the stratigraphic information obtained from these holes is shown in cross section on Figure A-2.*

*The results of the investigation in 1950 show the variability of alluvial groundwater supplies in lower Pajarito Canyon. In 1949 alluvial groundwater was readily available within 15 ft (4.5 m) of the surface, but in 1950 the water level was approximately 18 ft (5.4 m) below surface, and the alluvium was apparently devoid of water (Black and Veatch 1950, 57575, p. 1).*

*In 1985 Laboratory personnel drilled seven boreholes in Pajarito Canyon to document the location and extent of alluvial groundwater and to understand the behavior of the groundwater system. This investigation was implemented to determine the sediment, surface water, and alluvial groundwater conditions adjacent to TA-54 and to determine if alluvial groundwater extended laterally beneath MDAs on Mesita del Buey (Devaurs and Purtymun 1985, 7415, p. 12; Purtymun 1995, 45344, p. 113).*

*Three of the original seven boreholes drilled in 1985 were cased with perforated pipe that was open to the alluvial groundwater zone and were completed as Pajarito Canyon observation (PCO) wells. Four of the boreholes were cased with capped plastic or polyvinyl chloride pipe to seal alluvial groundwater out of the tubes (PCM holes). These boreholes were used as moisture access tubes to accommodate a neutron probe for determining the moisture content of the alluvium and underlying tuff. The installations were designated by a numbering system that began in lower Pajarito Canyon, with numbers increasing downstream.*

*The three alluvial monitoring wells in Pajarito Canyon are designated PCO-1, PCO-2, and PCO-3. The locations of these wells are shown on Figure A-1. PCO-1 and PCO-2 were drilled in abandoned borrow pits where the depth to the alluvial groundwater is relatively shallow. When the wells were drilled, shallow groundwater was encountered in the alluvium within a few feet of the surface. However, the rock units below the alluvium were found to be dry, ". . . indicating little infiltration of water from the alluvium into the underlying tuff" (Devaurs and Purtymun 1985, 7415, p. 12).*

*PCO-1 is located approximately 2000 ft (600 m) down canyon from TA-18 in a former borrow pit excavation where the upper portion of the alluvium has been removed. This well was drilled to a total depth of 22 ft (6.7 m) and was completed to a depth of 12 ft (3.6 m) (Purtymun 1995, 45344, p. 118). The depth to alluvial groundwater at this location is typically 1 to 2 ft (0.3 to 0.6 m) below ground surface (see Figure A-3).*

*PCO-2 is located approximately 0.8 mi (1.3 km) down canyon from PCO-1. This well is located downgradient from the former TA-18 sewage lagoon outfall, downgradient from MDA L, and upgradient from MDA G, which are both located on Mesita del Buey north of Pajarito Canyon. PCO-2 was drilled to a total depth of 22 ft (6.7 m) and was completed to a depth of 9.5 ft (2.9 m). Water levels at PCO-2 are typically 5 to 9 ft (1.5 to 2.7 m) below ground surface.*

*PCO-3 is located approximately 0.9 mi (1.4 km) down canyon from PCO-2 and approximately 2 mi (3.2 km) down canyon from TA-18. This well is downgradient from MDA G and is approximately 0.5 mi (0.8 km) west of the Laboratory boundary. PCO-3 was drilled to a total depth of 20 ft (6 m) and was completed to a depth of 17.7 ft (5.4 m). Water levels at PCO-3 are typically 3 to 4 ft (0.9 to 1.2 m) below ground level.*

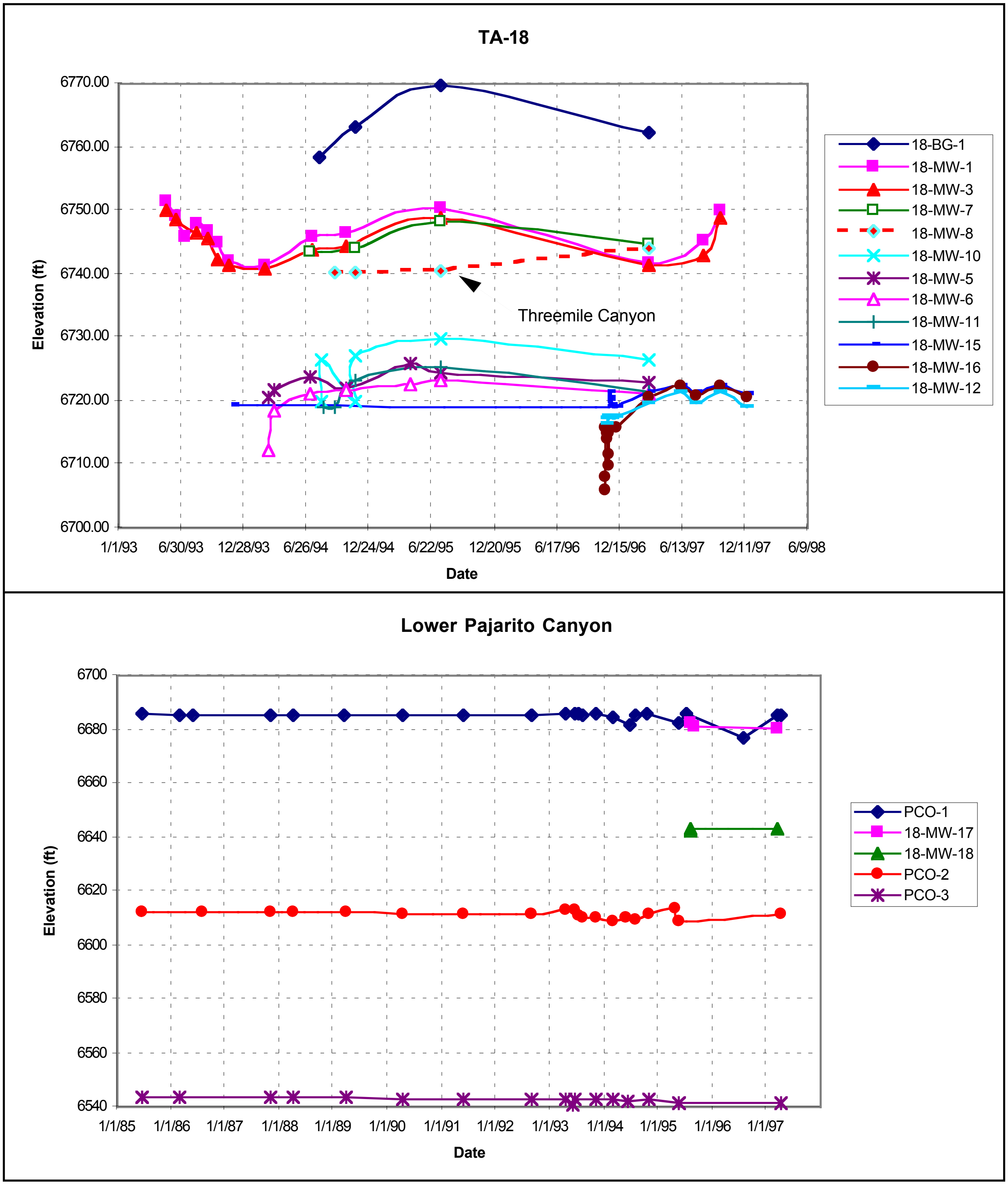
*The PCO wells were drilled through the alluvium into the underlying tuff using a truck-mounted rig equipped with a 7-in.- (18-cm-) diameter auger. The boreholes were cased using 4-in.- (10-cm-) diameter PVC casing and screened with perforated stainless steel through the saturated interval. The annular space around the casing was packed with gravel to within 2 ft (0.6 m) of the ground surface and finished to the ground surface with concrete. Well development was performed by water jetting and pumping with a centrifugal pump (Devaurs 1985, 7416). The PCO wells are sampled annually by ESH-18 personnel; the results of the analyses are discussed in Section 3.7.2.5.*

*Figure 3.7.2-1 shows the historic water level elevations measured at the alluvial wells in Pajarito Canyon, including the PCO series wells. The historic water level data for the wells in Pajarito Canyon is summarized in Table C-5. Water levels in the PCO wells have typically varied by less than 5 ft (1.5 m). Quarterly water level measurements obtained in 1993 and 1994 show the seasonal change in water levels, apparently primarily due to spring snowmelt runoff. The lowest water level recorded in PCO-1 was in 1996, but the water level recovered to normal in 1997. Since 1995 the water levels in PCO-2 and PCO-3 appear to have declined slightly.*

*Moisture access tubes PCM -1, -2, -3, and -4 were installed in 1985 along the north edge of Pajarito Canyon and near the base of the south cliff-wall of Mesita del Buey. PCM-1 and PCM-2 were installed near PCO-1 and PCO-2, respectively. PCM-3 and PCM-4 are located at the base of Mesita del Buey south of MDA G. These holes were located to potentially observe alluvial groundwater from Pajarito Canyon that might extend northward beneath Mesita del Buey. Each of the PCM boreholes was dry. These holes "document that perched water in Pajarito Canyon, adjacent to Mesita del Buey, is confined to the alluvium in the stream channel, and does not extend to the flank of the canyon" (Devaurs and Purtymun 1985, 7415, p. 12) and importantly, these holes document that perched alluvial groundwater does not extend beneath Mesita del Buey. Boreholes drilled on Mesita del Buey at TA-54 have confirmed that no saturated groundwater zones are present at the level of the perched alluvial groundwater.*

#### 3.7.2.2 Recent Alluvial Groundwater Investigations

*Since 1990 19 alluvial groundwater-monitoring wells have been installed at TA-18. Appendix C contains a summary of the information about these wells, including well status, location, water level data, and stratigraphic information. Figure A-1 shows the locations of the wells. The results of sampling these wells are discussed in Section 3.7.2.5.*




Source: LANL 1995, 55527; LANL 1997, 57015; environmental surveillance reports

**Figure 3.7.2-1. Historic water levels in Pajarito Canyon alluvial wells.**

During 1990 the Laboratory installed four monitoring wells at the LACEF at TA-18 (the Kiva 1 complex). These wells are informally referred to as the LACEF wells and in this work plan are referred to as 18-MW-1, 18-MW-2, 18-MW-3, and 18-MW-4. The Kiva 1 area is located in Pajarito Canyon west of the confluence with Threemile Canyon. These wells were installed to establish baseline levels of radionuclides in sediments and shallow groundwater surrounding the Kiva 1 portion of LACEF and to assess the potential for transport of radionuclides in the shallow groundwater system in Pajarito Canyon. All four wells were drilled through alluvium to a depth of approximately 25 ft (7.5 m); however, none of the boreholes fully penetrated the alluvium. Field observations indicate that the alluvium/tuff interface may be at a depth of 35 ft in the area (LATA 1991, 12464, p. 3-1). However, a geotechnical borehole drilled near Kiva 1 in 1984 reportedly encountered alluvium at a depth of only 18 ft (5.4 m) (Purtymun 1994, 58233, p. 162-1).

During 1994 the Laboratory installed seven monitoring wells at TA-18. Wells 18-MW-5 and 18-MW-6 were installed near a former underground storage tank (UST) TA-18-PL30 in support of a hydrogeologic investigation to monitor petroleum-derived contaminants in groundwater resulting from a release at the former UST site (LANL 1994, 47113). These two monitoring wells are located east and south of building TA-18-189 along the southern side of the main complex at TA-18. The UST was removed in September 1993, and the monitoring wells were installed in March 1994 in accordance with New Mexico UST regulations.

Monitoring well 18-MW-5 was drilled through predominantly silty and clayey sands and gravels with minor clay and clean sand layers, dacite, and tuff boulders. The well was drilled to a depth of 28 ft (8.5 m) where a dacite boulder was reportedly encountered near the anticipated bottom of the alluvium. Well 18-MW-6 was drilled through a similar stratigraphic sequence to a depth of 25 ft (7.5 m) and also was reported to have encountered a dacite boulder near the anticipated bottom of the alluvium. The static water levels below ground surface in 18-MW-5 and 18-MW-6 at the time of well installation were 16.5 ft (4.9 m) and 11.5 ft (3.5 m), respectively.

Monitoring wells 18-MW-7 through 18-MW-11 were installed to support the Phase I RFI activities of OU 1093 at TA-18 (LANL 1995, 55527, p. 1-1; LANL 1996, 54919). Well 18-MW-7 (borehole 18-1135) was drilled to a depth of 32 ft (9.6 m) along the southwest edge of the drainfield associated with septic system PRS 18-003(b), which formerly served building TA-18-23 at Kiva 1. Well 18-MW-8 (borehole 18-1166) was drilled in lower Threemile Canyon to a depth of 37.9 ft (11.4 m). This well is located near the southeastern corner of the drainfield associated with the septic system PRS 18-003(c), which formerly served building TA-18-32 at Kiva 2.

Monitoring well 18-MW-9 was drilled to a depth of 23 ft (6.9 m) within the drainfield associated with septic system PRS 18-003(e), which formerly served buildings TA-18-31, -37, and -129 at the TA-18 main complex. Well 18-MW-10 was drilled to a depth of 28.7 ft (8.6 m) near the southeast edge of the drainfield associated with septic system PRS 18-003(f), which is located along the western edge of the TA-18 main complex. Well 18-MW-11 was drilled to a depth of 49 ft (14.7 m) southeast of septic tank PRS 18-003(g), which formerly served building TA-18-1 at the TA-18 main complex. Corrective actions were subsequently performed for these septic systems, as described in Section 2.3 (LANL 1995, 55527, p. 4-43).

Five additional monitoring wells were installed at TA-18 during the fall of 1996 to support the RFI remediation activities at PRS 18-003(d). The wells were installed in the drainfield associated with the septic system that formerly served building TA-18-116 at Kiva 3 to better define the extent of dichloroethylene (DCE) in groundwater. Monitoring wells 18-MW-12, 18-MW-13, 18-MW-14, 18-MW-15, and 18-MW-16 were drilled to depths of 43.8, 40.1, 45, 48, and 37 ft (13.2, 12, 13.5, and 11.1 m), respectively. Quarterly sampling of these wells was initiated in December 1996 as described in the

*Corrective Action Report for TA-18 (LANL 1997, 55120). The results of the first two quarters of sampling are presented in the RFI report for groundwater sampling at PRS 18-003(d) (LANL 1997, 57015) and are discussed in Section 3.7.2.5. The results from subsequent quarterly sampling events are to be submitted in a future RFI report.*

*In 1995 18-MW-17 was installed as part of the expedited cleanup activities conducted at PRS 18-001(b), which is the decommissioned sanitary sewer line that connected TA-18 with the sewage lagoons in lower Pajarito Canyon (LANL 1996, 54841). The well was installed adjacent to a decommissioned manhole and south of PCO-1 to monitor groundwater quality beneath the former sewage line and manhole. This well was drilled to a depth of 23.8 ft (7.1 m) and yielded a static water level of 14.35 ft (4.3 m) below ground surface.*

*Monitoring well 18-MW-18 was installed in 1995 as part of the VCA activities conducted at PRS 18-001(a), which was the former sewage lagoons in lower Pajarito Canyon (LANL 1996, 54324). The well was installed at the northeast corner of the former sewage lagoons to monitor potential releases from the lagoons to the alluvial groundwater. This well was drilled to a depth of 24 ft (7.2 m) and yielded a static water level of 11.8 ft (3.5 m) below ground surface. The results of alluvial groundwater sampling at 18-MW-17 and 18-MW-18 suggest that these PRSs have not resulted in impacts to groundwater. These wells are planned to be monitored and sampled as part of the ongoing alluvial groundwater investigation (LANL 1997, 56356, p. A3).*

*In February 1996 monitoring well 18-BG-4 was installed in Threemile Canyon west of Kiva 2. This well was installed upgradient from known contaminant sources at TA-18 to provide baseline groundwater quality information for Threemile Canyon. The alluvium at this well was 6.5 ft (2 m) thick, and water was initially encountered at 2.5 ft (0.75 m); however, water did not readily enter the borehole after the well was completed. The well was drilled to a total depth of 25 ft (7.5 m) into apparently saturated bedrock. A summary of the information available for well 18-BG-4 is in Appendix C tables.*

*Groundwater monitoring was conducted at the RFI wells, the LACEF wells, and the PCO wells as part of the Phase I RFI. The results of the monitoring were reported in the RFI report for OU 1093 (LANL 1995, 55527; LANL 1996, 54919). The analytical results of the groundwater monitoring are summarized in Section 3.7.2.5.*

*Shallow groundwater elevations were measured periodically from 1993 through 1997 as part of the RFI. Before 1993 they were measured in the PCO wells, which were drilled and are monitored by the Environmental Surveillance Program conducted by ESH-18. Water level elevations obtained for the LACEF wells and the RFI wells are shown in Figure 3.7.2-1 and are listed in Table C-5. Water level elevations appear to show the greatest amount of variability in middle Pajarito Canyon at the 18-BG wells, varying as much as 13 ft (4 m) from 1993 through 1996 (see Figure 3.7.2-1). Variations in the water levels are observed both seasonally and annually. Measurements of the depth to the alluvial groundwater obtained by drilling conducted during the RFI at TA-18 were from 6 to 22 ft (1.8 to 6.6 m) below ground surface (LANL 1997, 55120, p. 7).*

*The elevation of the alluvial groundwater is generally lowest from November through February because snowfall precipitation during this time is not available for infiltration, and recharge from upstream areas is at a minimum. Water level elevations are highly variable during the spring and summer months, primarily because of the variability in seasonal rainstorms and recharge from associated streamflow. The amount of fluctuation in alluvial groundwater levels decreases down canyon, probably because of widening of the canyon and an associated increase in the volume of the alluvial groundwater body.*

*The stream channel and the borrow pit depressions in lower Pajarito Canyon may serve as groundwater discharge points through evapotranspiration when groundwater levels are high. However, these locations may also serve as recharge points when groundwater levels are low and the pits and/or stream contain surface water or runoff water.*

*Figure 3.7.2-2 is an isopleth map of the elevation of the alluvial groundwater based on measurements obtained in March 1997. During March 1997 the gradient of the surface of the alluvial groundwater in middle Pajarito Canyon from 18-BG-1 to the LACEF wells was 1.9%, and in the TA-18 area the gradient was 1.4%, which indicates that the alluvial hydraulic gradient decreases to the east. The gradient in lower Threemile Canyon was approximately 2%, which is steeper than in adjacent Pajarito Canyon. From TA-18 to PCO-1 the gradient was approximately 2.1%, and from PCO-1 to PCO-2 and from PCO-2 to PCO-3 the gradient averaged 1.5%. Alluvial groundwater probably does not extend for a significant distance east of PCO-3 because the alluvium pinches out against the basalt near state road NM4 (see Figure A-2).*

*Hydrologic characteristics of the shallow alluvial groundwater in Pajarito Canyon, such as permeability and transmissivity, have not been determined. However, it is likely that hydrologic characteristics of the alluvium in Pajarito Canyon are similar to those properties obtained from slug tests performed on alluvial observation wells in Los Alamos Canyon. The mean hydraulic conductivity obtained from five slug tests of alluvial wells in Los Alamos Canyon was 3.2 E–04 ft/sec (9.6 E–05 m/sec). Using a gradient of 0.027, which is equivalent to the slope of the steam channel, and an assumed porosity of 0.3, the average rate of groundwater movement in the alluvium in Los Alamos Canyon was estimated to be approximately 900 ft (270 m) per year (Gallaher 1995, 49679).*

*Figure A-3 also shows transverse cross sections of the alluvium-filled channel at the lines of wells where information about the shape of the channel is known. The alluvial groundwater is apparently restricted to the lower portion of the alluvium within the V-shaped channel in the middle canyon and in the U-shaped channel in the lower canyon. The width of the saturated zone in the V-shaped channel at 18-BG-1 is approximately 300 ft (91 m), with a saturated thickness of 15 to 20 ft (4.5 to 6 m). The alluvial saturated zone is probably widest at TA-18 below the intersection with Threemile Canyon, where the width of the alluvial groundwater zone is approximately 700 to 800 ft (213 to 244 m), and the saturated thickness is 15 to 20 ft (4.5 to 6 m).*

*The observed water level fluctuations show that saturated conditions in the alluvium are transient. Also, the nature of deposition of the alluvial sediments (shifting streambed and overbank flood deposits) indicates that a high degree of heterogeneity in the physical characteristics of the alluvial groundwater body is likely. Groundwater flow in the alluvium is probably controlled by highly conductive zones such as buried stream channels, braided deposits, and point-bar deposits. The flow may be limited in portions of the alluvium by finer-grained deposits such as floodplain and overbank deposits.*

*Currently, at least three groundwater wells are sampled as part of the Laboratory's routine monitoring program. These include PCO-1, PCO-2, and PCO-3, which range in completed depth from 20 to 22 ft (6 to 6.7 m). The depths to water in these wells typically range from 1 to 5 ft (0.3 to 1.5 m). In addition, the 18-MW-series wells are available for sampling and obtaining water level measurements. Five monitoring wells (18-MW -12, -13, -14, -15, and -16) were installed in November and December 1996 at PRS 18-003(d). These wells have been sampled quarterly since December 1996 because results of the initial RFI showed the presence of 1,2-dichloroethane in the groundwater above the NMWQCC groundwater standard for human health of 10 μg/L (LANL 1997, 57015, p. 1-1).*

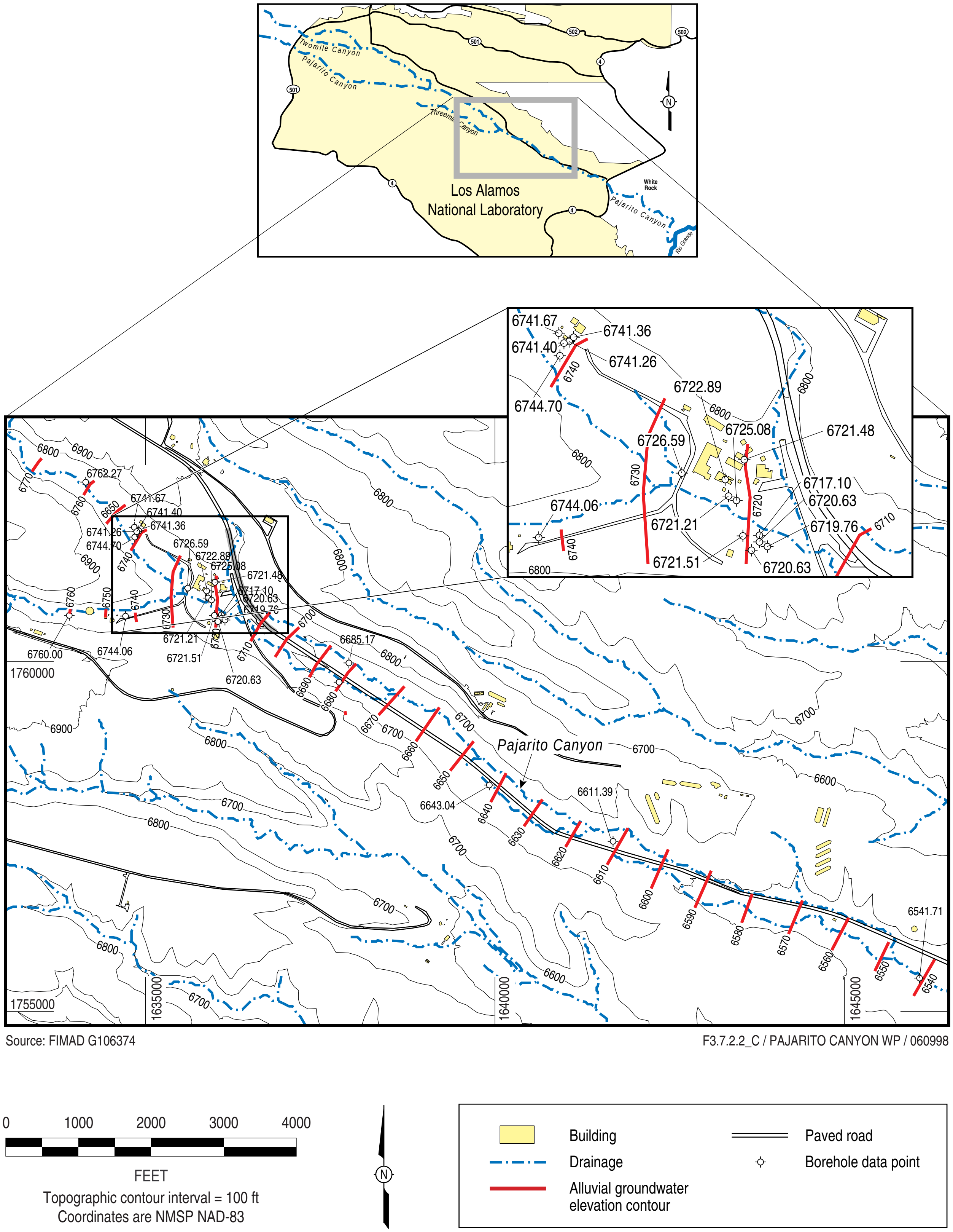



**Figure 3.7.2-2. Isopleth of alluvial groundwater in lower Pajarito Canyon.**

### 3.7.2.3 Relationship between Alluvium and Bedrock Stratigraphic Units

*Figure A-3 shows the bedrock stratigraphic units identified during borehole drilling for the test holes and the alluvial monitoring wells (Purtymun 1995, 45344, p. 113). The cross section shows the location and depth of the wells and the gamma log traces adjacent to the boreholes. The figure also shows the approximate base of the alluvium at the deepest part of the canyon (generally near the center of the canyon). Regionally, the Tsankawi Pumice Bed and the Cerro Toledo interval are present at the base of the Tshirege Member; however, none of the deep boreholes drilled in Pajarito Canyon identified the presence of these units because when the deep wells were drilled in Pajarito Canyon the presence of these units in the subsurface was not well documented.*

*Boreholes drilled at TA-54 on Mesita del Buey have confirmed the presence of the Tsankawi Pumice Bed and the Cerro Toledo interval. Stratigraphic data from these boreholes has been compiled into a site-wide geologic model (see Appendix D). Data from the model were extrapolated southward to determine the approximate subsurface stratigraphy in the Pajarito Canyon area. The stratigraphic data points obtained from the site-wide geologic model are shown as single vertical lines with tick marks at the tops of stratigraphic units on the longitudinal cross section of Pajarito Canyon in Figure A-2. The cross section shows the approximate stratigraphic position of the Tsankawi Pumice Bed and the Cerro Toledo interval in the Pajarito Canyon area. Table C-4 lists the revised stratigraphic picks that are interpreted to have been encountered in the deep boreholes in Pajarito Canyon.*

*The cross section shows the projected position of the stratigraphic contact between the base of the Tshirege Member and the Tsankawi Pumice Bed/Cerro Toledo interval in the Pajarito Canyon area. Based on this projection, the base of the alluvium intersects the Tsankawi Pumice Bed/Cerro Toledo interval in lower Pajarito Canyon between PCO-2 and PCO-3. Boreholes drilled near PCO-2 will probably encounter a thin, weathered section of the Tshirege Qbt 1g unit, which may be too thin to recognize in auger cuttings, and will then penetrate into the Cerro Toledo interval. The upper part of the Cerro Toledo interval consists of well-stratified tuffaceous sandstones, siltstones, and primary ash-fall and pumice-fall deposits as described in Section 3.3.1.4. In auger cuttings these deposits may be difficult to distinguish from the alluvial sediments. In the lower part of the canyon the Cerro Toledo interval and the Otowi Member thin eastward against a basalt high that is located near the intersection of Pajarito Canyon and state road NM4. These units usually have a southeastward dip similar to the regional dip of the Bandelier Tuff. However, in lower Pajarito Canyon a localized reversal of dip toward the west may occur on the west flank of the basalt high (see Figure A-2). Locally beneath lower Pajarito Canyon this may direct flow in the Cerro Toledo interval westward or southwestward around the basalt high.*

*The intersection of the alluvium and the Cerro Toledo interval demarks differing hydrogeologic units to the west and to the east. West of this intersection the Cerro Toledo interval may be present as a separate hydrogeologic unit and may form an intermediate perched zone of saturation. However, east of the intersection the alluvial hydrogeologic unit may merge with the Cerro Toledo interval to form a single hydrogeologic unit. If these hydrogeologic units merge, lateral flows of groundwater in this combined hydrogeologic unit may be controlled by the geometry and orientation of paleochannels in the Cerro Toledo interval. Efforts to characterize the fate of flow and contaminants in the alluvium will consider the possibility that paleochannels within the Cerro Toledo interval may not coincide with the orientation of Pajarito Canyon, thus creating pathways for groundwater flow laterally away from the canyon.*

### 3.7.2.4 Possible Perched Groundwater at TA-3

*The RFI for PRS 3-010(a) included drilling seven boreholes as part of the site characterization. Subsurface soil samples were collected from six of the boreholes for site characterization, and one* *borehole was completed as a monitoring well (B-1, which is called 03-MW-1 in this work plan) to provide geologic and hydrologic characterization information for the site. Monitoring well 03-MW-1 encountered water at approximately 23 ft (6.9 m) below ground surface. The well was drilled to a depth of 29 ft (8.7 m) and was completed as a 2-in.- (5.08-cm-) diameter, stainless steel monitoring well. Additional information about this well is located in the Appendix C tables.*

*Monitoring well 03-MW-1 was sampled on three occasions; however, the well was never properly developed or purged before sampling, and it is uncertain how this may have affected the analytical results. Subsurface soil samples were collected from every 5 ft (1.5 m) in boreholes B2 through B6. Water samples were collected from water encountered in boreholes B1, B4, and B6. Although water was also encountered in boreholes B4 and B6, the boreholes were not converted to monitoring wells or developed before sampling.*

*Constituents detected in borehole water samples are shown in Table 3.7.2-1. The groundwater contained solvents including 1,2-dichloroethane, 1,1-dichloroethene, and TCA above former SAL values. 1,2-dichloroethane was detected in concentrations as high as 12 μg/L (the former SAL value was 5 μg/L); 1,1-dichloroethene was detected in concentrations as high as 34 μg/L (the former SAL value was 7 μg/L); and TCA was detected in concentrations as high as 800 μg/L (the former SAL value was 200 μg/L). Water samples from Spring SM-30, which is located down gradient from these boreholes, also contained solvents but in lower concentrations than those measured in the monitoring wells (LANL 1995, 55638).*

**TABLE 3.7.2-1**

**DETECTED CONSTITUENTS IN GROUNDWATER AT PRS 3-010(a)**

| Location ID | Sample ID | Analyte | Result | Uncertainty | Units | Former SAL |
|---|---|---|---|---|---|---|
| 03-MW-1 B1 (03-2664) | AAC0469 | 1,1-Dichloroethane | 18 | 5 | μg/L | 3500 |
| | | 1,2-Dichloroethane | 12 | 4 | μg/L | 5 |
| | | 1,1-Dichloroethene | 34 | 10 | μg/L | 7 |
| | | 1,1,2-Trichloro-1,2,2-trifluoroethane | 26 | 8 | μg/L | NA |
| | | TCA | 800 | 240 | μg/L | 200 |
| | AAC1081 | Tritium | 2710 | 95 | pCi/L | 20 |
| B4 (03-2667) | AAC8056 | 1,1,2-Trichloro-1,2,2-trifluoroethane | 230 | 69 | μg/L | NA |
| | | TCA | 300 | 90 | μg/L | 200 |
| | | Tritium | 540 | 80 | pCi/L | 20 |
| B6 (03-2679) | AAC0856 | 1,1,2-Trichloro-1,2,2-trifluoroethane | 40 | 12 | μg/L | NA |
| | | TCA | 130 | 39 | μg/L | 200 |

Source: LANL 1995, 55638

### 3.7.2.5 Geochemistry of Alluvial Groundwater in Pajarito Canyon

*The purpose of this section is to discuss the geochemistry of alluvial groundwater in Pajarito Canyon. Since 1985 personnel from ESH-18 (or its predecessor) have routinely collected unfiltered water samples from alluvial wells PCO-1, PCO-2, and PCO-3. Additionally, samples have been collected from the LACEF wells 18-MW -1, -2, -3, and -4 occasionally since 1991. This discussion focuses on temporal variations in major ion chemistry, uranium, and radionuclide distributions in alluvial groundwater and the regional aquifer.*

#### 3.7.2.5.1 Results of Environmental Surveillance Sampling

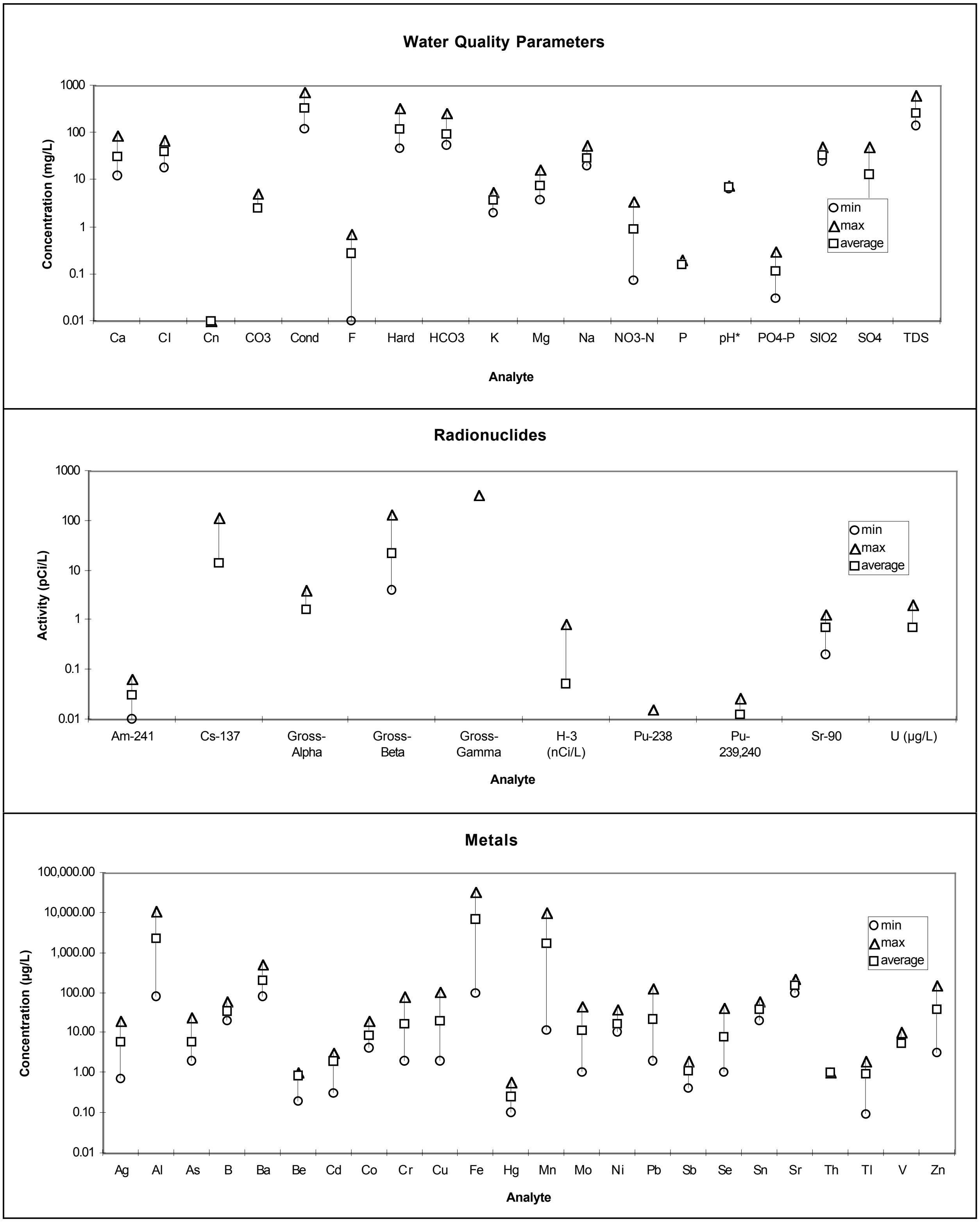
*Since 1985 ESH-18 personnel have collected groundwater samples from the PCO wells. The results of the analyses have been reported in the annual environmental surveillance reports (for example, Environmental Surveillance and Compliance Programs 1997, 56684). Most samples collected have not been filtered before analysis, so relatively wide ranges of concentrations of analytes have been measured. Background data are not yet available for comparison with alluvial groundwater upgradient from the Laboratory; therefore, comparison discussion of environmental surveillance report data in Pajarito Canyon is not possible.*

*Figure 3.7.2-3 shows a summary of the results of sampling PCO-1 for water quality parameters, radionuclides, and metals. This figure and other figures in this section show the minimum, maximum, and average values obtained from the annual environmental surveillance sampling. Water quality parameters observed at PCO-1 range in concentration over approximately an order of magnitude, probably caused by collecting nonfiltered samples. All concentrations of these water quality parameters are within NMWQCC standards. The concentrations of TDS at PCO-1 ranged from 144 to 612 mg/L and average 269 mg/L. Most results for metals concentrations also range approximately an order of magnitude, except aluminum, iron, and manganese, which vary approximately two orders of magnitude. This is likely caused by the collection of unfiltered samples. The highest activity of plutonium-238 measured was 0.016 pCi/L in 1988, and the highest activity of plutonium-239,240 was 0.027 pCi/L in 1990. The results of tritium analyses by liquid scintillation techniques have normally been near detection limits; the highest activity recorded was 0.8 nCi/L in 1986.*

*Figure 3.7.2-4 shows a summary of the results of sampling PCO-2. The concentrations of TDS at PCO-2 ranged from 142 to 600 mg/L and average 261 mg/L, which is very similar to PCO-1. The results of analyses for metals are similar to alluvial groundwater at PCO-1. The highest activity of plutonium-238 measured was 0.035 pCi/L in 1987, and the highest activity of plutonium-239,240 was 0.036 pCi/L in 1993. The results of tritium analyses by liquid scintillation techniques have normally been near detection limits; the highest activity recorded was 0.8 nCi/L in 1986.*

*Figure 3.7.2-5 shows a summary of the results of sampling PCO-3. The geochemistry of the water at this location is similar to the alluvial groundwater upstream. However, wider ranges in concentrations of aluminum, iron, and manganese are observed in the water from this site. The concentration of TDS ranged from 11 to 1420 mg/L and averages 405 mg/L, which is slightly higher than in wells up canyon. The results of analyses for metals are similar to alluvial groundwater at PCO-1. The highest activity of plutonium-238 measured was 0.059 pCi/L in 1993, and the highest activity of plutonium-239,240 was 0.027 pCi/L in 1992. The highest activity of tritium measured was 1.2 nCi/L in 1986; most tritium values have been near detection limits using liquid scintillation techniques.*

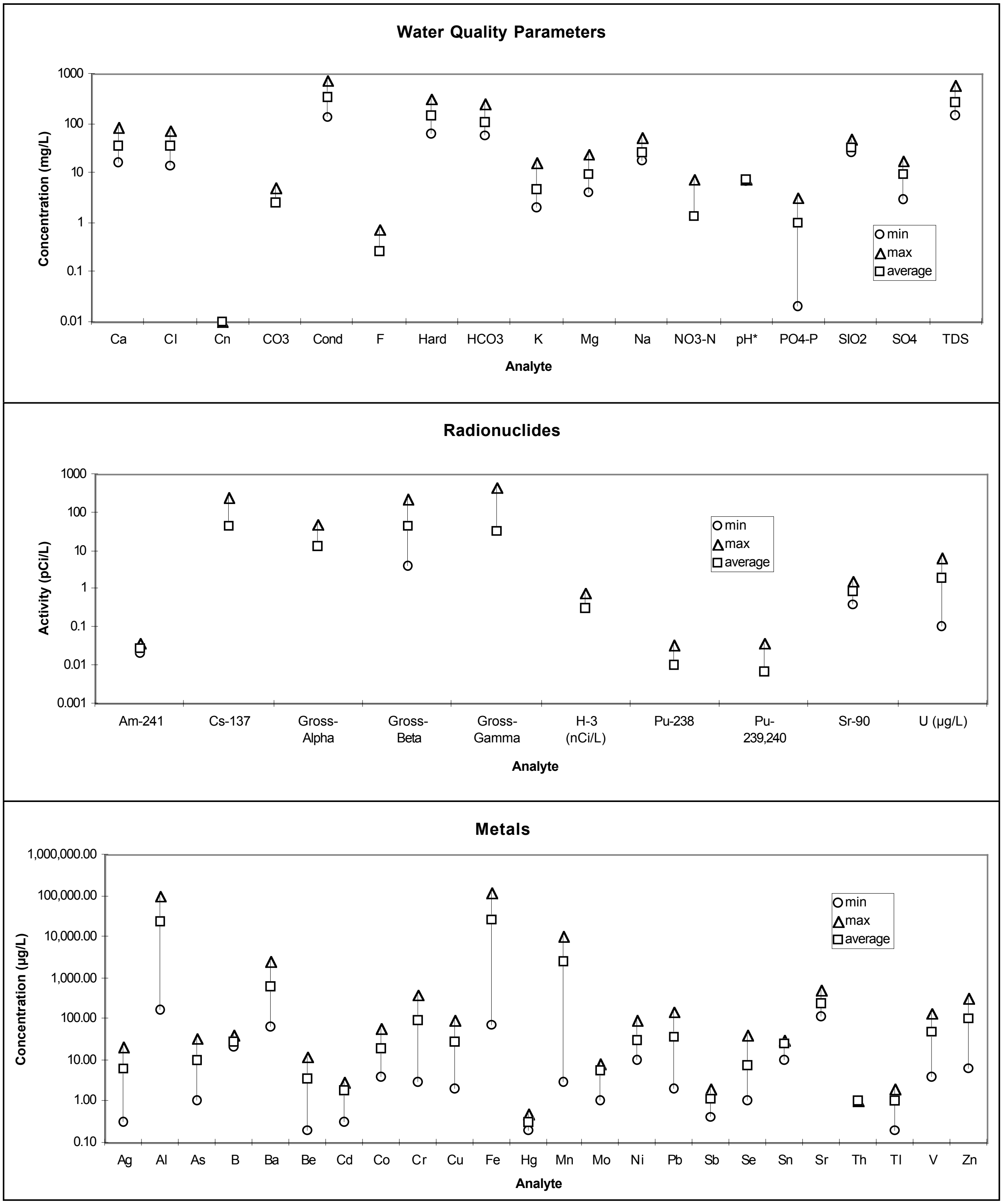
*Figure 3.7.2-6 shows the comparisons of the mean concentration measured for water quality parameter, radionuclides, and metals from 1985 to 1996 in each of the PCO wells. Generally, PCO-3 contains slightly higher concentrations of water quality parameters, which may be attributable to longer residence time in the alluvium. No trend is apparent in metal concentrations between the different sites. Slightly higher activities of cesium-137; gross-alpha, -beta, -gamma; and tritium are observed in the alluvial groundwater at PCO-2, but concurrent increases in activities of other radionuclides are not observed. Significant increases in radionuclides in the alluvial groundwater down canyon from PCO-1 to PCO-3 are not observed, which suggests that radionuclide contaminants from TA-54 have not been significantly detected in the alluvial groundwater in Pajarito Canyon.*




**pH is measured in standard units.*

Source: Environmental surveillance reports 1986–1997

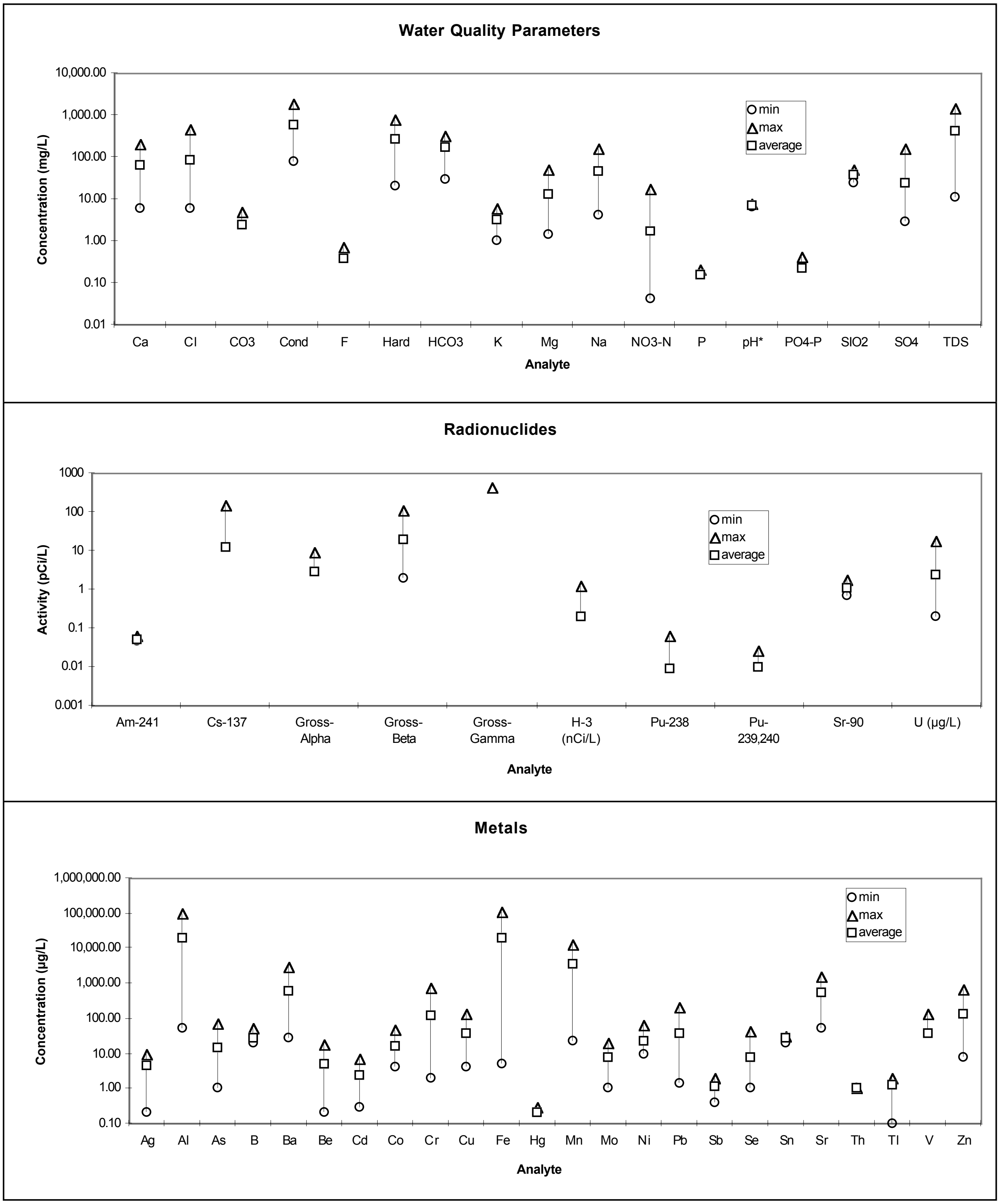
**Figure 3.7.2-3. Summary of environmental surveillance sampling of alluvial groundwater at PCO-1.**




**pH is measured in standard units.*

Source: Environmental surveillance reports 1986–1997

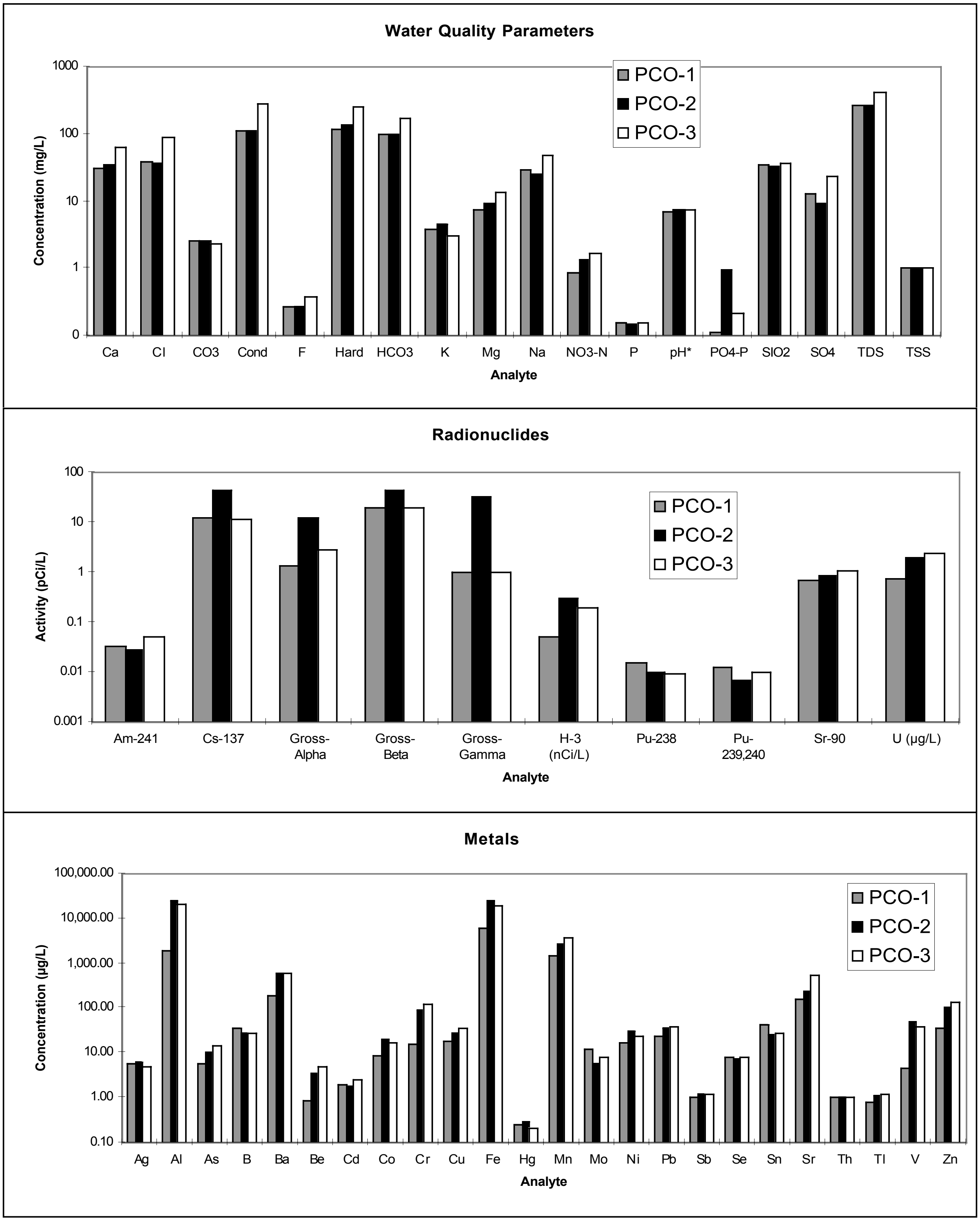
**Figure 3.7.2-4. Summary of environmental surveillance sampling of alluvial groundwater at PCO-2.**




**pH is measured in standard units.*

Source: Environmental surveillance reports 1986–1997

**Figure 3.7.2-5. Summary of environmental surveillance sampling of alluvial groundwater at PCO-3.**




*pH is measured in standard units.*

Source: Environmental surveillance reports 1986–1997

**Figure 3.7.2-6. Comparison of average concentrations of constituents in alluvial groundwater at PCO-1, PCO-2, and PCO-3.**

### 3.7.2.5.2 Results of RFI Sampling of Alluvial Groundwater

*Alluvial groundwater was sampled in lower Pajarito Canyon as part of the RFI for OU 1093. The results of the sampling are reported in the RFI report (LANL 1995, 55527), the addenda RFI report (LANL 1996, 54919), and the response to the notice of deficiency (LANL 1997, 56356). Similar to the environmental surveillance sampling, the alluvial groundwater samples collected for the RFI were not filtered at the time of collection. TA-18 site-specific baseline values for alluvial groundwater chemistry were obtained from background (baseline) wells 18-BG-1, 18-BG-2, and 18-BG-3, which are located in Pajarito Canyon west of TA-18. In the RFI report the data from these wells were used for comparison with alluvial groundwater collected at TA-18 to determine potential contributions from TA-18 to the alluvial groundwater (LANL 1995, 55527, p. B-1). However, as mentioned above, site-wide background data are not yet available for alluvial groundwater comparison. As it turned out, the alluvial groundwater from the baseline wells west of TA-18 contained contaminants above former SAL values.*

*Unlike the environmental surveillance sampling of the alluvial groundwater, the analysis of the RFI samples included HE compounds. The RFI sampling of TA-18 baseline wells 18-BG-1 and 18-BG-2 (Site IDs 18-1060 and 18-1063, respectively) showed the presence of several HE compounds. The HE compounds detected in the alluvial groundwater in these wells are listed in Table 3.7.2-2. Most compounds were detected at relatively low concentrations, and most were below former SAL values; however, RDX was measured at more than three times former SAL values in the alluvial groundwater upstream of TA-18 (LANL 1995, 55527, p. 3-7).*

**TABLE 3.7.2-2**

**HE COMPOUNDS IN ALLUVIAL GROUNDWATER UPSTREAM OF TA-18**

| Analyte | Well | Sample ID | Result (μg/L) | Former SAL (μg/L) |
|---|---|---|---|---|
| *Amino-2,6-dinitrotoluene [4-]* | *18-BG-1* | *AAB2442* | *0.499* | *73* |
| *Amino-4,6-dinitrotoluene [2-]* | *18-BG-1* | *AAB2442* | *0.178* | *37* |
| *Amino-4,6-dinitrotoluene [2-]* | *18-BG-2* | *AAB2450* | *0.096* | *37* |
| *Dinitrobenzene [1,3-]* | *18-BG-1* | *AAB2442* | *0.622* | *3.7* |
| *Dinitrotoluene [2,4-]* | *18-BG-1* | *AAB2442* | *0.09* | *73* |
| *HMX* | *18-BG-1* | *AAB2442* | *1.67* | *1800* |
| *HMX* | *18-BG-2* | *AAB2450* | *2.84* | *1800* |
| *Nitrobenzene* | *18-BG-1* | *AAB2442* | *0.544* | *18* |
| *Nitrobenzene* | *18-BG-2* | *AAB2450* | *0.927* | *18* |
| *Nitrotoluene [o-]* | *18-BG-1* | *AAB2442* | *3.66* | *N.A.* |
| *Nitrotoluene [p-]* | *18-BG-1* | *AAB2442* | *0.817* | *370* |
| *RDX* | *18-BG-1* | *AAB2442* | *2.07* | *0.61* |
| *RDX* | *18-BG-2* | *AAB2450* | *2.15* | *0.61* |
| *Tetryl(methyl-2,4,6-trinitrophenylnitramine)* | *18-BG-1* | *AAB2442* | *0.124* | *350* |
| *Trinitrobenzene [1,3,5-]* | *18-BG-2* | *AAB2450* | *1.28* | *1.8* |
| *Trinitrotoluene [2,4,6-]* | *18-BG-2* | *AAB2450* | *0.118* | *2.2* |

Source: LANL 1995, 55527

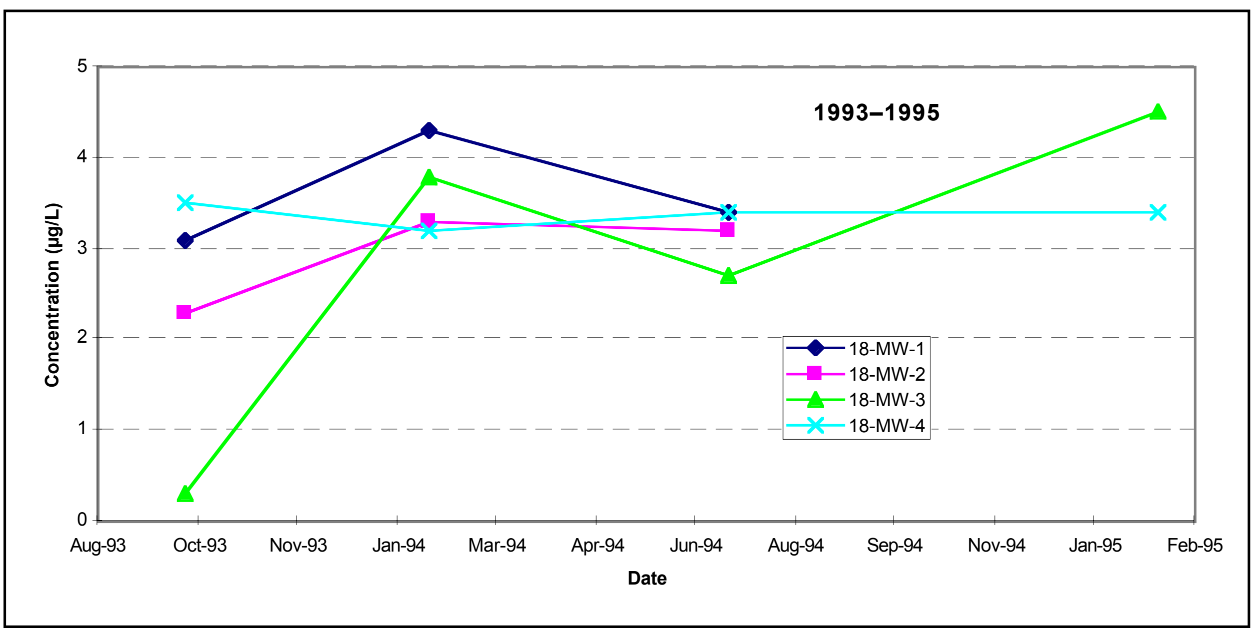
*Groundwater samples collected from the LACEF wells near Kiva 1 (18-MW-1 through -4) contained HE compounds HMX and RDX at concentrations greater than those measured in the baseline wells (18-BG wells). Table 3.7.2-3 lists the maximum concentration of HE compounds detected at each well during four* *sampling events that occurred from 1993 to 1995. Figure 3.7.2-7 shows the variability in the results of sampling the alluvial groundwater for HMX during four sampling events. For the period sampled the alluvial groundwater entering TA-18 in Pajarito Canyon contained 2 to 4 µg/L HMX. Additionally, thorium-228, thorium-230, uranium, and 1,2-dichloroethane were measured at concentrations above former SAL values in the LACEF wells (LANL 1996, 54919, p. 4-73).*

**TABLE 3.7.2-3**

**MAXIMUM CONCENTRATIONS OF HE COMPOUNDS IN LACEF WELLS NEAR KIVA 1 AT TA-18**

| Analyte | Well | Sample ID | Result (µg/L) | Former SAL (µg/L) |
|---|---|---|---|---|
| Amino-2,6-dinitrotoluene [4-] | 18-MW-1 | AAA9563 | 0.068 | 73 |
| Dichloroethane [1,2-] | 18-MW-4 | AAA9567 | 12 | 5 |
| HMX | 18-MW-1 | AAA9539 | 4.25 | 1800 |
| HMX | 18-MW-2 | AAA9542 | 3.31 | 1800 |
| HMX | 18-MW-3 | AAA9543 | 4.54 | 1800 |
| HMX | 18-MW-4 | AAA5961 | 3.45 | 1800 |
| Nitrobenzene | 18-MW-3 | AAA9565 | 0.085 | 18 |
| Nitrotoluene [m-] | 18-MW-1 | AAA9563 | 0.294 | N.A. |
| Nitrotoluene [m-] | 18-MW-2 | AAA9564 | 0.242 | N.A. |
| RDX | 18-MW-1 | AAA9539 | 1.55 | 3.2 |
| RDX | 18-MW-2 | AAA9542 | 1.29 | 3.2 |
| RDX | 18-MW-3 | AAA9543 | 3.01 | 3.2 |
| RDX | 18-MW-4 | AAA5961 | 1.07 | 3.2 |

Source: LANL 1995, 55527




Source: LANL 1996, 54919

**Figure 3.7.2-7. HMX in alluvial groundwater at the LACEF wells.**

*RFI sampling of the PCO wells downstream of TA-18 also showed the presence of HE compounds, but generally in lower concentrations. Table 3.7.2-4 shows the organic compounds detected in the PCO wells. Groundwater at PCO-1 contained dinitrobenzene and nitrobenzene, and groundwater at PCO-2 contained dinitrobenzene, HMX, nitrobenzene, and nitrotoluene. HE compounds were not detected at PCO-3. The concentrations of HE compounds observed in the alluvial groundwater in lower Pajarito Canyon were below former SAL values (LANL 1995, 55527, p. 4-176). These surface water and groundwater data suggest that the source of the alluvial groundwater at PCO-1 and PCO-2 is likely from infiltration of surface water in middle Pajarito Canyon and/or Threemile Canyon (see Section 3.6.6) and movement of alluvial groundwater down canyon. However, the alluvial groundwater near PCO-3 does not contain HE compounds, which suggests that HE compounds are adsorbed by the alluvium before reaching PCO-3 or that the alluvial groundwater at PCO-3 may not be from up-canyon sources. The alluvial groundwater at PCO-3 may be partially from other sources such as local runoff, suggesting that alluvial groundwater near PCO-2 may infiltrate into bedrock units before reaching PCO-3.*

**TABLE 3.7.2-4**

**ORGANIC COMPOUNDS DETECTED IN ALLUVIAL GROUNDWATER IN THE PCO WELLS**

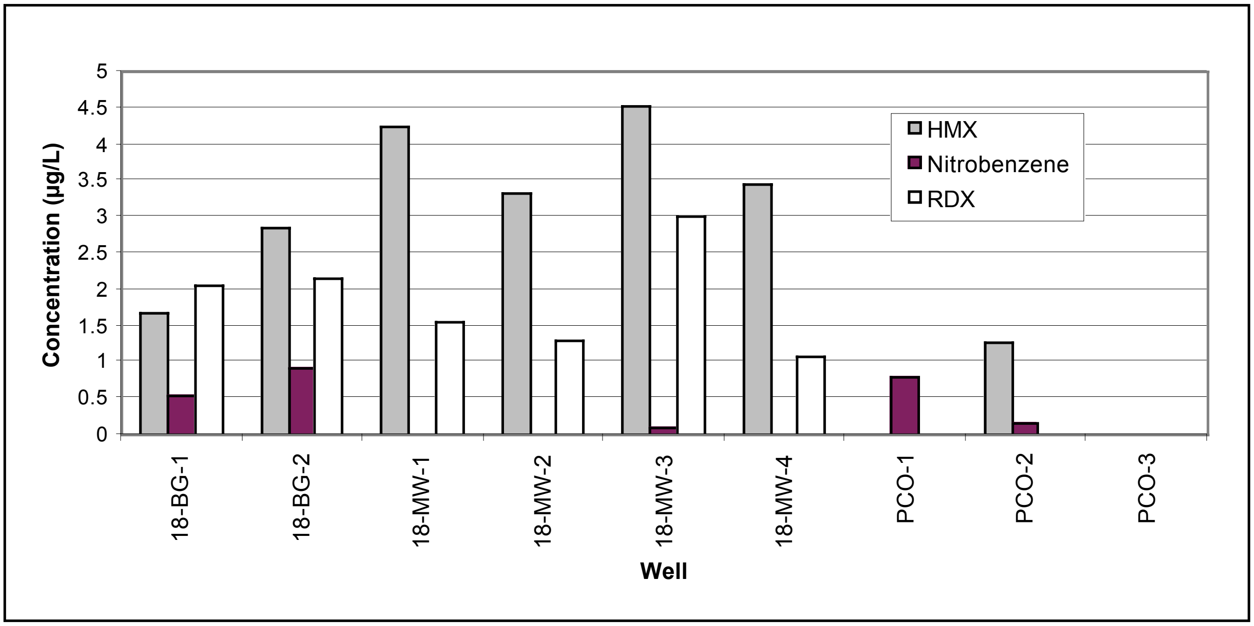
| Analyte | Well | Sample ID | Result (μg/L) | Former SAL (μg/L) |
|---|---|---|---|---|
| *Dinitrobenzene [1,3-]* | *PCO-1* | *AAA9571* | *0.041* | *3.5* |
| *Nitrobenzene* | *PCO-1* | *AAA9571* | *0.779* | *18* |
| *Dinitrobenzene [1,3-]* | *PCO-2* | *AAA9572* | *0.14* | *3.5* |
| *HMX* | *PCO-2* | *AAA9572* | *1.26* | *1800* |
| *Nitrobenzene* | *PCO-2* | *AAA9572* | *0.15* | *18* |
| *Nitrotoluene [m-]* | *PCO-2* | *AAA9572* | *1.01* | *N.A.* |
| *Bis(2-ethylhexyl)phthalate* | *PCO-3* | *AAA5987* | *16* | *6* |
| *Chloroform* | *PCO-3* | *AAA9589* | *5* | *100* |

Source: LANL 1995, 55527

*Figure 3.7.2-8 shows a summary of the concentrations of selected HE compounds that were detected in the alluvial groundwater in Pajarito Canyon. Concentrations of HE compounds in the PCO wells were lower than in the baseline wells located west of TA-18 and at the LACEF wells at TA-18. The LACEF wells contained the highest concentrations of HE compounds (LANL 1995, 55527, p. 4-184).*

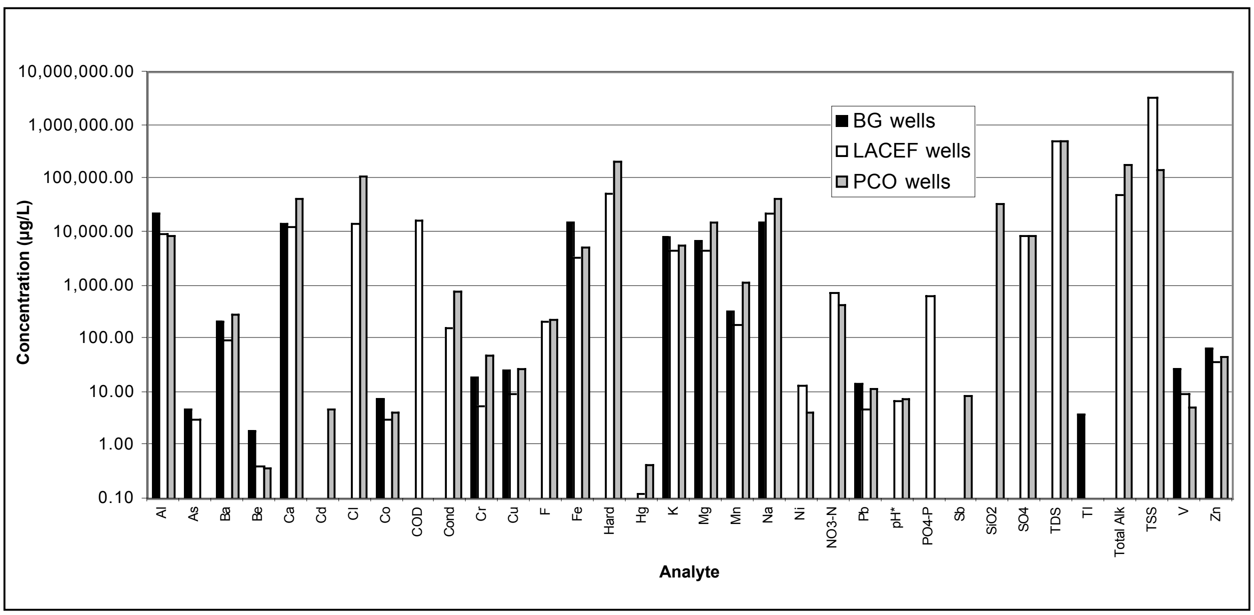
*On December 16, 1994, NMED DOE Oversight Bureau personnel sampled two wells at PRS 18-003(d) at TA-18 (18-MW-13 and 18-MW-15) and analyzed the groundwater samples for HE compounds. The locations of these wells are shown in Figure A-1. The analytical results were not above method detection limits for HMX and RDX (Yanicak 1997, 57582, Table 4).*

*Figure 3.7.2-9 shows the mean concentrations of inorganic constituents detected above method detection limits in the alluvial groundwater at the BG wells, LACEF wells, and PCO wells. A few analytes appear to increase in concentration down canyon, including barium, calcium, chloride, hardness, magnesium, manganese, and sodium. Other analytes appear to decrease in concentration down canyon, including aluminum, arsenic, beryllium, cobalt, and vanadium. The variation in concentrations could be attributable to the amount of suspended sediment in the samples. Generally, the data show that no significant changes in alluvial groundwater chemistry are observed between the different sections of the canyon.*




Source: LANL 1995, 55527

**Figure 3.7.2-8. Summary of HE compounds in alluvial groundwater in Pajarito Canyon.**




**pH is measured in standard units.*

**Figure 3.7.2-9. Mean concentrations of inorganic constituents in alluvial groundwater in lower Pajarito Canyon.**

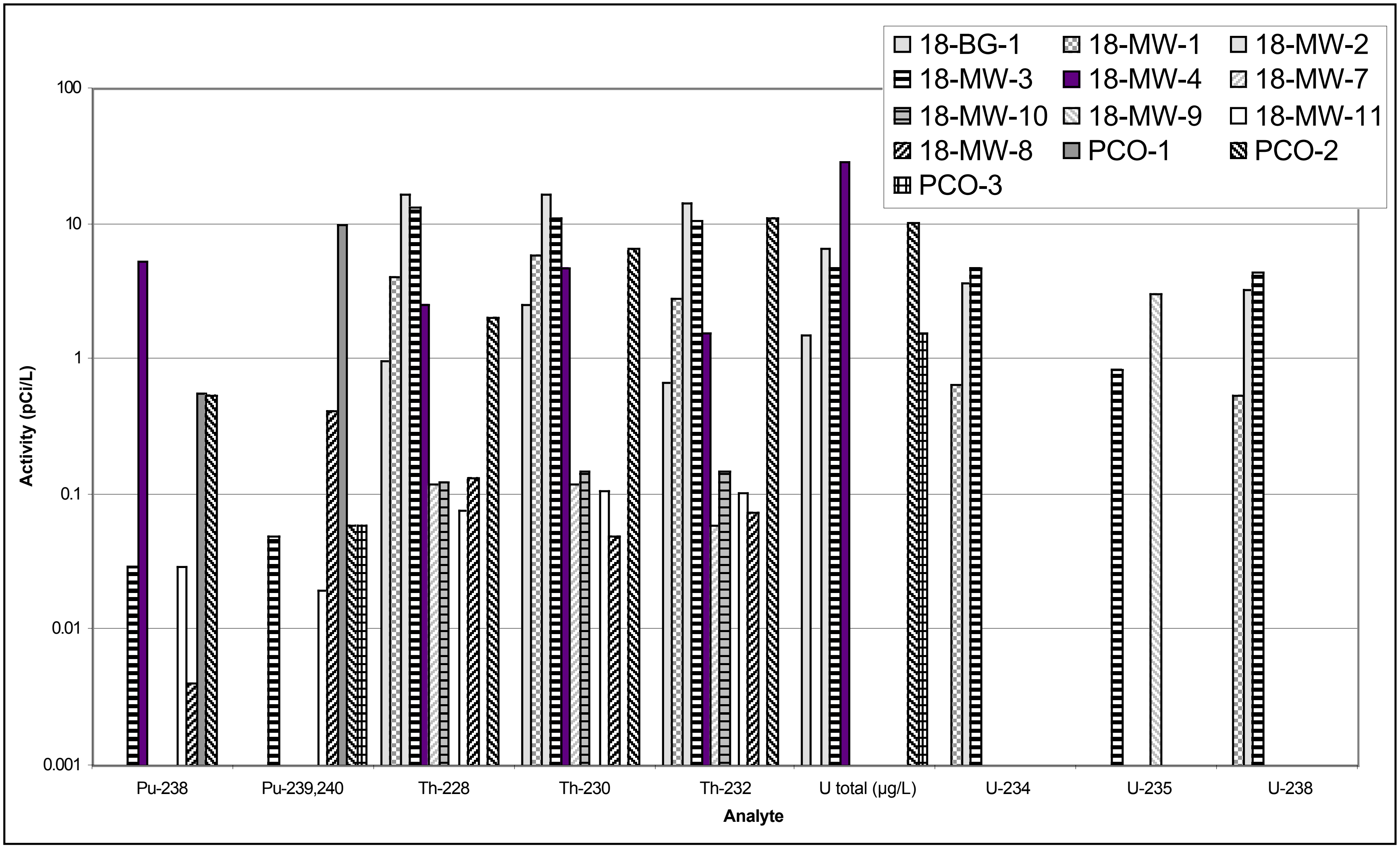
*The RFI sampling of alluvial groundwater from the PCO wells showed that the water contained barium, cadmium, chromium, copper, lead, and zinc in concentrations greater than those observed in the BG wells west of TA-18. The concentrations of these inorganic constituents were consistently observed* *throughout lower Pajarito Canyon and in the baseline wells. The inorganic constituents present in alluvial groundwater in lower Pajarito Canyon could be the result of natural variations in the water chemistry in the groundwater (LANL 1995, 55527, p. 4-176). Mean nitrate concentrations (nitrate [as nitrogen]) measured in the alluvial groundwater are less than 1 mg/L.*

*Radionuclides were analyzed in filtered groundwater samples collected from wells at TA-18 (BG, LACEF, and other wells) and from the PCO wells as part of the RFI for OU 1093 (LANL 1995, 55527; LANL 1996, 54919, p. 4-70). Figure 3.7.2-10 shows the maximum results of radionuclides detected in the alluvial groundwater samples that were obtained from several sampling events. The data for wells plotted in this figure are listed from west to east along Pajarito Canyon, except that 18-MW-8 is located in lower Threemile Canyon. The analytical results for plutonium species are not available for some samples because of quality assurance/quality control problems with the data. Therefore, only activities of thorium species are available for many wells (such as 18-BG-1).*

*The activities of thorium-228, thorium-230, and thorium-232 and the concentration of total uranium are elevated in the groundwater from the LACEF wells near Kiva 1 (wells 18-MW-1 through 18-MW-4) compared with the results from 18-BG-1, other wells at TA-18, and the PCO wells. The highest activity of thorium species measured was from 18-MW-2 near Kiva 1. The highest concentration of total uranium (29 μg/L) and the highest activity of plutonium-238 were from 18-MW-4. One groundwater sample from 18-MW-2 contained thorium-228 and thorium-230 above their respective former SAL values, and one sample from 18-MW-4 contained uranium above the former SAL value (LANL 1996, 54919, p. 4-73). The activities of other radionuclides in the alluvial groundwater were below former SAL values. The results of tritium analyses were all below method detection limits for liquid scintillation, and laboratory estimated values were below 120 pCi/L. Activities of thorium-228, thorium-230, and thorium-232 are elevated at 18-BG-1 relative to wells at central TA-18 (18-MW-10 and 18-MW-11). Elevated activities of thorium-228, thorium-230, and thorium-232 observed at the LACEF wells are not present at 18-MW-7, which is nearby and southwest of the LACEF wells. This suggests a local source of radionuclides in the Kiva 1 area that has apparently not migrated significantly in the alluvial groundwater.*

*RFI samples of alluvial groundwater collected from the PCO wells contained activities of 9.85 pCi/L plutonium-239,240 and 0.56 pCi/L plutonium-238 (PCO-1); one sample contained 700 pCi/L tritium. Samples from PCO-2 contained activities of thorium species and total uranium concentrations similar to those observed in the LACEF wells (see Figure 3.7.2-10). All activities of radionuclides in the alluvial groundwater from the PCO wells were below former SAL values (LANL 1996, 54919, p. 4-70).*

*Contaminants in groundwater at PRS 18-003(d), which is a septic system that served Kiva 3 at TA-18, were addressed by a corrective action. A corrective action report for TA-18 (LANL 1996, 55120) was submitted as part of the RFI at this site. Groundwater samples were initially collected from two temporary wells (18-1195 and 18-1196) located near the edge of the septic system drainfield. The analytical results for these samples showed the presence of 1,2-dichloroethane at the site, which is believed to be associated with waste disposal at the septic tank. As part of a corrective action, five monitoring wells (18-MW-12 through 18-MW-16) were drilled in December 1996. Two subsequent quarterly sampling events of the alluvial groundwater in the five monitoring wells have not shown the presence of contaminants (LANL 1997, 57015, p. 5-11).*




Source: LANL 1995, 55527; LANL 1996, 54919

**Figure 3.7.2-10. Maximum activity of radionuclides detected in groundwater at TA-18 and lower Pajarito Canyon.**

*Non-RFI investigations were conducted to characterize petroleum releases associated with two USTs at TA-18. The UST designated TA-18-PL30 was located east of building TA-18-189; this tank was removed in September 1993. The investigation at this site included the collection of samples from soil beneath and surrounding the former tank followed by excavation of contaminated soil to a TPH cleanup level of 100 µg/g (LANL 1993, 33314). In addition, monitoring wells 18-MW-5 and 18-MW-6 were installed in March 1994 in accordance with New Mexico UST regulations to monitor for potential impacts to groundwater associated with a release from the UST (LANL 1994, 47113). No measurable concentrations of petroleum-derived contaminants were detected in the groundwater. A summary of information for these wells is provided in Appendix C.*

*In June 1996 UST No. TA-18-26, located north of building TA-18-256, was the subject of an investigation because a release was confirmed during a trenching operation for a new gas line at TA-18 (LANL 1996, 55184). In July 1996 the tank was excavated and soil samples were collected from the excavation site (Location ID 18-10015). Additionally, three 28-ft- (8.5-m-) deep boreholes were drilled in November 1996 to collect subsurface borehole samples. Each borehole was located approximately 40 ft (12 m) from the center of the excavation (Location IDs 18-10016 through 18-10018) (LANL 1996, 55174). The tank was removed from the site in April 1997. Beneath the location of the former tank, at borehole 18-10015, TPH concentration above New Mexico UST action levels was found up to 12 ft (3.6 m) below ground surface. However, no TPH was found in the boreholes drilled around the site; therefore, it was determined that the release had not resulted in a significant impact on the environment (LANL 1997, 55884).*

*The RFI of PRSs that may have impacted the alluvial groundwater in Pajarito Canyon at TA-18 is currently ongoing. Recent discussions with NMED personnel have focused on transferring alluvial groundwater investigations to the canyon investigation, which is the subject of the work plan. RFIs at TA-18 (OU 1093) will focus primarily on characterization of contaminant source terms and removal of source terms. Potential impacts to alluvial groundwater and sediments down gradient from the source terms will primarily be investigated as part of this work plan.*

#### 3.7.2.5.3 Summary of the Alluvial Groundwater System and Data Requirements for Understanding the Alluvial Groundwater System

*The following bullets summarize the information known about the alluvial groundwater in Pajarito Canyon.*

- *The shallow alluvial groundwater body in Pajarito Canyon extends from approximately 1 mi (1.6 km) west of TA-18 to the eastern Laboratory boundary at state road NM4.*
- *Surface water infiltration from streamflow is likely to be the major source of recharge to the alluvial aquifer.*
- *The abandoned gravel excavations in lower Pajarito Canyon provide ponding areas for surface water and are likely areas of enhanced recharge to the alluvial groundwater. Alternately, at times of high groundwater levels, the alluvial groundwater intersects the bottom of the excavations where wetlands are formed.*
- *The only known groundwater discharges in Pajarito Canyon are the springs, the wetlands, and a sump that collects groundwater beneath building TA-18-30 and discharges to the stream channel through an outfall. Additional losses from evapotranspiration are likely, depending on the depth of the water table beneath the surface. An unknown volume of alluvial groundwater is hypothesized to seep downward into subsurface units through the base of the alluvium.*

- *Three alluvial groundwater monitoring wells were installed in Pajarito Canyon in 1985 for environmental surveillance purposes, and an additional 19 monitoring wells have been installed near TA-18 since 1990, most of which were installed in conjunction with ongoing RFI activities.*

- *The Bandelier Tuff underlies the alluvium throughout most of the canyon. However, in lower Pajarito Canyon between wells PCO-2 and PCO-3, the Cerro Toledo interval is likely to be present beneath the alluvium. This unit may provide an enhanced infiltration pathway and lateral groundwater flowpaths for movement of alluvial groundwater into the subsurface.*

- *RDX is present in concentrations greater than three times former SAL values in the alluvial groundwater upstream of TA-18. Additionally, HMX, other HE compounds, thorium-228, thorium-230, total uranium, and 1,2-dichloroethane were measured at concentrations above former SAL values in the LACEF wells.*

- *Alluvial groundwater in lower Pajarito Canyon east of TA-18 contains low levels of HE compounds, but no other constituents were measured above former SAL values. The alluvial groundwater at PCO-3 does not contain HE compounds.*

- *The RFI showed that groundwater near PRS 18-003(d), a septic system near Kiva 3, contained 1,2-dichloroethane. Two subsequent quarters of groundwater sampling from five wells installed at the site in December 1996 have not shown the presence of contaminants.*

*The following additional data are needed to understand the alluvial groundwater in Pajarito Canyon.*

- *To understand the movement of alluvial groundwater and the magnitude and apportionment of water balance components of the alluvial groundwater, additional monitoring wells will be installed at key locations within the canyon. Intact core samples of alluvial material will be collected during drilling of the well boreholes and analyzed for hydrologic properties (saturated hydraulic conductivity, effective porosity, and specific yield) to provide data necessary for the construction of a groundwater flow model of the alluvial aquifer. Transducers may be installed in selected wells to continuously monitor water level fluctuations during at least a two-year period.*

- *Alluvial groundwater samples will be collected from selected wells to determine seasonal water quality changes.*

- *To understand and model solid/solution phase interactions, both filtered and unfiltered groundwater samples will be collected from wells and analyzed for major cations and anions, trace elements, radionuclides, dissolved organic carbon, stable isotopes, and anthropogenic organic compounds.*

- *Geochemical modeling simulations of surface water and groundwater chemistry will be performed to quantify speciation, mineral stability, adsorption reactions, and mixing reactions between different media.*

- *Streamflow data will be collected from existing and newly installed gages as well as from intervening locations for seepage run measurements to be made during representative high runoff conditions. These data will provide information on recharge to the alluvial aquifer from surface water infiltration.*

- *Groundwater flow modeling simulations of the alluvial aquifer will be conducted to quantify water balance components for the alluvial system and estimate infiltration losses from the alluvium into deeper subsurface units.*

### 3.7.3 Deep Unsaturated Zone/Possible Intermediate Perched Zones

*Understanding the hydrogeologic properties of the unsaturated zone of the Bandelier Tuff and other units present beneath Pajarito Canyon is important because the unsaturated zone may serve as either a barrier or a conduit to the vertical and horizontal movement of alluvial groundwater within Pajarito Canyon or to potential transient perched intermediate groundwater zones beneath the canyon.*

*No perched intermediate zones of saturation have been delineated beneath Pajarito Canyon; however, possible intermediate wet zones have been reported in two boreholes at TA-18. In borehole SHB-4 wet core samples were retrieved from the interval 125 to 145 ft (38 to 44 m) within the Cerro Toledo interval. In PM-2 a possible wet zone was reported as "a show of water at 335 ft" (102 m), which may indicate a zone of intermediate perched groundwater (Cooper et al. 1965, 8582, p. 56; Davis et al. 1996, 55446, p. 38). The pilot hole for this well was drilled using cable tools to a depth of 617 ft (185 m). No other mention of water in the unsaturated zone is found in the descriptive log of drill cuttings for this well (Cooper et al. 1965, 8582, pp. 55–61). Electrical resistivity (geophysical) logs of the borehole at PM-2 did not confirm the presence of water at 335 ft (102 m). The middle of the Otowi Member is present in PM-2 at a depth of 335 ft (102 m); this zone has not previously been observed to contain perched groundwater. Boreholes drilled near PM-2 and SHB-1 will investigate the possible presence of perched groundwater below Pajarito Canyon.*

*On March 9, 1995, another small intermediate perched groundwater zone was encountered in borehole 54-1016 at MDA L. This borehole was drilled north of Mesita del Buey at an angle toward the south to intercept units beneath MDA L. The borehole was drilled to monitor the presence of VOCs as part of the RFI for OU 1148. A small pocket of groundwater was encountered in basalt within the Puye Formation at a depth of 592 ft (178 m), which was at an elevation of approximately 6188 ft (1856 m) (see Figure A-2). After encountering the water, drilling operations were halted until the next day when an attempt was made to obtain a sample of the water. However, no water accumulated in the borehole overnight and no water was present to sample the next day. The borehole was drilled to a total angle depth of 605 ft (182 m) and was completed as a monitoring well. A water sample collection port was installed at 600 ft (180 m), just below the occurrence of the wet zone (LANL 1995, 45978). The regional aquifer beneath the location of borehole 54-1016 is approximately 340 ft (102 m) below this possible intermediate perched zone at an approximate elevation of 5850 ft (1755 m).*

*At PM-2 there is approximately 800 ft (244 m) of unsaturated volcanic tuff, sediments, and basaltic rocks between the base of the alluvium and the top of the regional aquifer. However, the vadose zone in the Pajarito Canyon area has not been well characterized.*

*The subsurface geology and stratigraphy directly beneath most of Pajarito Canyon is largely undetermined; therefore, the presence of possible perched intermediate saturated zones beneath Pajarito Canyon have not been determined. Information from nearby deep boreholes indicates that the volcanic stratigraphy beneath the Bandelier Tuff is highly variable. Lower Pajarito Canyon is underlain by Cerros del Rio basalt flows within the Puye Formation, whereas the western and middle part of the canyon may be underlain by intermediate-composition volcanic rocks similar to the Tschicoma Formation. A horizontal stratigraphic discontinuity may occur between these two types of dense volcanic flows in the Puye Formation stratigraphic interval (see Figure A-2). The discontinuity may occur between the eastern* *margin of the Tschicoma Formation flows and the western margin of the Cerros del Rio basaltic flows. The sediments in this discontinuity are likely composed of conglomerates in the Puye Formation and may represent a local zone of preferable recharge to intermediate perched zones or to the regional aquifer; alternately, the discontinuity may restrict recharge to the deeper units.*

*The following features of the unsaturated tuff control the rates of vertical contaminant transport (Kearl et al. 1986, 8414):*

- *physical properties (density, porosity, and specific gravity);*
- *hydraulic 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 unit contacts or paleosurfaces (flow paths or barriers);*
- *geochemical properties (specific surface area, ion exchange capacity, retardation factors, and mineralogy); and*
- *depth to groundwater.*

### 3.7.4 Regional Aquifer

*The regional aquifer beneath the Laboratory has been partially delineated by information provided from the boreholes for 8 deep test wells and 14 water supply wells within the Laboratory boundaries (Environmental Protection Group 1996, 54769). The regional aquifer occurs in the Puye Formation and the Santa Fe Group at depths below Pajarito Canyon ranging from approximately 1300 ft (396 m) at the western Laboratory boundary to approximately 700 ft (213 m) near the eastern Laboratory boundary. The regional aquifer is separated from the water in the alluvium by more than 800 ft (244 m) of tuff and volcanic sediments at PM-2 near TA-18 (McLin et al. 1997, 57754). Continuously recorded water level data collected at test wells since the fall of 1992 indicate that throughout the Pajarito Plateau the regional aquifer responds to barometric and earth tide effects in a manner typical of confined to partially confined aquifers (McLin 1996, 56025).*

*In 1965 when water supply well PM-2 was drilled, the static water level of the regional aquifer was 823 ft (251 m) below ground level. The water level was not observed to rise above this level before pumping the well in 1966. However, when PM-4 was drilled in 1981, the depth to water was 1060 ft (323 m) below ground level. Before pumping in 1982, the level was 1050 ft (320 m) below ground level, which indicates that the water level rose between completion and pumping of the well or that some confining conditions may have been present at this location.*

*Figure A-2 shows the general construction information for PM-2 and the revised stratigraphy encountered in this well. A surface casing was installed to a depth of 504 ft (151 m) using 26-in.- (66-cm-) diameter steel pipe. The production casing was installed from the surface to a depth of 2300 ft (690 m) using a 14-in.- (36-cm-) diameter steel casing, which was slotted from 1004 to 2280 ft (301 to 684 m) (Purtymun 1995, 45344, pp. 275–276). The well was equipped with a down-hole turbine pump powered from the surface with a steel shaft drive. A pumping test of the well was conducted in July 1965 after the well was completed. At that time the specific capacity of the well was approximately 24 gpm per ft of drawdown,* *and the transmissibility of the aquifer was calculated from drawdown measurements to be approximately 40,000 gpd per ft (Cooper et al. 1965, 8582, p. 67).*

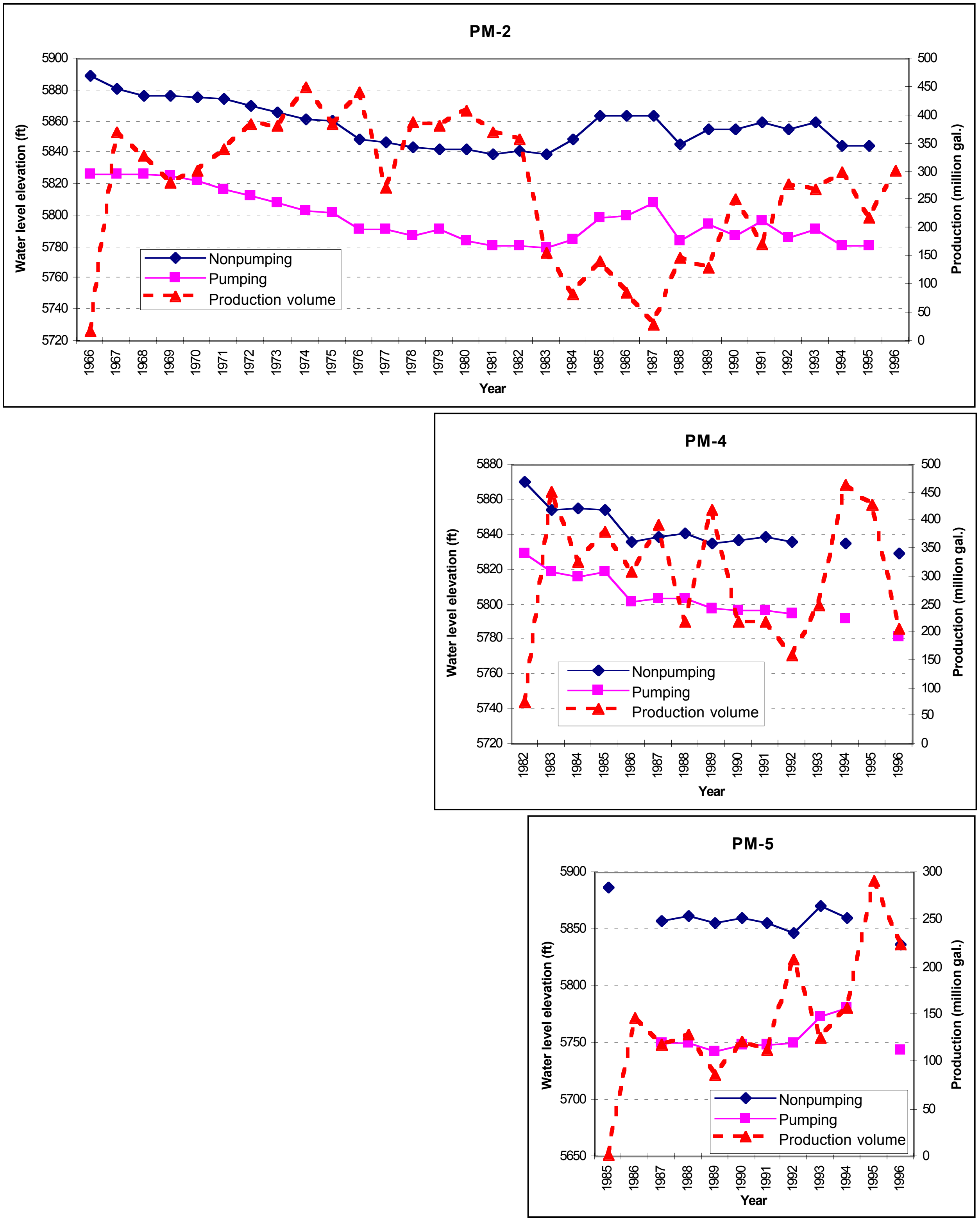
*Figure 3.7.4-1 shows the annual production history and nonpumping and pumping water levels for production wells PM-2, PM-4, and PM-5 (McLin et al. 1997, 57754, Appendix A). The drawdown of pumping water levels is approximately 60 ft (18 m) at PM-2, approximately 40 ft (12 m) at PM-4, and approximately 100 ft (30 m) at PM-5. The specific capacities of these wells are 23 gpm/ft (4.8 liters per second [Lps]/m), 33 gpm/ft (6.8 Lps/m), and 12 gpm/ft (2.5 Lps/m), respectively, which indicates that PM-4 is the most efficient producing well, followed by PM-2 and PM-5. Water levels at each well are related to production. In general, as production at each well increases the water levels decline, and conversely, if production is reduced water levels tend to rise slightly.*

*Since 1965 the static nonpumping water level at PM-2 has declined 47 ft (14 m); since 1982 the static nonpumping water level at PM-4 has declined 41 ft (12.5 m); since 1985 the static nonpumping water level at PM-5 has declined 50 ft (15 m).*

*Groundwater elevations obtained in deep wells located on the Pajarito Plateau indicate that the elevation of the potentiometric surface of the regional aquifer rises westward from the Rio Grande to the flanks of the Sierra del los Valle. In the Pajarito Canyon area the top of the aquifer is primarily in the fanglomerate member of the Puye Formation (see Figure A-2) (Purtymun and Johansen 1974, 11835; Rogers et al. 1996, 54714, Figure 2a; LANL 1997, 55622, p. 3-33; LANL 1996, 55430, p. 2-19). Near PM-2 the hydraulic gradient of the regional aquifer averages approximately 50 ft (15 m) per mile within the Puye Formation. Along the eastern edge of the Pajarito Plateau as the water in the aquifer nears discharge points in White Rock Canyon, the hydraulic gradient increases to 80 to 100 ft (24.4 to 30.5 m) per mile. The rate of movement of water in the upper section of the aquifer varies depending on the stratigraphy. Aquifer performance tests indicate that movement ranges from 20 ft/yr (6.1 m/yr) in the Santa Fe Group to 345 ft/yr (105 m/yr) in the more permeable Puye Formation (Purtymun 1984, 6513).*

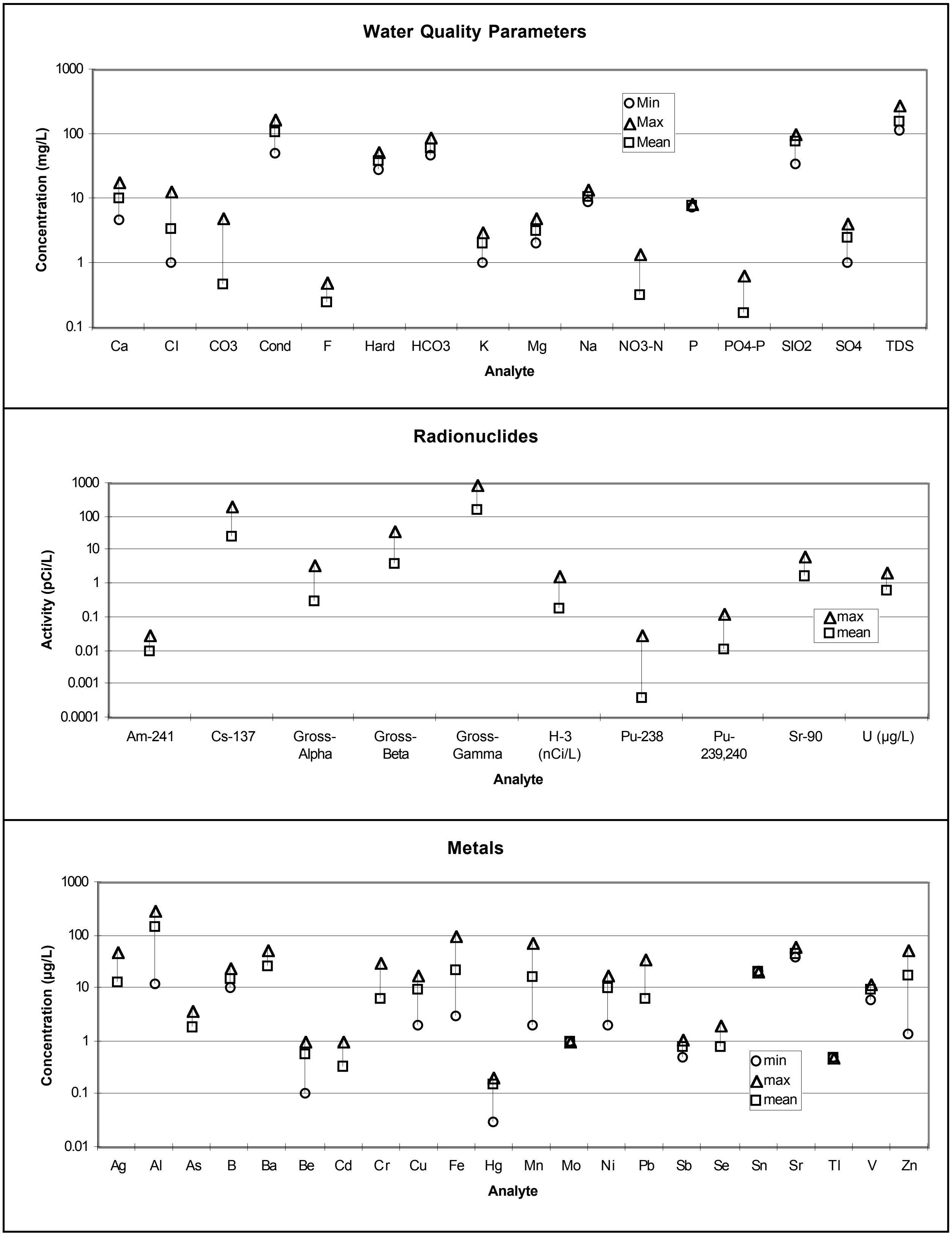
*The age of the regional aquifer groundwater has been estimated using carbon-14 and tritium dating methods. The carbon-14 data suggest that older water is found near the Rio Grande and that younger water is present under the central Pajarito Plateau. Water from PM-2 has been calculated to be as young as 45 years and as old as >10,000 years (see Table 3.6.6-4) (Blake et al. 1995, 49931, Table 4). Recent investigations suggest that the regional aquifer water that discharges to springs on the west side of the Rio Grande may be recharged from the Sangre de Cristo Mountains and that a groundwater divide is present within the aquifer west of the Rio Grande (Rogers et al. 1996, 54714, Figure 2b).*

*Personnel from ESH-18 have collected groundwater samples annually from supply well PM-2 and Pajarito Springs (Spring 4A) for analysis of water quality parameters, metals, and radionuclides. The results of the sampling are reported annually in the environmental surveillance reports (for example, Environmental Surveillance and Compliance Programs 1997, 56684). A summary of the results of the analyses is shown in Figure 3.7.4-2, and a summary of the results obtained at Spring 4A are shown in Figure 3.7.4-3. The data shown in these figures represent a summary of the analytes detected above method detection limits; results reported below method detection limits are not included in the summaries. A comparison of the mean concentrations of water quality parameters, metals, and radionuclides in groundwater at PM-2 and Spring 4A is shown in Figure 3.7.4-4.*



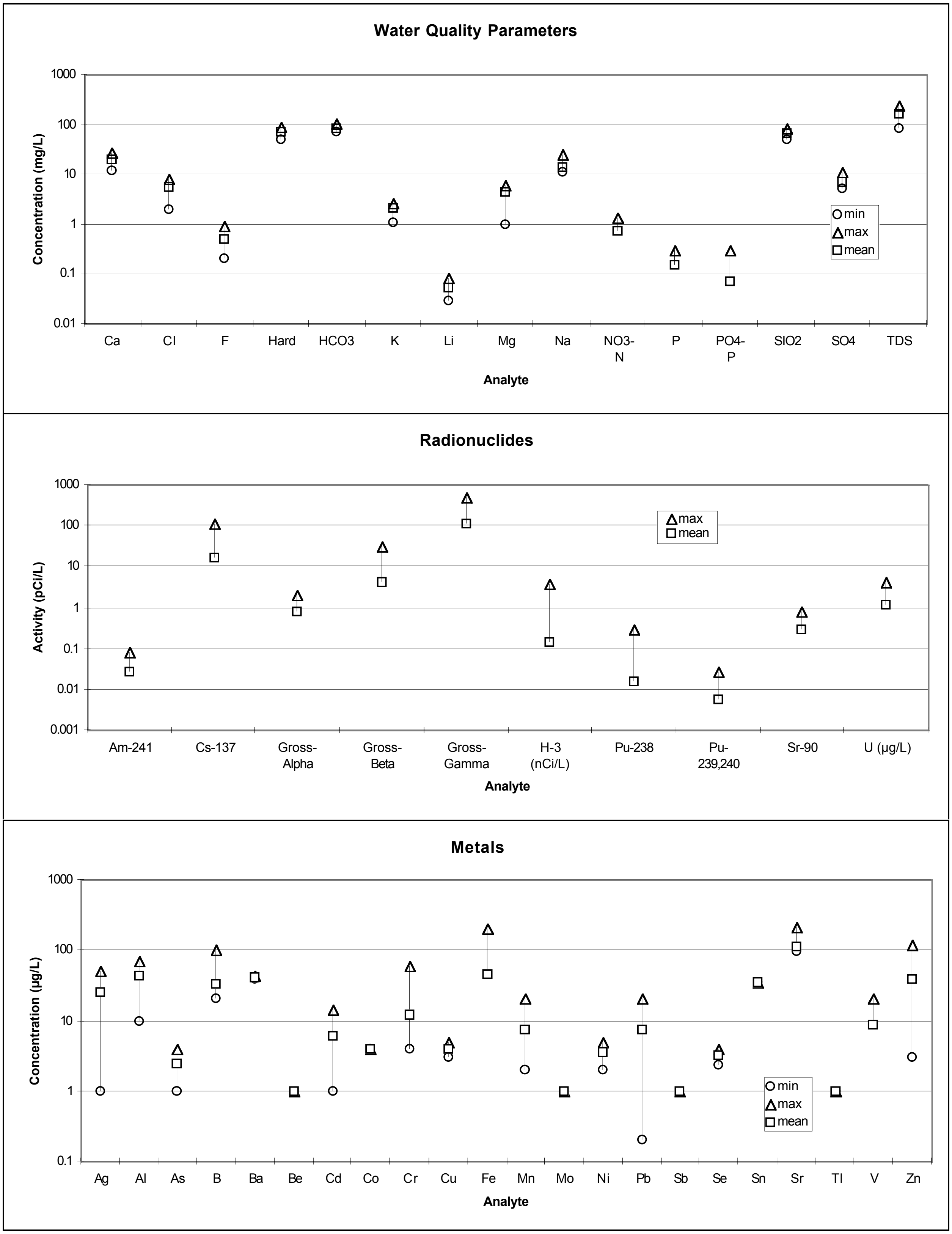

Source: McLin et al. 1997, 57754

**Figure 3.7.4-1. Annual production and water level measurements of the regional aquifer.**



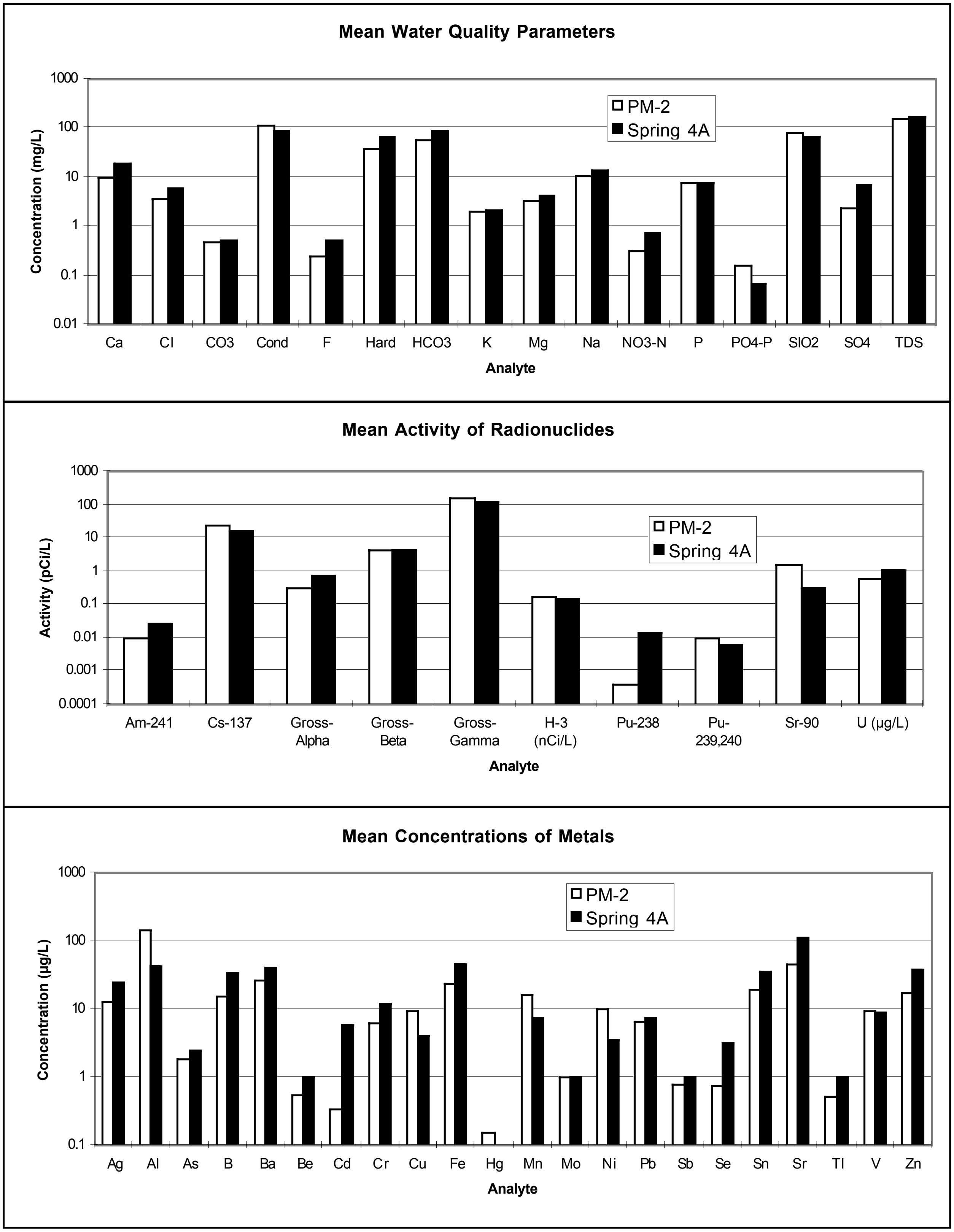

Source: Environmental surveillance reports 1971–1997; Purtymun 1975, 11787

**Figure 3.7.4-2. Summary of results from the regional aquifer at PM-2.**




Source: Environmental surveillance reports 1971–1997; Purtymun 1975, 11787

**Figure 3.7.4-3. Summary of results from the regional aquifer at Spring 4A.**




Source: Environmental surveillance reports 1971–1997; Purtymun 1975, 11787

**Figure 3.7.4-4. Comparison of results in the regional aquifer.**

*The ranges of some constituent concentrations observed in the regional aquifer from PM-2 between 1967 and 1996 have been 0 to 3.7 μg/L arsenic, 1 to 13 mg/L chloride, 0 to 34 μg/L lead, 0 to 48 μg/L silver, 9 to 14 mg/L sodium, 1 to 4 mg/L sulfate, and 33 to 101 mg/L silicon dioxide. The largest variation in concentrations is observed in inorganic constituents such as aluminum, iron, manganese, and zinc, which vary by more than an order of magnitude and which may be the result of collecting unfiltered samples. Radionuclides have been measured at relatively low levels near method detection limits, except for one result for plutonium-239,240 in 1993 of 0.127 pCi/L. The activity of plutonium-239,240 has typically been less than 0.024 pCi/L. The range of concentrations observed in the data may be caused by the collection of unfiltered samples for analyses.*

*The ranges of some constituent concentrations observed in the regional aquifer at Spring 4A from 1965 to 1996 have been 1 to 4 μg/L arsenic, 2 to 8 mg/L chloride, 0.2 to 21 μg/L lead, 1 to 50 μg/L silver, 11 to 25 mg/L sodium, 5 to 11 mg/L sulfate, and 51 to 83 mg/L silicon dioxide. Recent measurements for plutonium-238 have been approximately 0.006 pCi/L and for plutonium-239,240 have been approximately 0.02 pCi/L.*

*The comparison of the environmental surveillance data in Figure 3.7.4-4 shows that the water quality parameters at well PM-2 and Spring 4A are similar, which suggests that the water in the regional aquifer at these locations may have a similar provenance. Spring 4A has slightly higher mean concentrations of calcium, chloride, fluoride, hardness, bicarbonate, magnesium, and sulfate, which may be the result of longer residence time of the water in the formation, a slightly different aquifer composition, or a combination of both. The mean concentration of nitrate (as nitrogen) at Spring 4A is 0.75 mg/L compared with 0.31 at PM-2. This difference is probably not significant at these low concentration levels. Radionuclides measured at both sites are similar and are generally within background values. The highest plutonium activities measured at both locations are typically from 1973 analyses, which may suggest a problem with the analytical results from that year. Mean metals concentrations at Spring 4A are lower in aluminum, copper, manganese, and nickel, but the spring water contains higher concentrations of most metals, particularly cadmium, selenium, silver, strontium, and zinc, which is possibly caused by increased residence time or to a slightly different aquifer composition near Spring 4A.*

*In 1996 the tritium activity in the regional aquifer at PM-2 was below detection limits using standard liquid scintillation techniques (detection limit is 325 pCi/L). Historically, tritium has not been measured in the regional aquifer above detection limits at wells PM-2, PM-4, and PM-5 and at Spring 4A (Environmental Surveillance and Compliance Programs 1997, 56684). Low-level tritium measurements obtained for the regional aquifer at PM-2 have been less than 1.5 pCi/L and at Spring 4A have been less than 1 pCi/L (see Section 3.6.6.3). These tritium data, together with similar temperatures of the water from regional aquifer water and from Spring 4A, indicate that Spring 4A probably discharges from the regional aquifer.*

*Three possible pathways for contaminants, such as tritium in surface water, to reach the regional aquifer were proposed by Gallaher (1995, 54716).*

- *Alluvial groundwater could migrate down a well bore, such as at PM-2, where surface casing passes through the shallow alluvial groundwater. The surface casing was cemented in place to a depth of 504 ft (154 m) when the well was completed in 1965; however, the integrity of the seal may be questionable after more than 30 years.*

- *Water could migrate through fractures or faults as saturated flow.*

- *Water could migrate as unsaturated flow through the unsaturated zone.*

*Purtymun (1984, 6513) summarized the hydraulic characteristics of the regional aquifer that were determined during aquifer performance tests or during periods of production from supply wells and test boreholes.*

### 3.7.5 Summary of the Hydrology of Pajarito Canyon and Data Requirements for Understanding the Hydrogeology

*The following bullets summarize the hydrogeology of Pajarito Canyon.*

- *The primary inputs to the groundwater in Pajarito Canyon include PC Spring, contemporary precipitation as snowmelt or storm water runoff, liquid discharges from Laboratory operations that use deep regional aquifer groundwater via the municipal and industrial supply system.*

- *At least two perennial reaches of surface water are completely lost into the subsurface, probably initially to the alluvium. Then the water possibly moves along fractures, bedding planes, or contacts with some discharge to return flow or other near-channel springs, although the ultimate fate of most of the water is not known. In recent years, these measured losses have annually averaged approximately 6 million $ft^3$ (0.18 million $m^3$) of water.*

- *Alluvial groundwater is present in middle and lower Pajarito Canyon where significant accumulations of alluvium, probably up to approximately 35 ft (11 m), are present below the confluence with Twomile Canyon. Infiltration rates have been estimated to range from 20 to 100 mm (0.8 to 4 in.) per year beneath Pajarito Canyon.*

- *Most of the water entering the Pajarito Canyon system must be lost to either evapotranspiration or to seepage into deeper units because surface flow out of Pajarito Canyon beyond the Laboratory at state road NM4 is ephemeral and in recent years has occurred only after significant storm events. The amount and fate of water leaving the Pajarito Canyon alluvium is not known.*

- *Intermediate perched groundwater may be present in several subsurface units, including local perched zones within units of the Tshirege Member (Qbt 1v), the Cerro Toledo interval, Puye Formation, basalt, and possibly in the Otowi Member.*

- *The regional aquifer extends beneath much of the Pajarito Canyon watershed. The regional aquifer is pumped at supply well PM-2 in the canyon, and upper units of the aquifer probably discharge at Pajarito Springs (Spring 4A) and other smaller springs near the confluence with the Rio Grande.*

*The following additional data are needed to understand the hydrology of Pajarito Canyon.*

- *The lithology and stratigraphy of the alluvium and the bedrock units needs to be better understood to adequately characterize the hydrogeological system and to provide input to hydrogeologic models. Data on the lithology, stratigraphy, and hydraulic properties and* *geotechnical properties (including bulk density, porosity, saturated and unsaturated hydraulic conductivity, moisture content, storativity or specific yield, and matric potential) are needed. These data may be obtained from laboratory analyses of borehole core samples and by aquifer performance testing.*

- *The possible presence of saturated zones beneath the alluvium in Pajarito Canyon needs to be investigated by drilling several regional aquifer boreholes to characterize the Bandelier Tuff and underlying units to the regional aquifer. If saturation is found in the Cerro Toledo interval, the Guaje Pumice Bed, or basalt flows in the Puye Formation, investigations to determine the source and fate of the water should be considered.*

- *Data necessary to perform water balance calculations include additional water level measurements (preferably time series data from transducers), site-specific soil moisture measurements and precipitation amounts, evapotranspiration, and streamflow volumes.*

- *Water samples will be collected from the alluvial groundwater, the regional aquifer, and any other saturated zones encountered. The samples will be both filtered in the field and unfiltered followed by preservation of appropriate aliquots to provide appropriate data on dissolved and suspended constituent concentrations. Analyses for colloidal materials are needed to provide data on possible colloidal transport of contaminants.*

- *The pump in PM-2 or PM-4 should be relocated to within 20 ft (6.1 m) of the water level to sample water from the upper part of the regional aquifer. Time series sampling (48 hours) should be conducted for analysis of inorganic chemicals and radionuclides.*

### 3.8 Air Monitoring

*The Laboratory operates a network of more than 50 environmental air monitoring stations (called AIRNET) to sample radionuclides in ambient air. The network is designed to measure environmental levels of airborne radionuclides that may be released from Laboratory operations. Annual Laboratory emissions include microcurie (μCi) quantities of plutonium and americium, millicurie (mCi) quantities of uranium, and curie (Ci) quantities of tritium and activation products. In addition to Laboratory emissions, natural atmospheric and fallout radioactivity levels fluctuate and affect measurements made by the air surveillance program. Each station collects both a total particulate matter sample and a water vapor sample for analysis (Environmental Surveillance and Compliance Programs 1997, 56684).*

*Particulate matter in the atmosphere is primarily caused by the resuspension of soil, which is dependent on meteorological conditions. Windy, dry days can increase the soil resuspension, but precipitation can wash particulate matter out of the air. Consequently, there are often daily and seasonal fluctuations in airborne radioactivity concentrations caused by changing meteorological conditions. The measured airborne concentrations are less that the EPA concentration limit for the general public. The EPA limit represents a concentration that would result in an annual dose of 10 mrem (Environmental Surveillance and Compliance Programs 1997, 56684).*

*The environmental surveillance program monitors 15 air stations within the Pajarito Canyon watershed annually. Air samples are analyzed for tritium; americium-241; plutonium-238; plutonium-239,240; uranium-234; uranium-235; and uranium-238. A summary of air monitoring stations within the Pajarito*

*Canyon watershed is presented in Table 3.8-1. The station locations are shown in Figure 3.8-1 and Figure 3.8-2.*

**TABLE 3.8-1**

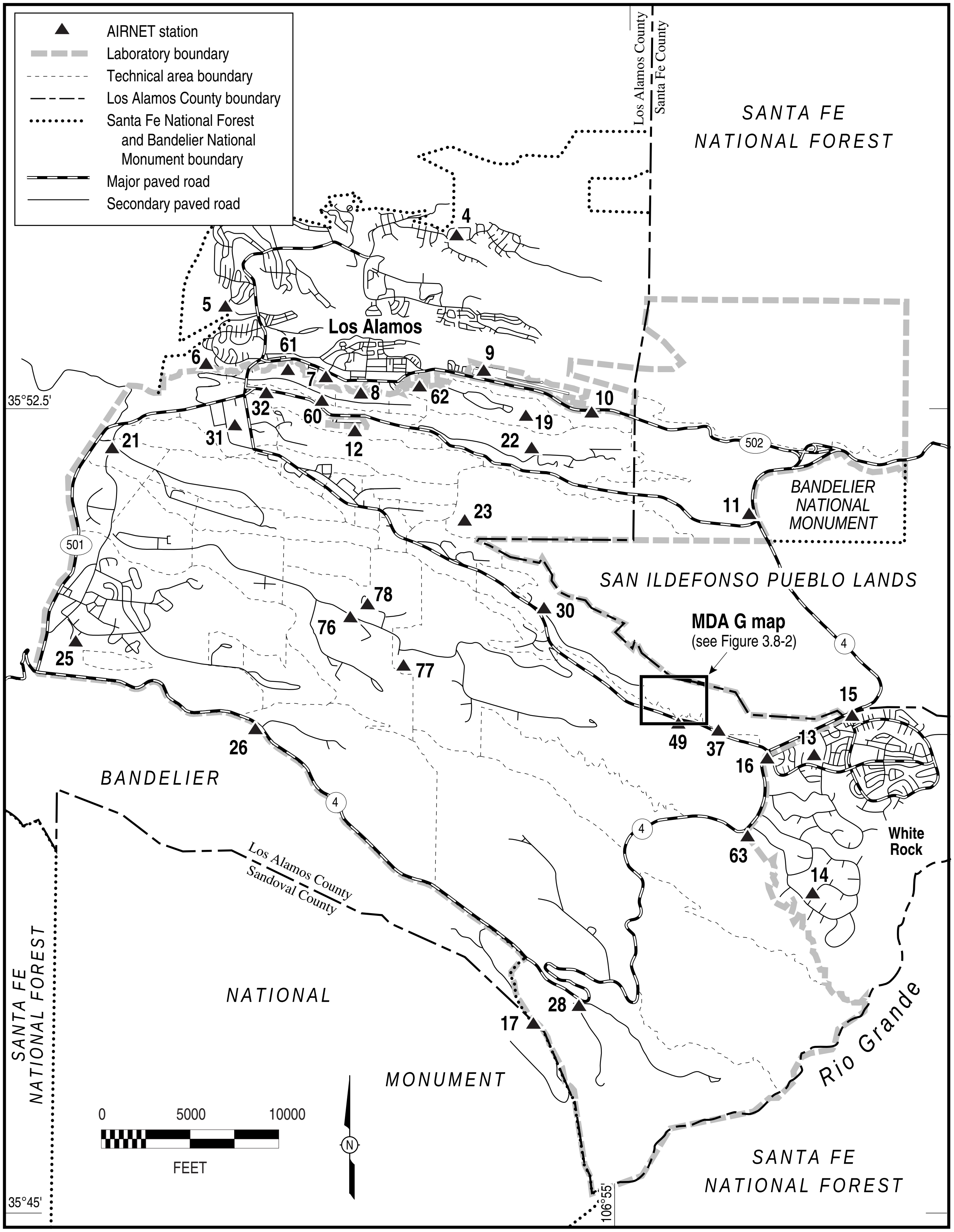
**PAJARITO CANYON AIR MONITORING STATIONS**

| Station Number | Station Location | Station Type |
|---|---|---|
| 14 | Pajarito Acres | Perimeter |
| 16 | White Rock Church of the Nazarene | Perimeter |
| 21 | TA-69 | On-site |
| 30 | Pajarito Booster (P-2) (Pajarito Road at TA-54) | On-site |
| 31 | TA-3 | On-site |
| 49 | Pajarito Road (TA-36) Sludge Pond | On-site |
| 27 | TA-54 MDA G | On-site |
| 34 | TA-54 MDA G-1 (behind trailer) | On-site |
| 35 | TA-54 MDA G-2 (back fence) | On-site |
| 36 | TA-54 MDA G-3 (by office) | On-site |
| 37 | TA-54 MDA G-4 (water tank) | On-site |
| 45 | MDA G (Southeast Perimeter) | On-site |
| 47 | MDA G (North Perimeter) | On-site |
| 50 | TA-54 MDA G | On-site |
| 51 | TA-54 MDA G | On-site |

Source: Environmental Surveillance and Compliance Programs 1997, 56684

*In 1996 several of the results of air sampling exceeded investigation levels established by the Laboratory Air Quality group (ESH-17). Three such instances occurred within or adjacent to the Pajarito Canyon watershed. At station 27, located on-site at MDA G, air concentrations of americium-241 and plutonium-239 have been increasing since 1995. During 1995 and 1996 average air concentrations of americium-241 and plutonium-239 increased from 11 aCi/m$^3$ for each radionuclide to approximately 600 aCi/m$^3$ and 900 aCi/m$^3$, respectively. A ground survey of the vicinity revealed a small area a few tens of meters from the station that had soil contamination at levels approximately 100 times the average concentration nearby. After investigation, it was determined that trenching operations related to the installation of water lines were conducted in this area during 1995 and 1996, and the nearby road had been rerouted in early 1996. The phases of construction activity correlated with the initial and subsequent observed increases in air concentrations. Evidently the trenching or the roadwork had brought some contaminated material to the surface. A remedial action that included covering the area with clean dirt followed by additional monitoring is discussed in the 1996 environmental surveillance report (Environmental Surveillance and Compliance Programs 1997, 56684). The increase in air concentrations appeared to be localized and was limited to americium-241 and plutonium-239; no other radionuclides were elevated significantly at station 27. Other monitoring stations at MDA G and other nearby off-site stations in White Rock did not show evidence of elevated activity in the air samples.*

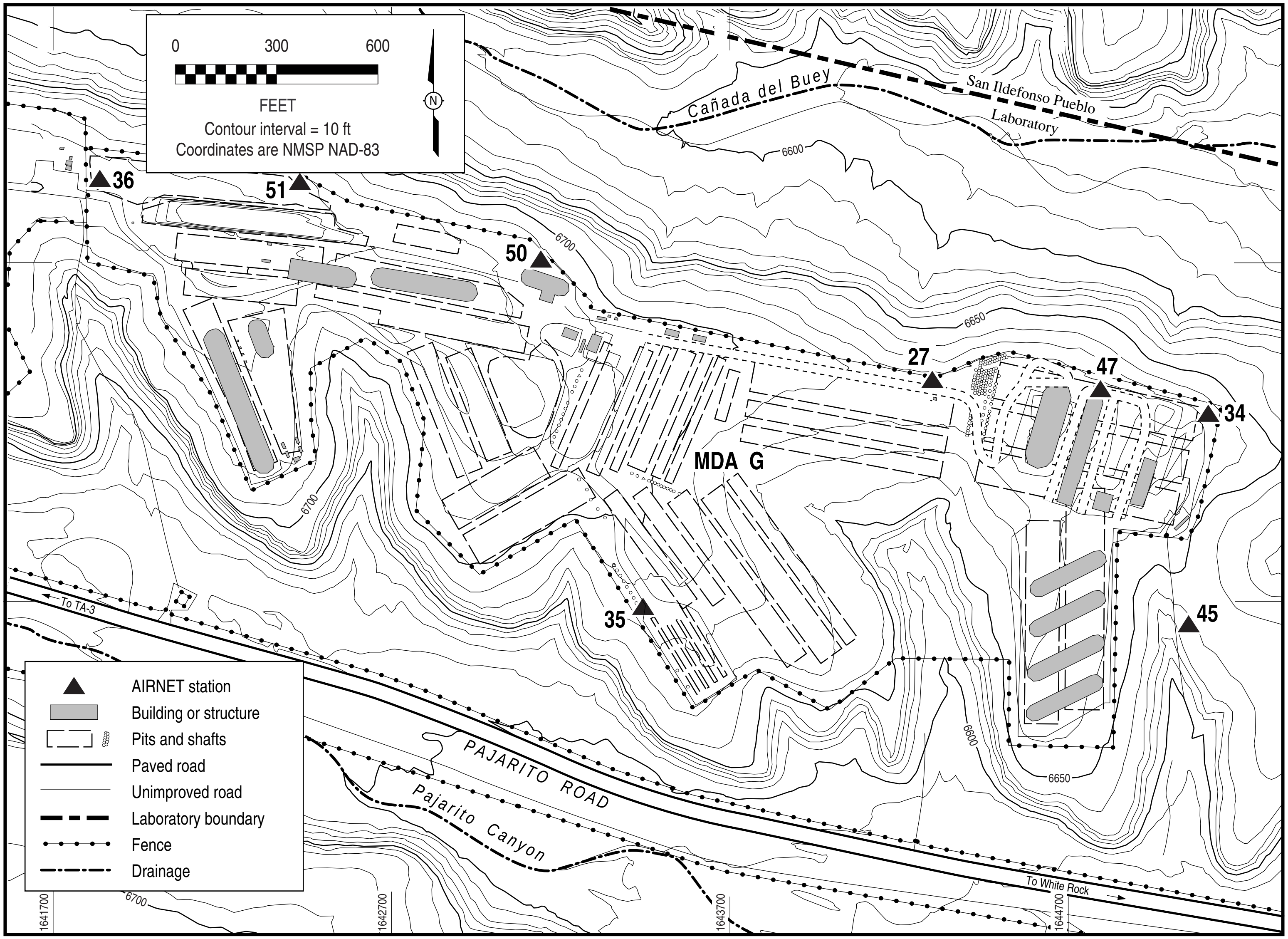
*Air station 30, which is located at the turnoff from Pajarito Road to TA-54, recorded elevated levels of americium-241 and plutonium-239 for the second quarter of 1996. Review of data from other sample periods did not identify a trend. The cause of the elevated measurements at this site is not known (Environmental Surveillance and Compliance Programs 1997, 56684).*




Source: FIMAD G104732; Environmental Surveillance and Compliance Programs 1997, 56684

F3.8-1 / PAJARITO CANYON WP / 060998

**Figure 3.8-1. Locations of off-site perimeter and on-site Laboratory AIRNET stations.**




Source: FIMAD G104546; Environmental Surveillance and Compliance Programs 1997, 56684

F3.8-2 / PAJARITO CANYON WP / 060898

**Figure 3.8-2. Locations of AIRNET stations at MDA G.**

*Elevated activities of isotopes of uranium observed in the air samples from firing site stations were attributed to open air explosive testing at the active PHERMEX facility at TA-15 (Environmental Surveillance and Compliance Programs 1997, 56684). Although the PHERMEX facility itself is not located within the Pajarito Canyon watershed, the air monitoring stations at TA-15 are located peripherally to the watershed and therefore potentially impact the watershed area.*

*The long-term trends identified by evaluation of historical data include the situation observed at station 27 (described above) and a significant decrease in ambient tritium activity compared with that measured in the 1970s and early 1980s (Environmental Surveillance Program 1996, 55333). Review of the monitoring data does not indicate other significant trends at this time.*

*Site-specific meteorological monitoring in Pajarito Canyon is provided by a Neighborhood Environmental Watch Network (NEWNET) meteorological station that is located in lower Pajarito Canyon adjacent to the former TA-18 sewage treatment lagoons. This station was established in 1995 and collects meteorological data at 15-minute intervals. The data are posted daily on the internet at the NEWNET site at (http://newnet.jdola.lanl.gov/newnet.html). The data include the date, time, gamma radiation intensity (μR/hr), wind direction, wind speed, barometric pressure, temperature, and humidity. Other NEWNET sites are located next to TA-18 at TA-36 (Kappa Site), TA-54 (MDA G), and at the TA-54 meteorological tower east of TA-54. Meteorological data from the sewage lagoon NEWNET station could be useful in determining the amount of ET occurring in lower Pajarito Canyon. Figure A-1 shows the locations of the NEWNET meteorological stations.*

### 3.9 Biological Setting

*The general biological setting for the Los Alamos region and the canyons is discussed in Section 3.8 of the core document (LANL 1997, 55622). This section discusses unique aspects of the biological setting of the Pajarito Canyon system.*

*Several anthropogenic sources of surface water, as well as storm water runoff, enter the Pajarito Canyon system. Discharges of liquid effluent have occurred into Pajarito Canyon since the earliest days of the Laboratory. In recent years many of these discharges were continued as NPDES-permitted discharges. These discharges and the natural runoff have served as recharge to the alluvial groundwater and wetlands in lower Pajarito Canyon. Since 1994 many of these NPDES discharges have been eliminated or redirected to the sanitary waste consolidation station at TA-46 (see Section 2.2.1). The reduction in both number and volume of discharges may impact the depth to alluvial water in lower Pajarito Canyon in the future (see Section 3.6) and may in turn impact the extent of wetland areas. A more important factor affecting the wetland areas may be the amount of precipitation in the watershed area. Portions of the Pajarito Canyon system are designated on national wetlands inventory maps as artificially and permanently flooded wetlands (Dunham 1992, 31276).*

*Personnel from the Laboratory Ecology group (ESH-20) have conducted a biological assessment of lower Pajarito Canyon from TA-18 eastward to the Laboratory boundary at state road NM4. This assessment document entitled "Characterization of a Palustrine Wetland and Wildlife Use, Pajarito Canyon: A Monitoring Study, 1990–1992" is currently in draft form, and publication of the final report is pending. The extensive report contains descriptions of the general environmental setting including geography, vegetation setting, climatology in the canyon, and locations of wetlands. Characterization includes descriptions of hydrology, hydrophytic plants, and hydric soils. The hydrology study includes weekly water levels in the three PCO monitoring wells from May through October 1985, 1986, and 1990 in correlation with observations of the conditions in the wetlands in lower Pajarito Canyon.*

### 3.9.1 Potential Receptors

*A summary of species thought to occur throughout the Laboratory canyons system can be found in Section 3.8 of the core document (LANL 1997, 55622). Only supplemental data specific to Pajarito Canyon will be presented here.*

#### 3.9.1.1 Flora

*Vegetation types vary by elevation within the Pajarito Canyon system. A detailed description of 6 major plant communities and 16 plant habitats were studied for the Los Alamos National Environmental Research Park (Foxx and Tierney 1984, 5950). The descriptions of plant communities were prepared from work in Pajarito Canyon and cover the entire length of the canyon from Pajarito Mountain to the Rio Grande. A study of plant succession on old homestead fields on the Pajarito Plateau includes floral succession information for an abandoned agricultural field located on Twomile Mesa between Twomile Canyon and Pajarito Canyon (Foxx et al. 1997, 57580).*

*ESH-20 personnel have completed six biological assessments, which address many of the technical areas within the Pajarito Canyon watershed area (Dunham 1992, 31276; Banar 1996, 58192; Cross 1996, 52021; Cross and Usner 1996, 52022; Salisbury 1995, 55596; Banar 1996, 55592). The purpose of the assessments was to evaluate the impact of ER Project site characterization activities on potentially present threatened, endangered, and sensitive species and on floodplains and wetlands. The assessments were based on reconnaissance surveys, habitat evaluations, and species-specific surveys that were conducted for compliance with the Federal Endangered Species Act, the New Mexico Wildlife Conservation Act, the New Mexico Endangered Plant Species Act, Federal Executive Order 11990, "Protection of Wetlands," Federal Executive Order 11988, "Floodplain Management," Federal Regulation 10 CFR 1022, the National Environmental Policy Act, and DOE Order 5400.1. The assessments identified the presence of habitats that are capable of supporting threatened, endangered, and sensitive species; however, the assessments do not conclude that these species are present. A summary of the threatened, endangered, and sensitive species that are potentially present based on the habitats identified by these assessments is discussed in Section 3.9.2.*

#### 3.9.1.2 Fauna

*The biological assessments discussed in Section 3.9.1.1 include fauna evaluations conducted in many of the technical areas within the Pajarito Canyon watershed area (Dunham 1992, 31276; Banar 1996, 58192; Cross 1996, 52021; Cross and Usner 1996, 52022; Salisbury 1995, 55596; Banar 1996, 55592). A summary of the threatened, endangered, and sensitive species that are potentially present based on the habitats identified by these assessments is presented in Section 3.9.2.*

### 3.9.2 Threatened, Endangered, and Sensitive Species

*Potential threatened and endangered species in the canyon systems are listed in Chapter 3 of the core document (Section 3.8, Table 3-6) (LANL 1997, 55622). The threatened Mexican spotted owl is believed to have nesting and/or roosting zones in an area of the upper Pajarito Canyon watershed area located approximately between TA-22 and TA-46 and in Threemile Canyon south of TA-67. A preliminary risk assessment for the owl has been completed by Gallegos et al. (1997, 57915). The endangered southwestern willow flycatcher has nesting zones in the lower portion of Pajarito Canyon (between TA-18 and state road NM4). There may be restrictions on activities in the canyon areas during nesting periods for either of these species. Draft Area of Environmental Interest Site Plans have been prepared and are currently undergoing review by the United States Fish and Wildlife Service for approval.*

*Biological evaluations and wetland/floodplain assessments were performed by ESH-20 personnel in 1991. The assessment and a subsequent survey in 1993 noted that suitable nesting areas for several raptors, including northern goshawks and bald eagles, occur in Pajarito Canyon (Cross 1996, 26071). No detailed investigation of reptile and amphibian species has been undertaken.*

*Table 3.9.2-1 presents a summary of the threatened, endangered, and sensitive species that are potentially present within the Pajarito Canyon watershed based on the habitats identified in the biological assessments conducted by ESH-20 personnel for the ER Project (discussed in Section 3.9.1.1 and Section 3.9.1.2).*

### 3.9.3 Species Viability Studies

*No studies addressing species viability have been identified for the Pajarito Canyon system.*

### 3.9.4 Contaminant Uptake

#### 3.9.4.1 Radionuclide Concentrations in Biota

*Firing Point E-F in Pajarito Canyon was selected for intensive study of uranium distribution. In 1977 through 1980 extensive investigations of uranium concentrations in animal tissues were undertaken (Hanson and Miera 1976, 5556; Hanson and Miera 1977, 5701; Hanson and Miera 1978, 5718; Miera et al. 1980, 57517). The studies examined concentrations of uranium in small mammals as well as related soils at Firing Point E-F. Individual animal tissues including gastrointestinal track contents, lungs, pelts, whole carcasses, and unspecified tissue were analyzed. Concentrations of uranium in three native grasses at Firing Point E-F were also examined (Hanson and Miera 1976, 5556; Miera et al. 1980, 57517; Alldredge et al. 1995, 57579).*

##### 3.9.4.1.1 Flora

*Vegetation samples collected at Firing Point E-F in 1974 and 1975 contained approximately 125 to 320 ppm of uranium. The selected vegetation was rooted in soil at the firing site, which averaged 2400 ppm of uranium in the upper 5 cm (2 in.) and 1600 ppm at 5 to 10 cm (2 to 4 in.) (Hanson and Miera 1976, 5556). In a later study the highest concentrations of uranium in surface soil (at 0 to 2.5 cm [0 to 1 in.]) occurred 0 to 10 m (0 to 33 ft) from the detonation point and averaged 4500 ppm. However, concentrations in surface soil 50 and 200 m (160 and 650 ft) from the detonation point were generally less than 15% of that value (Hanson and Miera 1977, 5701; Miera et al. 1980, 57517). Ratios of plant/soil uranium concentrations in the study area varied from 0.05 to 0.08 (Miera et al. 1980, 57517).*

*In response to the scarcity of data on the chemical toxicity of uranium to plants, a factorial experiment employing five uranium concentrations (0, 50, 500, 5000, and 25,000 ppm) and three moisture regimes (low, medium, and high) was performed using three grasses native to Firing Point E-F (Alldredge et al. 1995, 57579). Buchloe dactyloides (buffalo grass), Schizachyrium scoparium (little bluestem), and Aristida longiseta (purple threeawn) were grown in monocultures and in every mixture of two species under all combinations of uranium and moisture levels. This design allowed for the analysis of uranium effects as well as possible compound effects caused by moisture stress. Several measures of plant health and viability were made, including percent emergence, survivability of seedlings and mature plants, root and shoot biomass, and the number and mass of inflorescences. No significant differences between uranium levels were observed in terms of emergence and seedling survival. However, effects were evident for plant biomass, fecundity, and long-term survivability.*

**TABLE 3.9.2-1**

**THREATENED, ENDANGERED, AND SENSITIVE SPECIES POTENTIALLY OCCURRING IN THE PAJARITO CANYON WATERSHED**

| Common Name | Scientific Name | Legal Status | Potential for Occurrence |
|---|---|---|---|
| *Mexican spotted owl* | *Strix occidentalis lucida* | *Federally threatened* | *Not reported* |
| *Peregrine falcon* | *Falco peregrinus* | *Federally endangered* | *Low* |
| *Bald eagle* | *Haliaeetus leucocephalus* | *Federally endangered* | *Not reported* |
| *Northern goshawk* | *Accipiter gentilis* | *Federal candidate* | *Medium* |
| *Willow flycatcher* | *Empidonax traillii* | *Federal candidate* | *Low* |
| *Meadow jumping mouse* | *Zapus hudsonius* | *Federal candidate/State endangered* | *Not reported* |
| *Gramma grass cactus* | *Toumeya papyracantha* | *Federal candidate/State endangered* | *Medium* |
| *Spotted bat* | *Euderma maculatum* | *Federal candidate/State threatened* | *Medium* |
| *Gray vireo* | *Vireo vicinior* | *State threatened* | *Low* |
| *Baird's sparrow* | *Ammodramus bairdii* | *State threatened* | *Low* |
| *Wood lily* | *Lilium philadelphicum var. andium* | *State endangered* | *Not reported* |
| *Helleborine orchid* | *Epipactis gigantea* | *State endangered* | *Not reported* |
| *Jemez Mountain salamander* | *Plethodon neomexicaus* | *State endangered* | *Not reported* |
| *Say's pond snail* | *Lymneae captera* | *State endangered* | *Not reported* |
| *Broad-billed hummingbird* | *Cyantyhs latirostris* | *State endangered* | *Not reported* |
| *Mississippi kite* | *Ictinia mississippiensis* | *State endangered* | *Not reported* |
| *Common black hawk* | *Buteogallus anthracinus* | *State endangered* | *Not reported* |
| *Stream orchid* | *Epipactis gigantea* | *State endangered* | *High* |
| *Checker lily* | *Fritillaria atropurpurea* | *State sensitive* | *Not reported* |
| *Sandia alumroot* | *Heuchera pulchella* | *State sensitive* | *Not reported* |
| *Pagosa phlox* | *Phlox caryophylla* | *State sensitive* | *Low* |
| *Wright fishhook cactus* | *Mammillaria wrightii* | *State sensitive* | *Low* |
| *Sessile-flowered false carrot* | *Aletes sessiliflorus* | *State sensitive* | *Low* |
| *Plank's catchfly* | *Silene plankii* | *State sensitive* | *Low* |
| *Cyanic milkvetch* | *Astragalus cyaneus* | *State sensitive* | *Low* |
| *Santa Fe milkvetch* | *Astragalus feensis* | *State sensitive* | *Low* |
| *Taos milkvetch* | *Astragalus puniceus var. gertudis* | *State sensitive* | *Low* |
| *Tufted sand verbena* | *Abronia bigelovii* | *Federal candidate/ State sensitive* | *Low* |

Source: Banar 1996, 58192; Cross 1996, 52021; Cross and Usner 1996, 52022; Salisbury 1995, 55596

### 3.9.4.1.2 Small Mammals

*Small mammals trapped at Firing Point E-F in 1974 contained a maximum of 210 ppm of uranium in the gastrointestinal tract contents, 24 ppm in the pelts, and 4 ppm in the remaining carcasses. Mammals trapped in the same area in 1975 contained maximum concentrations of 110, 50, and 2 ppm in similar samples and 6 ppm in lungs (Hanson and Miera 1976, 5556). The soil in the study area averaged 2400* *ppm of uranium in the upper 5 cm (2 in.). The data emphasized the importance of resuspension of respirable particles in the upper few millimeters of soil as a contaminant transport pathway.*

*In a later study uranium concentrations in tissues of deer mice (Peromyscus maniculatus) and pocket gophers (Thomomys bottae) were compared to evaluate uranium uptake in small mammals. The uranium concentrations in the tissues were sufficiently different to conclude that the greater bioavailability of uranium in the top few millimeters of soil at Firing Point E-F, combined with the difference in grooming and food habits of the animals, resulted in greater concentrations in deer mice than in pocket gophers (Hanson and Miera 1978, 5718). A subsequent study reported internal tissue/soil ratios of $10^{-3}$ and $10^{-4}$, respectively (Miera et al. 1980, 57517).*

#### 3.9.4.2 Inorganic Contaminant Uptake

*No data were found on specific inorganic contaminant uptake in biota in the Pajarito Canyon system.*

#### 3.9.4.3 Bioaccumulator Uptake

*No data on the uptake of bioaccumulators have been reported for species in the Pajarito Canyon system.*

### 3.9.5 Data Needs for Understanding Biota Uptake of Contaminants

*Although data are available on radionuclide uptake in vegetation and small mammals, no data have yet been found to document uptake of inorganic or bioaccumulator chemicals. No data were found on tissue concentrations of contaminants for predator species such as coyotes, owls, and raptors in Pajarito Canyon, which makes it difficult to evaluate food chain transfer effects. However, data are available for pocket gophers. Because of the extensive burrowing of this species and its localized range, this species could present a significant pathway for contaminant dispersion and transfer.*

*Data reflecting current concentrations in biota are limited. Concentrations of contaminants are expected to have changed during the past 20 to 25 years, and contaminant transfer processes are not necessarily linear. In addition, some contaminants will compete for uptake processes in biota, which indicates a potential for differential uptake of the same contaminant if the mixture of contaminants is altered.*

*Because some recent data have pooled tissues and animals before analysis, no estimate of variability in the population can be determined. Measures of variability within the sample population are essential to evaluate uncertainty in both human health and ecological risk estimates. Because most contaminants localize within specific tissues in fauna, the practice of pooling tissues obscures variations among critical organs, which makes assessment of the impact of contaminants on the health of the population difficult.*

## REFERENCES FOR CHAPTER 3

*The following list includes all the references cited in this chapter. The parenthetical information following each reference provides the author, publication date, and ER identification (ER ID) number. This information is also included in the citations in the text and can be used to locate the documents.*

*ER ID numbers are assigned by the Laboratory's ER Project to track all material associated with Laboratory PRSs. These numbers can be used to locate copies of the documents at the ER Project's Records-Processing Facility and, where applicable, within the ER Project reference library. The references cited in this work plan can be found in the volumes of the reference library titled Reference Set for Canyons.*

*Copies of the reference library are maintained at the NMED Hazardous and Radioactive Materials Bureau, the Los Alamos Area Office of DOE, and the ER Project Office. This library is a living document that was developed to ensure that the administrative authority (AA) has all the necessary material to review the decisions and actions proposed in this work plan. However, documents previously submitted to the AA are not included in the reference library.*

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## 4.0 CONCEPTUAL MODEL

*The conceptual model provides the link between the existing knowledge of the Pajarito Canyon system, which is presented in the historic and environmental descriptions in Chapters 2 and Chapter 3 of this work plan, and the additional information needed to have an adequate understanding of the canyon system. This chapter includes brief summaries of the significant geologic, hydrologic, and biological features, events, and processes operating in the Pajarito Canyon system. Most importantly, this chapter describes working hypotheses based on*

- *the information presented in Chapter 2 and Chapter 3;*
- *information and processes applicable to canyon systems in general, which are described in Chapter 4 of the Core Document for Canyons Investigations (hereafter referred to as "the core document") (LANL 1997, 55622) and are not repeated here; and*
- *the unique environmental factors and processes occurring in Pajarito Canyon that need to be tested or confirmed.*

*The hypotheses presented in the conceptual model will be tested by collecting new data and by interpreting the new data together with the existing information. The result will be an improved understanding of the canyon and the processes that operate in the canyon and an improved conceptual model with less uncertainty. This understanding will lead to a greater ability to project future impacts of contaminants both spatially and temporally.*

*The improved conceptual framework is intended to permit a health risk assessment for current contaminant conditions and to project trends of reasonable future environmental impacts. The hypotheses and the proposals for testing the hypotheses presented in this section lead directly to elements of the sampling and analysis plan, which is presented in Chapter 7 of this work plan.*

*The conceptual model also includes updates and some new hypotheses regarding the regional aquifer that are particularly relevant to Pajarito Canyon and should be applicable on a wider scale across the Pajarito Plateau. These additions to concepts included in the core document (LANL 19997, 55622) and the Hydrogeologic Workplan (LANL 1996, 55430) have evolved as a result of information collected via the Resource Conservation and Recovery Act facility investigation (RFI) activities conducted through March 1998. This information comes from work accomplished in Pueblo Canyon and Los Alamos Canyon, at Technical Area (TA) -16 (Cañon de Valle) and TA-49 (Water Canyon), and as a result of drilling regional aquifer well R-9 in Los Alamos Canyon (LANL 1998, 57576).*

### 4.1 Overview of the Pajarito Canyon Conceptual Model

*Summaries of the important concepts obtained from the data described in Chapter 3 are presented in this section. References to the applicable sections in Chapter 3 are provided to aid understanding of the concepts. The conceptual illustration shown in Figure A-4 in Appendix A of this work plan is an integral part of this overview.*

#### 4.1.1 Sediment Transport Concepts

*Most contaminants within the Pajarito Canyon system that have reached active stream channels after release from outfalls or from surface transport from potential release sites (PRSs) are associated with sediment particles. The present and future distribution of these sediment particles are strongly affected by* *sediment transport processes occurring during flood events. Sediments and associated contaminants are deposited in different geomorphic locations within the canyon, such as active channels, inactive channels, and floodplains or low terraces. These sediments will remain in place for varying lengths of time. Sediment transport in surface water flow is the major mechanism for moving contaminants in canyon systems. Contaminants that are associated with sediment can be available for uptake by humans through ingestion of unfiltered water from stream flow or ponded water, ingestion of sediments either directly or as rain splash deposition on vegetation, inhalation of resuspended airborne particulates from sediments, and consumption of plants and animals that have been contaminant receptors.*

*The numerous borrow pits in lower Pajarito Canyon act as sediment traps that help prevent potentially contaminated sediments in the Pajarito Canyon system from moving beyond the Laboratory boundary.*

*Most elements of the conceptual model for sediment transport processes in Pajarito Canyon are the same as those described in the core document (LANL 1997, 55622) and are not repeated in this work plan. Section 3.4 of this work plan describes the information known about surface sediments, and Section 3.5 of this work plan describes the information known about subsurface sediments.*

### 4.1.2 Hydrologic Transport Concepts

*The canyon-specific hydrologic conditions identified in Pajarito Canyon are outlined in this section. Figure A-4 illustrates the major elements of the Pajarito Canyon hydrologic conceptual model and the current hypotheses regarding the connecting pathways and processes. The following brief descriptions highlight the most important elements of the Pajarito Canyon conceptual model. The descriptions are organized in a progression from west to east (left to right) across the figure. Features and geographic locations discussed in this section are also shown in Figure A-1 in Appendix A of this work plan.*

#### 4.1.2.1 High-Elevation Snowmelt and Runoff

*One of the major inputs of new water to the canyon system is contemporary precipitation, which includes annual snow fall and residual snowpack. Snowmelt runoff each spring usually releases the snowpack to the system (see Section 3.6).*

#### 4.1.2.2 PC Spring

*The water from PC Spring in upper Pajarito Canyon is also one of the major inputs of new water to the canyon system. Streamflow in the channel is perennial from the spring to near the western Laboratory boundary. This water apparently comes from deep, older, groundwater sources rather than from contemporary snowmelt infiltration and/or interflow (see Section 3.6.2 and Section 3.6.6.3). Much of the water appears to infiltrate into the Pajarito fault zone before reaching Laboratory property.*

#### 4.1.2.3 Perennial Stream Flow

*Perennial stream flow is maintained in upper Pajarito Canyon for a distance downstream from PC Spring. The perennial flow is augmented by ephemeral flow from seasonal snowmelt and thunderstorm runoff. The perennial flow in this reach of the canyon typically extends to the Pajarito fault zone near state road NM501 at the western Laboratory boundary.*

*Another perennial reach generally extends from Homestead Spring in Pajarito Canyon and Starmer Spring in the south fork of Pajarito Canyon (“Starmer Gulch”) downstream as far as the confluence with*

*Twomile Canyon. Periodic field checks of the stream through this reach have noted surface water flow; however, no systematic investigations have been performed to identify the perennial reach of the stream.*

*Perennial stream flow is also present in lower Pajarito Canyon for a distance of approximately 0.25 mi, extending from Pajarito Springs (Spring 4A) to the Rio Grande (see Section 3.6).*

#### 4.1.2.4 Pajarito Fault

*The Pajarito fault approximately parallels the western Laboratory boundary in the Pajarito Canyon area. The Pajarito fault appears to represent a major zone of streamflow loss and may extend to considerable depth, diverting streamflow to perched zones or to the regional aquifer. Perched groundwater zones recharged by the Pajarito fault could include the following:*

- *flow unit boundaries and fractures in Tshirege Member units (Qbt) 3 and 4;*
- *formation contacts with perching potential, such as the base of the Tshirege and the Otowi Members, and the top of interbedded volcanics such as the Tschicoma Formation;*
- *possible perching zones within the Cerro Toledo interval (Qct); and*
- *recharge to the regional aquifer or to a series of perched zones that lead to the regional aquifer.*

*(See Section 3.3 and Section 3.6)*

#### 4.1.2.5 Perched Groundwater

*Perched groundwater may be present in several places within the Pajarito Canyon watershed. Potential occurrences of perched groundwater include the following:*

- *shallow perched zones or fracture flow within Qbt 3 and Qbt 4 that may discharge to springs near the western Laboratory boundary;*
- *perched alluvial groundwater, mainly present from the confluence with Twomile Canyon to the eastern Laboratory boundary at state road NM4;*
- *interrupted stream flow, channel loss, and return flow within the alluvium;*
- *potential interflow along bedding planes or fractures within Qbt 1v in middle Pajarito Canyon that may discharge to springs in Threemile Canyon;*
- *potential intermediate-depth perched zones within the Cerro Toledo interval, such as the potential groundwater encountered at borehole SHB-3 and underlying basalt flows in lower Pajarito Canyon; and*
- *possible local perched zones within the uppermost layers of the regional aquifer.*

*(See Section 3.7)*

#### 4.1.2.6 Western Springs

*Numerous springs emerge from contacts, bedding planes, and/or fractures within the Bandelier Tuff near the western Laboratory boundary. Most springs are located in the south fork of Pajarito Canyon ("Starmer Gulch"), the north Anchor East basin ("Arroyo de LaDelfe"), and Pajarito Canyon, but springs are also present in Twomile Canyon and a tributary to the north fork of Twomile Canyon. Recharge to these springs may come from surface water that infiltrates into the Pajarito fault zone or from unknown sources.*

*Some springs that discharge into the bottom of the channels may come from temporarily stored channel loss, alluvial underflow, or interflow between channel reaches along perching layers within the alluvium (see Section 3.6.2).*

#### 4.1.2.7 Mesa-Top Runoff

*Storm water runoff from Laboratory installations and from mesa tops contributes to the volume of water entering the canyon. Nonpoint source contaminants are known to be scattered across the mesa tops as a result of dynamic testing of explosives throughout the central and western portion of the Laboratory (see Section 3.6.3).*

#### 4.1.2.8 Threemile Canyon Springs

*The source of springs in Threemile Canyon may be from alluvial groundwater in middle Pajarito Canyon. The alluvial groundwater may seep into bedrock fractures and move as intermediate perched groundwater down the structural dip within Qbt 1v. The water may move through the tuff via vertical fractures or along bedding planes within the tuff. The Qbt 1v/1g contact, fractures in the colonnade tuff (Qbt 1v-c), or a similar feature in the tuff may provide the perching mechanism beneath Pajarito Mesa (see Section 3.6.2). An alternative source for the springs in Threemile Canyon may be the stream in upper Cañon de Valle. Both potential sources contain high explosives (HE).*

#### 4.1.2.9 Horizontal Discontinuity between Dense Volcanic Flows

*The subsurface geology and stratigraphy directly beneath most of Pajarito Canyon is largely undetermined; therefore, the presence of possible perched intermediate saturated zones beneath Pajarito Canyon have not been determined. Information from nearby deep boreholes indicates that the volcanic stratigraphy beneath the Bandelier Tuff is highly variable and discontinuous. Lower Pajarito Canyon is underlain by Cerros del Rio basalt flows within the Puye Formation, whereas the western and middle part of the canyon may be underlain by intermediate-composition volcanic rocks similar to the Tschicoma Formation. A horizontal stratigraphic discontinuity may exist between these two types of dense volcanic flows in the Puye Formation stratigraphic interval (see Figure A-2 and Figure A-4). The discontinuity may exist between the eastern margin of Tschicoma Formation flows and the western margin of the Cerros del Rio basaltic flows. The sediments in this area without dense lavas may represent a local zone of preferable recharge to intermediate perched zones or to the regional aquifer; alternately, these sediments may restrict recharge to the deeper units (see Section 3.7.3).*

#### 4.1.2.10 Buried Paleochannels

*Buried paleochannels in the subsurface may provide collection points and conduits for intermediate perched zones and lateral transport pathways for groundwater (see Section 3.7.2.1). The following are possible locations of buried paleochannels.*

- *The Cerro Toledo interval channel/fluvial deposits may include a major channel system that extends from the upper reaches of Los Alamos Canyon southeast to Potrillo Canyon. This channel system may cross Pajarito Canyon near TA-18.*
- *The pre-Bandelier Tuff (pre-Guaje Pumice Bed) surface locally may be the top of the Puye Formation, the top of Tschicoma Formation intermediate volcanic flows, or the top of Cerros del Rio basalt flows. A paleochannel eroded into the pre-Bandelier Tuff surface appears to trend toward the south-southwest across the Pajarito Plateau and cross Pajarito Canyon west of TA-18 (see Section 3.3.3).*

#### 4.1.2.11 Regional Aquifer

*The regional aquifer is composed of many different rock types and is extremely heterogeneous and anisotropic both geologically and hydrologically. The uppermost layers of saturation in the regional aquifer are typically within the fanglomerate member of the Puye Formation, which is interbedded with layered dense volcanic flows that overlie Santa Fe Group sediments. Lateral flow of groundwater in the regional aquifer is probably controlled by near horizontal permeability contrasts within the different rock types. The deep water supply wells are screened across many stratigraphic layers with widely varying hydrogeologic and geochemical properties. Historically, the long screened intervals have resulted in a limited understanding of the aquifer based on averaging of hydrologic and geochemical characteristics across the screened intervals (see Section 3.7.4).*

#### 4.1.2.12 Lower Pajarito Canyon Alluvial System

*The lower part of the canyon, which extends from approximately one mile west of TA-18 downstream to approximately the Laboratory boundary at state road NM4, contains the largest volume of alluvium and a perched body of alluvial groundwater. This reach also contains numerous abandoned borrow pits that have created wetlands, which provide storage for infiltrating surface water. The wetlands also provide sites for increased evapotranspiration of the alluvial groundwater. A study of the water balance of the alluvial groundwater system will help understand flow and contaminant pathways (see Section 3.7.2).*

#### 4.1.2.13 Contact of Alluvium with the Cerro Toledo Interval and Older Units

*Throughout most of the canyon, the alluvium overlies the Bandelier Tuff, which tends to weather in place to clay and which may provide a perching layer for the alluvial groundwater. However, in lower Pajarito Canyon, from approximately 1000 ft (300 m) west of PCO-3 downstream for several hundred feet, the alluvium probably overlies the Cerro Toledo interval, which in part consists of older alluvial sediments. In this area the alluvial groundwater may seep into the Cerro Toledo interval sediments. Flow within the Cerro Toledo interval may be controlled by paleochannels that potentially provide flow pathways away from the stream channel, possibly toward the south or southeast.*

*At the location of PCO-3, the alluvium probably overlies the Otowi Member; farther east (near the Laboratory boundary) the alluvium probably overlies Cerros del Rio basalts. The alluvium thins eastward and pinches out against the basalt at the Laboratory boundary. Surface water and alluvial groundwater* *that seep into the basalt may flow laterally and/or downward via fractures or intermediate perched zones within the basalt (see Section 3.7.2.3).*

#### 4.1.2.14 Surface Water and Sediment Transport

*A major mechanism for moving contaminants in the canyon system is surface water and surface sediment transport. Several processes are involved, which are described in Chapter 4 of the core document (LANL 1997, 55622). Except for three relatively short perennial reaches of streamflow, surface water flow and sediment transport through the middle and lower canyon are ephemeral. Since 1996 surface flow at the eastern Laboratory boundary has been measured only a few times during periods of heavy precipitation (see Section 3.6.1).*

#### 4.1.2.15 Deep Water Supply Wells

*Groundwater withdrawals from the regional aquifer are used directly by people in Los Alamos County. No contaminants from Laboratory operations have been identified in the regional aquifer water supply wells in or adjacent to Pajarito Canyon. The water from the deep wells is collected from long screen intervals, often more than 1000 ft long, and is a mixture of water from different formations. The water from different formations may have different piezometric heads and geochemical signatures. Data from vertical flow measurements and down-hole videotape logs in some wells indicate that most water withdrawal comes from a relatively small number of layers within the screened interval.*

#### 4.1.2.16 Springs near the Rio Grande

*Pajarito Springs (Spring 4A) is a major source of groundwater discharge from beneath the Pajarito Plateau into the Rio Grande surface water system (see Sections 3.6.2, 3.6.6, and 3.7.4). The springs may be a mixture of some water infiltrating through the plateau, but geochemical data indicate that the water is mostly deeper, older water similar to the regional aquifer.*

### 4.1.3 Biological Transport Concepts

*The biological transport conceptual model is presented on page 4-12 of the core document (LANL 1997, 55622).*

*Numerous wetland areas are present in lower Threemile Canyon and Pajarito Canyon. Special wetland investigations have been initiated at the wetland sites, which will be completed as part of the canyons RFI. The results of the existing investigations will be evaluated for applicability to the Pajarito Canyon investigation (see Section 3.9).*

### 4.1.4 Potential Sources of Contaminants to the Pajarito Canyon Watershed

#### 4.1.4.1 Upper Canyon Contaminant Sources

*In upper Twomile Canyon and Pajarito Canyon, possible sources of contaminants to surface water, surface sediments, and possibly to shallow groundwater identified through RFIs include the following (see Figure A-1):*

- *Material Disposal Area (MDA) M (see Section 2.3.1 and Section 3.6.6);*
- *PRS 69-001 (see Section 2.3.1);*

- *PRS 3-010(a) (see Section 2.3.3 and Section 3.5.2);*

- *primary surface deposition of residual explosive compounds from dynamic testing at the firing sites;*

- *outfall discharges, which mostly consist of deep aquifer water from supply wells with altered constituents or added contaminants; and*

- *leaching of contaminants by runoff and/or infiltration at PRSs with contaminants.*

#### 4.1.4.2 Middle and Lower Canyon Contaminant Sources

*Possible sources of contaminants in the middle reaches of Pajarito Canyon include the following:*

- *mesa-top firing sites,*

- *nonpoint contaminant sources from firing sites, and*

- *outfalls and septic systems at TA-18 and TA-36 (see Section 2.3.10 and Section 2.3.11).*

*Firing sites may contain residual concentrations of HE, HE burn products, depleted uranium, beryllium, boron, lead, and zinc in the soil. Firing sites with histories of the greatest dynamic testing dispersal of contaminants that are potential contributors to contaminants in Threemile Canyon and Pajarito Canyon include*

- *Firing Point R-44 (see Section 2.3.9),*

- *Firing Point E-F (see Section 2.3.9),*

- *I-J Site (see Section 2.3.11), and*

- *TA-18 sites (see Section 2.3.10).*

*In the lower part of the canyon, a potential source of contaminants is TA-54. A subsurface tritium plume of unknown extent is present beneath MDA H; an organic vapor plume extends downward several hundred feet in the subsurface beneath MDA L; a subsurface tritium vapor plume and aqueous phase contaminants are potentially present beneath MDA G. Tritium and plutonium have been measured in runoff from MDA G into Pajarito Canyon, but significant amounts of contaminants have not been observed in lower Pajarito Canyon in either sediments or the alluvial groundwater (see Section 2.3.12 and Section 3.5.4).*

### 4.2 Hydrologic System and Processes

*The movement of contaminants in surface water and groundwater is a potentially significant transport pathway in the Pajarito Canyon system. Surface water as active channel flow and shallow alluvial groundwater in the thinnest part of the saturated alluvium exchange and interact rapidly and supply water for plants, animals, and livestock.*

*Groundwater under saturated flow conditions has been observed in two zones in Pajarito Canyon: the alluvium and the regional aquifer. Each of these saturated zones provides transport pathways within the environment and, potentially, to human and other biological receptors. Saturated flow conditions may also occur at some intermediate depths.*

*Contaminants are present in the alluvial groundwater and could migrate to deeper zones of saturation. Hydraulic interconnections between the alluvium and intermediate perched zones are known to occur in adjacent canyons; the Cerro Toledo interval, the Guaje Pumice Bed, and the Cerros del Rio basalts may contain intermediate perched zones beneath Pajarito Canyon. A better understanding of intermediate perched zones, if present, and the interconnections with the alluvium is important to evaluating potential exposures to humans and the environment by these pathways.*

### 4.2.1 Sources and Characteristics of Waters

*Understanding the origin and provenance of natural and anthropogenically altered waters is crucial to understanding the nature of the hydrologic connections, "the subsurface plumbing" so to speak, and thus the potential pathways for movement of contaminants. Four general classes of waters are useful to consider because each should have some unique "signature" of physical or chemical properties that permit identification. The four classes of water include (1) recent precipitation, (2) deep groundwater, (3) recent Laboratory discharges, and (4) mixtures of surface water and groundwater. A brief description of each type follows.*

#### 4.2.1.1 Recent Precipitation and/or Infiltration

*Recently precipitated water and/or melting snowpack will have distinct, easily measurable levels of tritium. During the last decade precipitation in the Los Alamos area has typically contained 50 to 450 pCi/L tritium (North American precipitation averages 20 to 30 pCi/L). In contemporary precipitation carbon-14 is in equilibrium with atmospheric carbon dioxide. After it is isolated from the atmosphere by infiltration, the carbon-14 concentration decreases by radioactive decay, which permits estimates of the age of groundwater from the time of isolation from the atmosphere. Departures of deuterium/hydrogen and oxygen-18/oxygen-16 from the standard mean ocean water values provide some insights as to the elevation of the condensation and precipitation or evaporation processes (Blake et al. 1995, 49931, p. 24).*

#### 4.2.1.2 Deep Groundwater

*Waters that have been isolated from the atmosphere typically come from deeper sources stratigraphically and are relatively older waters. These waters have lower levels of tritium and carbon-14 isotope ratios. The absence of or very low levels of measurable tritium (approximately 1.6 pCi/L or less) is diagnostic evidence that the water has been isolated from the atmosphere for at least 100 years. None of the Pajarito Mesa supply wells (PM-1 to PM-5) show recent recharge based on trace levels of tritium. Measurement of carbon-14 permits estimation of the time of isolation from the atmosphere ranging from a few hundred to several tens of thousands of years. Samples of the regional aquifer from deep wells have shown estimated ages from as low as approximately 45 years to 40,000 years. Most deep water beneath the Pajarito Plateau, such as the regional aquifer water, is present at relatively high temperatures (15° to 20° C). Stable isotopes of hydrogen and oxygen can be used to estimate the elevation at which infiltration occurred (Blake et al. 1995, 49931, p. 24). Water originating from higher elevations typically has more negative isotopic ratios of deuterium/hydrogen and oxygen-18/oxygen-16.*

#### 4.2.1.3 Discharges within the Past 20 Years

*For effluent discharges from Los Alamos Laboratory operations, most of the water originates from the deep regional aquifer water, which is pumped up through the supply wells and distributed across the Pajarito Plateau. Various processes permit contact with the atmosphere or add other constituents to the water before the water is discharged into the canyon. Therefore, much of the liquid discharged to surface streams has many of the geochemical characteristics of regional aquifer water such as higher sodium, calcium, and bicarbonate concentrations relative to alluvial groundwater, but with some alterations or additions such as nitrate, sulfate, chloride, and oxalate.*

#### 4.2.1.4 Mixtures of Surface Water and Groundwater

*Mixtures of the basic types of water occur through both natural processes and anthropogenic activities. Natural mixing of water may be observed at Spring 4 in White Rock Canyon (see Figure A-1 in Appendix A for the location), where recent precipitation infiltrating through rock and soil may mix with spring water from a deep groundwater source. Sometimes sources of mixtures may be difficult to detect without considering the effects of the recent transport history of water. For example, simply exposing water from the regional aquifer to air can change the apparent ages calculated from radioisotope measurements.*

### 4.2.2 Site-Specific Contaminant Sources and Distribution

*The following types of contaminant sources are specific to the Pajarito Canyon watershed. Major sources are identified in Figure A-4. In some cases sources may be hypothesized based on observation of contaminants in the hydrogeologic system.*

#### 4.2.2.1 Surface Runoff and/or Erosion from PRSs

- *The process of mobilizing contaminants associated with particles and sediments occurs where surface contaminants are present. Specific examples in the Pajarito Canyon watershed are firing sites and open disposal areas (such as MDA M) and surface contaminants at MDA G at TA-54 (see Section 3.4 and Section 3.6).*

- *Sediments along the perimeter of MDA G at TA-54 show plutonium concentrations that significantly exceed the background value for soil (see Section 3.4).*

- *HE compounds have been detected in surface water in upper Pajarito Canyon west of the Laboratory boundary. HE compounds have also been detected in surface water in middle Pajarito Canyon at stream gage E245 and in surface water and springs in Threemile Canyon. The surface water in Pajarito Canyon contains higher concentrations of HE than surface water and springs in Threemile Canyon (see Section 3.6.6.2 and Section 3.6.6.3).*

- *HE compounds octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine (HMX) and hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX) were detected in surface water in middle Pajarito Canyon and in the springs in Threemile Canyon. Concentrations of HMX and RDX are highest in the Pajarito Canyon surface water at gaging station E245 (4.4 μg/L and 1.01 μg/L, respectively) (see Section 3.6.6.2.3).*

- *The sampling data may suggest that the surface waters in middle Pajarito Canyon and Threemile Canyon have a similar source that is contaminated with HE compounds. An additional source of* *semivolatile organic compounds (SVOCs) may be present in upper Threemile Canyon (see Section 3.6.6.2).*

- *The HE compounds HMX, RDX, o-nitrotoluene, and tetryl (methyl-2,4,6-trinitrophenylnitramine) were detected in surface water collected from the wetlands downstream from TA-18. Figure 3.6.6-10 shows the results of the RFI sampling. The HE compounds were not detected in the baseline wetland surface water samples in Threemile Canyon but were detected in the baseline wells in Pajarito Canyon. The concentrations of HE were higher in the wetlands surface water, which suggests that the source of these compounds could be TA-18 or the nearby former firing site (see Section 3.6.6.2.3).*

- *Sediments adjacent to MDA M at TA-9 show elevated concentrations of arsenic, barium, cadmium, cobalt, copper, lead, and vanadium compared with site-wide background values (see Section 3.4.3.3.1).*

- *In May 1994 single-stage runoff samples were collected from three small rill channels draining the MDA M site. Metals detected significantly above former screening action level (SAL) values include aluminum, barium, beryllium, cadmium, chromium, lead, manganese, and tin. No volatile organic compounds (VOCs), SVOCs, pesticides, or polychlorinated biphenyls (PCBs) were detected in the runoff samples(see Section 3.6.6.1.2).*

- *Filtered runoff samples from MDA M showed all metals below detection limits except mercury, which was present at 0.0011 mg/L. The runoff contained approximately 5000 mg/L total suspended sediment; lead was present in the suspended sediment at 37 mg/kg (see Section 3.6.6.1.2).*

- *Chloride concentrations at PCO-1 range from 10 to 194 mg/L, and sodium concentrations range from 10 to 130 mg/L, which probably result from the use of road salt on Pajarito Road. The highest concentrations of sodium and chlorine are typically observed at sampling events conducted during spring runoff periods (see Section 3.6.6.1.1).*

- *Surface water samples collected in Threemile Canyon contain up to 2.22 pCi/L plutonium-239,240; up to 0.89 pCi/L thorium-228; up to 0.62 pCi/L thorium-230; and up to 3.7 μg/L uranium. The highest concentration of uranium detected in surface water was in Threemile Canyon. Surface water collected from wetlands in lower Pajarito Canyon east of TA-18 contained 0.02 pCi/L plutonium-238, 0.56 pCi/L thorium-228, 0.38 pCi/L thorium-230, and up to 1.1 μg/L uranium. The concentrations of uranium in the surface water samples steadily decreased in downstream wetlands to a concentration of 0.16 μg/L in WL-8 near 18-MW-18 (see Section 3.6.6.2.3).*

- *Higher levels of total uranium activity were observed in the surface and alluvial waters during the 1970s, which may reflect the larger input of depleted uranium from runoff from firing sites when much more hydrodynamic testing was conducted (see Section 3.6.6.1.1).*

#### 4.2.2.2 Infiltration and/or Leaching from PRSs

*Water from precipitation can infiltrate through canyon edge disposal areas (such as MDA M) or through the surface of firing sites. This infiltration mobilizes soluble contaminants, which creates an aqueous* *phase contaminant that can move into surface water as return flow or into groundwater. A summary of the sampling results detailed in Chapter 3 follows.*

- *Springs SM-30 and SM-30A are located at the north end of a group of springs that discharge from the Tshirege Member along the western Laboratory boundary (see Figure A-1 in the Appendix to this work plan). These springs may have a similar source and perching mechanism and may be hydraulically related to a "seep" identified during the RFI at PRS 03-010(a). In 1994 water samples from the "seep" contained 1,1,1-trichloroethane (TCA) at concentrations ranging from 7.9 to 13 μg/L. Perched groundwater collected from the nearby boreholes also contained similar concentrations of TCA (see Section 3.7.2.4).*

- *Several organic compounds were detected in surface water from the wetlands downstream from TA-18. The organic compounds included acetone, 2-butanone, and methylene chloride. Additionally, metal constituents including barium, beryllium, chromium, lead, nickel, silver, and zinc were detected in surface water collected from wetlands at concentrations exceeding upstream baseline levels but less than their respective former SAL values (see Section 3.6.6.2.3).*

- *In June 1995 Threemile (B) Spring contained HE compounds HMX (1100 μg/L) and RDX (77 μg/L). Additionally, Threemile (A) Spring contained 2.55 pCi/L uranium-238 and Threemile (B) Spring contained 0.88 pCi/L uranium-238. Threemile (B) Spring was subsequently resampled in August 1995 and analyzed for HE compounds. The results showed significantly lower concentrations of HMX (1.2 μg/L) and RDX (below the detection limit of 2 μg/L). This sampling occurred after a significant precipitation event that may have caused dilution of the contaminants (see Section 3.6.6.2.3).*

#### 4.2.2.3 Liquid Release to Surface Water

*Water (with or without contaminants) released by Laboratory activities can change the water balance and alter chemical conditions, either as additions or dilutions. The changes resulting from the termination of numerous surface discharges in recent years include water levels, concentrations of contaminants, and the extent of wetlands.*

#### 4.2.2.4 Subsurface Release of Liquid or Vapor

*Contaminants in alluvial groundwater suggest that releases of subsurface liquids have occurred near TA-18 from septic tanks and leaking storage tanks. Additionally, vapor releases of organic materials from MDA L, which is located north of Pajarito Canyon, have been traced to the basalt that extends beneath Pajarito Canyon. Significant sources of mobile tritium gas and tritiated water vapor are present on the north edge of Pajarito Canyon at MDA H and MDA G. The following bullets summarize the sampling results discussed in detail in Chapter 3, which implicate these sources.*

- *The HE compounds HMX, RDX, o-nitrotoluene, and tetryl (methyl-2,4,6-trinitrophenylnitramine) were detected in surface water collected from the wetlands downstream from TA-18 (see Section 3.6.6). The HE compounds were not detected in the upstream baseline wetland surface water samples in Threemile Canyon but were detected in the upstream baseline wells in Pajarito Canyon. The concentrations of HE were higher in the wetlands surface water compared with the baseline alluvial groundwater wells, which suggests that the source of these compounds could be TA-18 or the nearby former firing site. These results could be impacted by seasonal dilution of surface water and groundwater.*

- *From 1985 to 1990 a total of 27 boreholes were drilled at TA-54 to characterize the vadose zone beneath the chemical disposal pits and shafts at MDA L. The boreholes ranged in depth from 120 ft (36 m) to approximately 300 ft (90 m). In 1988 several boreholes were drilled to the basalts at the top of the Puye Formation. The basalts were encountered at depths ranging from 198 to 298 ft (60 to 90 m) (Purtymun 1995, 45344, p. 185). The results of the drilling showed that an organic vapor plume is present beneath MDA L. The plume extends to the depth of the basalt, which ranges from approximately 200 to 300 ft (60 to 90 m). The RFI for Operable Unit 1148 continued characterization of the vadose zone beneath MDA L. A total of 21 organic compounds have been identified in the plume; trichloroethane is the most concentrated (see Section 3.5.4).*

### 4.2.3 Surface Water Hydrology

*The following bullets summarize the surface water hydrology of Pajarito Canyon as discussed in Section 3.6.*

- *Two perennial reaches typically occur in upper Pajarito Canyon. One reach extends downstream from PC Spring to near the Laboratory boundary, and the second reach extends from Homestead Spring and Starmer Spring (in "Starmer Gulch") downstream to near the confluence with Twomile Canyon.*

- *The water from PC Spring in upper Pajarito Canyon shows no measurable tritium (see Table 3.6.6-3); therefore, the water apparently comes from a deeper, older water system, possibly similar to the regional aquifer water. This water does not appear to come from recent precipitation.*

- *In upper Pajarito Canyon a significant amount of surface flow (from snowmelt, ephemeral runoff, and discharge from PC Spring) is lost at the Pajarito fault zone west of the Laboratory boundary. Some of this flow loss may move as interflow through fractures and/or bedding planes in Tshirege units 4 and 3 and discharge as springs east of the fault zone. Some of the loss into the fault zone may move deeper, possibly providing some recharge to deeper perched zones (for example, as noted in borehole SHB-3 to the south) or possibly providing some recharge to the regional aquifer.*

- *In Twomile Canyon streamflow as high as 20 to 30 gal. per min. has been observed to be lost from the channel before the confluence with Pajarito Canyon.*

- *Surface water flow across the eastern Laboratory boundary at state road NM4 is ephemeral; occasionally flow reaches the Rio Grande as the result of high snowmelt runoff or periodic storm events.*

- *The geochemistry and temperature of surface water collected in Pajarito Canyon at the Rio Grande indicate that the water comes primarily from Pajarito Springs (Spring 4A) and is associated with discharge from the top of the regional aquifer.*

#### 4.2.3.1 Sediment Transport

*Sediments and associated adsorbed 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 the active channel occurs during relatively frequent small- to moderate-sized storm flows. Large flows cause bank erosion, which remobilizes some sediment from inactive* *channels and floodplains. Infrequent major precipitation events can result in sufficient precipitation runoff to transport accumulated sediments off-site onto Los Alamos County land and into the Rio Grande.*

*The following bullets summarize the significant information about surface sediments provided in Section 3.4.*

- *Sediment sampling in wetlands in Threemile Canyon shows that barium; zinc; plutonium-238; plutonium-239,240; thorium-228; thorium-230; and total uranium are above background values.*
- *Sediments in wetlands downstream of TA-18 contain barium, beryllium, chromium, lead, nickel, silver, and zinc in concentrations above background values.*
- *The stream channel in lower Pajarito Canyon has been highly disturbed by diversion of the stream channel and excavation of sand and gravel pits. The locations of sediment and contaminant deposition have not been adequately described or documented.*
- *Routine environmental surveillance sampling of active channel sediments at the downstream Laboratory boundary at state road NM4 shows near background values for most radionuclides. However, metals including barium, boron, cadmium, chromium, cobalt, lead, and zinc have been measured in concentrations greater than background values at state road NM4. The metals that have been observed at more than two times background values include cadmium, cobalt, and zinc. At the Rio Grande only cadmium is observed above background values, which may be the result of different bedrock types exposed in White Rock Canyon than on Laboratory land.*
- *In 1996 the environmental surveillance sampling of surface water included analyses for HE at the confluence of Pajarito Canyon and the Rio Grande. The concentrations of HE were below detection limits.*
- *Runoff samples collected at MDA M contained approximately 5000 mg/L total suspended sediment; lead was present in the suspended sediment at 37 mg/kg.*

#### 4.2.3.2 Solute Transport

*Precipitation runoff and effluent discharge across potential release sites can mobilize contaminants and move them in either suspended or dissolved phases into the canyon stream or groundwater. Precipitation runoff and surface flow transport of contaminants associated with suspended particles or bed sediments will dominate the transport of adsorbed species. However, contaminants such as tritium, uranium, and some HE residuals can also be transported in solution.*

*The following bullets summarize the significant information about solute transport provided in Section 3.6.6.*

- *PC Spring generally contains the lowest observed concentrations of calcium, chloride, fluoride, sodium, sulfate, total dissolved solids (TDS), and specific conductance values. The two springs in Twomile Canyon (Hanlon Spring and Anderson Spring) contain higher concentrations of bicarbonate and TDS than other springs in upper Pajarito Canyon and “Starmer Gulch.” Relative to the springs in upper Pajarito Canyon (PC Spring and Homestead Spring) and the springs in Twomile Canyon, the springs in “Starmer Gulch” (Starmer Spring and Charlie’s Spring) contain* *higher concentrations of calcium, chloride, and magnesium. The highest values of calcium, magnesium, bicarbonate, specific conductance, and highest temperatures are found at Pajarito Springs (Spring 4A) (which discharges from the Puye Formation in lower Pajarito Canyon).*

- *The surface water in middle Pajarito Canyon at gaging station E245 and the two springs in Threemile Canyon (Threemile Spring and TA-18 Spring) contain HE compounds. Of these three sites sampled in 1997, TA-18 Spring contained the lowest concentrations of HMX and RDX but at concentrations above detection limits.*

- *HE (2,4-DNT) was detected above Laboratory SAL values at Starmer Spring (1.52 μg/L) and at an upstream baseline surface water site in Pajarito Canyon west of state road NM501 (0.9 μg/L). Starmer Spring also contained 1.99 μg/L HMX. Generally, concentrations of water quality parameters are lower at the upstream baseline site west of state road NM501, but water from the western springs appears similar in water quality constituents. Low levels of radionuclide activities were detected in the western spring water samples, but the results did not exceed former SAL values.*

- *Surface water collected from TA-18 and the PCO-1 site show a range in nitrate (as nitrogen) up to 4 and 7 mg/L, respectively. Most cations and anions vary approximately an order of magnitude at the PCO-1 site, which reflects seasonal variations in water quality parameters. These variations are likely caused by lesser or greater dilution effects depending on runoff magnitudes. No significant trends are obvious in the annual variation of surface water quality data at the PCO-1 site. The mean concentrations of calcium, chloride, specific conductance, sodium, nitrate (as nitrogen), sulfate, and TDS are highest in the surface water at the PCO-1 site below TA-18.*

- *From 1967 to 1972 the concentration of nitrate (as nitrogen) in surface water at TA-18 ranged from 0.1 to 4 mg/L. The highest nitrate concentration measured at the PCO-1 site was 7 mg/L in 1983. The chloride concentrations range from 10 to 194 mg/L, and sodium concentrations range from 10 to 130, which probably result from the use of road salt on Pajarito Road. The highest concentrations of sodium and chloride are typically observed at sampling events conducted during spring runoff periods.*

- *In surface water the mean concentrations of aluminum, arsenic, barium, beryllium, cadmium, cobalt, iron, manganese, mercury, molybdenum, nickel, strontium, and vanadium are higher at the PCO-1 site, whereas the mean concentrations of antimony, chromium, copper, lead, selenium, silver, thallium, tin, and zinc are higher in the surface water at the Rio Grande site. The range of concentrations of most metals, especially cadmium, lead, silver, and zinc (see Figure 3.6.6-3), are greater at the Rio Grande site. The surface waters at these two sites are not necessarily related because most surface water in lower Pajarito Canyon infiltrates into the subsurface, whereas the surface water at the Rio Grande site comes mainly from Pajarito Springs (Spring 4A).*

- *During the 1970s the concentration of total uranium in surface water was highest near TA-18 (0.6 μg/L in 1973 at TA-18 and 20 μg/L at the PCO-1 site in 1980), although the overall mean uranium concentration at the PCO-1 site is much lower (1.5 μg/L). The higher concentrations of total uranium observed in the surface and alluvial waters during the 1970s may reflect the larger input of depleted uranium from firing site runoff when much more hydrodynamic testing was conducted.*

- *The highest activity of tritium in surface water (15.8 nCi/L) was measured at TA-18 during the 1970s. The average activity of tritium at the PCO-1 site is 1.8 nCi/L, which shows probable Laboratory contribution of tritium to the surface water. The activity of tritium during the past 10 years in surface water at the PCO-1 site has been less than 600 pCi/L. Surface water at the Rio Grande site typically contains tritium activity near detection limits, but it has possibly contained up to 13 nCi/L tritium (in 1987). However, this result has not been substantiated by subsequent analyses.*

- *Runoff samples were collected from Pajarito Canyon at the PCO-1 site in 1984, 1992, 1993, and 1994 and analyzed for selected radionuclides. The results of the analyses showed that the total uranium concentration was 0.2 μg/L (1992). During the 10-year period the activity of cesium-137 ranged from 0.9 to 91.4 pCi/L, and maximum tritium activity was 0.6 nCi/L. Activities of the plutonium isotopes were near the detection limits.*

- *Radionuclides are present in runoff in Pajarito Canyon at state road NM4. The activity of tritium has ranged from 0.3 to 4.4 nCi/L. Activities of plutonium-238 range as high as 1.0 pCi/L, and activities of plutonium-239,240 range as high as 1.36 pCi/L, which suggests a source of contaminants in the runoff, possibly from MDA G. Total uranium activities vary from 0.2 to 3.8 μg/L.*

- *The results of metal analyses of surface water show that all water samples from Pajarito Canyon and Threemile Canyon, including the TA-18 Spring water, have similar metal concentrations. The Pajarito Canyon surface water and the TA-18 Spring water are within detection limits for SVOCs, but the surface water collected in Threemile Canyon is below detection limits. Threemile Spring contains elevated concentrations of acenaphthene; bis(2-ethylhexyl)phthalate; 4-chloro-3-methylphenol; 2-chlorophenol; 1,4-dichlorobenzene; diethylphthalate; 2,4-dinitrotoluene; 4-nitrophenol; N-nitroso-di-n-propylamine; pentachlorophenol; phenol; and pyrene.*

### 4.2.4 Subsurface Hydrology

*The following bullets summarize the hydrology of Pajarito Canyon, as discussed in Sections 3.6 and 3.7.*

- *The primary inputs of water to the groundwater in Pajarito Canyon include PC Spring, contemporary precipitation as snowmelt or storm water runoff, liquid discharges from operations that use deep regional aquifer groundwater via the municipal and industrial supply system.*

- *At least two perennial reaches of surface water are completely lost into the subsurface, probably initially into the alluvium. The water may then move along fractures, bedding planes, or contacts with some discharge to return flow or other near-channel springs, although the ultimate fate of all the water is not known. In recent years these gaged losses have averaged approximately 6 million $ft^3$ of water annually.*

- *Alluvial groundwater is present in middle and lower Pajarito Canyon where significant accumulations of alluvium are present below the confluence with Twomile Canyon. Infiltration rates have been estimated to range from 20 to 100 mm/yr beneath Pajarito Canyon (see Section 3.6.5).*

- *Most water entering the Pajarito Canyon system must be lost to either evapotranspiration or to seepage into deeper units because surface flow out of Pajarito Canyon beyond the Laboratory* *boundary at state road NM4 is ephemeral, and in recent years it has occurred only after significant storm events. The amount and fate of water leaving the Pajarito Canyon alluvium is not known.*

- *Intermediate perched groundwater may be present in several subsurface units, including local perched zones within units of the Tshirege Member (Qbt 1v), the Cerro Toledo interval, Puye basalt, and possibly the Otowi Member.*

- *The regional aquifer extends beneath much of the Pajarito Canyon watershed. The regional aquifer is pumped at supply well PM-2 in the canyon, and it probably discharges at Pajarito Springs (Spring 4A) and other smaller springs near the confluence with the Rio Grande.*

#### 4.2.4.1 Perched Alluvial Groundwater

*It will be necessary to understand the mechanisms that govern the occurrence of the saturated alluvial groundwater in Pajarito Canyon to determine if any significant exposure pathway potential exists for future use scenarios. Currently, the alluvial groundwater is not consumed by humans, but it does support vegetation that is used as forage by animals.*

*Most of the water entering the alluvium is lost either by return flow in interrupted portions of the stream, by evapotranspiration (especially in the wetland areas), or by downward or lateral seepage into other hydrologic units. The location and magnitude of water loss from the alluvium is not known.*

#### 4.2.4.2 Interflow/Underflow Movement of Groundwater

*The following hypotheses could explain the fate of water lost from the alluvium laterally or downward by saturated or unsaturated flow channel.*

- *Lateral movement occurs as near-surface interflow along contacts between flows and/or fractures moving from one section of a canyon to another or even between tributary canyons. Recent work at TA-16 suggests that narrow fracture vertical flow may be more likely than distributed planar or saturated media flow.*

- *Perched alluvial groundwater in middle Pajarito Canyon may recharge fractures or localized perched zones within the Tshirege Member beneath Pajarito Mesa, which discharges to springs in Threemile Canyon.*

- *Deeper percolation along fractures or faults, or saturated or unsaturated flow through porous media provide recharge to potential intermediate perched zones or the regional saturated zone.*

#### 4.2.4.3 Intermediate-Depth Perching and Confining Layers

*Perching and confining layers have been observed beneath other canyons in the following units:*

- *in the Cerro Toledo interval;*

- *at the base of the Guaje Pumice Bed and the top of the Otowi Member;*

- *in the Cerros del Rio basalts; and*

- *within units of the Tshirege Member of the Bandelier Tuff, especially in the western and central parts of the Pajarito Plateau where distinct subhorizontal flow unit boundaries and/or fractures occur.*

*No perched intermediate zones of saturation have been delineated beneath Pajarito Canyon. Possible intermediate wet zones have been reported in two boreholes at TA-18 and one borehole at TA-54 (see Section 3.7.3).*

- *In borehole SHB-4 wet core samples were retrieved from the interval of 125 to 145 ft (38 to 44 m), apparently within the Cerro Toledo interval.*

- *In supply well PM-2 a possible wet zone was reported at 335 ft (100 m), which may indicate a zone of intermediate perched groundwater.*

- *A small intermediate perched groundwater zone was encountered in borehole 54-1016 at MDA L (see Section 3.7.3) beneath Mesita del Buey just north of Pajarito Canyon. This borehole, drilled at an angle beneath MDA L, encountered a small pocket of groundwater in basalt within the Puye Formation at a depth of 592 ft (178 m), which was at an elevation of approximately 6188 ft (1856 m) (see Figure A-2 in Appendix A of this work plan).*

#### 4.2.4.4 Regional Aquifer

*The regional aquifer occurs in the Puye Formation and the Santa Fe Group at depths below Pajarito Canyon ranging from approximately 1300 ft (396 m) at the western Laboratory boundary to approximately 700 ft (213 m) near the eastern Laboratory boundary. The regional aquifer is separated from the perched groundwater in the alluvium by more than 800 ft (244 m) of tuff and volcanic sediments at supply well PM-2 near TA-18. Since the fall of 1992 continuously recorded water level data collected at test wells indicate that throughout the Pajarito Plateau the regional aquifer responds to barometric pressure changes and solar and lunar tide effects in a manner typical of confined to partially confined aquifers (see Section 3.7.4).*

*The term "regional aquifer" may be misleading in part because the regional aquifer is not a single, homogenous, porous medium. Continuous saturation may be present at some locations. However, it is possible that at many locations beneath the Pajarito Plateau, the top of the aquifer is composed of several discrete zones of saturation due to differences in lithology and hydrologic conductivity. The deep water supply wells and test wells penetrate to different depths; because screened intervals cross several stratigraphic units, the apparent observed piezometric head and chemical quality are actually averages of the properties of multiple units. The regional aquifer will be better understood after information is obtained from drilling regional aquifer test wells pursuant to work performed as a result of this work plan and the Hydrogeologic Workplan (LANL 1996, 55430).*

*The regional aquifer is discussed in detail in Section 3.7.4. Figure A-4 illustrates the relationship between some of the major hydrogeologic units in the Pajarito Canyon vicinity. These units are (from older to younger sediments)*

- *Santa Fe Group sediments, including the coarse upper facies ("Chaquehui formation" of Purtymun 1995, 45344, p. 6);*

- *Tschicoma Formation volcanic rocks; and*

- *Puye Formation including fanglomerate facies and axial facies ("Totavi lentil").*

*The degrees of interconnection between different zones of saturation in the regional aquifer are not well understood; numerous hypotheses and variations are possible and are being considered by Laboratory personnel. The following major features of the regional aquifer need to be better understood.*

- **Confined and Artesian Conditions**

  *Confined and artesian conditions are observed in places across the Pajarito Plateau, especially east of the Laboratory boundary and west of the Rio Grande. Several deep water supply wells in lower Los Alamos Canyon and several test wells, including the recently drilled regional aquifer well R-9, exhibit confined and artesian characteristics. Some boreholes demonstrate confined behavior as interpreted from particular patterns of water level responses to solar and lunar tides.*

- **Unconfined Conditions**

  *Some wells completed in the regional aquifer demonstrate unconfined behavior as evidenced by water level fluctuations associated with barometric pressure changes and patterns of response to solar and lunar tides.*

- **Wide-Ranging Apparent Ages of Water**

  *Carbon-14 age dates obtained for water from the regional aquifer cover a wide range (from 1000 to 40,000 years), which is far greater than would be inferred from homogenous porous media or fracture flow.*

- **Possible Sources of Recharge**

  *The interpretation of chemical, radiochemical, and stable isotope data suggests that some recharge to the regional aquifer in lower Los Alamos Canyon may come from the east, from deep beneath the Rio Grande in west-dipping beds of the Santa Fe Group. Some recharge may potentially come from the north along ancestral Rio Grande axial deposits. Some recharge may come from deeper groundwater sources from the west (for example, low tritium in PC Spring and the Water Canyon Gallery). Some connections between young water (such as surface water and alluvial groundwater in canyons that are less than a few decades old) and the regional aquifer evidently occur, based on the presence of tritium and oxalate above background values at some places in the regional aquifer.*

#### 4.2.4.5 Pumping of Water Supply Wells

*The depression in the apparent regional water table can account for most of the historic water supply withdrawals from the regional aquifer, which suggests the possibility of "mining" of the aquifer. However, at the old Los Alamos well field in lower Los Alamos Canyon the water levels have evidently recovered to near prepumping artesian levels, which possibly is caused by confined conditions influenced by groundwater flow from east of the Rio Grande. Most groundwater withdrawals from the regional aquifer in the central portion of the Pajarito Plateau apparently come from relatively thin stratigraphic zones, such as from the coarse upper Santa Fe Group sediments (the "Chaquehui formation" of Purtymun [1995, 45344, p. 6]).*

#### 4.2.4.6 Groundwater Discharge to Springs

*Groundwater discharges occur at the extreme western and eastern ends of Pajarito Canyon. Apparently old deep-source groundwater discharges from PC Spring at the western end of Pajarito Canyon. The source of this spring water is not known, but it may come from deep groundwater beneath the Sierra Jemez. Discharges from the regional aquifer are the probable source of the water at Pajarito Springs (Spring 4A) at the eastern end of Pajarito Canyon within White Rock Canyon.*

*Groundwater discharges to springs in the western area of the Laboratory from the Bandelier Tuff. The source of the spring water is not known, but it may be from the infiltration of surface water in upper Pajarito Canyon (mostly water from PC Spring) into the Pajarito fault zone. The water moving down along the Pajarito fault zone may become perched along flow unit boundaries and fractures in the Bandelier Tuff.*

*Groundwater discharges to springs in Threemile Canyon from the Bandelier Tuff. The source of the spring water is not known, but trace metal concentrations and HE in the water suggest that the water could be from infiltration of alluvial groundwater in middle Pajarito Canyon into the Bandelier Tuff. The water may move down dip along fractures or bedding planes in the Bandelier Tuff to discharge to springs and seeps in Threemile Canyon.*

#### 4.2.4.7 Potential Recharge by Unsaturated Flow

*Unsaturated flow may provide a pathway for some recharge to the regional aquifer. In the Pajarito Canyon area possible unsaturated flow from beneath MDA H could introduce tritium, and unsaturated flow from MDA L could introduce dense organic vapor contaminants to possible perched intermediate zones of saturation. Estimates based on available data suggest that percolation beneath Mesita del Buey is approximately 1 mm (0.4 in.) per year and beneath Pajarito Canyon approximately 20 to 100 mm (0.8 to 4 in.) per year (See Section 3.6.5).*

## 4.3 Other Pathways and Processes

### 4.3.1 Airborne Transport

*Transport of fine-grained contaminated particles by wind could be a means of contaminant dispersal in the Pajarito Canyon system. Resuspension of contaminated sediment by wind is potentially one of the predominant pathways for exposure to humans because dust can easily be transported high enough to be inhaled by humans. Chapter 6 of the core document provides a discussion of airborne transport, exposure pathways, and scenarios (LANL 1997, 55622, p. 6-9). Resuspension from firing sites and hydrodynamic testing has been extensively studied and continues to be monitored and reported in the annual environmental surveillance reports. Because most of the sediments in the Pajarito Canyon watershed do not contain highly elevated levels of contaminants, airborne resuspension of sediments is not expected to be a significant contaminant transport pathway.*

### 4.3.2 Biological Transport Processes

*Biological transport is considered less important than surface water, sediment, or groundwater transport as a means of dispersing contaminants. However, uptake and transport of contaminants by plants and animals can be important transport and exposure pathways. Plants and animals can be exposed directly* *to contaminants and can assimilate contaminants from water, sediments, and soils into tissues. Animals can ingest the contaminants and transport them to other organisms, including humans (see Section 3.9).*

### 4.4 Validation and Refinement of the Pajarito Canyon Conceptual Model

*The conceptual model will be refined by interpretation and analysis of new data obtained from the sampling and analyses proposed in Chapter 7 of this work plan. The conceptual model will also be refined based on the results of work accomplished by other Environment Restoration (ER) investigations and the results of new well installations proposed under the Laboratory's Groundwater Protection Management Program Plan (LANL 1995, 50124), the Hydrogeologic Workplan (LANL 1996, 54430), and the Groundwater Annual Status Summary Report (LANL 1998, 57576). Additionally, surface water and sediment investigations will be coordinated with requirements of the Laboratory's Watershed Management Plan when it becomes available.*

*The following major topics may be refined:*

- *development of a higher-confidence probabilistic estimation of exposure potential associated with sediment transport. This process could be extremely complicated and require consideration of many variables, each with its own probabilistic distributions. The variables include precipitation, antecedent moisture effects on runoff and infiltration, sediment supply, degree of incision in a given canyon or reach, and mixing of sediment sources during transport;*

- *improved understanding of the mechanisms for most water loss from the alluvium with sufficient confidence to know if the water loss represents a pathway with a significant exposure potential; and*

- *improved understanding of the mechanisms for potential contaminants in the regional aquifer with sufficient confidence to know if the mechanism represents a pathway with a significant exposure potential.*

#### 4.4.1 Refinement of Geologic Data

*The following data are needed in the geologic investigations of the Pajarito Canyon system to resolve uncertainties in the conceptual model for the canyon, particularly those that relate to potential contaminant pathways:*

- *the geologic nature and distribution of possible perching layers for intermediate-depth groundwater. Additional hydrologic information at the interfaces between the Cerro Toledo interval, Otowi Member, Guaje Pumice Bed, and the Cerros del Rio basalts would be especially important;*

- *the geologic nature of possible saturated zones in the Tshirege Member of the Bandelier Tuff and the relationship with springs in Threemile Canyon and near the western Laboratory boundary;*

- *the axis and downgradient direction for pre-Tshirege and pre-Otowi paleodrainages;*

- *the occurrence of saturated conditions in the paleodrainages;*

- *possible areas of faulting and high fracture densities in Pajarito Canyon; and*

- *the geometry and distribution of geologic units below Pajarito Canyon in the area between the dense volcanic flows (Tschicoma Formation and Cerros del Rio basalts) overlying the regional aquifer.*

*The refinement of geologic data for Pajarito Canyon will be obtained primarily by borehole information resulting from the groundwater investigations described in Section 7.4.4.*

### 4.4.2 Refinement of Sediment Data

*The following additional data are required to evaluate contaminants within the sediments of the Pajarito Canyon system.*

- *The full suite of contaminants that are present within the sediments above background values will be determined.*

- *The locations of significant contaminant sources and approximate dates of discharge will be determined.*

- *The percentage of organic carbon in sediments will be determined because solid organic carbon is the dominant adsorbent for HE compounds.*

- *The average concentrations, the range of concentrations, and approximate inventories of contaminants contained within different geomorphic units and different sediment facies will be investigated, particularly for those contaminants that may be shown to be risk drivers.*

- *The horizontal and vertical distribution of contaminated sediments that have been deposited by flood events (including the nature and effects of historic channel changes) will be investigated. For example, channel bed aggradation and/or degradation, lateral migration and diversion of the active channel, and abandonment of inactive channels will be investigated at key locations within Pajarito Canyon.*

*The sampling and analysis plan for sediments is presented in Section 7.2.*

### 4.4.3 Refinement of Surface Water Data

*The following additional data collection is required to understand the surface water hydrology in appropriate reaches within Pajarito Canyon.*

- *Monitor streamflow volumes upstream and downstream of the Pajarito fault in upper Pajarito Canyon to determine the amount of stream loss in that area. This process will require the installation of a new streamflow gage approximately 2000 ft west of state road NM501 in upper Pajarito Canyon.*

- *Monitor streamflow in Pajarito Canyon below the confluence with "Arroyo de LaDelfe" to determine the volume of flow downstream from springs in Pajarito Canyon, "Starmer Gulch," and "Arroyo de LaDelfe." This process will require the installation of a new streamflow gage at a suitable location in upper Pajarito Canyon.*

- *Sample surface water in upper and middle Pajarito Canyon and Threemile Canyon to determine where HE compounds are entering the surface water system. Sampling semiannually during a two-year period can also assess seasonal variations in water quality.*

- *Monitor streamflow at several locations in Twomile Canyon during selected discrete periods to determine the contribution to streamflow and/or infiltration from springs, surface runoff, and snowmelt runoff.*

- *Monitor streamflow at several locations in Threemile Canyon during selected discrete periods to determine the contribution to streamflow and/or infiltration from springs, surface runoff, and snowmelt runoff.*

- *Monitor streamflow at several locations in upper Pajarito Canyon during selected discrete periods to determine the contribution to streamflow and/or infiltration from springs, surface runoff, and snowmelt runoff.*

- *Monitor streamflow immediately downstream of TA-18. The streamflow passes through a culvert beneath the access road near the eastern boundary of TA-18, which facilitates the installation of a new gaging station at this location.*

- *Quantify surface water contribution to water balance in appropriate reaches within Pajarito Canyon.*

- *Determine the relative contribution of surface water flowing into middle Pajarito Canyon from upper Pajarito Canyon compared with surface water flow from Twomile Canyon.*

- *Many locations in the canyon are not favorable for the installation of gaging stations because of the large amount of sediment that accumulates during storm water runoff. Investigate the possibility of installing an additional gaging station in upper Pajarito Canyon upstream of the confluence with Twomile Canyon.*

*The sampling and analysis plan for data collection to refine the surface water concepts is presented in Section 7.3.*

#### 4.4.4 Refinement of Hydrogeologic Data

*The subsurface hydrogeologic system in the Pajarito Canyon area requires additional data to refine the conceptual model of the system. The following important concepts need to be refined.*

- *The lithology and stratigraphy of the alluvium and the bedrock beneath selected areas of the canyon need to be better described and understood to adequately characterize the hydrogeological system and to provide input to hydrogeologic models. Data on the lithology, stratigraphy, hydraulic properties, and geotechnical properties (including bulk density, porosity, saturated and unsaturated hydraulic conductivity, moisture content, storativity or specific yield, and matric potential) are needed. These data will be obtained from laboratory analyses of borehole core samples and by aquifer performance testing.*

- *The possible presence of intermediate saturated zones below Pajarito Canyon will be investigated by drilling boreholes to characterize the Bandelier Tuff and underlying units to the* *regional aquifer. If intermediate zones of saturation are found in the Cerro Toledo interval, Guaje Pumice Bed, or basalts, investigations will be considered to determine the source and fate of the water.*

- *The location and amount of water loss from the alluvium at specific locations is necessary to determine possible contaminant transport pathways. Data necessary to perform water-balance calculations include additional water level measurements (preferably time series data from transducers), site-specific soil moisture measurements and precipitation amounts, evapotranspiration, and streamflow volumes.*

*The sampling and analysis plan that will provide data for refining the hydrogeologic concepts is presented in Section 7.4.*

### 4.4.5 Refinement of Geochemical Data

*An understanding of the geochemistry of sediments, bedrock units, surface water, and groundwater is necessary to understand the hydrogeologic system. To better refine the geochemical conceptual model the following data will be obtained.*

- *To characterize individual zones of saturation, water samples will be collected from the alluvial groundwater, the regional aquifer, and any other saturated zones that are encountered. The samples will be both filtered in the field and unfiltered to provide appropriate data on dissolved and suspended constituent concentrations. Analyses for colloidal materials will identify possible colloidal transport of contaminants.*

- *Water samples will be collected from the upper part of the regional aquifer to identify if contaminants have reached the aquifer. Time series sampling will be conducted to analyze for inorganic constituents and radionuclides. Special attention will be given to the well bore at PM-2 where the surface casing passes through the shallow alluvial groundwater (see Section 3.7.4).*

- *Sediments will be characterized chemically in terms of particle size and percent or amount of solid organic carbon to evaluate the mobility of HE compounds.*

- *To understand and model solid/solution phase interactions, both filtered and unfiltered surface water and groundwater samples will be collected from characterization boreholes and wells and analyzed for major cations and anions, trace elements, radionuclides, dissolved organic carbon, stable isotopes, and anthropogenic organic compounds.*

- *To understand the role of sorption reactions on the transport of radionuclides, batch sorption experiments may be performed on different aquifer material (alluvium, Bandelier Tuff, Cerro Toledo sediments, Cerros del Rio basalts, Puye Formation, and Santa Fe Group) using selected radionuclides (americium-241; cesium-137; plutonium-238; plutonium-239,240; and strontium-90) and metals (barium, beryllium, and uranium).*

- *Geochemical modeling of surface water and groundwater will be performed to quantify speciation, precipitation, and adsorption capacities of selected elements or species.*

- *Mineral stability, adsorption reactions, and mixing reactions between different media will be calculated and/or measured from borehole core and water data.*

### 4.4.6 Refinement of Ecosystem Data

*Although considerable data are available on radionuclide uptake in vegetation and small mammals, no data have yet been found to document uptake of inorganic or bioaccumulator chemicals. In addition, portions of the Pajarito Canyon watershed appear on national wetlands inventory maps as artificially and permanently flooded wetlands (Dunham 1992, 31276). Therefore, bioaccumulator toxins (such as mercury) that are suspected to be present in the system will be evaluated for present-day concentrations in water, sediments, and wetland biota that represent primary species of concern for contaminant uptake. These species may also be important for food-chain transfer to higher trophic levels.*

*The biological sampling and analysis plan is presented in Section 7.6.*

**REFERENCES FOR CHAPTER 4**

*The following list includes all the references cited in this chapter. The parenthetical information following each reference provides the author, publication date, and ER identification (ER ID) number. This information is also included in the citations in the text and can be used to locate the documents.*

*ER ID numbers are assigned by the Laboratory's ER Project to track all material associated with Laboratory PRSs. These numbers can be used to locate copies of the documents at the ER Project's Records-Processing Facility and, where applicable, within the ER Project reference library. The references cited in this work plan can be found in the volumes of the reference library titled Reference Set for Canyons.*

*Copies of the reference library are maintained at the New Mexico Environment Department Hazardous and Radioactive Materials Bureau, the Los Alamos Area Office of the Department of Energy, and the ER Project Office. This library is a living document that was developed to ensure that the administrative authority (AA) has all the necessary material to review the decisions and actions proposed in this work plan. However, documents previously submitted to the AA are not included in the reference library.*

*Blake, W. D., F. Goff, A. I. Adams, and D. Counce, May 1995. "Environmental Geochemistry for Surface and Subsurface Waters in the Pajarito Plateau and Outlying Areas, New Mexico," Los Alamos National Laboratory Report LA-12912-MS, Los Alamos, New Mexico.* **(Blake et al. 1995, ER ID 49931)**

*Dunham, D. A., December 17, 1992. "Biological and Floodplain/Wetlands Assessment for Environmental Restoration Program, Operable Unit 1129, TA-4, -5, -35, -42, -48, -52, -55, -63, -66 and Operable Unit 1147, TA-50" (draft), Environmental Protection Group (EM-8), Los Alamos National Laboratory, Los Alamos, New Mexico.* **(Dunham 1992, ER ID 31276)**

*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 50124)**

*LANL (Los Alamos National Laboratory), December 6, 1996. "Hydrogeologic Workplan" (draft), Revision 1.0, Los Alamos, New Mexico.* **(LANL 1996, ER ID 55430)**

*LANL (Los Alamos National Laboratory), April 1997. "Core Document for Canyons Investigations," Los Alamos National Laboratory Report LA-UR-96-2083, Los Alamos, New Mexico.* **(LANL 1997, ER ID 55622)**

*LANL (Los Alamos National Laboratory), March 25, 1998. "Groundwater Annual Status Summary Report, FY97," Los Alamos, New Mexico.* **(LANL 1998, ER ID 57576)**

*Purtymun, W. D., January 1995. "Geologic and Hydrologic Records of Observation Wells, Test Holes, Test Wells, Supply Wells, Springs, and Surface Water Stations in the Los Alamos Area," Los Alamos National Laboratory Report LA-12883-MS, Los Alamos, New Mexico.* **(Purtymun 1995, ER ID 45344)**

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## 5.0 TECHNICAL APPROACH

*The technical approach employed in the Pajarito Canyon investigations is identical to that described in Chapter 5 of the Core Document for Canyons Investigations (LANL 1997, 55622).*

**REFERENCE FOR CHAPTER 5**

*The following list includes the reference cited in this chapter. The parenthetical information following the reference provides the author, publication date, and Environmental Restoration identification (ER ID) number. This information is also included in the citation in the text and can be used to locate the document.*

*ER ID numbers are assigned by the Laboratory's ER Project to track all material associated with Laboratory potential release sites. These numbers can be used to locate copies of the documents at the ER Project's Records-Processing Facility and, where applicable, within the ER Project reference library. The references cited in this work plan can be found in the volumes of the reference library titled Reference Set for Canyons.*

*Copies of the reference library are maintained at the New Mexico Environment Department Hazardous and Radioactive Materials Bureau, the Los Alamos Area Office of the Department of Energy, and the ER Project Office. This library is a living document that was developed to ensure that the administrative authority (AA) has all the necessary material to review the decisions and actions proposed in this work plan. However, documents previously submitted to the AA are not included in the reference library.*

*LANL (Los Alamos National Laboratory), April 1997. "Core Document for Canyons Investigations," Los Alamos National Laboratory Report LA-UR-96-2083, Los Alamos, New Mexico.* **(LANL 1997, ER ID 55622)**

## 6.0 RISK ASSESSMENT

*The approach to risk assessment employed in the Pajarito Canyon investigations is identical to that described in Chapter 6 of the Core Document for Canyons Investigations (LANL 1997, 55622). Details on data collection for the present-day human health risk assessment and the ecological risk assessment are discussed in Chapter 7 of this work plan.*

**REFERENCE FOR CHAPTER 6**

*The following list includes the reference cited in this chapter. The parenthetical information following the reference provides the author, publication date, and Environmental Restoration identification (ER ID) number. This information is also included in the citation in the text and can be used to locate the document.*

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*Copies of the reference library are maintained at the New Mexico Environment Department Hazardous and Radioactive Materials Bureau, the Los Alamos Area Office of the Department of Energy, and the ER Project Office. This library is a living document that was developed to ensure that the administrative authority (AA) has all the necessary material to review the decisions and actions proposed in this work plan. However, documents previously submitted to the AA are not included in the reference library.*

*LANL (Los Alamos National Laboratory), April 1997. "Core Document for Canyons Investigations," Los Alamos National Laboratory Report LA-UR-96-2083, Los Alamos, New Mexico.* **(LANL 1997, ER ID 55622)**

## 7.0 SAMPLING AND ANALYSIS PLAN FOR THE PAJARITO CANYON SYSTEM

### 7.1 Introduction

*This chapter describes the rationale and plans for collecting and analyzing samples and field survey data to characterize the Pajarito Canyon system. These data will be used to support an evaluation of present-day risks to human health and the environment from Laboratory-derived contaminants that move through the Pajarito Canyon system and an evaluation of the potential for future off-site exposure and impact on the Rio Grande. Evaluation of these risks and impacts requires testing and refining of the conceptual model of occurrence, transport, and exposure route of contaminants in the Pajarito Canyon system (hereafter referred to as "the conceptual model") (see Chapter 4 of this work plan). In accordance with the focused sampling strategy described in Chapter 5 of the Core Document for Canyons Investigations (hereafter referred to as "the core document") (LANL 1997, 55622), results of field surveys and sample analyses initially conducted will be used in conjunction with comparison to and reinterpretation of existing data to revise subsequent sampling and analyses. Sampling and analysis plans (SAPs) presented in this chapter describe general approaches to be followed and general areas to be sampled. Specific sampling locations will be defined based on data collected from the initial tasks.*

*Sections of this chapter present the plans for sampling and analysis of each of the transport pathways and exposure routes described in Chapter 3 and Chapter 4 of this work plan. Each section will (1) state the objectives for the investigation of each media and transport pathway; (2) discuss elements of the transport pathways and their importance; (3) identify issues to be addressed to assess risk and impacts and identify appropriate remedial measures; and (4) describe the approaches used to resolve the issues.*

*The remainder of this section defines issues to be addressed and provides overviews of the information to be collected, the specific objectives of the SAP, and the data quality objectives for the investigations. Section 7.2 describes plans for sediment characterization. Section 7.3 describes plans for characterizing surface water. Section 7.4 describes plans for characterizing groundwater including (1) alluvial groundwater (and the alluvium that contains it), (2) intermediate-depth groundwater, if present, and (3) the regional aquifer. Section 7.5 discusses the air exposure pathway. Section 7.6 describes the biological sampling program, which includes an evaluation of the impact of Laboratory-derived contaminants on the canyon ecosystems and an evaluation of the human health risks from contaminants in plants and animals.*

*Table 7.1-1 summarizes the known chemicals of potential concern (COPCs) and their potential original source areas in the Pajarito Canyon system. The COPCs are grouped in part according to protocols that will be used for sample analyses. This table is based on the list of COPCs and on data collected from previous studies (summarized in Chapter 3 of this work plan) showing actual occurrence of contaminants in the Pajarito Canyon system.*

*Table 7.1-2 shows the initial estimates of the numbers and types of samples to be collected during the investigations. The numbers will be revised throughout the characterization in accordance with the focused sampling strategy and the various tests of data adequacy discussed in Section 5.3.7 and Section 5.3.8 in Chapter 5 of the core document (LANL 1997, 55622). Changes to the numbers of samples will be recorded and described in reports on these investigations.*

**TABLE 7.1-1**

**CHEMICALS OF POTENTIAL CONCERN IN PAJARITO CANYON AND SOURCE AREAS***

| Known COPCs | Source Areas |
|---|---|
| **Radionuclides** | |
| *Americium-241* | *TA-54* |
| *Cobalt-60* | *TA-6, TA-7* |
| *Cesium-137* | *TA-3, TA-6, TA-7, TA-22, TA-40* |
| *Plutonium-238* | *TA-3, TA-6, TA-7, TA-18, TA-22, TA-40, TA-54, TA-55* |
| *Plutonium-239* | *TA-3, TA-6, TA-7, TA-18, TA-22, TA-40, TA-54, TA-55* |
| *Strontium-90* | *TA-6, TA-8, TA-9, TA-12, TA-22, TA-40* |
| *Tritium* | *TA-3, TA-15, TA-54* |
| *Uranium* | *TA-6, TA-7, TA-8, TA-9, TA-12, TA-15, TA-18, TA-27, TA-36, TA-40, TA-54* |
| **Organic Chemicals** | |
| *High explosives* | *TA-6, TA-7, TA-8, TA-9, TA-12, TA-15, TA-18, TA-22, TA-27, TA-36, TA-40* |
| *Hydrocarbons* | *TA-3, TA-8, TA-9, TA-12, TA-18* |
| *PCBs* | *TA-3, TA-6, TA-8, TA-9, TA-36, TA-40, TA-54* |
| *Pesticides* | *General* |
| *Photographic chemicals (organic acids)* | *TA-6, TA-8, TA-15, TA-18, TA-36, TA-59* |
| *Solvents* | *TA-3, TA-6, TA-7, TA-8, TA-9, TA-18, TA-22, TA-40* |
| *SVOCs* | *TA-8, TA-9, TA-12, TA-15, TA-36, TA-59* |
| **Inorganic Chemicals** | |
| *Antimony* | *TA-9, TA-15, TA-40, TA-69* |
| *Asbestos* | *TA-8, TA-9, TA-54* |
| *Arsenic* | *TA-12, TA-15, TA-22* |
| *Barium* | *TA-6, TA-7, TA-8, TA-9, TA-12, TA-22, TA-36, TA-40, TA-54, TA-69* |
| *Beryllium* | *TA-8, TA-9, TA-15, TA-18, TA-27, TA-54* |
| *Cadmium* | *TA-8, TA-9, TA-15, TA-22, TA-36, TA-69* |
| *Chromium* | *TA-8, TA-9, TA-12, TA-22, TA-36, TA-40, TA-69* |
| *Copper* | *TA-6, TA-7, TA-8, TA-12, TA-15, TA-22, TA-36, TA-40, TA-54, TA-69* |
| *Fluoride* | *TA-9, TA-18, TA-22, TA-40* |
| *Lead* | *TA-3, TA-6, TA-8, TA-9, TA-12, TA-15, TA-22, TA-36, TA-40, TA-54, TA-69* |
| *Manganese* | *TA-36, TA-69* |
| *Mercury* | *TA-3, TA-8, TA-9, TA-15, TA-36* |
| *Nickel* | *TA-12, TA-22, TA-36, TA-69* |
| *Nitrate* | *TA-6, TA-8, TA-9, TA-22, TA-40* |
| *Phosphate* | *TA-6, TA-22, TA-40* |
| *Silver* | *TA-8, TA-9, TA-15, TA-22, TA-36, TA-40, TA-69* |
| *Sulfate* | *TA-6, TA-22, TA-40* |

**This table contains preliminary information from RFI work plans, draft RFI reports, and other available reports.*

**TABLE 7.1-2**

**INITIAL ESTIMATES OF SAMPLE COLLECTION AND ANALYSIS**

| Sample Type | Pajarito Canyon | Twomile Canyon | Threemile Canyon | Total |
|---|---|---|---|---|
| **Sediment[a] and Core** | | | | |
| *Full-suite[b] sediment* | 30 | 25 | 15 | 70 |
| *Limited-suite[c] sediment* | TBD[d] | TBD | TBD | TBD |
| *Key contaminants[e] sediment* | TBD | TBD | TBD | TBD |
| *Alluvial borehole core[f]* | 25 | N/A[g] | 3 | 28 |
| *Regional borehole core* | 196 | 64 | N/A | 260 |
| **Groundwater[h] and Surface[i] Water** | | | | |
| *Surface water – stream* | 32 | N/A | N/A | 32 |
| *Surface water – springs* | 60 | 10 | 10 | 80 |
| *Alluvial (new monitoring wells)* | 80 | N/A | 16 | 96 |
| *Alluvial (existing monitoring wells)* | 24 | N/A | 8 | 32 |
| *Regional aquifer* | 160 | 32 | N/A | 182 |
| **Biological** | | | | |
| *Wild plant species[j]* | TBD | TBD | TBD | TBD |
| *Livestock forage plants[k]* | TBD | TBD | TBD | TBD |

a. *Sediment samples will be collected to determine COPCs, to define contaminant concentrations and distributions, and to define risk.*

b. *Full-suite analyses are for all organic and inorganic chemicals and radionuclides, and for the determination of COPCs.*

c. *Limited-suite analyses are for identified COPCs.*

d. *TBD = to be determined*

e. *Sediment samples will be collected and analyzed for "key contaminants" (for example, HE or metal constituents) to obtain information about contaminant concentrations, contaminant distributions, and sediment transport processes. The "key contaminants" for each canyon and the actual number of samples collected will be decided by the technical team based on the initial survey and sampling results. (The collection of approximately 35 to 60 samples per canyon is anticipated.)*

f. *At a minimum, one core sample will collected above and below each major stratigraphic contact. Additional samples may be collected at the judgment of the field geologists (see Table 7.4.4-2)*

g. *N/A = not applicable*

h. *The number of groundwater samples reflects the total number of filtered and unfiltered samples to be collected after well completion and semiannually for two years.*

i. *If surface water is present, samples will be collected semiannually during low flow and high flow.*

j. *Two samples each of four different wild plant species will be collected.*

k. *Two samples of livestock forage plants will be collected from two locations.*

### 7.1.1 Issues To Be Addressed

*The general objectives for the canyons investigations discussed in the Executive Summary of the core document (LANL 1997, 55622) will be addressed in the investigations described in this work plan. The following issues, which are specific to the Pajarito Canyon system (excluding mesa-top potential release sites [PRSs]), will be addressed in priority order.*

1. *Are there any risks to human health or the environment as a result of legacy and present-day contaminants in sediments, surface water, or groundwater, including risks from exposure to plant*

*and animal tissues? This issue will be addressed quantitatively on-site and in selected off-site areas.*

2. *What is the potential for human health or ecological risk (in the present as well as the future) as a result of migration of present-day contaminants? Pueblo and state concerns indicate that the effect of contaminant migration on altering risk estimates needs to be evaluated along with the present-day risk. The complexity of the problem makes identification of trends a feasible approach.*

### 7.1.2 Site Description

*A detailed description of Pajarito Canyon and its tributaries is provided in Chapter 3 of this work plan.*

### 7.1.3 Historical Data

*Detailed discussions of historical uses, sources of environmental data, sources of potential contaminants, and current environmental conditions in the Pajarito Canyon system are provided in Chapter 2 and Chapter 3 of this work plan.*

*Pajarito Canyon and/or its tributaries have served as the location of the Los Alamos Critical Experiments Facility (LACEF) at Technical Area (TA) -18 and surface and subsurface material disposal areas (MDAs), as a buffer zone for mesa-top firing site activities, and to a lesser extent for liquid waste disposal. These operations have been conducted in and have possibly discharged to Pajarito Canyon and its tributaries since the Laboratory began operation in 1943. These early discharges were associated with outfalls, surface runoff, and dispersion from firing sites located at TA-6, -7, -8, -9, -12, -15, -18, -22, -27, and -69 (see Sections 2.3.2, 2.3.6, 2.3.7, 2.3.8, 2.3.11, and 2.3.12 in Chapter 2 of this work plan). With the continued expansion of Laboratory operations to new sites in the 1950s through the 1970s, specifically at TA-3, -36, -40, -48, and -59, additional discharges began. A summary of COPCs in the Pajarito Canyon system by technical area is presented in Table 7.1-1. The principal contaminants are organic chemicals (including high-explosives [HE] compounds and solvents) and inorganic chemicals.*

### 7.1.4 Regulatory Requirements

*A summary of regulatory requirements for this work plan is presented in Section 1.4 in Chapter 1 of the core document (LANL 1997, 55622). The primary regulatory requirements are found in the Hazardous and Solid Waste Amendments (HSWA) Module of the Laboratory's Resource Conservation and Recovery Act (RCRA) Hazardous Waste Facility Permit (EPA 1990, 1585). The Environmental Protection Agency (EPA) (EPA 1996, 55500) and the New Mexico Water Quality Control Commission (1995, 50265; 1995, 54406) have set standards for nonradionuclides and some radionuclides for drinking water, surface water, and groundwater that may be applicable to water examined during these investigations; Department of Energy (DOE) Order 5400.5 sets guidelines for radionuclide concentrations in water.*

### 7.1.5 Overview of Information To Be Collected

*To address the general objectives and canyon-specific issues discussed Section 7.1.1, data sufficient to meet the following objectives will be necessary.*

1. *Identification of contaminant concentrations and distributions in (1) sediments, (2) surface water, (3) groundwater, and (4) the biological environment in the Pajarito Canyon system within and*

*outside the Laboratory boundaries. These data may be obtained through a combination of literature review, compilation and interpretation of previously unpublished data, media sampling and analysis, and techniques such as geostatistical modeling, as appropriate, for uncertainty reduction.*

2. *Refinement of the conceptual model, which is discussed for the canyons in general in Chapter 4 of the core document (LANL 1997, 55622) and for the Pajarito Canyon system specifically in Chapter 4 of this work plan. The refinement will include quantifying known pathways, testing hypotheses to determine the existence of potential or suspected pathways, and defining the transport processes sufficiently to permit projections of transport that could alter estimates of human health or ecological risk in the future as a result of migration of present-day contaminants. The process of refinement will involve identification of "reaches" or locations for investigating sediments, surface water, and groundwater most important for addressing present-day risk to human health and ecosystems and contaminant transport components of the conceptual model including a variety of contaminant sources.*

3. *Identification of contaminant transport pathways and improvement in understanding transport mechanisms and the ability to predict the potential for movement of present-day contaminants to off-site areas.*

4. *Identification of risks to biological communities (including humans) that inhabit or use the Rio Grande (now and in the future) as a result of transport of contaminants from Pajarito Canyon.*

5. *Identification of remediation strategies for potential cleanup of specific areas in Pajarito Canyon, as determined in these investigations.*

6. *Long-term monitoring needs and/or needs for institutional controls.*

*The following topics will be addressed in each section that follows, which describe the sampling and analysis of each media and transport pathway:*

- *how the data will be used to address the issues and objectives discussed above,*
- *assumptions underlying the data collection process,*
- *requirements for data quality to meet the intended use, and*
- *measurements to verify the underlying assumptions and data quality requirements.*

*The decisions driving data collection are described in Section 5.2 of the core document (LANL 1997, 55622, p. 5-3 et seq.) and in Appendix 4 of the Hydrogeologic Workplan (LANL 1996, 55430). Decisions specific to Pajarito Canyon are discussed in Section 1.4 of this work plan and include obtaining information sufficient to reduce uncertainties in model input parameters for transport, human health risk assessment, and ecological risk assessment to acceptable levels. The focus is on reducing uncertainties only to a point where (1) a remediation decision will not be affected by further reduction in uncertainty or (2) the cost of the additional data needed to further reduce uncertainty exceeds the cost of the remediation decision.*

*Objectives 1, 2, and 3 listed above are partly met by summarizing existing data (Chapter 3 of this work plan), using the data to develop preliminary distributions of parameters where possible, and designing appropriate field SAPs to iteratively reduce uncertainties in those parameters that contribute most to the uncertainty in assessment and contaminant transport evaluation. These parameters might include field analyte concentrations, hydrological connectivity and groundwater extent, groundwater geochemistry, particle size determination, bioconcentration/bioaccumulation in plant and animal tissues, or extent of geomorphic units with respect to area, thickness, and age of deposition. These and other parameters will be addressed by sampling and analysis to the extent necessary to either minimize uncertainty in the distributions or to distinguish between risk and remediation decisions with a high degree of confidence.*

## 7.2 Sediment Sampling and Analysis Plan

*This section presents the SAP for investigating potentially contaminated sediment in the Pajarito Canyon system. A minimum of 14 canyon reaches downstream of known Laboratory sources of contaminants initially have been selected for investigation; these reaches are shown in solid outlines on Figure A-1 (in Appendix A). Additional subreaches or "contingency" reaches may be investigated contingent upon the findings of initial investigations in upgradient or downgradient reaches; the contingency reaches are shown in dashed outlines on Figure A-1. These reaches will be characterized by geomorphic surveys and by chemical analysis of sediment samples collected from potentially contaminated geomorphic units. Some geomorphic characterization of pre-1943 sedimentary deposits may also be conducted to improve the ability to evaluate longer-term (greater than 50 years) sediment transport processes.*

### 7.2.1 Objectives

*The objectives of the sediment investigation are summarized as follows:*

- *determine the nature and extent of Laboratory-derived contaminants associated with post-1942 sediment deposits;*
- *evaluate the present-day risk to human health and ecosystems from contaminated sediments on-site and off-site;*
- *collect data to evaluate and refine the contaminant transport components of the conceptual model; and*
- *assess the projected impact of contaminated sediments on off-site receptors and on the Rio Grande by identifying the types, concentrations, and distribution of contaminants that have migrated beyond Laboratory boundaries; evaluating processes associated with potential future migration; and projecting trends in risk estimates that may result from migration of contaminants off-site.*

*The following sections present the sampling and analysis plan for the sediment investigation and describe the technical approach adopted to achieve these objectives.*

### 7.2.2 General Approach for Sediment Investigation

*This section briefly describes the general approach for the geomorphic surveys and the sediment sampling and analysis portion of this chapter.*

### 7.2.2.1 Geomorphic Survey Approach

#### Issue

*What is the nature and extent of potentially contaminated post-1942 sediment deposits within the canyons?*

#### Approach

*Determine what geomorphic subdivisions of the canyon floors are most appropriate for delineating the major spatial variations in geomorphic units and sedimentary facies that are important in the context of contamination. Post-1942 sediments will be categorized by geomorphic unit, and a separate sampling strategy will be developed for each unit. If units have significant vertical variation in sedimentary facies or contaminant concentrations, the units may be subdivided into two or more distinct stratigraphic layers. Laboratory analyses will be examined to determine whether the original geomorphic unit designations are appropriate to define the contaminant inventories and risks using average values for these units.*

*Determine which locations in each geomorphic unit should be sampled for full-suite, key contaminant, and limited-suite analyses to meet the investigation objectives (see Section 7.2.1). Full-suite, key contaminant, and limited-suite analyses are discussed in Section 5.6.3 in Chapter 5 of the core document (LANL 1997, 55622) and summarized in Section 7.2.3 and Section 7.2.5.1 of this work plan. This determination will be based on the following information:*

- *identified mapping units,*
- *characteristics of post-1942 sedimentary deposits, and*
- *areal extent of units.*

*Generally, the sampling will be restricted to sediments deposited after 1942, when potential contamination of the canyons began. Limited sampling of older sediments may be conducted to test the validity of criteria for distinguishing post-1942 sediment and to gauge the importance of other potential contaminant transport pathways.*

*The sampling will be largely restricted to the stream channel and its floodplain in Pajarito Canyon and selected tributary canyons and to areas downstream of the first identified location of Laboratory-derived contaminants. Some limited sampling may occur upstream of identified PRSs to confirm that these areas are not contaminated.*

*Post-1942 sediments will be categorized by geomorphic unit and possibly by stratigraphic layer within each unit, and a separate sampling strategy for contaminants will be developed for each unit. The sampling and analyses will be conducted as described in Section 7.2.5.1 for full-suite, key contaminant, and limited-suite analyses. If the field mapping data indicate mappable subdivisions within any geomorphic unit (definable areas with potential variations in thickness, history, and/or contaminants), then the site geomorphologist will identify appropriate subdivisions of the unit.*

*Limits on decision errors will be based on the relation of uncertainty to the decision points discussed in Chapter 5 and Chapter 6 of the core document (LANL 1997, 55622). Additional data will be obtained if* *reduction in uncertainty has the potential of changing the risk-based decision as discussed in Chapter 6 of the core document.*

#### 7.2.2.2 Sediment Sampling Approach

**Issue**

*What is the nature, extent, and inventory of contaminants in sediments in the Pajarito Canyon system? More specifically stated, the problem is to develop descriptions of the spatial distributions of contaminants at levels of uncertainty sufficient to (1) determine whether any risks to human health or the ecosystem currently exist on-site or off-site, and (2) quantitatively estimate contaminant transport with regards to spatial and temporal trends and future risks.*

**Approach**

*Determine what contaminants are present in the sediments in Pajarito Canyon and selected tributary canyons and their horizontal and vertical distribution based on data obtained from sample analyses in the geomorphic units within each reach. The following information will be used for this determination:*

- *archival information,*
- *sample location,*
- *sample unit, and*
- *concentrations of contaminants in each sample.*

*Spatial boundaries will be determined by the boundary of each specified reach.*

*Area and thickness data will form part of the basis for selecting locations to be sampled for laboratory analyses. Samples will be selected to represent the range of geomorphic units observed but will be biased to sample most intensively the units with the largest area and/or the greatest thickness of fine-grained sediments.*

*Any contaminant identified at concentrations exceeding the 95% upper tolerance limit (UTL) of the current sediment background (Ryti et al. 1998, 58093) or whose distribution is different from that of the background data in the full-suite analyses will be added to the limited-suite analytical protocol for all samples from that reach (see Table 7.2.5-3 and Table 7.2.5-4 for 95% UTLs for background levels in sediments).*

*Any contaminant identified at concentrations exceeding the 95% UTL of the current background or whose statistical distribution is different from that of the background data will be evaluated in the risk assessment for that reach.*

*Limits on decision errors will be based on the relation of uncertainty to the decision points discussed in Chapter 5 and Chapter 6 of the core document (LANL 1997, 55622). Additional data will be obtained if reduction in uncertainty has the potential of changing the risk-based decision as discussed in Chapter 6 of the core document.*

### 7.2.3 Sampling and Analysis Plan for Sediment Investigation

*The sampling and analysis plan for the sediment investigation follows the decision logic discussed in Chapter 5 of the core document (LANL 1997, 55622) and includes the testing of key hypotheses of the conceptual model for the Pajarito Canyon system, which are discussed in Chapter 4 of this work plan. The investigation will focus on potentially contaminated sediment deposits but may also include supplemental characterization of pre-1943 deposits.*

*The sediment SAP focuses on selected areas of the Pajarito Canyon system downstream of known or potential contaminant sources. Field surveys and mapping, as well as sampling and analysis tasks, will initially concentrate on 14 reaches, which may be expanded to include up to 29 additional canyon reaches for a maximum of 43 reaches that may be investigated. Figure A-1 shows the locations of the reaches and Table 7.2.3-1 summarizes the reaches that are planned to be investigated.*

*Each reach may include one to four subreaches each approximately 100 to 500 m (110 to 550 yd) long. A "reach" refers to a specific area of a canyon that will be treated as a single unit for sampling, analysis, and present-day human health and ecosystem risk assessment. The regions of the main canyon and selected tributary canyons planned for investigation are shown in Figure A-1 (in Appendix A of this work plan). The precise length and area of each canyon subreach will be defined by both the geomorphic survey and the results of sediment sampling and will be designed to encompass the local variability in geomorphic units and to constitute a reasonable area for use in the risk assessments. Initially many subreaches will be short (100 to 200 m [110 to 220 yd]) and may be either eliminated from further investigation or expanded depending on the results of sediment sampling. Focusing on relatively short subreaches will allow the collection of high-quality data in an efficient manner. The approach will be iterative to allow the expansion of specific reaches to supplement the data set if significant contaminants are detected in these reaches or other relevant reaches. Supplemental investigations, such as field mapping and measurements of the sizes of sediment deposits, may be conducted in intervening areas to improve confidence in extrapolation between reaches.*

*One or more of the following criteria were used to select the reaches:*

- *areas where contaminant concentrations are expected to be highest as judged from previous sampling and analysis activities and from the proximity of the canyon reach to the source areas;*
- *immediately upstream and downstream of drainage confluences to allow better identification of significant contaminant sources and evaluation of contaminant dilution;*
- *areas with a variety of geomorphologic characteristics to allow better estimates of the total contaminant inventory in the canyon and of variations in contaminant distribution between reaches; and*
- *institutional boundaries, to define contaminants that have migrated off Laboratory property.*

*Each reach will be used to address particular issues regarding potential contaminants in the Pajarito Canyon system. The set of reaches is intended to represent key aspects of the entire system. Issues to be addressed by sampling in the individual reaches are discussed in Section 7.2.4.*

**TABLE 7.2.3-1**

**SUMMARY OF CANYON REACHES**

| Canyon/Tributary | Reach | Subreach | Full-Suite Sampling[a] | Downstream of PRSs[b] | Downstream of PRSs[c] | Upstream of PRSs[d] |
|---|---|---|---|---|---|---|
| *Pajarito* | *PA-1* | *PA-1 West* | | | | *1* |
| | | *PA-1 Central* | | | *1* | |
| | | *PA-1 East* | | | *1* | |
| | *PA-2* | *PA-2 West* | *1* | | | |
| | | *PA-2 East* | | | *1* | |
| | *PA-3* | *PA-3 West* | | *1* | | |
| | | *PA-3 East* | *1* | | | |
| | *PA-4* | *PA-4* | *1* | | | |
| | *PA-5* | *PA-5 West* | | | *1* | |
| | | *PA-5 East* | | | *1* | |
| *South fork of Pajarito* | *PAS-1* | *PAS-1 West* | | | | *1* |
| | | *PAS-1 East* | | *1* | | |
| | *PAS-2* | *PAS-2 West* | *1* | | | |
| | | *PAS-2 East* | | | *1* | |
| *Anchor West* | *AW-1* | *AW-1* | | *1* | | |
| *North Anchor East* | *AEN-1* | *AEN-1* | *1* | | | |
| *South Anchor East* | *AES-1* | *AES-1* | *1* | | | |
| *Twomile* | *TW-1* | *TW-1 West* | | | | *1* |
| | | *TW-1 East* | *1* | | | |
| | *TW-2* | *TW-2 West* | | | *1* | |
| | | *TW-2 East* | | | *1* | |
| | *TW-3* | *TW-3 West* | | | *1* | |
| | | *TW-3 East* | | | *1* | |
| | *TW-4* | *TW-4 West* | *1* | | | |
| | | *TW-4 East* | | | *1* | |
| *North fork of Twomile* | *TWN-1* | *TWN-1 West* | | *1* | | |
| | | *TWN-1 Central* | | *1* | | |
| | | *TWN-1 East* | *1* | | | |
| *Southwest fork of Twomile* | *TWSW-1* | *TWSW-1 West* | | | | *1* |
| | | *TWSW-1 Central* | | *1* | | |
| | | *TWSW-1 East* | *1* | | | |
| *Southeast fork of Twomile* | *TWSE-1* | *TWSE-1 West* | | *1* | | |
| | | *TWSE-1 East* | *1* | | | |
| *Threemile* | *TH-1* | *TH-1 West* | | | | *1* |
| | | *TH-1 Central* | | *1* | | |
| | | *TH-1 East* | *1* | | | |
| | *TH-2* | *TH-2 West* | | | *1* | |
| | | *TH-2 East* | | | *1* | |
| | *TH-3* | *TH-3* | | | *1* | |
| *West fork of Threemile* | *THW-1* | *THW-1* | | *1* | | |
| *Middle fork of Threemile* | *THM-1* | *THM-1* | *1* | | | |
| *South fork of Threemile* | *THS-1* | *THS-1 West* | | *1* | | |
| | | *THS-1 East* | *1* | | | |
| **Total** | **23** | **43** | **14** | **10** | **14** | **5** |

*a. First priority*
*b. Sampling contingent on results of downstream sampling*
*c. Sampling contingent on results of upstream sampling*
*d. Sampling contingent on results of downstream sampling*

*In addition to the field survey and mapping tasks (which are described in Section 7.2.4), the sediment SAP includes three types of sampling tasks.*

- *Collect samples for "full-suite" analysis (see Section 7.2.5.1 in this work plan and Chapter 5 of the core document for a discussion of full-suite analysis)*

  *Purpose: analyze for the full suite of COPCs (organic and inorganic chemicals and radionuclides) to define the limited suite of COPCs for the sediment investigation*

- *Collect samples for "key contaminant" analysis (see Section 7.2.5.1 in this work plan and Chapter 5 of the core document for a discussion of key contaminants)*

  *Purpose: analyze for one or more key contaminants to define vertical and horizontal variations in contamination and evaluate recent sediment transport processes*

- *Collect samples for "limited-suite" analysis (see Section 7.2.5.1 in this work plan and Chapter 5 of the core document for a discussion of limited-suite analysis)*

  *Purpose: analyze for the limited suite of COPCs to define the degree of collocation between different contaminants and to perform the present-day risk assessment*

*In addition, the samples will be analyzed for particle-size distribution to identify relationships between sediment particle sizes and contaminant concentrations.*

*Section 7.2.5 presents the strategy and rationale for sample collection. The strategy for each sampling task will be decided based on the data collected during the initial field surveys and/or prior sampling. Requirements for additional data will be developed based on the judgment of the technical team and through frequent dialogue with the regulators. Some sampling may also address particular stakeholder concerns that could arise based on data collected early in the investigation.*

*The products of the sediment investigation will be*

- *data to support an assessment of the present-day risk to on-site (within Laboratory boundaries) receptors and the potential for off-site exposure from deposits of contaminated sediments in the canyon system;*

- *a description of contaminant transport associated with sediments in the canyon system; and*

- *an assessment of the potential future trends in risk estimates due to existing contaminated sediments moving downstream on Laboratory property, across Los Alamos County and privately owned land, and to the Rio Grande.*

### 7.2.4 Canyon Reaches Planned for Investigation

*The following sections describe each of the canyon reaches planned for investigation and the significance of each reach for evaluating present-day risk and potential future trends in risk from exposure to*

*Laboratory-derived contaminants (see Figure A-1 in Appendix A for reach locations). The following reaches have been chosen for the sediment investigation:*

- *five reaches in Pajarito Canyon (PA-1 through PA-5),*
- *two reaches in the south fork of Pajarito Canyon (PAS-1 through PAS-2),*
- *one reach in the Anchor West basin (AW-1),*
- *one reach in the North Anchor East basin (AEN-1),*
- *one reach in the South Anchor East basin (AES-1),*
- *four reaches in Twomile Canyon (TW-1 through TW-4),*
- *one reach in the north fork of Twomile Canyon (TWN-1),*
- *one reach in the southwest fork of Twomile Canyon (TWSW-1),*
- *one reach in the southeast fork of Twomile Canyon (TWSE-1),*
- *three reaches in Threemile Canyon (TH-1 through TH-3),*
- *one reach in the west fork of Threemile Canyon (THW-1),*
- *one reach in the middle fork of Threemile Canyon (THM-1), and*
- *one reach in the south fork of Threemile Canyon (THS-1).*

*This list of potential reaches contains many subreaches, which are summarized in Table 7.2.3-1 and are described in the following sections. The strategy is to begin with a series of short subreaches, each approximately 100 to 200 m (110 to 220 yd) long located near identified PRSs within the many subbasins in the Pajarito Canyon watershed. This planned strategy is intended to identify the PRSs that contribute significant contaminants to the stream channels to potentially eliminate parts of the watershed from further investigations and to narrow the analytical suite planned for each reach. A second phase of investigations could expand the size of the key subreaches and perhaps add additional subreaches if questions remain. The list of subreaches also contains "contingency" reaches that may or may not be sampled, depending on the results from the investigations of upstream or downstream reaches. For example, subreaches in each drainage that are located west of identified PRSs may be sampled only if contaminants are found downstream of the PRSs and questions remain about possible undocumented releases upstream or the significance of contaminants derived from road runoff. In addition, some subreaches intended to evaluate dilution of contaminants from upstream PRSs may not be sampled if significant levels of contaminants are not found upstream close to the PRSs. The boundaries shown in Figure A-1 indicate the general areas that will be investigated; more precise definitions of the investigation boundaries will be based on the significant geomorphic units found within each reach. Characterization activities will focus on those geomorphic units that are most likely to contain Laboratory-derived contaminants, supplemented by some limited geomorphic characterization of pre-1943 sediment deposits.*

#### 7.2.4.1 Pajarito Canyon Reaches

**Reach PA-1: Pajarito Canyon near the South Fork of Pajarito Canyon**

*Reach PA-1, in upper Pajarito Canyon, includes three potential subreaches that are planned to evaluate potential contaminants from a series of PRSs located at TA-8, -9, and -22. Potential contaminants associated with these sources include strontium, uranium, HE compounds, hydrocarbons, polychlorinated biphenyls (PCBs), photographic chemicals, semivolatile organic compounds (SVOCs), asbestos, antimony, barium, beryllium, cadmium, chromium, copper, fluoride, lead, mercury, nitrate, and silver. The subreaches are described below.*

- *PA-1 West is located in Pajarito Canyon immediately upstream of the south fork of Pajarito Canyon. This location is intended to confirm the absence of upstream contaminant sources, if necessary. However, HE compounds have been detected in surface water collected in this area, which suggests that it is possible that Laboratory operations have impacted sediment in regions located upgradient of the south fork of Pajarito Canyon.*

- *PA-1 Central, located in Pajarito Canyon downstream of the confluence with the south fork of Pajarito Canyon and upstream of the confluence with the North Anchor East basin, is planned to evaluate the potential contribution of contaminants from the south fork of Pajarito Canyon, which flows through TA-8 and TA-9 and which may receive runoff from PRS 9-013 (MDA M). The reach will also allow the determination of possible additions of contaminants from TA-22.*

- *PA-1 East is located in Pajarito Canyon downstream of the South Anchor East basin and all TA-8, -9, and -22 PRSs.*

*Collectively, the PA-1 subreaches will allow the determination of the relative contributions of contaminants from these different sources and the contaminant inventory in upper Pajarito Canyon.*

**Reach PA-2: Pajarito Canyon near Twomile Canyon**

*Reach PA-2, located near the confluence of Pajarito Canyon and Twomile Canyon, contains two subreaches that are planned to evaluate the dilution of contaminants from TA-8, -9, and -22 (observed in Reach PA-1); the possible addition of contaminants from TA-40 and former TA-12; and the possible addition of contaminants from Twomile Canyon. Potential contaminants associated with these sources include strontium, uranium, plutonium, HE compounds, hydrocarbons, PCBs, photographic chemicals, SVOCs, asbestos, antimony, arsenic, barium, beryllium, cadmium, chromium, copper, fluoride, lead, mercury, nitrate, and silver. The subreaches are described below.*

- *PA-2 West, located within Pajarito Canyon upstream of the confluence with Twomile Canyon, will allow evaluation of the dilution of contaminants observed in Reach PA-1 and the potential addition of contaminants from TA-40 and former TA-12.*

- *PA-2 East, located within Pajarito Canyon downstream of the confluence of Twomile Canyon, will target the potential contribution of contaminants from Twomile Canyon to Pajarito Canyon.*

*PA-2, in combination with PA-1 and the Twomile Canyon reaches, will allow the determination of the relative contributions of contaminants from these different sources, the contaminant inventory of Pajarito*

*Canyon upstream of the confluence with Twomile Canyon, and the possible addition of contaminants from Twomile Canyon.*

**Reach PA-3: Pajarito Canyon near TA-18**

*Reach PA-3, located near TA-18 and the confluence with Threemile Canyon, contains two subreaches that are planned to evaluate the dilution of contaminants from PRSs upstream of TA-18 and the possible addition of contaminants from TA-18 and Threemile Canyon. Potential contaminants associated with TA-18 and TA-36 (located on the south rim of Threemile Canyon) include plutonium, uranium, HE compounds, hydrocarbons, PCBs, photographic chemicals, SVOCs, barium, beryllium, cadmium, chromium, copper, fluoride, lead, mercury, nickel, and silver. The subreaches are described below.*

- *PA-3 West, located in Pajarito Canyon upstream of TA-18 and the confluence with Threemile Canyon, is intended to evaluate the dilution of contaminants observed in upstream reaches (reaches PA-1 and PA-2).*

- *PA-3 East, located in Pajarito Canyon downstream of TA-18 and the confluence with Threemile Canyon, is planned to determine the relative contribution of contaminants from TA-18 and Threemile Canyon. PA-3 East includes the upper wetlands east of TA-18.*

**Reach PA-4: Pajarito Canyon near state road NM4**

*Reach PA-4, located upstream of the intersection of Pajarito Canyon and state road NM4, is planned to evaluate dilution of contaminants from TA-18 and upstream PRSs, identify the possible addition of contaminants from TA-54 and former TA-27, and identify the types and concentrations of contaminants present at the eastern Laboratory boundary. Potential contaminants in this reach include plutonium, tritium, uranium, HE compounds, hydrocarbons, PCBs, photographic chemicals, SVOCs, barium, beryllium, cadmium, chromium, copper, fluoride, lead, mercury, nickel, and silver. The reach will include the lower wetlands located west of the eastern Laboratory boundary.*

**Reach PA-5: Pajarito Canyon in White Rock Canyon**

*Reach PA-5, located east of the community of White Rock, contains two subreaches that are planned to evaluate the potential contribution of contaminants to the Rio Grande. Potential contaminants in this reach include plutonium, tritium, uranium, HE compounds, hydrocarbons, PCBs, photographic chemicals, SVOCs, barium, beryllium, cadmium, chromium, copper, fluoride, lead, mercury, nickel, and silver. Sampling of this reach is contingent on identification of significant levels of contaminants in reach PA-4. The subreaches are described below.*

- *PA-5 West, located in Pajarito Canyon on an alluvial fan deposited on a large landslide block, is the location of sediment accumulation that will allow the evaluation of the dilution of contaminants potentially transported across the Laboratory boundary and the contaminants in the community of White Rock.*

- *PA-5 East, located on an alluvial fan at the Rio Grande, will allow the determination of the nature and concentration of contaminants discharged to the Rio Grande.*

#### 7.2.4.2 Reaches in the South Fork of Pajarito Canyon

**Reach PAS-1**

*Reach PAS-1, located in the south fork of Pajarito Canyon upstream of the confluence with Anchor West basin, contains two subreaches that are planned to evaluate the potential contaminants contributed by PRSs associated with TA-8 and TA-9. Potential contaminants associated with these sources include strontium, uranium, HE compounds, hydrocarbons, PCBs, photographic chemicals, SVOCs, asbestos, antimony, barium, beryllium, cadmium, chromium, copper, fluoride, lead, mercury, nitrate, and silver. The subreaches are described below.*

- *PAS-1 West is located in the south fork of Pajarito Canyon upstream of Anchor Ranch Road. This location is upstream of all potential surficial Laboratory sources and is intended to confirm the absence of upstream contaminant sources, if necessary.*
- *PAS-1 East is located in the south fork of Pajarito Canyon upstream of the confluence with the Anchor West basin. This subreach is planned to evaluate the contribution of contaminants from a series of TA-8 PRSs.*

**Reach PAS-2**

*Reach PAS-2, located in the south fork of Pajarito Canyon downstream of the confluence with Anchor West basin, contains two subreaches that are planned to evaluate the potential contaminants contributed by PRSs associated with TA-8 and TA-9. Potential contaminants associated with these sources include strontium, uranium, HE compounds, hydrocarbons, PCBs, photographic chemicals, SVOCs, asbestos, antimony, barium, beryllium, cadmium, chromium, copper, fluoride, lead, mercury, nitrate, and silver. The subreaches are described below.*

- *PAS-2 West is located in the south fork of Pajarito Canyon downstream of the confluence with the Anchor West basin and upstream of MDA M (PRS 9-013). This subreach is planned to evaluate the contribution of contaminants from a series of TA-8 and TA-9 PRSs.*
- *PAS-2 East is located in the south fork of Pajarito Canyon upstream of the confluence with Pajarito Canyon (this area is also referred to as "Starmer Gulch"). This subreach is planned to evaluate the concentrations and inventory of contaminants identified in PAS-2 West.*

*Collectively, the PAS-1 and PAS-2 subreaches will allow the determination of the contaminant inventory of the south fork of Pajarito Canyon.*

#### 7.2.4.3 Anchor West Basin Reach

**Reach AW-1**

*Reach AW-1, located in the lower part of the Anchor West basin, is planned to evaluate the contribution of contaminants from a series of TA-8 PRSs. Potential contaminants associated with these sources include uranium, HE compounds, hydrocarbons, photographic chemicals, solvents, SVOCs, asbestos, barium, beryllium, cadmium, chromium, copper, lead, mercury, nitrate, and silver.*

#### 7.2.4.4 North Anchor East Basin Reach

**Reach AEN-1**

*Reach AEN-1, located in the lower part of the North Anchor East basin (also referred to as "Arroyo de LaDelfe"), is planned to evaluate the contribution of contaminants from a series of TA-9 PRSs. Potential contaminants associated with these sources include uranium, HE compounds, hydrocarbons, solvents, SVOCs, asbestos, antimony, barium, beryllium, cadmium, chromium, fluoride, lead, mercury, nitrate, and silver.*

#### 7.2.4.5 South Anchor East Basin Reach

**Reach AES-1**

*Reach AES-1, located in the lower part of the South Anchor East basin, is planned to evaluate the contribution of contaminants from a series of TA-9 PRSs. Potential contaminants associated with these sources include uranium, HE compounds, hydrocarbons, solvents, SVOCs, asbestos, antimony, barium, beryllium, cadmium, chromium, fluoride, lead, mercury, nitrate, and silver.*

#### 7.2.4.6 Twomile Canyon Reaches

**Reach TW-1: Twomile Canyon Near Anchor Ranch Road**

*Reach TW-1, located near Anchor Ranch Road, contains two subreaches that are planned to evaluate the potential contribution of contaminants from PRS 69-001, a former incinerator ash pond. Potential contaminants associated with the pond include antimony, barium, cadmium, copper, lead, manganese, and nickel. The subreaches are described below.*

- *TW-1 West is located in Twomile Canyon immediately upstream of PRS 69-001. This location is upstream of all potential surficial Laboratory sources and is intended to confirm the absence of upstream contaminant sources, if necessary.*
- *TW-1 East, located in Twomile Canyon downstream of PRS 69-001, will allow the determination of the possible contribution of contaminants from the incinerator ash pond.*

**Reach TW-2: Twomile Canyon Near the North Fork of Twomile Canyon**

*Reach TW-2, located near the confluence of Twomile Canyon and the north fork of Twomile Canyon, contains two subreaches that are planned to evaluate the dilution of contaminants from PRS 69-001 and the possible addition of contaminants from the north fork of Twomile Canyon derived from TA-3. Potential contaminants associated with these sources include cesium, tritium, hydrocarbons, PCBs, antimony, barium, cadmium, copper, lead, manganese, and nickel. The subreaches are described below.*

- *TW-2 West, located in Twomile Canyon upstream of the confluence with the north fork of Twomile Canyon, is planned to evaluate the dilution of contaminants observed in reach TW-1 and allow an estimate of the contaminant inventory of upper Twomile Canyon.*
- *TW-2 East, located in Twomile Canyon downstream of the confluence with the north fork of Twomile Canyon, will allow evaluation of the possible addition of contaminants from the north fork of Twomile Canyon.*

**Reach TW-3: Twomile Canyon Near the Southwest Fork of Twomile Canyon**

*Reach TW-3, located near the confluence of Twomile Canyon and the southwest fork of Twomile Canyon, contains two subreaches that are planned to evaluate the dilution of contaminants from upstream PRSs and the possible addition of contaminants into the southwest fork of Twomile Canyon from PRSs at TA-6 and TA-7. Potential contaminants associated with these sources include cobalt, cesium, tritium, strontium, hydrocarbons, PCBs, photographic chemicals, antimony, barium, cadmium, copper, lead, manganese, nickel, and nitrate. The subreaches are described below.*

- *TW-3 West, located in Twomile Canyon upstream of the confluence with the southwest fork of Twomile Canyon, is planned to evaluate the dilution of contaminants from upstream sources as observed in reaches TW-1 and TW-2.*

- *TW-3 East, located in Twomile Canyon downstream of the confluence with the southwest fork of Twomile Canyon, will allow the determination of the relative contributions of contaminants from Twomile Canyon (as observed in reach TW-3 West) and from sources from TA-6 and TA-7 in the southwest fork of Twomile Canyon.*

**Reach TW-4: Twomile Canyon Near Pajarito Canyon**

*Reach TW-4, located near the confluence of Twomile Canyon and Pajarito Canyon, contains two subreaches that are planned to evaluate the dilution of contaminants from PRSs upstream of Reach TW-3, the possible addition of contaminants from TA-48 and TA-55 to Twomile Canyon, and from TA-6, -7, -22, and -40 that may have contributed to the southeast fork of Twomile Canyon. Potential contaminants associated with these sources include cobalt, cesium, tritium, strontium, hydrocarbons, PCBs, photographic chemicals, barium, cadmium, copper, lead, manganese, nickel, and nitrate. The subreaches are described below.*

- *TW-4 West, located in Twomile Canyon upstream of the confluence with the southeast fork of Twomile Canyon, is planned to evaluate the dilution of contaminants from upstream sources as observed in reaches TW-1, TW-2, and TW-3.*

- *TW-4 East, located in Twomile Canyon downstream of the confluence with the southeast fork of Twomile Canyon, will allow the determination of the relative contributions of contaminants from Twomile Canyon (as observed in reach TW-4 West) and from sources from TA-6, -7, -22, and -40 in the southeast fork of Twomile Canyon.*

*Collectively, TW-1 through TW-4 will allow the determination of the relative contributions of contaminants from these different sources and the contaminant inventory of Twomile Canyon.*

### 7.2.4.7 Reach in the North Fork of Twomile Canyon

**Reach TWN-1: North Fork of Twomile Canyon Near TA-3**

*Reach TWN-1, beginning near the Laboratory Wellness Center, contains three subreaches that are planned to evaluate the potential contaminants contributed by PRSs associated with TA-3. Potential* *contaminants associated with these sources include plutonium, tritium, hydrocarbons, PCBs, solvents, lead, and mercury. The subreaches are described below.*

- *TWN-1 West, located in the north fork of Twomile Canyon upstream of the Wellness Center, is upstream of PRS sources and is intended to confirm the absence of upstream contaminant sources, if necessary.*

- *TWN-1 Central, located in the north fork of Twomile Canyon downstream of the Wellness Center and PRS 3-010(a), is planned to evaluate the possible contribution of contaminants from upstream PRSs at TA-3.*

- *TWN-1 East, located in the north fork of Twomile Canyon upstream of the confluence with Twomile Canyon, is planned to evaluate the dilution of contaminants observed in reach TWN-1 Central and the possible addition of contaminants from adjacent mesa-top PRSs at TA-3.*

*Collectively, the TWN-1 subreaches will allow the determination of the contaminant inventory of the north fork of Twomile Canyon.*

#### 7.2.4.8 Reach in the Southwest Fork of Twomile Canyon

**Reach TWSW-1**

*Reach TWSW-1, located in the southwest fork of Twomile Canyon upstream of its confluence with Twomile Canyon, contains two subreaches that are planned to evaluate potential contaminants contributed by PRSs associated with TA-6. Potential contaminants associated with these sources include cobalt, cesium, plutonium, strontium, uranium, HE compounds, PCBs, photographic chemicals, barium, copper, and nitrate. The subreaches are described below.*

- *TWSW-1 West is located near the head of the southwest fork of Twomile Canyon. TWSW-1 West is located upstream of all TA-6 PRSs and is intended to confirm the absence of upstream contaminant sources, if necessary.*

- *TWSW-1 Central is located downstream of most the TA-6 PRSs in a relatively low-gradient area that may contain the largest volume of post-1942 sediment in this basin.*

- *TWSW-1 East, located in the southwest fork of Twomile Canyon downstream of the unnamed drainage that heads at PRS 6-008, will allow evaluation of the possible addition of contaminants from TA-6.*

*Collectively, the TWSW-1 subreaches will allow the determination of the contaminant inventory in the southwest fork of Twomile Canyon.*

#### 7.2.4.9 Reach in the Southeast Fork of Twomile Canyon

**Reach TWSE-1**

*Reach TWSE-1, located in the southeast fork of Twomile Canyon upstream of its confluence with Twomile Canyon, contains two subreaches that are planned to evaluate potential contaminants* *contributed by PRSs associated with TA-6, -7 and -22. Potential contaminants associated with these sources include cobalt, cesium, plutonium, strontium, uranium, HE compounds, PCBs, photographic chemicals, arsenic, barium, cadmium, copper, fluoride, lead, nickel, nitrate, and silver. The subreaches are described below.*

- *TWSE-1 West, located in the southeast fork of Twomile Canyon immediately downstream of TA-22, is planned to evaluate the potential contaminants associated with PRSs from TA-6 and TA-22.*

- *TWSE-1 East, located in the southeast fork of Twomile Canyon upstream of the confluence with Twomile Canyon, is planned to evaluate the dilution of contaminants from TA-6 and TA-22 PRSs and the possible addition of contaminants from TA-7 and TA-40.*

*Collectively, the TWSE-1 subreaches will allow the determination of the relative contributions of contaminants from these different sources and the contaminant inventory of the southeast fork of Twomile Canyon.*

#### 7.2.4.10 Threemile Canyon Reaches

**Reach TH-1: Threemile Canyon**

*Reach TH-1, beginning near the head of Threemile Canyon, contains three subreaches that, in conjunction with reach THW-1 (described in Section 7.2.4.11), are planned to evaluate the potential contaminants contributed by PRSs associated with the western groups of PRSs at TA-15 and former TA-12. Potential contaminants associated with these sources include strontium, tritium, uranium, HE compounds, hydrocarbons, photographic chemicals, SVOCs, antimony, arsenic, barium, beryllium, cadmium, chromium, copper, lead, mercury, nickel, and silver. The subreaches are described below.*

- *TH-1 West is located near the head of Threemile Canyon. TH-1 West is upstream of all TA-12 and TA-15 PRSs and is intended to confirm the absence of upstream contaminant sources, if necessary.*

- *TH-1 Central, located in Threemile Canyon upstream of the confluence with the west fork of Threemile Canyon, is planned to evaluate the potential contribution of contaminants from the westernmost PRSs at TA-15 and former TA-12.*

- *TH-1 East, located in Threemile Canyon downstream of the confluence with the west fork of Threemile Canyon, is planned to evaluate the combined contribution of contaminants from the western groups of PRSs at TA-15 and former TA-12.*

*Collectively, the TH-1 subreaches will allow the identification of sources and concentrations of contaminants in upper Threemile Canyon sediments derived from the western PRSs at TA-15 and former TA-12.*

**Reach TH-2: Threemile Canyon**

*Reach TH-2, located near the confluence of Threemile Canyon and the middle fork of Threemile Canyon contains two subreaches that, in conjunction with reach THM-1 (described in Section 7.2.4.12), are planned to evaluate the potential contaminants contributed by PRSs in this tributary basin and the dilution* *of contaminants observed in reach TH-1. Potential contaminants associated with these sources include tritium, uranium, HE compounds, photographic chemicals, SVOCs, antimony, arsenic, beryllium, cadmium, copper, lead, mercury, and silver. The subreaches are described below.*

- *TH-2 West is located in Threemile Canyon upstream of the confluence with the middle fork of Threemile Canyon. TH-2 West is planned to evaluate the dilution of contaminants from upstream PRSs at TA-15 and former TA-12 (as observed at TH-1 West).*
- *TH-2 East is located in Threemile Canyon downstream of the confluence with the middle fork of Threemile Canyon. TH-2 East is planned to evaluated the combined contribution of contaminants from the western and central groups of PRSs at TA-15 and former TA-12.*

*Collectively, the TH-2 subreaches will allow the identification of sources and concentrations of contaminants in middle Threemile Canyon sediments and the determination of the contaminant inventory of Threemile Canyon upstream of the confluence with the south fork of Threemile Canyon.*

**Reach TH-3: Threemile Canyon at TA-18**

*Reach TH-3, located in Threemile Canyon upstream of TA-18, is planned to evaluate the dilution and storage of contaminants associated with TA-15, TA-36, and former TA-12. Potential contaminants associated with these sources include strontium, tritium, uranium, HE compounds, hydrocarbons, PCBs, photographic chemicals, SVOCs, antimony, arsenic, barium, beryllium, cadmium, chromium, copper, lead, manganese, mercury, nickel, and silver. TH-3 will allow the determination of the contaminant inventory of Threemile Canyon upstream of TA-18.*

#### 7.2.4.11 Reach in the West Fork of Threemile Canyon

**Reach THW-1**

*Reach THW-1, located in the west fork of Threemile Canyon upstream of the confluence with Threemile Canyon, is planned to evaluate the potential contaminants from a group of PRSs at TA-15. Potential contaminants associated with these sources include tritium, uranium, HE compounds, photographic chemicals, SVOCs, antimony, arsenic, beryllium, cadmium, copper, lead, mercury, and silver. Reach THW-1 will be evaluated collectively with the TH-1 subreaches to allow the identification of sources and concentrations of contaminants in upper Threemile Canyon sediments derived from the western PRSs at TA-15 and former TA-12.*

#### 7.2.4.12 Reach in the Middle Fork of Threemile Canyon

**Reach TWM-1**

*Reach TWM-1, located in the middle fork of Threemile Canyon upstream of the confluence with Threemile Canyon, is planned to evaluate the potential contribution of contaminants from a group of PRSs at TA-15, which includes Firing Site R-44 (PRS 15-006[c]). Potential contaminants associated with these sources include tritium, uranium, HE compounds, photographic chemicals, SVOCs, antimony, arsenic, beryllium, cadmium, copper, lead, mercury, and silver. Reach TWM-1 will be evaluated collectively with the TH-2 subreaches to allow the identification of sources and concentrations of contaminants in middle Threemile Canyon sediments and the determination of the contaminant inventory of Threemile Canyon upstream of the confluence with the south fork of Threemile Canyon.*

### 7.2.4.13 Reach in the South Fork of Threemile Canyon

**Reach THS-1**

*Reach THS-1, located in the south fork of Threemile Canyon upstream of the confluence with Threemile Canyon, contains two subreaches that are planned to evaluate the potential contaminants contributed by PRSs associated with TA-15 and TA-36. Potential contaminants associated with these sources include tritium, uranium, photographic chemicals, SVOCs, antimony, barium, beryllium, cadmium, chromium, copper, lead, mercury, and silver. The subreaches are described below.*

- *THS-1 West, located near the head of the south fork of Threemile Canyon and northeast of Firing Site E-F (PRS 15-004[f]), is planned to evaluate the contribution of contaminants from the surrounding PRSs at TA-15, including Firing Site E-F and possibly Firing Site R-44.*
- *THS-1 East, located in the south fork of Threemile Canyon upstream of the confluence with Threemile Canyon, is planned to evaluate the dilution of contaminants from the TA-15 PRSs located near the head of the south fork of Threemile Canyon and the possible addition of contaminants from Firing Site I-J (PRS 36-004[e]).*

*Collectively, the THS-1 subreaches will allow the determination of the relative contributions of contaminants from these different sources and the contaminant inventory of the south fork of Threemile Canyon.*

### 7.2.5 Sediment Sample Collection and Analysis

*This section describes the sediment sample collection process in the canyon reaches. Particular emphasis is given to the criteria for selecting sample locations within each reach and the rationale for the choice of analytical suites. The methods for sample collection and for the chemical, radiochemical, and geotechnical analyses are also provided in this section.*

### 7.2.5.1 Sampling Design

*Samples of sediments from potentially contaminated geomorphic units will be collected in most reaches planned for investigation (see Section 7.2.4). The locations of sediment samples will be determined based on the criteria provided in Section 5.6.3 of the core document (LANL 1997, 55622, p. 5-24 et seq.). Specific sample locations in the initial sampling phases will be selected following the geomorphic survey and will include the full range in age and particle size characteristics in post-1942 sediments as identified in the geomorphic survey. Specific sampling locations in subsequent sampling rounds will be based both on the geomorphic survey and on analytical results from the initial sampling phases and will be biased to locations where the highest levels of contaminants are expected.*

*Surface and shallow subsurface samples will be collected at variable depths depending on the thickness and variability of the sediment layers at each location. In general, each sample will be collected from a discrete sediment layer or from a series of adjacent texturally similar layers to avoid mixing layers that may have very different contaminant concentrations. For example, discrete flood layers only 1 to 2 in. (2.5 to 5.0 cm) thick may comprise some samples, whereas other samples may homogenize 1 ft (0.30 m) or more of relatively uniform layers.*

*Each sample location will be marked, surveyed, and assigned a unique Environmental Restoration (ER) Project sample location identification number. All samples will be field-screened using hand-held* *instruments at the point of collection for gross radioactivity. Before the samples are submitted to the Field Support Facility, gross-alpha, -beta, and -gamma radiation measurements will be taken on each sample.*

*As explained in Section 7.2.3, three sampling tasks have been defined for the sediment investigation: full-suite COPC, key contaminant, and limited-suite COPC analyses. Field quality assurance and quality control samples, such as field blanks and collocated samples, will be collected in accordance with the guidelines of the Quality Assurance Project Plan Requirements for Sampling and Analysis (LANL 1996, 53450).*

*Because of the scarcity of information available on contaminants in the Pajarito Canyon system, the initial round of sampling and analysis will be full-suite analyses from a series of subreaches throughout the watershed.*

*Sample collection for full-suite analyses, as described below, will be distributed on a canyon-system-wide rather than a reach-wide basis in the initial round to ensure that no contaminants were overlooked during the historical analyses. Subsequent analyses will probably involve both limited-suite and key contaminant analyses, depending on the results of the full-suite sampling.*

#### 7.2.5.1.1 Sample Collection for Full-Suite Analysis

*The general approach discussed in Section 5.6.3.2 in Chapter 5 of the core document (LANL 1997, 55622) will be followed. Sediment samples will be collected in the initial sampling task and analyzed for a full suite of potential contaminants to define the limited-suite analyses (see Section 7.2.5.1.3) for subsequent sampling and analysis tasks.*

*In addition, sediment samples for full-suite analysis will be collected from canyon subreaches located closest to known source areas, containing the widest distribution of contaminants, and located immediately upstream of the eastern Laboratory boundary.*

#### 7.2.5.1.2 Sample Collection for Key Contaminant Analysis

*The general approach discussed in Section 5.6.3.3 in Chapter 5 of the core document (LANL 1997, 55622) will be followed. The selection of key contaminants allows analyses to be obtained from a large number of samples at a reasonable cost.*

*One or more constituents present at levels that may contribute significantly to present-day risk will be selected as key contaminants. The key contaminant analyses are critical to the sediment investigations because those analytes are most important for evaluating risk.*

#### 7.2.5.1.3 Sample Collection for Limited-Suite Analysis

*The general approach discussed in Section 5.6.3.4 in Chapter 5 of the core document will be followed (LANL 1997, 55622). Because the database on radionuclide and metal contaminants in Pajarito Canyon is sparse, potential contaminant suites in the sediments are poorly defined. The number of samples will be determined by the technical team based on the complexity of the contamination and will be sufficient to develop a defensible, representative statistic for present-day risk assessment purposes. To best sample a range of contaminant concentrations it is expected that more of these samples will be collected in reaches close to contaminant sources than in downstream reaches.*

*The results of the limited-suite and full-suite analyses comprise part of the data set that will be used for the present-day human health and ecological risk assessments. The analyte suite for limited-suite analyses will be decided by the technical team on the basis of analytes identified as being present at concentrations above background levels from the full-suite analyses.*

#### 7.2.5.2 Sampling Methods

*Sediment samples will be collected using the methods and ER Project standard operating procedures (SOPs) (most recent revisions) listed in Table 7.2.5-1. Sampling intervals will be determined in the field based on the judgment of field geologists. The tools used to collect the sediment samples will depend on the cohesion of the sediment material, the collection depth, and the presence of flowing or standing surface water. A spade and scoop will be used to collect surface sediment samples at depths of 0 to 1.0 ft (0.0 to 30.5 cm). Depth samples will be collected from either stream bank exposures or shallow excavations, homogenizing through the thickness of selected sediment layers. If surface water is present at the sampling location, a scoop, trowel, or hand corer will be used to collect grab sediment samples.*

**TABLE 7.2.5-1**

**SUMMARY OF SEDIMENT SAMPLING METHODS REQUIREMENTS**

| Sampling Tool | Sample Type | Sampling Depth (ft) | LANL-ER-SOP No. |
|---|---|---|---|
| *Spade and scoop* | *Surface grab* | *0–1* | *06.09* |
| *Thin-wall tube* | *Surface grab; lithologic (undisturbed)* | *0–5* | *06.10* |
| *Hand auger* | *Surface or subsurface grab; vertical composite* | *0–5* | *06.10* |
| *Open tube (Trier)* | *Lithologic (undisturbed)* | *0–5* | *06.17* |
| *Scoop and trowel* | *Grab (under surface water)* | *0–0.5* | *06.14* |
| *Hand corer* | *Grab (under surface water)* | *0–0.5* | *06.14* |

*All samples will be collected using the most recent revised versions of the applicable ER Project SOPs for the collection, preservation, identification, storage, transport, and documentation of environmental samples. Decontamination of sampling equipment will be performed in accordance with LANL-ER-SOP-01.08, "Field Decontamination of Drilling and Sampling Equipment." Wash water and other wastes generated during the sampling operation will be managed and disposed of in accordance with LANL-ER-SOP-1.06, "Management of RFI Program Wastes."*

#### 7.2.5.3 Analytical Methods

*Sediment samples will be collected to represent specific geomorphic strata; therefore, it is important that the laboratory sample be representative of the sediment stratum that is collected in the field. To identify patterns in the distribution of metals and radionuclides in the geomorphic strata, it is important that the sample preparation method be consistent. To meet the objectives for representativeness and comparability, the sediment samples will be homogenized in the field using a stainless steel bowl and spoon before being placed in a container. All samples will be sieved, in either the field or the laboratory, to remove stones and organic matter greater than 2 mm (0.08 in.) in diameter. The laboratory will be instructed to take representative aliquots from the homogenized sample for each analysis.*

*All analyses for the limited suite of COPCs will use the methods and procedures described for the full-suite analyses.*

*Analyses for key contaminants will use fixed-site laboratory procedures. The technical team chemist will choose the appropriate methods based on the data quality objectives developed for the key contaminant sampling task.*

### 7.2.5.3.1 Organic Chemicals

*Sediment samples collected in accordance with criteria outlined in Section 7.2.5.1.1 will undergo full-suite analyses for organic (total organic carbon [TOC] or solid organic carbon) and inorganic chemicals and radionuclides. All analyses will be performed at ER Project-approved fixed-site laboratories. The analytical suites and methods for analysis of organic chemicals are listed in Table 7.2.5-2. The analytical suites include SVOCs, organochlorine pesticides, PCBs, and HE compounds, which will be analyzed for in each full-suite sample. All analyses for organic chemicals will be performed in accordance with the EPA SW-846 protocols (EPA 1987, 57589). The detailed analyte lists, estimated quantitation limits (EQLs), required quality control (QC) procedures, and the acceptance criteria are found in the 1995 ER Project analytical services statement of work (LANL 1995, 49738) or the version that is current when this work plan is implemented.*

**TABLE 7.2.5-2**

**ANALYTE SUITES AND ANALYTICAL METHODS FOR ANALYSIS OF ORGANIC CHEMICALS IN SEDIMENT SAMPLES[a]**

| Analyte Suite | Analytical Method | Analytical Protocol[b] |
|---|---|---|
| *Organochlorine pesticides* | *Gas chromatography/electron capture detector* | *SW-8081A* |
| *TOC* | *Oxidation of organic matter* | *SW-415.1* |
| *PCBs* | *Gas chromatography/electron capture detector* | *SW-8081A or SW-8082* |
| *SVOCs* | *Gas chromatography/mass spectrometry* | *SW-8270* |
| *HE* | *High-performance liquid chromatography* | *SW-8330* |

a. *Detailed analyte lists and estimated quantitation limits can be found in the 1995 ER Project analytical services statement of work (LANL 1995, 49738).*

b. *EPA SW-846 Methods (EPA 1987, 57589)*

### 7.2.5.3.2 Inorganic Chemicals and Radionuclides

*For inorganic chemicals the target analytes, conservative estimated detection limits (EDLs), analytical methods, and 95% UTLs for background levels in sediments are listed in Table 7.2.5-3. All analyses for inorganic chemicals will be performed in accordance with EPA SW-846 protocols using mineral acid (nitric acid at a pH value of one) sample extraction procedures for the inductively coupled plasma emission spectroscopy (ICPES), electrothermal vapor atomic absorption (ETVAA), cold vapor atomic absorption (CVAA), and inductively coupled plasma mass spectrometry (ICPMS) techniques.*

*For radionuclides the target analytes and their half-lives, detected emission, minimum detectable activities, analytical methods, and background levels in sediments are listed in Table 7.2.5-4. Before chemical separation and counting for alpha or high-energy beta emissions, samples will undergo a complete digestion or fusion procedure. Measurements of strontium-90 will be performed by beta-counting of yttrium-90 progeny after an ingrowth period of at least 10 days after separation. All samples submitted for tritium analysis will also be analyzed for moisture content.*

**TABLE 7.2.5-3**

**ANALYTE LIST, ESTIMATED DETECTION LIMITS, AND ANALYTICAL METHODS FOR INORGANIC CHEMICALS IN SEDIMENT SAMPLES**

| Analyte | EDL (mg/kg) | Background[a] (mg/kg) | Analytical Method | Analytical Protocol[b] |
|---|---|---|---|---|
| **Metals** | | | | |
| Aluminum | 40 | 15,400 | ICPES | SW-6010B |
| Antimony | 1.0 | 0.83 | ICPMS | SW-6020 |
| Arsenic | 2 | 3.98 | ETVAA | SW-7060A |
| Barium | 40 | 127 | ICPES | SW-6010B |
| Beryllium | 1 | 1.31 | ICPES | SW-6010B |
| Cadmium | 1 | 0.4 | ICPES or ICPMS | SW-6010B or SW-6020 |
| Calcium | 500 | 4420 | ICPES | SW-6010B |
| Chromium | 2 | 10.5 | ICPES | SW-6010B |
| Cobalt | 10 | 4.73 | ICPES | SW-6010B |
| Copper | 5 | 11.2 | ICPES | SW-6010B |
| Iron | 20 | 13,800 | ICPES | SW-6010B |
| Lead | 0.6 | 19.7 | ETVAA or ICPMS | SW-7421 or SW-6020 |
| Magnesium | 1000 | 2370 | ICPES | SW-6010B |
| Manganese | 3 | 543 | ICPES | SW-6010B |
| Mercury | 0.1 | 0.1 | CVAA | SW-7470A |
| Nickel | 8 | 9.38 | ICPES | SW-6010B |
| Potassium | 500 | 2690 | ICPES | SW-6010B |
| Selenium | 1 | 0.3 | ETVAA | SW-7740 |
| Silver | 2 | 1 | ICPES | SW-6010B |
| Sodium | 500 | 1470 | ICPES | SW-6010B |
| Thallium | 2 | 0.73 | ICPMS | SW-6020 |
| Titanium | 10 | N.A.[c] | ICPES | SW-6010B |
| Uranium | 0.5 | 2.22 | ICPMS | SW-6020 |
| Vanadium | 10 | 19.7 | ICPES | SW-6010B |
| Zinc | 4 | 60.2 | ICPES | SW-6010B |
| **Other Inorganic Chemicals** | | | | |
| Total cyanide | 0.05 | 0.82 | Colorimetry | SW-9012A |

a. Background for sediment samples from Ryti et al. 1998, 58093.
b. EPA SW-846 Method (EPA 1987, 57589)
c. N.A. = not available

**TABLE 7.2.5-4**

**ANALYTE LIST, MINIMUM DETECTABLE ACTIVITIES, AND ANALYTICAL METHODS FOR RADIONUCLIDES IN SEDIMENT SAMPLES**

| Analyte | Half-Life (yr) | Detected Emission | Minimum Detectable Activity (pCi/g) | Background[a] (pCi/g) | Analytical Method |
|---|---|---|---|---|---|
| Americium-241 | 432.2 | $\alpha$ | 0.05 | 0.040 | $\alpha$-Spectrometry |
| Plutonium-238 | 87.7 | $\alpha$ | 0.05 | 0.006 | $\alpha$-Spectrometry |
| Plutonium-239,240[b] | $2.411 \times 10^4$ | $\alpha$ | 0.05 | 0.068 | $\alpha$-Spectrometry |
| Strontium-90 | 28.7 | $\beta$ | 0.5 | 1.3 | Gas proportional counter (GPC) |
| Tritium | 12.3 | $\beta$ | 250 pCi/L | 0.093 | Liquid scintillation counting (LSC) |
| Uranium-234 | $2.46 \times 10^5$ | $\alpha$ | 0.1 | 2.59 | $\alpha$-Spectrometry |
| Uranium-235 | $7.04 \times 10^8$ | $\alpha$ | 0.1 | 0.20 | $\alpha$-Spectrometry |
| Uranium-236 | $2.34 \times 10^7$ | N/A[c] | 0.001 | N.A.[d] | Thermal ionization mass spectrometry (TIMS) |
| Uranium-238 | $4.47 \times 10^9$ | $\alpha$ | 0.1 | 2.29 | $\alpha$-Spectrometry |
| Gamma spectroscopy[e] | N/A | $\gamma$ | 0.2[f] | N/A | $\gamma$-Spectroscopy |
| Gross-alpha | N/A | $\alpha$ | 1.0 | N.A. | GPC |
| Gross-beta | N/A | $\beta$ | 1.0 | N.A. | GPC |
| Gross-gamma | N/A | $\gamma$ | 2.0 | N.A. | Thallium-doped sodium iodide (NaI[Tl]) or high-purity germanium (HPGe) detection |

a. Background for sediment samples from Ryti et al. 1998, 58093

b. The plutonium-239 and plutonium-240 isotopes cannot be distinguished by alpha spectrometry. The half-life of plutonium-239 is given.

c. N/A = not applicable

d. N.A. = not available

e. The gamma spectroscopy analyte list is given in Table 7.2.5-5.

f. The minimum detectable activity for cesium-137 is 0.2 pCi/g; the minimum detectable activity for other analytes will vary.

*Sediment samples will be prepared for gamma spectroscopy measurements by homogenization and drying; no sample extraction will be performed. The ER Project analyte list for the gamma spectroscopy analysis (see Table 7.2.5-5) includes the decay series of the naturally occurring radionuclides thorium-232, uranium-235, and uranium-236 as well as fission and activation products and their progeny. Measurements of naturally occurring radionuclides known to be present in Laboratory soils provide an indication of the quality of the gamma spectroscopy measurement. Radionuclides with half-lives less than 365 days are not considered to be COPCs. Data for these short-lived radionuclides can be useful when evaluating values reported for a parent radionuclide because the relative activity concentration of parent and daughter isotopes is a known quantity. The shorter-lived radionuclides are usually included in the analyte list to verify the presence of longer-lived parent isotopes, but they are not evaluated as primary radionuclides because they decay to unmeasurable concentrations within the span of several years or less. The naturally occurring radionuclide potassium-40 is present in Laboratory soils at concentrations ranging from 25 to 40 pCi/g and is always present in the gamma spectra of Laboratory soil samples. The potassium-40 gamma emission peak provides a qualitative indicator of the accuracy and precision of the* *gamma spectroscopy measurement, but potassium-40 is not considered to be a potential contaminant in Pajarito Canyon sediments.*

**TABLE 7.2.5-5**

**ANALYTE LIST AND HALF-LIVES OF RADIONUCLIDES MEASURED USING GAMMA SPECTROSCOPY**

| Radionuclide | Half-life* | Emissions |
|---|---|---|
| **Th-232 decay series (Thorium series)** | | |
| *Lead-212* | *10.64 h* | β,γ |
| *Thallium-208* | *3.053 m* | β,γ |
| **U-235 decay series (Actinium series)** | | |
| *Bismuth-211* | *2.14 m* | α,β,γ |
| *Thorium-227* | *18.72 d* | α,γ |
| *Uranium-235* | *7.04 x $10^8$ y* | α,γ |
| **U-238 decay series (Uranium series)** | | |
| *Bismuth-214* | *19.9 m* | α,β,γ |
| *Lead-214* | *26.8 m* | β,γ |
| *Thorium-234* | *24.10 d* | β,γ |
| **Activation products (and their decay products)** | | |
| *Americium-241* | *432.7 y* | α,γ |
| *Cobalt-60* | *5.271 y* | β,γ |
| *Sodium-22* | *2.605 y* | β,γ |
| *Protactinium-233* | *27.0 d* | β,γ |
| **Fission products** | | |
| *Cesium-134* | *2.065 y* | β,γ |
| *Cesium-137* | *30.17 y* | β,γ |
| *Europium-152* | *13.48 y* | β,γ |
| *Ruthenium-106* | *372.6 d* | β |
| **Other** | | |
| *Potassium-40* | *1.25 x $10^9$ y* | β,γ |
| **m = minutes, h = hours, d= days, y = years* | | |

*The required QC procedures and acceptance criteria for both the inorganic chemical and radiochemical analyses (except uranium-236) are found in the 1995 ER Project analytical services statement of work (LANL 1995, 49738) or the version that is current when this work plan is implemented.*

### 7.2.5.3.3 Geotechnical Analysis

*In addition to the chemical and radiochemical analyses, sediment samples will undergo geotechnical analysis for particle size distribution using a method determined appropriate to meet the investigation goals. Methods used may be those recommended by the United States Geological Survey for geological applications (Janitzky 1986, 57674) or methods recommended for engineering applications by the American Society for Testing and Materials (ASTM) described in LANL-ER-SOP-11.02, "Particle Size Distribution of Soil/Rock Samples" (ASTM Method D-422-63). Goals of these analyses may include* *evaluating relationships between contaminant concentrations and particle size distribution and determining the 10-µm size fraction (respirable particulate) in sediment samples. Other geotechnical analyses, such as mineralogy or organic matter content, may be performed at the discretion of the technical team geologists.*

### 7.3 Surface Water Sampling and Analysis Plan

*Surface water investigations are planned to be conducted contingent upon the presence of contaminants in sediments, alluvial groundwater, and deeper saturated zones. These investigations will focus on quantifying pathways for contaminant migration as part of the risk analysis. If contaminants are not identified in surface sediments, the surface water investigation will be limited in scope and coordinated with the Watershed Management Program Plan, which is currently under development. However, a detailed SAP is presented for surface water investigations if contaminants are found in surface sediments and investigation is deemed necessary. Surface water investigations will be considered for specific perennial reaches that warrant such investigations.*

*This section presents the SAP for investigating surface water in selected reaches in the Pajarito Canyon system. The strategy for sampling surface water in appropriate reaches (including streamflow and spring discharges) is described. To meet the objectives of the surface water investigation, three new streamflow gages and two evapotranspiration (ET) measurement stations are planned. Sampling and analysis of surface water in appropriate reaches is planned to characterize both the baseline surface water quality and the occurrence and extent of Laboratory-derived contaminants present in the surface water. Periodic measurements of water quantity and quality parameters are designed to take advantage of chemical and isotopic tracers to understand and quantify hydrologic processes.*

#### 7.3.1 Objective

*The objective of the surface water SAP is to address the HSWA Module (EPA 1990, 1585) requirements for characterizing the hydrogeology of the Pajarito Canyon watershed and to determine the Laboratory's impact on surface water. The surface water investigation is a component of characterizing the natural setting of the Laboratory as required by Task III (Facility Investigation) Section A (Environmental Setting) of the HSWA Module. These requirements are discussed in detail in Chapter 1 of the core document (LANL 1997, 55622). The surface water investigations address the presence of Laboratory-derived contaminants and will evaluate the present and future potential for off-site exposures and impacts extending along the entire canyon to the Rio Grande.*

*More specifically, the objectives of this plan are to clearly define*

- *the role of surface water in the potential transport of contaminants through selected reaches of the canyon system,*
- *all or relevant parts of the system's overall water budget,*
- *the role of surface water as a potential recharge source to underlying units, and*
- *the role of spring discharges from underlying hydrogeologic units.*

*The qualitative understanding of hydrologic interconnections as well as quantitative descriptions of process rates are necessary to evaluate the hydrologic and contaminant transport relationships pertinent to surface water within appropriate reaches of the Pajarito Canyon hydrogeologic system. Understanding the interactions between surface water and groundwater in different water-bearing zones within the* *canyon system is needed to optimize future environmental surveillance efforts. The integration of existing information and new data from planned field investigations will provide a basis for understanding if surface water contaminant concentrations, inventories, or spatial and temporal projections approach or exceed regulatory or administrative thresholds. If the results indicate unacceptable present-day or potential future risks, a corrective measures study would be required.*

*The SAP consists of three phases:*

1. *field investigation phase,*
2. *data analysis phase, and*
3. *developmental and refinement phase for the detailed conceptual model of the canyon hydrogeologic and geochemical system.*

*In conjunction with the field investigation and data analysis phases, the surface water investigations, if conducted, will be performed coincident with the groundwater investigations described in Section 7.4 to develop an integrated hydrogeologic conceptual model of the Pajarito Canyon system. The conceptual model is the basis for applying numerical computer models that simulate hydrologic processes and interactions of the surface water and groundwater. Geochemical interactions within the system will also be modeled as needed. These models will quantitatively describe the pertinent aspects of surface water within the Pajarito Canyon hydrogeologic system that address the three primary objectives described above.*

*The field investigation phase includes the following activities.*

- *Sample and analyze surface water at appropriate locations of the perennial stream reaches (including streamflow and spring discharges) to determine baseline water quality, the origin of the water (for example, contemporary precipitation, older groundwater, or Laboratory effluent), and characterize potential contaminants.*
- *Measure field parameters in water samples (pH, temperature, specific conductance, alkalinity, dissolved oxygen, and turbidity) to characterize general water quality variability.*
- *Collect surface water flow time-series data from permanently installed and continuous recording streamflow gaging stations and from discrete flow measurements (velocity, mixing ratios, dilution-depletion proportions, and dispersion parameters) obtained periodically at selected locations along the major and tributary stream courses.*
- *Measure flow at or near springs (where possible) seasonally during spring snowmelt runoff and during dry conditions for use in water-balance calculations.*
- *Collect data on latent heat energy flux from two stations instrumented for continuous simultaneous measurements of absolute humidity and vertical wind speed to be located at representative canyon-floor sites. Latent heat flux rates will be determined by application of the eddy correlation method. These data will be used to quantify ET for water-balance calculations.*

*The data analysis phase includes the following activities.*

- *Quantify surface runoff volumes and assess relative contributions from various runoff sources such as storm water, snowmelt, spring discharges, and Laboratory effluent discharges.*

- *Evaluate surface water infiltration losses into the alluvium and/or underlying formations.*
- *Quantify precipitation inputs to the canyon system watershed by analyzing historical weather data and recent data obtained from nearby meteorological stations operated by the Laboratory Air Quality group (ESH-17).*
- *Evaluate ET losses from the canyon system watershed by analyzing site-specific latent heat flux data from the two ET stations to be located on the canyon floor and from two meteorological stations located at nearby representative mesa-top sites (TA-6 and TA-54) operated by ESH-17.*
- *Prepare a surface water budget for the watershed.*
- *Evaluate the geochemistry of surface water samples.*
- *Evaluate the potential for hydraulic and mass transport of contaminants via surface water to off-site locations and also to underlying hydrogeologic units.*

*Further development and refinement of details of the conceptual model (described in Chapter 4 of this work plan) include the following activities.*

- *Integrate the results of surface water field investigations and data analyses with groundwater investigation results to more precisely describe the interconnections and interactions between hydrologic (surface water) and hydrogeologic (subsurface) components of the conceptual model.*
- *Validate and refine the conceptual model by synthesizing the results of field investigations and data analyses into an integrated flow-transport model (or models) that quantitatively describes and simulates interactions between surface water and groundwater within the Pajarito Canyon hydrogeologic system.*
- *Where necessary, use numeric simulations to describe present-day and project future concentrations and inventories at various potential receptor locations.*
- *Evaluate potential contaminant exposure pathways for present-day and projected future risks at potential receptor locations.*
- *Compare present-day exposures and projected future exposures at important receptor locations to evaluate the regulatory and administrative risk levels to identify contaminants that require remedial action.*

*After all three phases have been successfully completed, the Laboratory will satisfy the following requirements:*

- *hydrogeological and geochemical characterization of surface water in the Pajarito Canyon system;*
- *evaluation of historical, present, and future exposure risks associated with surface water in the Pajarito Canyon system; and*
- *detailed recommendations for a long-term environmental surveillance program plan that optimizes future surface water sample collection and the frequencies and locations of streamflow measurements.*

*The SAP is designed to be flexible, and the objectives and approaches will be refined and modified as new data are obtained. Revisions or refinements to the different components of the conceptual model (see Chapter 4 of this work plan) will be based on the integration of results from all components of the investigation as well as an integration and further interpretive analysis of data from other previous and ongoing Laboratory studies (as discussed in Chapter 2 and Chapter 3 of this work plan). Information gathered from implementing this work plan will also be used to focus geologic, geochemical, and hydrogeologic characterization efforts in future work plans for other canyon systems.*

### 7.3.2 General Approach for Surface Water Investigation

*This section describes the general approach for the surface water sampling and analysis portion of this chapter.*

**Issue**

*What is the nature and extent of contaminants in perennial surface water in the Pajarito Canyon system? What is the present-day risk posed by contaminants present in surface water in the Pajarito Canyon system? How will that risk change with time?*

**Approach**

*Determine if contaminants in surface water are at levels above the maximum contaminant levels (MCLs), New Mexico Water Quality Control Commission standards (1995, 54406), or UTLs for background or at levels exceeding other regulatory or administratively adopted levels that define unacceptable human health or ecological risks in appropriate land use scenarios. Additionally, other physical properties of surface water need to be understood, such as the following.*

- *Determine if there is a process or pathway for contaminant exposure.*
- *Determine the volume and extent of surface water flow in the Pajarito Canyon system.*
- *Determine which reaches exhibit perennial surface water flow.*
- *Determine the character (timing, flow volume, and location) of ephemeral and intermittent surface water flow in the canyon.*
- *Determine how much recharge to perched groundwater in the alluvium is provided by surface water infiltration.*
- *Determine how much surface water infiltrates into the subsurface through fractures associated with the Pajarito fault zone.*

*The following data will be collected to provide input to the decisions.*

- *Measurements of surface water quality parameters (including streamflow and spring discharges) and geochemical parameters and species (including indicators of natural or contaminant sources, temporal water quality variations, and a validated conceptual model of surface water geochemistry)*

- *Volumetric streamflow runoff information (both time-series and discrete data) at specific locations within the canyon system during representative maximum flow (spring snowmelt and summer storms) and minimum flow conditions*

- *Amounts of surface water infiltration within the Pajarito fault zone and within other discrete reaches defined by measurement station locations*

  – *Spring discharge volumes and temporal variability*

  – *Site-specific and/or representative precipitation and ET rates*

  – *Land use (and potential surface water use) scenarios*

  – *A validated conceptual model of the hydrologic system including a surface water budget*

*For initial planning use, the investigation will be limited to specific locations within boundaries established for the Pajarito Canyon investigation. Surface water samples will be collected at each identified spring discharge point and at permanent streamflow gage locations. In situ field measurements for volumetric flux and selected water quality parameters will be collected twice yearly throughout the first two years. Sampling events will be conducted four times, during annual high and low flow conditions, for two years, and chemical indicators sufficient to determine seasonal effects will be analyzed.*

*The interpretive investigation will be a major component of the investigation. Existing data for streamflow runoff, surface water quality, and meteorological parameters (precipitation and ET) including both published and unpublished archival data, will be integrated with the newly collected data, followed by conceptual and quantitative interpretation of the entire data set. Data necessary to evaluate potential impacts from contaminant transport within or outside the Laboratory boundary must provide adequate validation of water-balance assumptions, streambed infiltration characteristics, and geochemical transport properties to evaluate trends over time relative to present-day risks.*

*Data needed to evaluate the present-day human health risk will be collected as part of a single field investigation and should reflect high and low runoff conditions to establish appropriate ranges and uncertainties in source term distribution. Sufficient data will be collected to evaluate potential annual variations in separate elements of the risk assessment.*

*Because the field data will be collected during the first two years of the investigation, it is anticipated that the present-day human health risk assessment will be completed in the third year (see Chapter 6 of the core document [LANL 1997, 55622]).*

*Present-day human health risk assessments will include evaluation of surface water with the following assumptions.*

*Drinking water pathways*

- *Contaminants will be evaluated it they have concentrations above standards or UTLs for background or show trends (observed or predicted) in concentrations over time, which indicate that contaminants may exceed standards, UTLs, or other quantitative risk levels administratively adopted for remedial decisions in the future.*

*Livestock and wildlife watering pathways*

- *Appropriate state and other regulatory agency standards will be used to identify COPCs.*

*Plant uptake pathways*

- *Contaminants that exceed the limits noted above will be evaluated.*

*Additional data will be obtained if reduction in uncertainty of the data has the potential to change any risk-based decision. This process is discussed in detail in Chapter 6 of the core document (LANL 1996, 55622).*

### 7.3.3 Sampling and Analysis Plan for Surface Water Investigation

*The SAP for the surface water investigation follows the decision logic discussed in Chapter 5 of the core document (LANL 1997, 55622).*

*The following key hypotheses of the current conceptual model (discussed in Chapter 4 of this work plan) will be tested during the surface water investigation.*

- *Snowmelt and stormwater runoff are major sources of water input to the canyon system.*
- *PC Spring is a major contributor of groundwater to surface water in the upper reaches of the canyon system, supporting perennial streamflow extending from the spring downstream to the vicinity of the Pajarito fault near state road NM501 at the western Laboratory boundary. The major portion of this streamflow is lost before reaching the western Laboratory boundary and is hypothesized to infiltrate into the subsurface along joints and fractures associated with the Pajarito fault.*
- *Streamflow losses are primarily due to infiltration into the underlying alluvium.*
- *A substantial portion of the surface water budget in the Pajarito Canyon system is probably accounted for by ET losses. As much as 80% of the annual total precipitation within the canyon system's watershed may be lost to ET based on a recent water-balance investigation in Los Alamos Canyon (Gray 1997, 58208, p. 36).*
- *The springs that discharge from the Bandelier Tuff in upper Pajarito Canyon near the western Laboratory boundary may be fed by surface water infiltrating into the subsurface along joints and fractures associated with the Pajarito fault, which provides recharge to localized, preferential flowpaths through fractures and/or flow unit boundaries in units 3 and 4 of the Tshirege Member.*
- *The water discharged from PC Spring in upper Pajarito Canyon may be from a deeper, older groundwater system rather than derived from recent precipitation and runoff. This is suggested by a single water sample collected in 1993 (Blake et al. 1995, 49931) that showed nondetection for tritium. Therefore, the spring discharges and streamflow in the immediate downstream vicinity should be free of Laboratory-derived contaminants.*
- *Soluble HE compounds have been detected in surface water in middle Pajarito Canyon (at streamflow gage E245), in Threemile Canyon, and at TA-18 Spring and are hypothesized to be derived from source terms located within the Laboratory boundaries. Previous detection of HE*

*compounds in surface water in upper Pajarito Canyon west of the Laboratory boundary is suspected to be attributable to analytical error or sample cross-contamination.*

- *The canyon reach extending from the confluence with the south fork of Pajarito Canyon ("Starmer Gulch") downstream to near the confluence with Twomile Canyon may support perennial streamflow based on prior periodic but nonsystematic field observations.*
- *Storm water runoff from adjacent mesa tops and Laboratory facilities is a significant surface water pathway in the canyon system. This surface water component is an important mechanism for mobilizing nonpoint source contaminants (such as HE compounds and uranium) from the mesa tops into the canyon.*
- *Surface water flow and attendant sediment transport provides an important mechanism for moving contaminants in the Pajarito Canyon system. The lack of continuous perennial streamflow throughout the canyon system and historical records indicating minimal streamflow at the eastern Laboratory boundary (including gaged measurements since 1993) suggest that the potential is low for contaminant migration off-site as either dissolved species or in association with sediments transported by surface water.*
- *Intermittent flow from outfalls in the upper parts of Twomile Canyon and Threemile Canyon infiltrates into alluvial sediments and potentially mixes with alluvial groundwater, which is hypothesized to reemerge downstream as springs (for example, TW-1.72 Spring and possibly Threemile Spring).*
- *Streamflow in lower Pajarito Canyon depends on prior saturation conditions in the alluvium, with high saturation levels inhibiting streambed infiltration and promoting greater runoff versus unsaturated conditions that facilitate streambed infiltration and reduced streamflow.*
- *Some springs that discharge from channel sediments may result from alluvial underflow between channel reaches along perching layers in the alluvium.*

*Significant streamflow losses occur in the Pajarito Canyon system, as described in Section 3.6 in Chapter 3 of this work plan. For the period of record of available data, streamflow losses in lower Pajarito Canyon averaged 89% of the total flow measured at gaging station E245. During the 1997 water year, these losses totaled 99% of the flow at E245. However, the distribution of streamflow losses in the lower canyon reach is not known, which has important implications for potential infiltration of contaminants dissolved in surface runoff below the PRSs at TA-18. The distribution and magnitude of streamflow losses in upper Pajarito Canyon are poorly understood. Because gaging station E240 is located downstream from the Pajarito fault, the magnitude of infiltration losses into the fault zone is not known, but it is thought to be significant based on field observations. This information is important for quantifying the potential recharge source for the springs located in the upper canyon system, which in turn appear to supply much of the streamflow in this part of the canyon system. Except during peak snowmelt runoff, observed streamflow between gaging stations E240 and E245 does not appear to be continuous. Most of the flow at E245 is apparently supported by upstream spring discharges of an unknown magnitude. Therefore, the extent of streambed infiltration losses in upper Pajarito Canyon between the spring sources and gage E245 is currently not quantified. These streamflow losses could represent a significant pathway into the subsurface for soluble contaminants previously detected in surface runoff, such as tritium and HE compounds.*

*The general approach to the surface water investigation, if contaminants are present in surface sediments and alluvial groundwater, will be to collect new field data and extend existing interpretations as necessary to establish adequate confidence in the upper limits of the risk estimates or to clarify surface water* *occurrence and geochemical and transport processes sufficiently to meet the requirements of the HSWA Module for continued surface water monitoring (EPA 1990, 1585).*

- *Data collected in this surface water investigation will be integrated with data from other previous and ongoing Laboratory studies, such as the activities described in the Groundwater Protection Management Program Plan (LANL 1995, 50124) and the Watershed Management Program Plan, which is currently under development, to improve the understanding of the surface water hydrology of the Pajarito Plateau.*

- *Investigations of surface water will focus on determining (1) the nature and extent of surface water contaminants; (2) the magnitude, distribution, and temporal characteristics of streamflow in specific reaches of the canyon system; (3) the magnitude and distribution of infiltration losses from streamflow; (4) the possible hydrologic connectivity between surface runoff in the upper canyon reaches and spring discharges further downstream; and (5) the significance of the surface water component of the canyon's water budget and its role in facilitating contaminant mobilization and migration into the subsurface.*

- *If conducted, water-balance studies for the Pajarito Canyon watershed will be performed by the Canyons Focus Area technical team with technical input from the personnel in the Laboratory Water Quality and Hydrology group (ESH-18) and the Watershed Management Protection Plan team concurrently with the other investigations described herein. The water-balance studies may include a variety of data collection methods including techniques employing measurement of natural tracers, the existing and planned streamflow gaging stations, and the two planned ET stations along with meteorological data collected by ESH-17 personnel. These studies will define and quantify the magnitude of water infiltration into the subsurface, which is a critical component of the water budget.*

- *Recommendations will be made regarding corrective measures to alleviate any significant surface water contaminants and monitoring strategies for the ER Project and/or the Laboratory environmental surveillance program.*

#### 7.3.3.1 Surface Water Flow Measurements

*Surface water flow measurement will be made by a comprehensive investigation of appropriate reaches employing several proven methodologies including continuous data recording at permanent flow gaging stations, periodic in situ field measurements of flow and related parameters, and possibly tracer techniques.*

**Surface Water Gaging Techniques**

*Three new stream gaging stations are planned:*

- *gage E239 will be located in upper Pajarito Canyon downstream from PC Spring and upstream from the Pajarito fault, approximately 2000 ft (610 m) west of state road NM501;*

- *gage E242 will be located in upper Pajarito Canyon a short distance downstream from the confluence with north Anchor East basin ("Arroyo de LaDelfe"); and*

- *gage E247 will be located at or near a culvert, which runs beneath the access road to TA-18 immediately downstream of the TA-18 facilities.*

*The planned new streamflow gaging stations are listed in Table 7.3.3-1. Locations of the existing and planned gaging stations are shown in Figure 7.3.3-1. A brief discussion of the data applications and rationale for each new gaging station follows.*

**TABLE 7.3.3-1**

**PLANNED SURFACE WATER GAGING STATIONS AND ET STATIONS**

| Designation[a] | Description[b] |
|---|---|
| *E239* | *Planned permanent station for flow gaging, sampling, possible use for tracer introduction, and water quality parameter measurement with continuous data recording capability. To be located approximately 2000 ft (610 m) west of state road NM501 downstream from PC Spring and upstream from the Pajarito fault* |
| *E242* | *Planned permanent station for flow gaging, sampling, possible use for tracer introduction, and water quality parameter measurement with continuous data recording capability. To be located downstream from the confluence with north East Anchor basin ("Arroyo de LaDelfe")* |
| *E247* | *Planned permanent station for flow gaging, sampling, possible use for tracer introduction, and water quality parameter measurement with continuous data recording capability. To be located at the culvert beneath the access road near the east boundary of TA-18* |
| *PCET-1* | *Planned ET station in upper Pajarito Canyon (mounted on a tower at a height of approximately 33 ft [10 m])[c]* |
| *PCET-2* | *Planned ET station in middle or lower Pajarito Canyon[c]* |

*a. PC = Pajarito Canyon, ET = evapotranspiration measurement station*

*b. See Figure 7.3.3-1 for planned locations.*

*c. Planned ET station locations are tentative, pending field reconnaissance of site suitability.*

*Streamflow at planned gaging station E239 and existing gaging station E240 will be measured to determine the amount of flow loss by infiltration into the subsurface within the Pajarito fault zone, which is thought to be a significant source of groundwater recharge. Streamflow at planned gaging station E242 will be measured to determine the amount of surface water flow immediately downstream from multiple spring discharges in the south fork of Pajarito Canyon ("Starmer Gulch") and the north Anchor East basin ("Arroyo de LaDelfe"), which may support perennial flow in this area. Comparison of the data from stations E240 and E242 will quantify streamflow gains and losses in the intervening reach, which provides information necessary for water-balance analyses in this portion of upper Pajarito Canyon. Flow measurements will be made at each spring (where possible) at the times of semiannual sampling to quantify their contributions to surface water flow and their seasonal variability, which further refines the water-balance analysis. Streamflow measurements at existing gaging stations E245 and E250 and at planned gaging station E247 will likewise provide information on runoff and infiltration rates for use in water-balance analyses in the middle and lower reaches of Pajarito Canyon, including determination of surface flow contributions from Twomile Canyon and Threemile Canyon.*

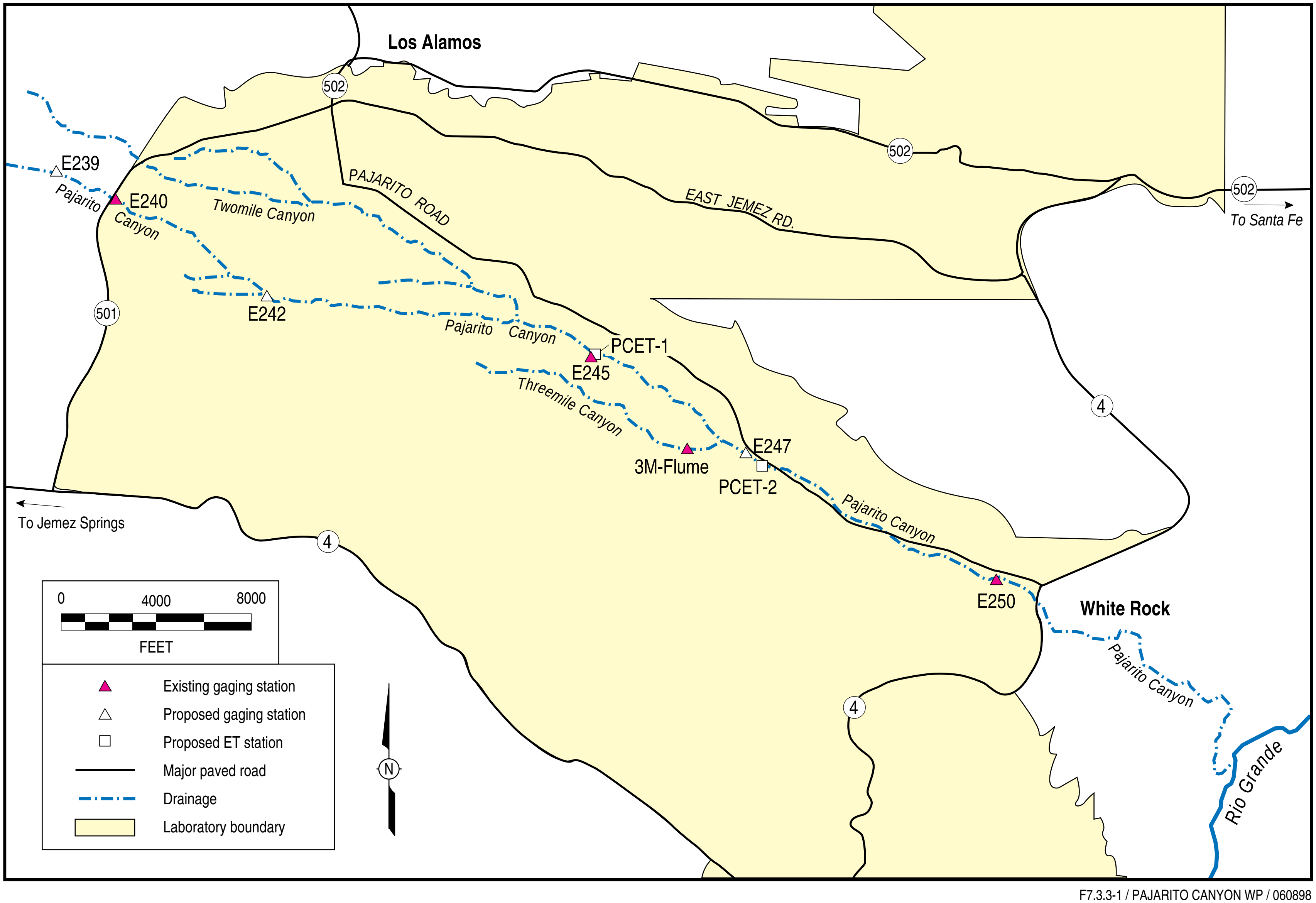


**Figure 7.3.3-1. Locations of existing and proposed gaging stations and proposed evapotranspiration stations in Pajarito Canyon.**

*Additional streamflow information will be obtained from seepage run measurements that will be made during significant runoff events (for example, spring snowmelt). Flow measurements using a portable current meter will be made at multiple locations spaced approximately 0.5 mile (0.8 km) apart in the reaches between the permanent gaging stations. The measurements will be completed in a single day per analyzed event. These data, in combination with data from the permanent gaging stations, will provide detailed data to identify and quantify stream loss or gain in the canyon system at discrete times (assuming simultaneous measurements) during short intense runoff conditions. Preferably, one snowmelt runoff event and one summer storm runoff event will be measured. Because significant storm runoff events are more difficult to predict, logistical planning may alternately require that two snowmelt events be measured.*

**Tracer Methods**

*If determined necessary to characterize contaminants in the canyon system, flow measurements using tracer methods may be conducted periodically (seasonally or in response to major runoff events) at selected locations. Flow measurements using tracer methods may be conducted to help determine spring volume discharges, amounts of surface water loss, locations of channel return flow, and surface flow parameters including velocity, dispersion, and mixing or depletion. Tracer-based flow measurements may be made at each spring (where possible) at the times of semiannual sampling to quantify contributions to surface water flow and seasonal variability of each spring, further refining the water-balance investigation.*

*Introduced tracers may be used for measuring surface water channel flow parameters such as flow velocity, dispersion, dilution, as well as depletion or addition of water to the system by physical, biological, and geochemical processes. The introduction of tracers may be planned to occur at specific locations, such as gaging stations. Different tracers may be introduced at different locations in the canyon system to determine flow paths and contributions to downgradient water from different locations. Collection and analysis of water samples for the appearance of the tracers will be made periodically in conjunction with planned surface water and groundwater investigations.*

#### 7.3.3.2 Evapotranspiration Measurements

*If a water-balance investigation is conducted, based on the presence of contaminants in surface sediments, surface water, and/or groundwater, measurements will be obtained to determine ET parameters. The measurement of ET is included in the surface water SAP because ET is a significant component of the overall water budget. ET is typically the most difficult water-balance parameter to measure, even indirectly. Data directly relevant to the determination of this parameter are currently available from two existing continuously recording meteorological stations (operated by ESH-17), which are located on mesa-top sites at TA-6 and TA-54). These stations are equipped with instrumentation located 10 m (33 ft) above ground level to measure absolute humidity and vertical wind speed. The upward flux of latent evaporative heat within the atmosphere is then determined through the application of the eddy correlation method. ET amounts can be computed by dividing the latent heat flux rates by the latent heat of evaporation.*

*Two additional solar-powered ET stations using this technology are currently located at sites on the floor of Mortandad Canyon, with instrumentation mounted 2 m (6.6 ft) above ground level. ESH-18 personnel installed these stations to characterize ET rates specific to the environment on the floor of Mortandad Canyon. ET rates on the floor of the canyon are thought to differ significantly from the mesa-top sites because of denser vegetation and generally wetter conditions. Operational difficulties have precluded accurate data collection from the Mortandad Canyon stations (the solar panels were not situated properly to maintain continuous power to the instruments), and they are currently inactive pending relocation to sites with favorable solar exposure.*

*The installation of two new continuous recording ET stations is being considered in Pajarito Canyon to quantify ET amounts in the Pajarito Canyon site-specific canyon-floor environment. The planned new ET stations are listed in Table 7.3.3-1, and their tentative locations are shown in Figure 7.3.3-1. A brief discussion of the data applications and rationale for the new ET stations follows.*

*One proposed ET station (PCET-1) will be located in middle Pajarito Canyon in an area representative of the more heavily vegetated and wooded parts of the canyon. The instruments at this station will be tower-mounted at a height of approximately 10 m (33 ft) or at whatever height is necessary where the transpiration from the trees can be measured. This station will provide data to ensure that the transpiration component from treetops will be included in the measurements.*

*Another proposed ET station (PCET-2) will be located in middle or lower Pajarito Canyon at a height of 2 m (6.6 ft) in an area representative of an open canyon-floor setting with ground cover vegetation (grasses and forbs). This station will provide data representative of the open canyon-floor environment typical of lower Pajarito Canyon. The data from these two stations can then be extrapolated throughout the canyon based on aerial photograph analysis of vegetative cover. The currently proposed locations are tentative, subject to site accessibility and other logistical considerations.*

*These data will allow an assessment of ET rates for differing site-specific environments on the canyon floor that, in combination with representative ET data from the adjacent mesa-top stations operated by ESH-17, will enable quantification of this component of the canyon's surface water budget. This information is important for quantifying the water balance for the canyon watershed because ET is the predominant component of the water budget for surface water.*

### 7.3.4 Surface Water Sampling and Analysis

*The HSWA Module (EPA 1990, 1585) requires that this work plan include an investigation of the potential for transport of contaminants within canyon watersheds. Because surface water is a primary mechanism for contaminant mobilization in Pajarito Canyon system, chemical analyses of surface water samples are necessary to address this requirement. This section describes the sampling design for collecting surface water samples. The methods for sample collection and for chemical and radiochemical analyses are also provided in this section.*

#### 7.3.4.1 Surface Water Sampling

*All surface water samples will be collected and handled in accordance with the most recent revision of the appropriate ER Project SOP (LANL-ER-SOP-06.13, "Surface Water Sampling").*

*Surface water samples will be collected during two different snowmelt events at four of the permanent gaging stations. The sampling will be timed to occur during approximate peak flow conditions, which will be determined from analysis of the appropriate gaging station records. The following stations have been designated as sampling locations; the sampling rationale for each location is also included.*

- *E240 to provide baseline samples upstream from the Laboratory boundary,*
- *E242 or E245 (depending on flow conditions) to determine possible impacts from PRSs and nonpoint sources within the Laboratory boundaries in upper and middle Pajarito Canyon and on the adjacent mesa tops,*

- *E247 to assess possible impacts from PRSs and nonpoint sources at TA-18, and*
- *E250 to determine possible impacts in lower Pajarito Canyon from MDA G and MDA L at TA-54.*

*Surface water samples may also be collected during two separate summer storm events at four gaging stations selected similarly. At each station samples will be collected at five discrete time intervals spaced approximately 15 to 30 min apart. The time series sampling will be undertaken to increase the probability that samples are collected during maximum flow conditions. The actual time of maximum flow at each sampling location will be determined from the gaging station records. These data will be used to assess the impact of storm flow conditions on contaminant mobility via suspended sediment transport by comparing the results from filtered and unfiltered samples collected before, during, and after the streamflow hydrograph peak at each location for each event. Additionally, all identified springs will be sampled (if flowing) semiannually, once during low flow conditions and once during high flow conditions each year for a period of two years.*

*Samples will be collected in the middle of the stream to provide representative surface water chemical data for each reach. Spring samples will be collected as close to the discharge point as possible to identify the groundwater source chemistry. Duplicate surface water samples will be collected at each site, and one sample will be filtered (to remove particulates larger than 0.45 μm) before preservation, whereas the other sample will remain unfiltered. Comparison of these data will permit an evaluation of chemical concentrations in solution versus. constituents adsorbed onto suspended particulate matter.*

*Table 7.3.4-1 summarizes the collection design for surface water samples.*

**TABLE 7.3.4-1**

**SUMMARY OF COLLECTION DESIGN FOR SURFACE WATER SAMPLES**

| Sample Type | No. of Sites | Sampling Frequency | Annual No. of Samples |
|---|---|---|---|
| *Surface water (streamflow)* | *4* | *During snowmelt and summer storm runoff events*[a] | *96 (48 filtered, 48 unfiltered)* |
| *Surface water (springs)* | *10*[b] | *Two times per year at six-month intervals for two years* | *80 (40 filtered, 40 unfiltered)* |

*a. If surface water is present, samples will be collected during two snowmelt runoff events (one sample at each location for each event) and during two summer storm runoff events (five samples collected at 15- to 30-min intervals at each location for each event) (see Section 7.3.4.1). Numbers of samples are the maximum that will be collected if water is available.*

*b. Although a total of 20 springs have been identified within the Pajarito Canyon watershed (see Table 3.6.2-1), the number of sites given here is the estimated average number of semiannual samples assuming that not every spring would be flowing at each sampling event and that some springs are identified as multiple discharges from the same source.*

#### 7.3.4.2 Analysis of Surface Water Samples

*This section describes the methods for analyzing surface water samples for inorganic and organic chemicals, radionuclides, and radiogenic and stable isotopes. The analysis of surface water samples has three purposes: (1) to detect and measure Laboratory-derived COPCs, (2) to obtain information about the natural geochemistry of surface water within the Pajarito Canyon watershed, and (3) to assess potential recharge sources for spring discharges, thus identifying potential groundwater flow paths and mixing scenarios.*

*Specific conductance, turbidity, pH, temperature, dissolved oxygen, and alkalinity will be measured in the field at the time of water sampling. Each sample will be analyzed for the parameters listed in Table 7.3.4-2. Where appropriate, these data will be combined with analyses of unfiltered samples collected either by ER Project personnel or for environmental monitoring by ESH-18 personnel to reduce uncertainty in the distributions of surface water quality for contaminant transport and risk model inputs.*

**TABLE 7.3.4-2**

**ANALYTICAL SUITE FOR SURFACE WATER SAMPLES**[a]

| | | |
|---|---|---|
| **Field-Measured Parameters** | | |
| *Alkalinity* | *pH* | *Temperature* |
| *Dissolved oxygen* | *Specific conductance* | *Turbidity* |
| **Major and Minor Ions** | | |
| *Aluminum* | *Fluoride* | *Phosphate* |
| *Ammonium* | *Iron* | *Potassium* |
| *Bromide* | *Magnesium* | *Sodium* |
| *Calcium* | *Manganese* | *Sulfate* |
| *Chlorate* | *Nitrate* | |
| *Chloride* | *Nitrite* | |
| **Trace Elements** | | |
| *Aluminum* | *Chromium* | *Silver* |
| *Antimony* | *Cobalt* | *Thallium* |
| *Arsenic* | *Copper* | *Titanium* |
| *Barium* | *Lead* | *Uranium* |
| *Beryllium* | *Mercury* | *Vanadium* |
| *Boron* | *Nickel* | *Zinc* |
| *Cadmium* | *Selenium* | |
| **Organic Chemicals** | | |
| *TOC* | | |
| *HE* | | |
| **Dissolved Organic Carbon (fractionation analysis)** | | |
| **Total Suspended Solids** | | |
| **Total Dissolved Solids** | | |
| **Neutral Species ($SiO_2$)** | | |
| **Hardness** | | |
| **Cyanide** | | |
| **Radionuclides** | | |
| *Americium-241* | *Strontium-90* | *Uranium-238* |
| *Cesium-137* | *Uranium-234* | *Gamma spectroscopy* |
| *Plutonium-238* | *Uranium-235* | *Gross-alpha, -beta, and -gamma* |
| *Plutonium-239,240* | *Uranium-236* | *Tritium*[b] |

*a. Filtered (<0.45 μm) and unfiltered water samples will be analyzed.*

*b. Low detection limit (1 pCi/L)*

**Analytical Methods**

*Surface water samples collected according to the strategy outlined in Section 7.3.4.1 will initially undergo full-suite analyses for organic and inorganic chemicals and radionuclides at ER Project-approved fixed-site laboratories. The analytical suites for analysis of organic and inorganic chemicals and radionuclides are listed in Table 7.3.4-2. All analyses for organic chemicals will be performed in accordance with EPA SW-846 protocols (EPA 1987, 57589). The detailed analyte lists, EQLs, minimum detectable activities, required QC procedures, and the acceptance criteria are found in the 1995 ER Project analytical services statement of work (LANL 1995, 49738) or the version that is current when this work plan is implemented. The first sample collected from each surface water sampling location will undergo analysis for the full suite of organic and inorganic chemicals and radionuclides. If organic chemicals are identified as COPCs for a particular sampling location, all subsequent samples from that location will be analyzed for organic COPCs. Any organic compound reported as not detected will be excluded from subsequent limited-suite analyses.*

*All water samples will be analyzed for inorganic chemicals to identify COPCs and to obtain a better understanding of the baseline geochemistry of surface water in Pajarito Canyon. The target analytes, conservative EDLs, and analytical methods for inorganic chemicals are listed in Table 7.3.4-3. Measurements for inorganic chemicals include analyses for 26 trace metals; major anions (chloride, fluoride, nitrate, sulfate, and field alkalinity); minor anions (bromide, chlorate, nitrite, and orthophosphate); dissolved silica; and total cyanide. All analyses for inorganic chemicals will be performed in accordance with EPA SW-846 protocols (EPA 1987, 57589), EPA standard methods (EPA 1983, 56406), or standard methods for chemical analysis of water (Franson 1995, 56405). The required QC procedures and acceptance criteria for the metals and total cyanide analyses are found in the 1995 ER Project analytical services statement of work (LANL 1995, 49738) or the version that is current when this work plan is implemented.*

*The target analytes and their half-lives, detected emission, minimum detectable activities, and analytical methods for radionuclides are listed in Table 7.3.4-4. In addition to measurements of gross-alpha, -beta, and -gamma radioactivity, the radionuclide analytes include americium-241; plutonium-238; plutonium-239,240; strontium-90; tritium; uranium-234; uranium-235; uranium-236; and uranium-238*

*The ER Project analyte list for the gamma spectroscopy analysis (see Table 7.2.5-5) includes the decay series of the naturally occurring radionuclides thorium-232, uranium-235, and uranium-238 as well as fission and activation products and their progeny. Measurements of naturally occurring radionuclides known to be present in Laboratory soils provide an indication of the quality of the gamma spectroscopy measurement. Radionuclides with half-lives less than 365 days are not considered to be COPCs. Data for these short-lived radionuclides can be useful when evaluating values reported for a parent radionuclide because the relative activity concentration of parent and daughter isotopes is a known quantity. The shorter-lived radionuclides are usually included in the analyte list to verify the presence of longer-lived parent isotopes, but they are not evaluated as primary radionuclides because they decay to unmeasurable concentrations within the span of several years or less. The naturally occurring radionuclide potassium-40 is present in Laboratory soils at concentrations ranging from 25 to 40 pCi/g and is always present in the gamma spectra of Laboratory soil samples. The potassium-40 gamma emission peak provides a qualitative indicator of the accuracy and precision of the gamma spectroscopy measurement, but potassium-40 is not considered to be a potential contaminant. The required QC procedures and acceptance criteria for the radiochemical analyses (except low-level tritium and uranium-236) are found in the 1995 ER Project analytical services statement of work (LANL 1995, 49738) or the version that is current when this work plan is implemented.*

## TABLE 7.3.4-3

## ESTIMATED DETECTION LIMITS AND ANALYTICAL METHODS FOR INORGANIC CHEMICALS IN SURFACE WATER SAMPLES[a]

| Analyte | EDL (µg/L) | Analytical Method | Analytical Protocol[b] |
|---|---|---|---|
| **Metals (total and dissolved)** | | | |
| *Aluminum* | *10* | *ICPES* | *SW-6010B* |
| *Ammonium* | *20* | *IC* | *SW-9056* |
| *Antimony* | *0.1* | *ICPMS* | *SW-6020* |
| *Arsenic* | *1* | *ETVAA* | *SW-7060A* |
| *Barium* | *2* | *ICPES* | *SW-6010B* |
| *Beryllium* | *5* | *ICPES* | *SW-6010B* |
| *Boron* | *10* | *ICPES* | *SW-6010B* |
| *Cadmium* | *1* | *ICPMS* | *SW-6020* |
| *Calcium* | *10* | *ICPES* | *SW-6010B* |
| *Chromium* | *2* | *ICPES* | *SW-6010B* |
| *Cobalt* | *2* | *ICPES* | *SW-6010B* |
| *Copper* | *2* | *ICPES* | *SW-6010B* |
| *Iron* | *10* | *ICPES* | *SW-6010B* |
| *Lead* | *3* | *ETVAA or ICPMS* | *SW-7421 or SW-6020* |
| *Magnesium* | *10* | *ICPES* | *SW-6010B* |
| *Manganese* | *2* | *ICPES* | *SW-6010B* |
| *Mercury* | *0.2* | *CVAA* | *SW-7470A* |
| *Nickel* | *2* | *ICPES* | *SW-6010B* |
| *Potassium* | *10* | *ICPES* | *SW-6010B* |
| *Selenium* | *0.2* | *ETVAA* | *SW-7740* |
| *Silver* | *0.2* | *ICPES* | *SW-6010B* |
| *Sodium* | *50* | *ICPES* | *SW-6010B* |
| *Thallium* | *2* | *ICPMS* | *SW-6020* |
| *Titanium* | *2* | *ICPES* | *SW-6010B* |
| *Uranium* | *1* | *ICPMS or KPA*[c] | *SW-6020* |
| *Vanadium* | *2* | *ICPES* | *SW-6010B* |
| *Zinc* | *10* | *ICPES* | *SW-6010B* |
| **Anions (dissolved)** | | | |
| *Bromide* | *20* | *IC* | *SW-9056* |
| *Chlorate* | *20* | *IC* | *SW-9056* |
| *Chloride* | *20* | *IC* | *SW-9056* |
| *Fluoride* | *20* | *IC* | *SW-9056* |
| *Nitrate* | *40* | *IC* | *SW-9056* |
| *Nitrite* | *40* | *IC* | *SW-9056* |
| *Orthophosphate* | *20* | *IC* | *SW-9056* |
| *Sulfate* | *100* | *IC* | *SW-9056* |
| **Other Inorganic Chemicals (dissolved)** | | | |
| *Silica* | *200* | *Colorimetry* | *EPA Method 370.1* |
| *Total cyanide* | *50* | *Colorimetry* | *SW-9012A* |

*a. Both unfiltered (total) and filtered (dissolved) water samples will be collected. Water samples will be filtered at the time of collection to remove particles larger than 0.45 µm.*

*b. EPA SW-846 Method (EPA 1987, 57589) or equivalent*

*c. KPA = kinetic phosphorametric analysis*

**TABLE 7.3.4-4**

**MINIMUM DETECTABLE ACTIVITY AND ANALYTICAL METHODS FOR RADIONUCLIDES IN SURFACE WATER SAMPLES[a]**

| Analyte | Half-Life (yr) | Detected Emission | Minimum Detectable Activity (pCi/L) | Analytical Method |
|---|---|---|---|---|
| *Americium-241* | *432.2* | α | *0.05* | *α-Spectrometry* |
| *Plutonium-238* | *87.7* | α | *0.05* | *α-Spectrometry* |
| *Plutonium-239,240[b]* | *2.411 x $10^4$* | α | *0.05* | *α-Spectrometry* |
| *Strontium-90* | *28.7* | β | *1.0* | *GPC* |
| *Tritium* | *12.3* | β | *250* | *LSC* |
| *Tritium (low level)* | *12.3* | β | *1* | *Electrolytic enrichment/GPC* |
| *Uranium-234* | *2.46 x $10^5$* | α | *0.1* | *α-Spectrometry[c]* |
| *Uranium-235* | *7.04 x $10^8$* | α | *0.1* | *α-Spectrometry[c]* |
| *Uranium-236* | *2.342 x $10^7$* | α | *0.1* | *TIMS* |
| *Uranium-238* | *4.47 x $10^9$* | α | *0.1* | *α-Spectrometry[c]* |
| *Gamma spectroscopy[e]* | *N/A[f]* | γ | *10[g]* | *γ-Spectroscopy* |
| *Gross-alpha* | *N/A* | α | *1.0* | *GPC or LSC* |
| *Gross-beta* | *N/A* | β | *1.0* | *GPC or LSC* |
| *Gross-gamma* | *N/A* | γ | *20* | *NaI(Tl) or HPGe detection* |

*a. All water samples will be filtered at the time of collection to remove particles larger than 0.45 µm.*

*b. The plutonium-239 and plutonium-240 isotopes cannot be distinguished by alpha spectrometry. The half-life of plutonium-239 is given.*

*c. Radionuclide may also be analyzed by ICPMS.*

*d. Water sampling for uranium-236 analysis should use clean protocols including EPA 1669 or United States Geological Survey 94-539*

*e. The gamma spectroscopy analyte list is given in Table 7.2.6-5.*

*f. N/A = not applicable*

*g. The minimum detectable activity for cesium-137 is 1.0 pCi/L; the minimum detectable activities for other analytes will vary.*

*Surface water samples will also be analyzed for the additional parameters listed in Table 7.3.4-5. Analysis for stable isotope ratios of deuterium/hydrogen and oxygen-18/oxygen-16 will be performed only on the spring samples to characterize their water chemistry with regard to these constituents and permit assessment of potential recharge sources. Analyses for carbon-13 and dissolved organic carbon (humic acids by fractionation analysis) will be performed to provide a better understanding of the organic geochemistry of the surface water.*

*Table 7.3.4-6 lists the field measurements that will be made at the time of sample collection.*

**TABLE 7.3.4-5**

**ANALYTICAL METHODS FOR ADDITIONAL PARAMETERS IN SURFACE WATER SAMPLES[a]**

| Analyte | Analytical Method |
|---|---|
| **Stable and Radiogenic Isotopes[b]** | |
| *Deuterium/hydrogen* | *Accelerator MS* |
| *Oxygen-18/oxygen-16* | *MS* |
| **Organic Chemicals** | |
| *SVOCs* | *SW-8270* |
| *HE* | *EPA Method 8330 (high-performance liquid chromatography)[c]* |
| **Other Analytes** | |
| *Total organic carbon* | *SW-415.1[d]* |
| *Dissolved organic carbon (humic substances)* | *USGS/WRI 79-4* |
| *Hardness (as calcium carbonate)* | *EPA Method 130* |

*a. All water samples will be filtered at the time of collection to remove particles larger than 0.45 µm.*
*b. Stable and radiogenic isotopes will be measured in spring samples only.*
*c. EPA SW-846 Methods (EPA 1987, 57589)*
*d. EPA 1983, 56406*

**TABLE 7.3.4-6**

**FIELD MEASUREMENTS FOR SURFACE WATER SAMPLES**

| Measurement | Precision[a] | Method |
|---|---|---|
| *Alkalinity* | *±1 mg/L calcium carbonate* | *EPA Method 310.1* |
| *Dissolved oxygen* | *±0.1 mg/L* | *LANL-ER-SOP-06.02[b]* |
| *pH* | *±0.02* | *LANL-ER-SOP-06.02* |
| *Specific conductance* | *±1 mmho/cm (µS/cm)* | *LANL-ER-SOP-06.02* |
| *Temperature* | *±1 °C* | *LANL-ER-SOP-06.02* |
| *Turbidity (nephelometric)* | *±1 NTU* | *EPA Method 180.1* |

*a. Precision with which measurement will be recorded*
*b. ER Project SOP*

## 7.4 Groundwater Sampling and Analysis Plan

*This section presents the SAP for investigating groundwater in the Pajarito Canyon system. The strategy for sampling alluvial groundwater, intermediate groundwater zones, if encountered, and the regional aquifer is described. Borehole cores will also be sampled and analyzed to determine the baseline and contaminant geochemistry and hydraulic properties of water-bearing zones. To meet the objectives of the groundwater investigation, 18 wells are planned: 12 alluvial wells, and 6 regional aquifer wells.*

*The regional aquifer wells are being drilled as part of the Groundwater Protection Management Program Plan (LANL 1995, 50124), a Laboratory program to characterize the hydrogeology of the Pajarito Plateau by installing a Laboratory-wide groundwater monitoring network. The regional aquifer wells are being* *installed as part of a cooperative effort between Laboratory Defense Programs and the ER Project; the planning for these wells is described in the Hydrogeologic Workplan (LANL 1996, 55430). Five of the regional aquifer wells are planned to be installed by the ER Project to characterize potential contaminants in perched groundwater systems and the regional aquifer. One regional aquifer well is planned to be installed by Defense Programs to satisfy hydrogeological characterization goals of the Hydrogeologic Workplan.*

*Sampling and analysis of groundwater will focus on characterizing the hydrogeology of the Pajarito Canyon system as well as characterizing the nature of Laboratory-derived contaminants present in groundwater.*

### 7.4.1 Objective

*The objective of the groundwater SAP is to address the HSWA Module (EPA 1990, 1585) requirements for characterizing the hydrogeology of the Pajarito Canyon system to determine the potential impact on groundwater by the Laboratory. These requirements are discussed in detail in Chapter 1 of the core document (LANL 1997, 55622). The groundwater investigations address the presence of Laboratory-derived contaminants and will evaluate present and future potential off-site exposures and impacts extending along the entire canyon to the Rio Grande, which result from interactions between surface water and groundwater in different water-bearing zones.*

*The SAP consists of three phases:*

1. *field investigation phase,*
2. *data analysis phase, and*
3. *developmental and refinement phase for the detailed conceptual model of the canyon's hydrogeological and geochemical system.*

*The execution of each phase will interface with each of the other phases in an iterative fashion until all phases have successfully merged into conceptual models that describe the hydraulic and contaminant mass transport relationships between surface water and groundwater. An important objective of the plan is to evaluate the interactions between surface water and groundwater in different water-bearing zones within the canyon system so that future environmental surveillance efforts can be optimized. A corrective measures study may be identified during the field investigation. This study would be implemented after the field investigation phase is completed and data have been evaluated.*

*The field investigation phase includes the following activities.*

- *Sample and analyze alluvial, intermediate perched zone (if present), and regional aquifer groundwater to characterize nature and extent of the water and of any contaminants that are present.*
- *Collect water level time-series data from each groundwater zone; measure field parameters in water samples (pH, temperature, specific conductance, alkalinity, dissolved oxygen, and turbidity).*
- *Collect hydrogeologic data to characterize the vadose zone and other hydrologic zones.*

*The data analysis phase includes the following activities.*

- *Evaluate surface water infiltration losses into the alluvium.*
- *Measure infiltration into bedrock units.*
- *Compare and contrast (through geochemical modeling and analysis) the geochemistry of all water samples.*
- *Evaluate the potential for hydraulic and mass transport among all water-bearing zones.*

*Development of a detailed conceptual model includes the following activities*

- *Validate and refine the conceptual model by integrating the results of field investigations and data analyses into a flow-transport model(s).*
- *Evaluate present-day and future exposure at various locations.*
- *Evaluate potential contaminant migration pathways and future concentrations.*
- *Identify contaminant problems that may require remediation.*

*After all three phases have been successfully completed, the Laboratory will satisfy the following requirements:*

- *hydrogeological and geochemical characterization of the Pajarito Canyon system;*
- *evaluation of historical, present, and future exposure risks; and*
- *detailed recommendations for a long-term environmental surveillance program plan that optimizes future environmental surveillance of the canyon, primarily water sample collection and the frequencies and locations of water level measurements.*

*The SAP is designed to be flexible, and the objectives and approaches will be refined and modified as new data are obtained. Revisions or refinements to the different components of the conceptual model (see Chapter 4 of this work plan) will be based on the integration of results from all components of the investigation as well as an integration and further interpretive analysis of data from other previous and ongoing Laboratory studies (as discussed in Chapter 2 and Chapter 3 of this work plan). Information gathered from implementing this work plan will also be used to focus geologic, geochemical, and hydrogeologic characterization efforts in future work plans for other canyon systems.*

### 7.4.2 General Approach for Groundwater Investigation

#### 7.4.2.1 Alluvial Groundwater General Approach

*This section describes the general approach for the groundwater sampling and analysis portion of this chapter.*

**Issue**

*What is the present-day risk posed by contaminants in the alluvial groundwater in Pajarito Canyon? How will that risk change with time?*

**Approach**

*Determine if contaminants are present at levels above the MCLs, New Mexico Water Quality Control Commission standards (1995, 54406), EPA standards, or UTLs for background or at levels that pose unacceptable human health or ecological risks in appropriate land use scenarios. Additionally, other physical properties of alluvial groundwater need to be understood, such as*

- *the flux of groundwater moving through the alluvium in upper, middle, and lower Pajarito Canyon;*
- *the areal extent of groundwater in the alluvium;*
- *the source of springs and alluvial groundwater in Threemile Canyon; and*
- *if there is a process or pathway for exposure.*

*The following data will be collected to provide input to the decisions.*

- *Analyses of core and/or water samples for geochemical parameters and species, including contaminant indicators, temporal water quality variations, and a validated conceptual model of groundwater geochemistry*
- *Infiltration rates of surface water and alluvial groundwater*
- *Moisture content/saturation, water levels, saturated thickness, and temporal variations in the alluvium and possible perched zones in the Bandelier Tuff*
- *Hydrologic properties, geologic structure, hydraulic gradients and predicted flow directions, land use scenarios, spring discharge information, current and planned well-withdrawal points, and a validated conceptual model of the hydrologic system*

*For initial planning use, the study will be limited by the boundaries of the Pajarito Canyon investigation. Semiannual sampling events will be conducted approximately six months apart for two years, and chemical indicators sufficient to determine seasonal effects will be analyzed. Sampling of the background alluvial well will be conducted semiannually for two years to determine background conditions.*

*The interpretive study will be a major component of the investigation because of the amount of existing data, including both published and unpublished archival data, to be integrated and interpreted conceptually and quantitatively. Data needed to evaluate potential impacts from contaminant transport within or outside the Laboratory boundary must provide adequate validation of models of saturated zone and geochemical transport properties to evaluate trends over time relative to present-day risks.*

*Data needed to evaluate the present-day human health risk will be collected as part of a single field investigation and should reflect high and low water levels to establish appropriate ranges and* *uncertainties in source term distribution. Any major delay (more than three years from start to finish) could make it difficult to evaluate potential annual variations in separate elements of the risk assessment.*

*Because the field data will be collected during the first three years of the planned investigations, it is anticipated that the present-day human health risk assessment will be completed in the fourth year (see Chapter 6 of the core document [LANL 1997, 55622]).*

*Present-day human health risk assessments will include evaluation of alluvial groundwater with the following assumptions.*

*Drinking water pathways*

- *Contaminants will be evaluated if they have concentrations above standards or UTLs for background or show trends (observed or predicted) in concentrations over time, which indicates that contaminants may exceed standards or UTLs in the future.*
- *Duration and pathway of exposure will be adjusted to reflect characteristics of the alluvium considering specific yield.*

*Livestock and wildlife watering pathways*

- *Appropriate state and other regulatory authority standards will be used to identify COPCs.*
- *Duration parameters will be adjusted to reflect water saturation times.*

*Additional data will be obtained if reduction in uncertainty of the data has the potential to change any risk-based decision. This process is discussed in detail in Chapter 6 of the core document (LANL 1996, 55622).*

#### 7.4.2.2 Intermediate Perched Zone (if Present) and Regional Aquifer Groundwater General Approach

**Issue**

*Does the potential exist for contaminants to move into intermediate perched zones (Bandelier Tuff, Cerro Toledo interval, Guaje Pumice Bed, and/or Puye Formation basalt) and/or the regional aquifer? Does the movement of contaminants pose a potential risk?*

**Approach**

*Determine if there could be contaminant levels at or above the MCLs, New Mexico Water Quality Control Commission standards (1995, 54406), EPA standards, or UTLs for background or at levels that pose unacceptable human health or ecological risks in appropriate land use scenarios. Additionally, other physical properties of intermediate perched zone water need to be understood, such as the following.*

- *Does intermediate-depth perched groundwater occur beneath Pajarito Canyon, and if so what are the water quality, hydrologic, and geologic characteristics?*

- *Does spring water contain contaminants, and of so what is (are) the source(s) of the springs?*
- *Is there a process or pathway for exposure?*

*The following data will be collected to provide input to the decisions.*

- *Moisture content/saturation, water levels, saturated thickness, temporal variations, and spatial variations*
- *Analyses of core and/or water samples for geochemical parameters and species including contaminant indicators, distribution coefficients, temporal water quality variations, and a validated conceptual model of groundwater chemistry*
- *Hydrologic properties, geologic structure, hydraulic gradients and predicted flow directions, land use scenarios, spring discharge information, current and planned well-withdrawal points, and a validated conceptual model of the hydrologic system*

*For initial planning use, the study will be limited by the boundaries for the Pajarito Canyon investigation. Decisions 1, 2, and 4 may require extension of the study area north or south of the limits of the canyons and possibly deeper toward the regional aquifer, depending on the actual observations. Continuous groundwater levels will be recorded for two years in wells containing pressure transducers, and chemical indicators sufficient to determine seasonal effects will be analyzed.*

*The interpretive study will be a major component of the investigation because of the amount of existing data, including both published and unpublished archival data, to be integrated and interpreted conceptually and quantitatively. Data needed to evaluate potential impacts from contaminant transport within or outside the Laboratory boundary must provide adequate validation of models of aquifer distribution and transport properties to evaluate trends over time relative to present-day risks.*

*Data needed to evaluate the present-day human health risk will be collected as part of a single field investigation. Any major delay (more than three years from start to finish) could make it difficult to evaluate potential annual variations in separate elements of the risk assessment. Otherwise, the present-day risk can be evaluated at any time after the data have been collected.*

*Because the field data will be collected during the first three years of the investigation, it is anticipated that present-day human health risk assessment investigations will be completed in the fourth year (see Chapter 6 of the core document [LANL 1997, 55622]).Present-day human health risk assessments will include evaluation of intermediate perched zone groundwater and the regional aquifer with the following assumptions.*

*Drinking water pathways*

- *Contaminants will be evaluated if they have concentrations above standards or UTLs for background or show trends (observed or predicted) in concentrations over time, which indicates that contaminants may exceed standards or UTLs in the future.*
- *Duration and pathway of exposure will be adjusted to reflect characteristics of the alluvium considering specific yield.*

*Livestock and wildlife watering pathways*

- *Appropriate state and other regulatory agency standards will be used to identify COPCs.*
- *Duration parameters will be adjusted to reflect water saturation times.*

*Plant uptake pathways*

- *Contaminants that exceed the limits noted above will be evaluated.*

*Additional data will be obtained if reduction in uncertainty of the data has the potential to change any risk-based decision. This process is discussed in detail in Chapter 6 of the core document (LANL 1996, 55622).*

### 7.4.3 Sampling and Analysis Plan for Groundwater Investigation

*The SAP for the groundwater investigation follows the data needs outlined in Chapter 4 of this document and the decision logic discussed in Chapter 5 of the core document (LANL 1997, 55622).*

*The following key hypotheses of the current conceptual model (discussed in Chapter 4 of this work plan) will be tested during the groundwater investigation.*

1. *Evaluating the location and amount of water loss from the alluvium is necessary to determine possible contaminant transport pathways. Data necessary to perform water-balance calculations include additional water level measurements (preferably time-series data from transducers), site-specific soil moisture measurements and precipitation amounts, ET, and streamflow volumes.*

2. *It is estimated that ET removes up to 80% of the water that is added to Pajarito Canyon each year. An unknown amount of shallow alluvial groundwater may be lost from the alluvium by moving downward into underlying units. Alluvial groundwater infiltrates into the underlying Bandelier Tuff and possibly other hydrogeologic units. Neither the mechanism nor the location of the loss is known.*

3. *It is not known whether losses from alluvium recharge any intermediate perched zone(s). Based on information from boreholes SHB-4 and PM-2, possible saturation may be present in the Cerro Toledo interval and/or the Otowi Member; however, no saturated zones have been documented in any unit beneath the alluvium until the depth of the regional aquifer. When the deep supply boreholes were drilled, intermediate perched zones were not anticipated.*

4. *Conservative dissolved species such as most HE compounds may move into underlying stratigraphic units with the flow of groundwater. The migration process (for example, saturated and unsaturated liquid-film or unsaturated vapor-phase flows) and the rate depend on the properties of the interface between the stratigraphic units, which may be highly variable both spatially and temporally.*

5. *Springs in the western Laboratory area and in Threemile Canyon may be recharged from intermediate perched zones in the Bandelier Tuff. The source of the springs is not known, but in*

*the western Laboratory area the groundwater may be from infiltration of surface water into the Pajarito fault zone.*

6. *Dilution and attenuation of contaminants by geochemical processes leads to generally decreased contaminant concentrations (relative to conservative species such as chloride and tritium) downgradient within a water-bearing zone. HE compounds are observed in PCO-1 and PCO-2, but HE compounds have not been measured in alluvial groundwater from PCO-3.*

7. *The rates of infiltration into and percolation through tuff and the underlying units by unsaturated flow depend primarily on the unsaturated hydraulic properties of the rock units and the degree of saturation. The relative importance of horizontal versus vertical flow is not fully understood in Pajarito Canyon.*

8. *Open joints, faults, and fractures may provide additional pathways for deeper infiltration, transient flow, and lateral transport in the subsurface. Such pathways could account for some of the major losses of water from the alluvium.*

9. *Intermediate perched zones have not been observed to extend laterally beneath mesas. However, lateral spreading of such perched zones could occur if the canyon course and the gradient of the perched zone do not coincide. There are indications of the presence of buried paleochannels beneath Pajarito Canyon, which suggests the possibility of movement south or southeast from the axis of the canyon if intermediate perched zones occur.*

10. *Intermediate-depth units within the Bandelier Tuff such as the Guaje Pumice Bed, Cerro Toledo interval, basalts, and the Puye Formation in the Pajarito Canyon system have the potential to contain perched groundwater zones due to recharge from the overlying alluvium, similar to those found in canyons to the north (Mortandad Canyon, Pueblo Canyon, Los Alamos Canyon, and Sandia Canyon).*

11. *Intermediate perched zones could be expected in areas where a sufficient water source is present to maintain saturation. The annual losses from the Pajarito Canyon alluvium are sufficient to warrant further investigation of potential intermediate perched zones if contaminants are present, especially within the Cerro Toledo interval and the Guaje Pumice Bed.*

12. *Contrast in hydraulic properties between layers causes zones of high moisture content to develop near the contacts of the Tshirege Member, the Tsankawi Pumice Bed, the Cerro Toledo interval, the Otowi Member, and the Guaje Pumice Bed. These zones may also divert flow laterally and may be a mechanism for losses from the alluvium.*

13. *Vapor-phase transport is important for some volatile contaminants and is a viable mechanism by which organic vapors and tritium may have moved into the subsurface beneath MDA H and MDA L at TA-54.*

14. *Groundwater may move laterally downgradient along contacts within the Bandelier Tuff and/or may also infiltrate vertically to deeper zones of saturation, such as the Guaje Pumice Bed. The Cerro Toledo interval and the alluvial hydrogeologic units merge into a single hydrogeologic unit in lower Pajarito Canyon between well PCO-2 and well PCO-3. This merging may cause mixing*

*of groundwater between these two units and additional loss of alluvial groundwater into the Cerro Toledo interval. Groundwater potentially present in the combined alluvial/Cerro Toledo interval hydrogeologic unit in the lower canyon may (1) move downgradient within the Cerro Toledo interval, (2) remain wholly or partially perched within the alluvium and move downgradient, and/or (3) infiltrate through the Otowi Member to the Guaje Pumice Bed. Groundwater movement in the Cerro Toledo interval is likely controlled by paleochannels within this unit.*

15. *The Guaje Pumice Bed may also intersect the alluvial hydrogeologic unit in lower Pajarito Canyon near the eastern Laboratory boundary. A similar commingling of water in the alluvium and the Guaje Pumice Bed may occur that could provide a pathway for alluvial groundwater to infiltrate into the subsurface. A pre-Bandelier Tuff paleochannel has been mapped near TA-18. Groundwater movement in the Guaje Pumice Bed may be controlled by the axis of this paleochannel.*

16. *Groundwater in the upper saturated zones of the regional aquifer apparently moves generally eastward from the Jemez Mountains toward the Rio Grande under natural hydraulic gradients. The water that discharges at Pajarito Springs (Spring 4A) in lower Pajarito Canyon may come from the upper part of the regional aquifer. However, isotopic dating of the regional aquifer water and transport rates calculated from hydraulic gradients and hydraulic properties are widely divergent and inconsistent. The groundwater flow system is poorly understood, especially concerning layering and the influence of anisotropy in the vertical and horizontal permeability.*

*The hydrodynamics of the loss of groundwater from the alluvium in Pajarito Canyon are not well understood (as discussed in Chapter 3 of this work plan). The conceptual model of groundwater loss (as outlined in Chapter 4 of this work plan) includes vertical or lateral infiltration of alluvial groundwater to the Bandelier Tuff units including the Tshirege Qbt 1v unit in middle Pajarito Canyon, the Tshirege Qbt 1g unit in lower Pajarito Canyon, the Cerro Toledo interval east of PCO-2, and possibly the Guaje Pumice Bed near the Laboratory boundary at state road NM4. Figure A-4 in Appendix A illustrates these potential groundwater pathways.*

*The general approach to the groundwater investigation will be to collect new field data and extend existing interpretations only when necessary to establish adequate confidence in the upper limits of the risk estimates or to clarify groundwater occurrence and geochemical and transport processes sufficient to meet the requirements of the HSWA Module (EPA 1990, 1585). Data collected in this groundwater investigation will be integrated with data from other previous and ongoing Laboratory studies to improve the conceptual model of the hydrogeology of the Pajarito Plateau. The following investigations are planned for the hydrogeology of Pajarito Canyon.*

- *The lithology and stratigraphy of the alluvium and the bedrock beneath the canyon need to be better described and understood to adequately characterize the hydrogeological system and to provide input to hydrogeologic models. Data on the lithology, stratigraphy, hydraulic properties and geotechnical properties (possibly including bulk density, porosity, saturated and unsaturated hydraulic conductivity, moisture content, storativity or specific yield, and matric potential) are needed. Where appropriate, these data will be obtained from laboratory analyses of borehole core samples and by aquifer performance testing.*

- *Water-balance studies for the alluvial groundwater may be necessary if contaminants are found above regulatory levels. If necessary, water-balance investigations may be performed by the Canyons Focus Area technical team and ESH-18 personnel. The water-balance studies will use* *existing wells and newly installed wells possibly equipped with pressure transducers, plus the existing and planned stream gaging stations and the two planned ET stations. These studies will be coordinated with the other surface water and groundwater investigations discussed herein and with the implementation of work proposed in the Hydrogeologic Workplan (LANL 1996, 55430).*

- *Investigations of the alluvial groundwater will focus on determining (1) the nature and extent of contaminants, (2) the potential for recharge from the alluvium to deeper zones, and (3) the physical and geochemical nature of perching layers at the alluvium/Bandelier Tuff interface.*

- *To characterize individual zones of saturation, water samples will be collected from the alluvial groundwater, the regional aquifer, and any other saturated zones that are encountered. The samples will be both filtered in the field and unfiltered to provide appropriate data on dissolved and suspended constituent concentrations. Analyses for colloidal materials will identify possible colloidal transport of contaminants.*

- *To identify if contaminants have reached the regional aquifer, water samples will be collected from the upper part of the aquifer. Time-series sampling will be conducted for analysis of inorganic chemicals and radionuclides. Special attention will be given to the well bore at PM-2 where the surface casing passes through the shallow alluvial groundwater.*

- *Investigations of potential intermediate zones of saturation will focus on determining the geochemical and hydrogeologic features that control moisture distributions within the strata.*

- *The regional aquifer studies will be integrated with those of the Hydrogeologic Workplan (LANL 1996, 55430) and, during the present investigations, will consist of installing six regional aquifer characterization wells within the Pajarito Canyon watershed area.*

- *The six new regional aquifer wells will be sampled for analyses of HE, low-level tritium, and other chemical species to further evaluate impacts of Laboratory-derived contaminants on the regional aquifer. These analyses will also be used to test the hypothesis of mixing of young water (derived from shallow sources) with old water (the regional aquifer) in Pajarito Canyon.*

- *Recommendations will be made regarding possible corrective measures to groundwater zones and monitoring strategies for the ER Project and/or the Laboratory environmental surveillance program.*

*Planned alluvial wells and regional aquifer wells are listed in Table 7.4.3-1 and Table 7.4.3-2, respectively. Locations of the regional aquifer wells are shown in Figure 7.4.3-1 and Figure 7.4.3-2 (and in Figure A-1 in Appendix A).*

## TABLE 7.4.3-1

## DESCRIPTION OF PLANNED ALLUVIAL GROUNDWATER MONITORING WELLS

| Well Designation[a] | Location[b] |
|---|---|
| PCAO-B | Background well west of Laboratory boundary at state road NM501 |
| PCAO-1 | Planned observation well 1000 ft (300 m) east of Laboratory boundary at state road NM501 |
| PCAO-2 | Observation well downstream of the confluence with the south fork of Pajarito Canyon |
| PCAO-3 | Observation well downstream of the confluence with south Anchor East basin |
| PCAO-4 | Observation well downstream of TA-40 and upstream of the confluence with Twomile Canyon |
| PCAO-5 | Observation well downstream of the confluence with Twomile Canyon |
| PCAO-6 | Observation well approximately 1 mile (1.6 km) downstream of the confluence with Twomile Canyon |
| PCAO-7A | Downgradient of PRSs at TA-18 |
| PCAO-7B | Downgradient of PRSs at TA-18 |
| PCAO-7C | Downgradient of PRSs at TA-18 |
| 3MAO-1 | Observation well in Threemile Canyon between TA-15 and the confluence with the south fork of Threemile Canyon |
| 3MAO-2 | Observation well at base of Threemile Canyon |

a. PC = Pajarito Canyon, A = Alluvial, O = observation, 3M = Threemile Canyon

b. See Figure A-1 for planned locations.

## TABLE 7.4.3-2

## DESCRIPTION OF PLANNED REGIONAL AQUIFER WELLS

| Well Designation[a] | Funding Source | Location[b] |
|---|---|---|
| R-17 | ER[c] | Twomile Mesa north of the southwest fork of Twomile Canyon |
| R-18 | ER | Pajarito Mesa near the head of Threemile Canyon |
| R-19 | ER | Pajarito Canyon west of TA-18 and upstream of the confluence with Threemile Canyon |
| R-20 | DP[d] | Approximately 700 ft (210 m) west of PCO-1, north of Pajarito Road |
| R-21 | ER | Mesita del Buey north of Pajarito Canyon near MDA L |
| R-22 | ER | Lower Pajarito Canyon just west of Laboratory boundary at state road NM4 |

a. R = regional aquifer

b. See Figures 7.4.3-1 and 7.4.3-2 for planned locations.

c. ER = Environmental Restoration Project

d. DP = Defense Programs

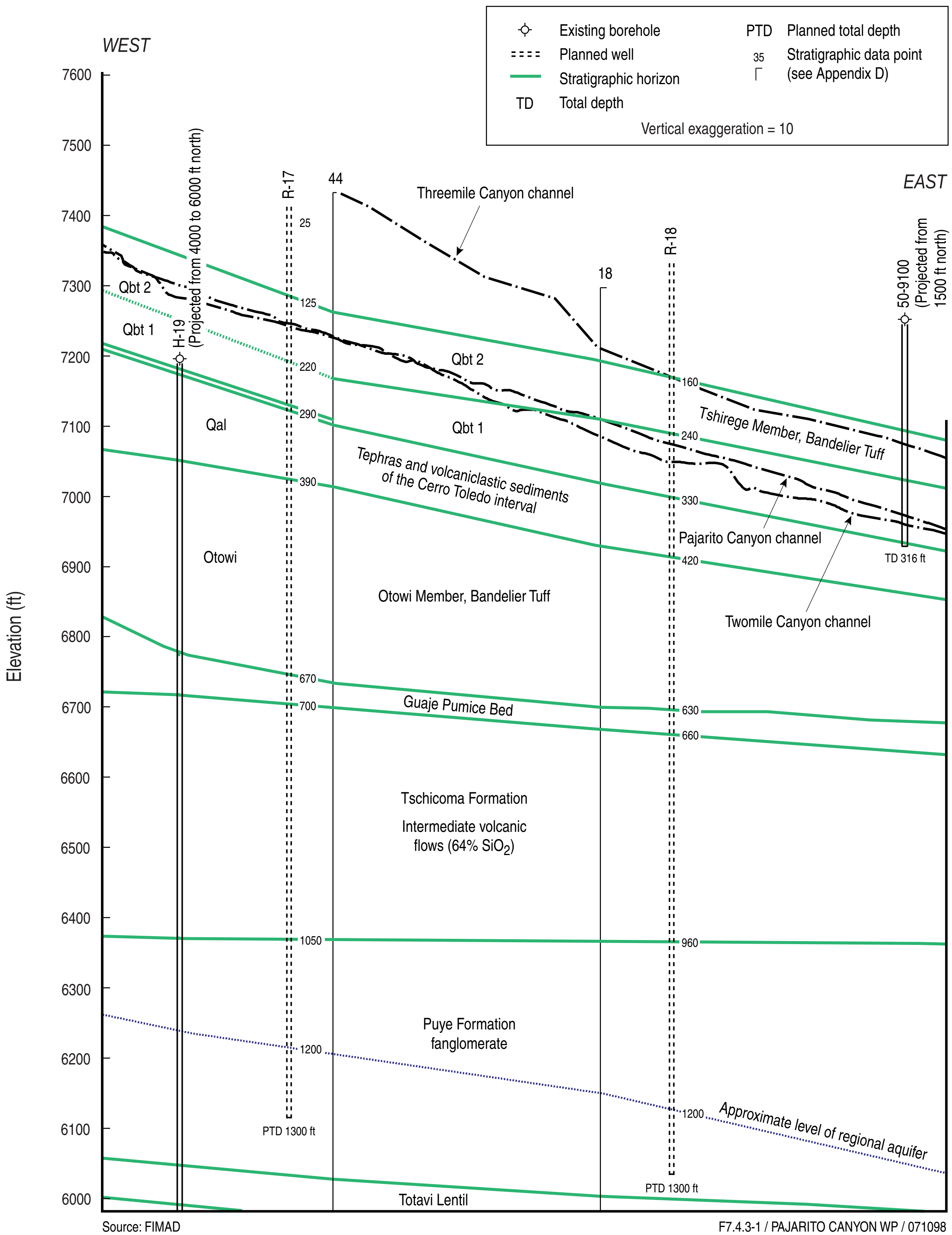


**Figure 7.4.3-1. Projected stratigraphic sections for planned regional aquifer wells in upper Pajarito Canyon.**

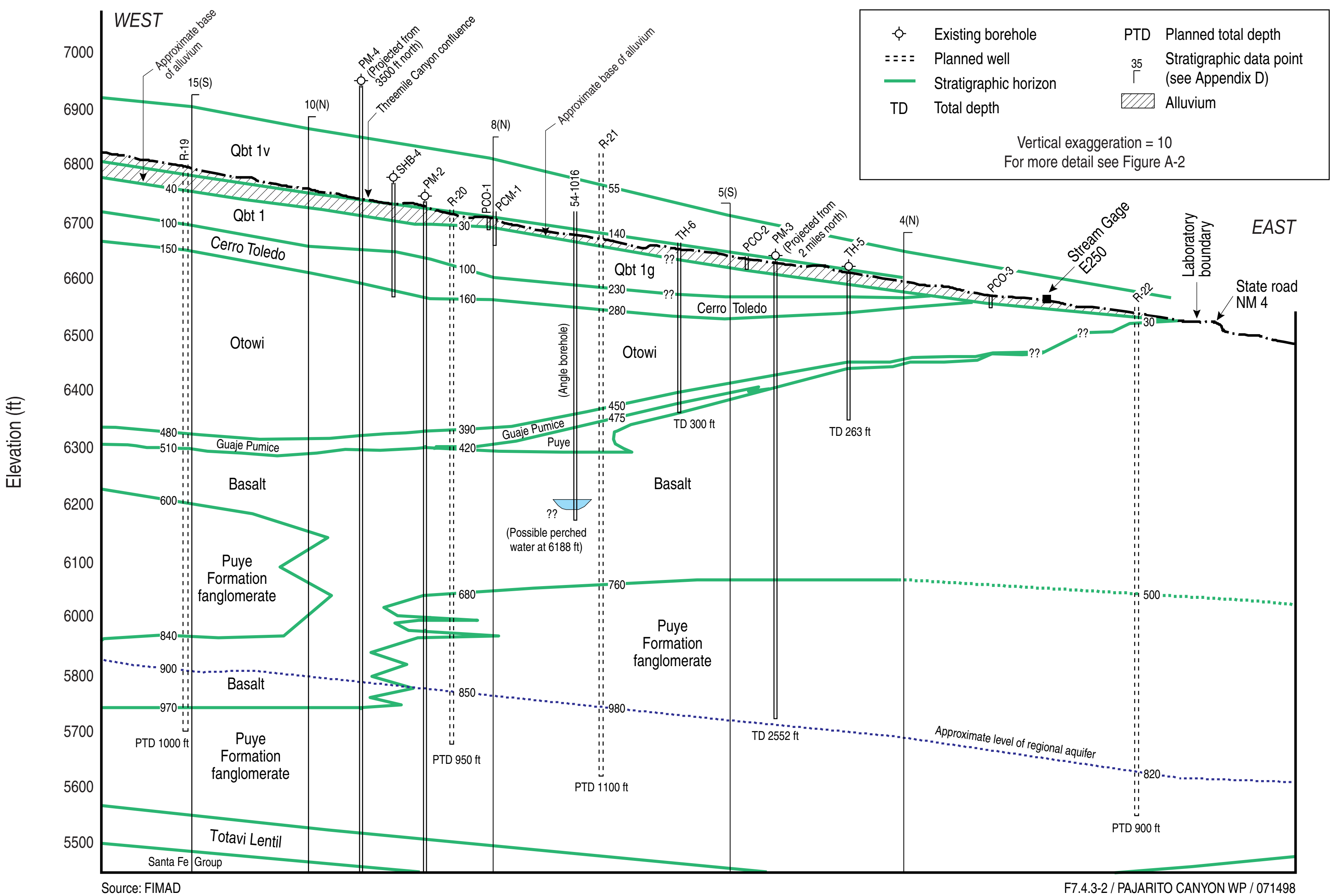


**Figure 7.4.3-2. Projected stratigraphic sections for planned regional aquifer wells in lower Pajarito Canyon.**

### 7.4.4 Groundwater Characterization

*This section describes the sampling design for collecting groundwater samples and borehole core samples. Particular emphasis is given to the criteria for selecting the locations of the planned new wells. The methods for sample collection and for chemical, radiochemical, and geotechnical analyses are also provided in this section. The groundwater sampling strategy involves installation of 12 alluvial observation wells. The regional aquifer will be sampled through existing wells and a total of 6 new wells, 5 of which will be drilled by the ER Project. Intermediate-depth wells may be planned in the future if saturation and contaminants are encountered while drilling the regional aquifer wells.*

#### 7.4.4.1 Alluvial, Perched Intermediate, and Regional Groundwater Investigations

**Alluvial Groundwater Characterization**

*The planned alluvial wells are listed in Table 7.4.3-1. The rationale for each well is discussed in detail in the following sections.*

- **PCAO-B.** *Install an alluvial well or drive point in upper Pajarito Canyon west of the Laboratory boundary to determine the background geochemistry and alluvial groundwater conditions. This well will be located west state road NM501 to determine background water chemistry in the upper portion of the canyon.*

- **PCAO-1.** *Install one alluvial well in upper Pajarito Canyon on Laboratory property downstream of state road NM501 to determine the contribution to alluvial groundwater chemistry, if any, from state road NM501. Potential contributions may be from the use of road salt on the state road during winter months. If necessary, this well could also determine water balance and seepage loss across the Pajarito fault zone. This well will satisfy planned well A-30 in the Hydrogeologic Workplan (LANL 1996, 55430).*

- **PCAO-2.** *Install one alluvial well in upper Pajarito Canyon downstream of the confluence with the south fork of Pajarito Canyon to determine the contribution to alluvial groundwater chemistry from springs, outfalls, and PRSs at TA-8 (Anchor West Site) and MDA M in the south fork of the Pajarito Canyon watershed. If necessary, this well could also be used to determine water balance in this portion of the canyon. This well will satisfy planned well A-31 in the Hydrogeologic Workplan (LANL 1996, 55430).*

- **PCAO-3.** *Install one alluvial well in upper Pajarito Canyon downstream of the confluence with south Anchor East basin to determine the contribution to alluvial groundwater chemistry from springs, outfalls, and PRSs at TA-9 (Anchor East Site) that drain into north and south Anchor East basins. If necessary, this well could also be used to determine water balance in this portion of the canyon.*

- **PCAO-4.** *Install one alluvial well or drive point in middle Pajarito Canyon upstream of the confluence with Twomile Canyon. This well will determine the potential contribution to alluvial groundwater chemistry from PRSs and National Pollutant Discharge Elimination System outfalls at TA-6 that drain into Pajarito Canyon. If necessary, this well could also be used to determine water balance in this portion of the canyon. This well will satisfy well A-32 in the Hydrogeologic Workplan (LANL 1996, 55430).*

- **PCAO-5.** *Install one alluvial well or drive point in middle Pajarito Canyon downstream of the confluence with Twomile Canyon. This well will determine the contribution to alluvial groundwater chemistry from outfalls, PRSs, and storm water runoff from Twomile Canyon. If necessary, this well could also be used to determine water balance in this portion of the canyon. This well will satisfy well A-33 in the Hydrogeologic Workplan (LANL 1996, 55430).*

- **PCAO-6.** *Install one alluvial well in middle Pajarito Canyon about midway between the confluence of Twomile Canyon and Threemile Canyon. This well will determine the potential contribution to alluvial groundwater chemistry from storm water runoff. If necessary, this well could also be used to determine water balance in this portion of the canyon. This well will satisfy well A-34 in the Hydrogeologic Workplan (LANL 1996, 55430).*

- **PCAO-7A, -7B, -7C.** *Install a transect of three alluvial groundwater monitoring wells in Pajarito Canyon below the confluence with Threemile Canyon and east of TA-18. These wells will determine the geochemistry of alluvial groundwater downgradient of TA-18 and the potential contribution of contaminants to the alluvial groundwater from PRSs at TA-18. If necessary, these wells could also be used to determine water balance in this portion of the canyon. These wells will satisfy wells A-35, A-36, and A-37 in the Hydrogeologic Workplan (LANL 1996, 55430).*

- **3MAO-1.** *Install one alluvial well in Threemile Canyon above the confluence with the south fork of Threemile Canyon to determine the presence of saturation in the alluvium and bedrock units. This well will determine the contribution to alluvial groundwater chemistry from firing sites, PRSs, and outfalls in upper Threemile Canyon and could provide information about the source of Threemile Spring and water balance in Threemile Canyon, as necessary. This well will satisfy well A-42 in the Hydrogeologic Workplan (LANL 1996, 55430).*

- **3MAO-2.** *Install one alluvial well in lower Threemile Canyon at the confluence with Pajarito Canyon to determine the geochemistry of alluvial groundwater in Threemile Canyon and to determine the potential contribution of contaminants from Threemile Canyon to Pajarito Canyon. If necessary, this well could also be used to determine water balance in lower Threemile Canyon.*

- **Sampling of existing wells.** *Alluvial groundwater may be collected from selected existing wells in lower Pajarito Canyon and Threemile Canyon if appropriate samples can be obtained from the wells. Existing wells that may be sampled in Pajarito Canyon include 18-BG-1 (west of TA-18), 18-MW-4 (near Kiva 1), 18-MW-17, PCO-1, 18-MW-18, PCO-2, and PCO-3. Existing wells 18-BG-4 and 18-MW-8 may be sampled in Threemile Canyon.*

*Pressure transducers may be installed in the newly drilled alluvial wells in Pajarito Canyon to provide real-time water level data that will be used to determine water balance in the alluvium. Down-hole bladder pumps may be installed in each well to enable sampling of the groundwater without removal of the pressure transducers and to collect groundwater samples more representative of the natural groundwater in the alluvium.*

**Regional Aquifer Characterization**

*The planned regional aquifer characterization wells are listed in Table 7.4.3-3. Five regional aquifer wells are planned for Pajarito Canyon in the Hydrogeologic Workplan (LANL 1996, 55430). Generally, these wells are planned to* *identify the presence of intermediate perched zones, measure the thickness of the zones, and analyze for the presence of contaminants within those zones that would indicate contaminant transport is actively occurring (LANL 1996, 55430, p. 4-58).*

*In addition, a regional aquifer well (R-21) is planned to be drilled on Mesita del Buey near MDA L at TA-54. This well is included in the following list because information obtained for this well will be used with information from wells in Pajarito Canyon to determine the possible impact to intermediate perched zones and the regional aquifer from TA-54.*

*The rationale for each well is discussed in detail in the following sections.*

- **R-17.** *The ER Project will install one regional aquifer well in the Twomile Canyon watershed. This well will be located on a finger of Twomile Mesa north of the southwest fork of Twomile Canyon and south of TA-3 and TA-59. This well will provide information about perched groundwater, depth to the regional aquifer, and water quality information for potential perched zones and the regional groundwater systems in a hydrologically and geologically uncharacterized part of the Laboratory.*

- **R-18.** *The ER Project will install one regional aquifer well in middle Pajarito Canyon downgradient from technical areas and PRSs in the western area of the Laboratory. This well will investigate the presence of intermediate zones of saturation and characterize water quality. Water level data from this well will enable the creation of an accurate water level map for the regional aquifer in the west-central part of the Laboratory, supporting the placement of long-term monitoring wells.*

- **R-19.** *The ER Project will install one regional aquifer well in middle Pajarito Canyon between the confluence of Twomile Canyon and Threemile Canyon. This well will provide hydrogeologic information about possible perched zones of saturation and the regional aquifer in the central portion of the Laboratory. This well is downgradient of PRSs in upper Pajarito Canyon including MDA C and former impoundments at TA-35. Importantly, this well will be located at the approximate axis of the pre-Bandelier Tuff paleochannel that extends north to south across the central portion of the Pajarito Plateau. Possible perched zones in the Guaje Pumice Bed may be localized within this paleochannel. This well will determine the presence of perched zones of saturation within the paleochannel and will provide additional stratigraphic and structural control for the location of the paleochannel.*

- **R-20.** *Defense Programs will install one regional aquifer monitoring well in lower Pajarito Canyon east of TA-18 and near existing well PM-2. This well will determine the presence of potential perched zones of saturation reported in PM-2 within the Otowi Member and will provide geologic data for the location of the axis of the pre-Bandelier Tuff paleochannel. This well will also provide early detection monitoring for contaminants present beneath Mesita del Buey associated with MDA H (tritium) and MDA L (organic vapor) that have been detected at depth. This well may be continuously cored to determine the stratigraphy beneath lower Pajarito Canyon.*

- **R-21.** *The ER Project will install one regional aquifer well north of Pajarito Canyon on Mesita del Buey near MDA L (LANL 1996, 55430). This well will evaluate and monitor hydrologic and geochemical conditions in the regional aquifer beneath MDA L. An organic vapor plume is present to a depth of at least 500 ft (150 m) beneath MDA L in the Cerros del Rio basalts. A tritium plume is present to at least 40 ft (12 m) beneath MDA H, which is located adjacent to MDA*

*L. Data obtained from this well will be compared with data from well R-20 to evaluate the migration of the organic chemicals and potential movement toward supply well PM-2.*

- **R-22.** *The ER Project will install one regional aquifer monitoring well in lower Pajarito Canyon near the eastern Laboratory boundary. This well will determine the presence and quality of intermediate perched zones downgradient of the TA-54 disposal areas. This well is located where the alluvium and the Bandelier Tuff units thin over a paleotopographic high of Cerros del Rio basalts. A possible intermediate perched zone of saturation was encountered in a borehole beneath MDA L on Mesita del Buey. The water chemistry from intermediate zones and the regional groundwater chemistry will be compared with the water chemistry of Pajarito Springs (Spring 4A) and other springs in White Rock Canyon to evaluate the potential hydrologic connections between groundwater bodies. Stratigraphic and hydrogeologic data obtained from units below the Bandelier Tuff encountered in this well will be used to support the MDA G performance assessment (a waste management activity) and ER Project assessment activities.*

*Table 7.4.4-1 summarizes groundwater sample collection design; Table 7.4.4-2 summarizes the planned borehole core sample collection design. The planned drilling and sampling program includes collecting a total of 94 core samples for full-suite analysis, 70 core samples for limited-suite analysis, and 153 core samples for minimum suite analysis. Additionally, a total of 50 water samples will be collected for analyses when the wells are completed. Additional water samples are planned to be collected semiannually during a two-year period.*

**TABLE 7.4.4-1**

**SUMMARY OF COLLECTION DESIGN FOR GROUNDWATER SAMPLES**

| Hydrological Zone | No. of Wells | Sampling Frequency | Annual No. of Samples |
|---|---|---|---|
| *New alluvial observation wells** | *12* | *At completion and semiannually for 2 years* | *96 (48 filtered, 48 unfiltered)* |
| *Existing alluvial observation wells* | *4* | *Semiannually for 2 years* | *32 (16 filtered, 16 unfiltered)* |
| *Regional aquifer wells** | *6* | *At completion and semiannually for 2 years* | *48 (24 filtered, 24 unfiltered)* |
| **See Table 7.4.4-2 for planned core collection and analysis.* | | | |

*The sampling strategy for each of the hydrogeologic zones is described in the following sections, as is the strategy for the collection of borehole core samples. Where new wells are planned, the rationale for the well location is discussed in terms of a specific issue to be addressed as well as the approach taken to address the issue.*

#### 7.4.4.1.1 Alluvial Groundwater Sampling and Analysis Plan

*The HSWA Module (EPA 1990, 1585) requires that this work plan include an investigation of the potential for transport of contaminants within canyon watersheds and the interactions with alluvial groundwater and other groundwater. Three characteristics of groundwater in the alluvium are relevant to these requirements: continuity, potential recharge to deeper groundwater, and levels of contaminants.*

## TABLE 7.4.4-2

## SUMMARY OF CORE AND WATER SAMPLES PLANNED FOR PAJARITO CANYON BOREHOLES

| Borehole | Planned Depth (ft) | Formation | Planned Depth Beginning (ft) | Planned Depth Ending (ft) | Core Sampling Frequency (ft) | Analytical Suite/ Planned No. of Core Samples | | | Planned No. of Water Samples | Comment |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | a | b | c | | |
| PCAO-B | <15 | Qal | 0 | 5 | 5 | 1 | | | | |
| | | Perched water | 4 | 5 | N/A[d] | | | | 2 | Water sample[e,f] |
| | | Qbt | 5 | 15 | 10 | 1 | | | | |
| PCAO-1 | <15 | Qal | 0 | 5 | 5 | 1 | | | | |
| | | Perched water | 4 | 5 | N/A | | | | 2 | Water sample[e,f] |
| | | Qbt | 5 | 15 | 10 | 1 | 1 | | | |
| PCAO-2 | <15 | Qal | 0 | 5 | 10 | 1 | | | | |
| | | Perched water | 4 | 5 | N/A | | | | 2 | Water sample[e,f] |
| | | Qbt | 5 | 15 | 10 | 1 | | | | |
| PCAO-3 | <15 | Qal | 0 | 5 | 10 | 1 | | | | |
| | | Perched water | 4 | 5 | N/A | | | | 2 | Water sample[e,f] |
| | | Qbt | 4 | 5 | 10 | 1 | | | | |
| PCAO-4 | <20 | Qal | 0 | 10 | 10 | 1 | | | | |
| | | Perched water | 8 | 10 | N/A | | | | 2 | Water sample[e,f] |
| | | Qbt | 10 | 20 | 10 | 1 | | | | |
| PCAO-5 | <30 | Qal | 0 | 15 | 10 | 1 | | | | |
| | | Perched water | 10 | 15 | N/A | | | | 2 | Water sample[e,f] |
| | | Qbt | 15 | 25 | 10 | 1 | | | | |
| PCAO-6 | <30 | Qal | 0 | 20 | 10 | 1 | 1 | | | |
| | | Perched water | 15 | 20 | N/A | | | | 2 | Water sample[e,f] |
| | | Qbt | 20 | 30 | 10 | 1 | | | | |
| PCAO-7A | <50 | Qal | 0 | 40 | 20 | 1 | 1 | | | |
| | | Perched water | 30 | 40 | N/A | | | | 2 | Water sample[e,f] |
| | | Qbt | 40 | 50 | 10 | 1 | | | | |
| PCAO-7B | <50? | Qal | 0 | 40 | 20 | 1 | 1 | | | |
| | | Perched water | 30 | 40 | N/A | | | | 2 | Water sample[e,f] |
| | | Qbt | 40 | 50 | 10 | 1 | | | | |
| PCAO-7C | <40? | Qal | 0 | 30 | 20 | 1 | 1 | | | |
| | | Perched water | 25 | 30 | N/A | | | | 2 | Water sample[e,f] |
| | | Qbt | 30 | 40 | 10 | 1 | | | | |
| 3MAO-1 | <30? | Qal | 0 | 15 | 10 | 1 | 1 | | | |
| | | Perched water | 10 | 15 | N/A | | | | 2 | Water sample[e,f] |
| | | Qbt | 15 | 25 | 10 | 1 | | | | |

a. Full-suite core sample analysis listed in Table 7.4.4-5
b. Limited-suite core sample analysis, including the following: trace elements, tritium (high detection limit), hydrologic properties, anions, and HE?
c. Minimal analyses on core samples for moisture, chloride, bromide, and nitrate only
d. N/A = not applicable
e. Water sample analysis includes those analytes listed in Table 7.4.4-4 and Table 7.4.4-6
f. Water samples will be collected semiannually for two years (see text)

## TABLE 7.4.4-2 (continued)

## SUMMARY OF CORE AND WATER SAMPLES PLANNED FOR PAJARITO CANYON BOREHOLES

| Borehole | Planned Depth (ft) | Formation | Planned Depth Beginning (ft) | Planned Depth Ending (ft) | Core Sampling Frequency (ft) | Analytical Suite/ Planned No. of Core Samples | | | Planned No. of Water Samples | Comment |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | a | b | c | | |
| 3MAO-2 | <40 | Qal | 0 | 30 | 20 | 1 | 1 | | | |
| | | Perched water | 25 | 30 | N/A[d] | | | | 2 | Water sample[e,f] |
| | | Qbt | 30 | 40 | 10 | 1 | | | | |
| R-17 | 1300 | Qbt 4 | 0 | 25 | 10 | 1 | 1 | 1 | | |
| | | Qbt 3 | 25 | 125 | 10 | 1 | 2 | 7 | | |
| | | Qbt 2 | 125 | 220 | 10 | 1 | 2 | 7 | | |
| | | Qbt 1 | 220 | 280 | 10 | 1 | 1 | 4 | | |
| | | Qbt t | 280 | 290 | 10 | 1 | | | | |
| | | Qct | 290 | 390 | 10 | 1 | 2 | 7 | | |
| | | Perched water | 345 | 350 | N/A | | | | 2 | Water sample[e,f] |
| | | Qbo | 390 | 670 | 30 | 1 | 1 | 5 | | |
| | | Qbog | 670 | 700 | 10 | 1 | 1 | 1 | | |
| | | Tp volc. | 700 | 1050 | 50 | 1 | 1 | 5 | | |
| | | Tp fanglom | 1050 | 1300 | 50 | 1 | 1 | 5 | | |
| | | Regional aquifer | 1200 | 1300 | N/A | | | | 2 | Water sample[e,f] |
| R-18 | 1300 | Qbt 3 | 0 | 160 | 20 | 1 | 2 | 5 | | |
| | | Qbt 2 | 160 | 240 | 20 | 1 | 2 | 5 | | |
| | | Qbt 1 | 240 | 330 | 20 | 1 | 1 | 7 | | |
| | | Qbt t | 330 | 333 | 10 | 1 | | | | |
| | | Qct | 333 | 420 | 10 | 1 | 2 | 7 | | |
| | | Perched water | 345 | 350 | N/A | | | | 2 | Water sample[e,f] |
| | | Qbo | 420 | 630 | 30 | 1 | 1 | 5 | | |
| | | Qbog | 630 | 660 | 10 | 1 | 1 | 1 | | |
| | | Tp volc. | 660 | 960 | 50 | 1 | 1 | 4 | | |
| | | Tp fanglom | 960 | 1300 | 50 | 1 | 1 | 5 | | |
| | | Regional aquifer | 1200 | 1300 | N/A | | | | 2 | Water sample[e,f] |
| R-19 | 1000 | Qal | 0 | 40 | 20 | 1 | 1 | | | |
| | | Qbt 1g | 40 | 100 | 20 | 1 | 1 | 4 | | |
| | | Qbt t | 100 | 103 | 10 | 1 | | | | |
| | | Qct | 103 | 150 | 20 | 1 | 1 | 3 | | |
| | | Perched water | 130 | 140 | N/A | | | | 2 | Water sample[e,f] |
| | | Qbo | 150 | 480 | 30 | 1 | 1 | 9 | | |
| | | Qbog | 480 | 510 | 10 | 1 | 1 | 1 | | |
| R-19 | 1000 | Tp basalt | 510 | 600 | 50 | 1 | 1 | | | |
| | | Tp fanglom | 600 | 840 | 50 | 1 | 1 | 3 | | |
| | | Tp basalt | 840 | 970 | 50 | 1 | 1 | 1 | | |

a. Full-suite core sample analysis listed in Table 7.4.4-5

b. Limited-suite core sample analysis, including the following: trace elements, tritium (high detection limit), hydrologic properties, anions, and HE?

c. Minimal analyses on core samples for moisture, chloride, bromide, and nitrate only

d. N/A = not applicable

e. Water sample analysis includes those analytes listed in Table 7.4.4-4 and Table 7.4.4-6

f. Water samples will be collected semiannually for two years (see text)

## TABLE 7.4.4-2 (continued)

### SUMMARY OF CORE AND WATER SAMPLES PLANNED FOR PAJARITO CANYON BOREHOLES

| Borehole | Planned Depth (ft) | Formation | Planned Depth Beginning (ft) | Planned Depth Ending (ft) | Core Sampling Frequency (ft) | Analytical Suite/ Planned No. of Core Samples | | | Planned No. of Water Samples | Comment |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | a | b | c | | |
| R-19 | 1000 | Tp fanglom | 970 | 1000 | 50 | | 1 | | | |
| | | Regional aquifer | 900 | 1000 | N/A[d] | | | | 2 | Water sample[e,f] |
| R-20 | 950 | Qal | 0 | 30 | 20 | 1 | 1 | | | |
| | | Qbt 1g | 30 | 97 | 20 | 1 | 1 | 2 | | |
| | | Qbt t | 97 | 100 | 10 | 1 | | | | |
| | | Qct | 100 | 160 | 20 | 1 | 1 | 1 | | |
| | | Perched water | 135 | 140 | N/A | | | | 2 | Water sample[e,f] |
| | | Qbo | 160 | 390 | 30 | 1 | 1 | 5 | | |
| | | Qbog | 390 | 420 | 10 | 1 | 1 | 1 | | |
| | | Tp basalt | 420 | 680 | 50 | 1 | 1 | 3 | | |
| | | Tp fanglom | 680 | 950 | 50 | 1 | 1 | 4 | | |
| | | Regional aquifer | 850 | 950 | N/A | | | | 2 | Water sample[e,f] |
| R-21 | 1100 | Qbt 2 | 0 | 55 | 10 | 3 | 2 | 1 | | |
| | | Qbt 1v | 55 | 140 | 10 | 3 | 2 | 4 | | |
| | | Qbt 1g | 140 | 230 | 10 | 3 | 2 | 5 | | |
| | | Qct | 230 | 280 | 20 | 2 | 2 | 1 | | |
| | | Perched water | 245 | 250 | N/A | | | | 2 | Water sample[e,f] |
| | | Qbo | 280 | 450 | 30 | 2 | 2 | 2 | | |
| | | Qbog | 450 | 475 | 20 | 1 | 1 | 1 | | |
| | | Tp | 475 | 520 | 20 | 1 | 1 | 1 | | |
| | | Tp basalt | 520 | 760 | 50 | 1 | 1 | 3 | | |
| | | Tp fanglom | 760 | 1100 | 50 | 1 | 1 | 5 | | |
| | | Regional aquifer | 980 | 1100 | N/A | | | | 2 | Water sample[e,f] |
| R-22 | 900 | Qal | 0 | 15 | 10 | 1 | 1 | | | |
| | | Qbo | 15 | 27 | 10 | 1 | | | | |
| | | Qbog | 27 | 30 | 10 | 1 | | | | |
| | | Perched water | 29 | 30 | N/A | | | | 2 | Water sample[e,f] |
| | | Tp basalt | 30 | 500 | 100 | 1 | 1 | 3 | | |
| | | Tp fanglom | 500 | 900 | 100 | 1 | 1 | 2 | | |
| | | Regional aquifer | 820 | 900 | N/A | | | | 2 | Water sample[e,f] |

a. Full-suite core sample analysis listed in Table 7.4.4-5

b. Limited-suite core sample analysis, including the following: trace elements, tritium (high detection limit), hydrologic properties, anions, and HE?

c. Minimal analyses on core samples for moisture, chloride, bromide, and nitrate only

d. N/A = not applicable

e. Water sample analysis includes those analytes listed in Table 7.4.4-4 and Table 7.4.4-6

f. Water samples will be collected semiannually for two years (see text)

**Continuity**

*The alluvium in Pajarito Canyon is at least partially saturated for nearly the entire length of the canyon on Laboratory property. However, the amount of saturation in the lower part of the canyon near PCO-3 appears to have fluctuated during the past few years and is strongly dependent on the amount of precipitation and runoff that occurs in the watershed area. The alluvium may intersect the Cerro Toledo interval between wells PCO-2 and PCO-3 in the lower part of the canyon. The intersection of these units may result in saturated conditions; migration of contaminants is controlled by both the geometry and the hydraulic properties of the combined alluvial/Cerro Toledo interval hydrogeologic unit. The alluvium in lower Threemile Canyon appears to contain saturation within a few feet of the surface, which may be the result of springs or seeps.*

*Investigations are planned to determine the presence of saturation in the alluvium and underlying bedrock units in Threemile Canyon (at wells 3MAO-1 and 3MAO-2) and the extent of any contribution to the saturated alluvium in Pajarito Canyon. Significant amounts of saturation are not expected to occur east of state road NM4 because of thinning and the absence of alluvium in that reach.*

**Potential Recharge to Deeper Groundwater**

*The observed loss of alluvial groundwater either downward or laterally from the Pajarito Canyon alluvium may constitute recharge to the Cerro Toledo interval, Guaje Pumice Bed, Puye Formation, Cerros del Rio basalt, and possibly the regional aquifer.*

**Levels of Contaminants**

*The highest level of contaminants observed in the alluvial groundwater has been soluble HE compounds including hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX), which is present in concentrations more than three times its former screening action level (SAL) value in the alluvial groundwater upstream of TA-18. Additionally, octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine (HMX), other HE compounds, thorium-228, thorium-230, uranium, and 1,2-dichloroethane concentrations were measured at concentrations above former SAL values in the LACEF wells at TA-18. Alluvial groundwater in lower Pajarito Canyon east of TA-18 contains low levels of HE compounds, but no other constituents were measured above former SAL values. The alluvial groundwater at PCO-3 does not contain HE compounds.*

*Groundwater will be sampled and analyzed from new and selected existing wells semiannually for two years, once after relatively high surface water flow (summer storm event) and again at relatively low (or no) surface water flow (winter). Groundwater in the alluvium of Pajarito Canyon responds rapidly to seasonal variations in streamflow, which likely results in detectable changes in the groundwater quality. The purpose of two sampling events is to define the effect of seasonal variation in surface water flow on contaminant concentrations in alluvial groundwater.*

*Existing wells in lower Pajarito Canyon and Threemile Canyon may be sampled for chemical analysis. These wells include PCO-1, PCO-2, PCO-3, 18-MW-4, and possibly other wells. These wells will be sampled semiannually for two years to assess water chemistry and contaminant distributions. Water level measurements will be recorded for two years. These measurements will be used to assemble a hydraulic database that will be used for water-balance calculations for the alluvium. This information will enable an understanding of the movement of groundwater and the storage capabilities of the alluvium and, in* *conjunction with surface water gaging station data, will be the principle tool for gaining a better understanding of where water losses occur.*

*Specific conductance, turbidity, pH, temperature, dissolved oxygen, and alkalinity will be measured in the field at the time of water sampling. All groundwater samples will be both filtered (to remove particulates larger than 0.45 µm) and unfiltered. These data will be combined, where appropriate, with analyses of unfiltered samples collected either by ER Project personnel or for environmental monitoring by ESH-18 personnel to reduce uncertainty in the distributions of alluvial groundwater quality for contaminant transport and risk model inputs.*

**Planned Alluvial Wells and Hydrologic and Geochemical Investigations**

*This section describes the rationale for the planned hydrologic and geochemical investigations of the alluvial groundwater in Pajarito Canyon. The most fundamental questions to be addressed for the alluvial system are identified as follows.*

- *What is the nature and extent of contaminants in alluvial groundwater?*
- *If the groundwater has contaminants, where does the loss from the alluvial system occur in Pajarito Canyon and what is the flux?*
- *If contaminants are being transported in alluvial groundwater, what are the flow paths for this alluvial groundwater?*
- *What are the major processes by which the alluvial groundwater moves?*
- *What geochemical processes influence water chemistry and contaminant migration in alluvial groundwater?*

*Addressing each of these questions requires an integrated strategy of data collection and evaluation. This strategy is described in terms of specific technical issues that will be addressed by investigation, the importance of each issue relative to the questions, and the technical approach to addressing the issue. Each technical approach to an issue also addresses one or more of the key hypotheses.*

*Table 7.4.4-3 summarizes the relationship between the key hypotheses outlined in Section 7.4.3 and in Chapter 4 of this work plan and the hypotheses addressed by each planned well.*

*Unless otherwise noted, all wells discussed below are listed in Table 7.4.3-1 and shown in Figure 7.4.3-1. The analytical suite for alluvial groundwater samples is presented in Table 7.4.4-4. The analytical suite for borehole core samples is presented in Table 7.4.4-5. Methods for analysis of water samples are described in Section 7.4.4.3.1. Methods for analysis of borehole core samples are described in Section 7.4.4.3.2.*

**TABLE 7.4.4-3**

**RELATIONSHIP BETWEEN KEY HYPOTHESES AND THE PLANNED WELLS TO ADDRESS THE HYPOTHESES**

| Key Hypothesis[a] | Alluvial Wells | | | | | | | | | Regional Aquifer Wells | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *B*[b] | *1*[b] | *2*[b] | *3*[b] | *4*[b] | *5*[b] | *6*[b] | *7*[c] | *3M*[d] | *R-17* | *R-18* | *R-19* | *R-20* | *R-21* | *R-22* |
| *1* | • | • | • | • | • | • | • | • | • | | | • | • | | |
| *2* | • | • | • | • | • | • | • | • | • | | | • | • | | |
| *3* | | | | | | | | | | • | • | • | • | • | • |
| *4* | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • |
| *5* | | | | • | • | • | • | • | • | | | | | | |
| *6* | • | • | • | • | • | • | • | • | | | | • | • | | |
| *7* | | | | | | | | | | • | • | • | • | • | • |
| *8* | | | | | | • | • | • | | • | • | • | • | • | • |
| *9* | | | | | | | | | | • | • | • | • | • | • |
| *10* | | | | | • | • | • | • | | • | • | • | • | • | • |
| *11* | | | | | • | • | • | • | | • | • | • | • | • | • |
| *12* | | | | | | | | | | • | • | • | • | • | • |
| *13* | | | | | | | | | | | | | • | • | • |
| *14* | | | | | | | | | | | | • | • | • | • |
| *15* | | | | | | | | | | | | • | • | • | • |
| *16* | | | | | | | | | | • | • | • | • | • | • |

*a. See Section 7.4.3 for descriptions of key hypotheses.*

*b. PCAO wells*

*c. PCAO-7A, PCAO-7B, and PCAO-7C*

*d. 3MAO-1 and 3MAO-2*

**TABLE 7.4.4-4**

**ANALYTICAL SUITE FOR ALLUVIAL GROUNDWATER SAMPLES***

| | | |
|---|---|---|
| **Field-Measured Parameters** | | |
| *Alkalinity* | *pH* | *Temperature* |
| *Dissolved oxygen* | *Specific conductance* | *Turbidity* |
| **Major and Minor Ions** | | |
| *Aluminum* | *Fluoride* | *Nitrite* |
| *Ammonium* | | |
| *Bromide* | *Iron* | *Phosphate* |
| *Calcium* | *Magnesium* | *Potassium* |
| *Chlorate* | *Manganese* | *Sodium* |
| *Chloride* | *Nitrate* | *Sulfate* |
| **Trace Elements** | | |
| *Aluminum* | *Chromium* | *Silver* |
| *Antimony* | *Cobalt* | *Thallium* |
| *Arsenic* | *Copper* | *Titanium* |
| *Barium* | *Lead* | *Uranium* |
| *Beryllium* | *Mercury* | *Vanadium* |
| *Boron* | *Nickel* | *Zinc* |
| *Cadmium* | *Selenium* | |
| **Organic Chemicals** | | |
| *VOCs* | | |
| *SVOCs* | | |
| *HE* | | |
| **Dissolved Organic Carbon (fractionation analysis)** | | |
| **Total Suspended Solids** | | |
| **Total Dissolved Solids** | | |
| **Neutral Species ($SiO_2$)** | | |
| **Hardness** | | |
| **Cyanide** | | |
| **Radionuclides** | | |
| *Americium-241* | *Strontium-90* | *Uranium-238* |
| *Cesium-137* | *Uranium-234* | *Gamma spectroscopy* |
| *Plutonium-238* | *Uranium-235* | *Gross-alpha, -beta, and -gamma* |
| *Plutonium-239,240* | *Uranium-236* | *Tritium (low detection limit)* |

**Filtered (<0.45 μm) and unfiltered water samples will be collected.*

**TABLE 7.4.4-5**

**ANALYTICAL SUITE FOR BOREHOLE CORE SAMPLES**

| | | |
|---|---|---|
| **Hydrologic Analyses** | | |
| *Moisture content* | | |
| *Moisture potential* | | |
| *Saturated hydraulic conductivity* | | |
| **Anions** | | |
| *Bromide* | *Fluoride* | *Sulfate* |
| *Chloride* | *Nitrate* | |
| **Trace Elements** | | |
| *Aluminum* | *Cobalt* | *Selenium* |
| *Antimony* | *Copper* | *Silver* |
| *Arsenic* | *Iron* | *Thallium* |
| *Barium* | *Lead* | *Titanium* |
| *Beryllium* | *Manganese* | *Uranium* |
| *Cadmium* | *Mercury* | *Vanadium* |
| *Chromium* | *Nickel* | *Zinc* |
| **Organic Chemicals** | | |
| *TOC* | | |
| *SVOCs* | | |
| *HE* | | |
| **Total Organic Carbon** | | |
| **Cyanide** | | |
| **Radionuclides** | | |
| *Americium-241* | *Strontium-90* | *Uranium-238* |
| *Cesium-137* | *Uranium-234* | *Gamma spectroscopy* |
| *Plutonium-238* | *Uranium-235* | *Gross-alpha, -beta, and gamma* |
| *Plutonium-239,240* | *Uranium-236* | *Tritium (low detection limit)* |
| **Selected Samples for the Following** | | |
| *Petrography* | | |
| *X-ray fluorescence* | | |
| *X-ray diffraction* | | |
| *Potassium/argon or argon-30/argon-40 isotopic dating* | | |

### Issue Number 1

*What is the seepage loss across the Pajarito fault in terms of water balance for upper Pajarito Canyon?*

### Importance

*The Pajarito fault approximately parallels the western Laboratory boundary in the Pajarito Canyon area and is approximately perpendicular to the path of upper Pajarito Canyon. The Pajarito fault appears to represent a major zone of streamflow loss and may extend to considerable depth, diverting streamflow to perched zones or to the regional aquifer. Perched groundwater zones recharged by the Pajarito fault* *could include bedding planes and fractures in Qbt 1, 3 and 4, which could provide pathways for spring discharge zones that lead to the regional aquifer.*

*To define the potential water loss across the Pajarito fault, it is necessary to define the volumes of groundwater present in the alluvium upgradient and downgradient of the fault.*

**Approach**

*One well or drive point (PCAO-B) will be installed in the alluvium approximately at the west Laboratory boundary. Another well (PCAO-1) will be installed in the alluvium approximately 1000 ft (300 m) east of the Laboratory boundary at state road NM501. The wells are expected to encounter less than 10 ft (3 m) of alluvium and will be extended 5 to 10 ft (1.5 to 3 m) into the bedrock. The wells are expected to be approximately 15 ft (4.5 m) deep; a screen will be placed at the top of the water table. The wells will be installed and completed as described in Section 7.4.4.2.1. The water level data obtained will be used with information obtained from surface water investigations described in Section 7.3 to determine the amount of infiltration of water into the Pajarito fault zone. Groundwater samples will be collected semiannually for two years. Samples will be analyzed for the parameters listed in Table 7.4.4-4.*

**Issue Number 2**

*What is the background alluvial water quality in upper Pajarito Canyon west of the Laboratory boundary?*

**Importance**

*The determination of background alluvial water quality at the western boundary of the Laboratory is necessary to identify the potential impact of PRSs to alluvial groundwater at downgradient locations. The RCRA facility investigation (RFI) of PRS 9-013 (MDA M) identified the presence of HE compounds in surface water upgradient of the Laboratory boundary. Confirmation of alluvial groundwater quality west of the Laboratory boundary is essential to determine whether the quality represents background conditions or if Laboratory operations have potentially impacted upstream locations. The assessment of upgradient groundwater quality will be used in conjunction with data derived from downgradient locations to determine the relative impact of PRSs within the canyon.*

**Approach**

*One well (PCAO-B) will be installed in the alluvium approximately at the Laboratory boundary at state road NM501. The well is expected to encounter less than 10 ft (3 m) of alluvium and will be extended 5 to 10 ft (1.5 to 3 m) into the bedrock. The well is expected to be approximately 15 ft (4.5 m) deep; a screen will be placed at the top of the water table. The well will be installed and completed as described in Section 7.4.4.2.1. Groundwater samples will be collected semiannually for two years. Samples will be analyzed for the parameters listed in Table 7.4.4-4.*

**Issue Number 3**

*What is the elevation of the water table in the alluvium, and what contaminants are potentially present in groundwater in upper Pajarito Canyon below the confluence with the south fork of Pajarito Canyon?*

**Importance**

*Homestead Spring discharges into Pajarito Canyon and several springs, including the perennial Starmer Spring and Charlie's Spring, discharge to the south fork of Pajarito Canyon in "Starmer Gulch." These springs support streamflow in upper Pajarito Canyon. The amount of saturation and the variation of saturation content in the alluvium and the water balance associated with the springs and the alluvium in Pajarito Canyon downstream from these springs have not previously been investigated. Pajarito Canyon and the south fork of Pajarito Canyon drain TA-22, Anchor West Site (TA-8), and a portion of Anchor East Site (TA-9).*

*TA-8 contains some of the earliest Manhattan Project sites built at the Laboratory, and these TAs have been historically and are currently used for the development, production, study, and testing of explosives. TA-8 was the site of the Manhattan Project Gun-Firing Site as well as MDA Q. In 1945 prototypes of the Little Boy weapon were tested at the Gun-Firing site. In these tests depleted uranium was used in place of the enriched uranium contained in the actual weapon. MDA M, within TA-9, is located on the mesa between Pajarito Canyon and the south fork of Pajarito Canyon. This surface disposal site was the subject of a cleanup action in 1995. Contaminants potentially released from operations at TA-8 and TA-9 that are potentially present in Pajarito Canyon include solvents, photographic processing chemicals, HE compounds, metals, and radionuclides. HE compounds have been detected in the surface water in Pajarito Canyon and in the springs in the lower south fork of Pajarito Canyon ("Starmer Gulch").*

**Approach**

*One well (PCAO-2) will be installed downstream of the confluence of Pajarito Canyon and the south fork of Pajarito Canyon ("Starmer Gulch"). The well is expected to encounter less than 10 ft (3 m) of alluvium and will be extended 5 to 10 ft (1.5 to 3 m) into the bedrock. The well is expected to be approximately 15 ft (4.5 m) deep; a screen will be placed at the top of the water table. The well will be installed and completed as described in Section 7.4.4.2.1. A continuous recording pressure transducer may be installed to obtain water level data for a period of two years. Groundwater samples will be collected semiannually for two years. Samples will be analyzed for the parameters listed in Table 7.4.4-4.*

**Issue Number 4**

*What is the extent of saturation in the alluvium and water quality in Pajarito Canyon below the north and south Anchor East basins that drain the TA-9 area?*

**Importance**

*Bulldog Spring (perennial) and Kieling Spring (seasonal) are located in lower north Anchor East basin ("Arroyo de LaDelfe") and contribute to streamflow in Pajarito Canyon. The contribution to the water budget of Pajarito Canyon from these springs is not known. Anchor Site East (TA-9) contains many outfalls that may have contributed contaminants to the north Anchor East basin and to the south Anchor East basin. Field observations suggest that the springs that discharge to the lower portion of north Anchor East basin ("Arroyo de LaDelfe") may sustain perennial surface flow.*

*Old Anchor East Site, the original TA-9, was established in 1943 to house explosives production, development, and test experiments and x-ray work. TA-9 includes the former Far Point and Nu Site firing sites. These sites were used extensively in the early to mid-1940s; TA-9 is currently active and continues* *to support the development and testing of explosives. A detailed discussion of historical Laboratory operations TA-8 and TA-9 is presented in Section 2.3.1 in Chapter 2 of this work plan.*

**Approach**

*One well (PCAO-3) will be installed near the confluence of Pajarito Canyon and the south Anchor East basin tributary. The well is expected to encounter less than 10 ft (3 m) of alluvium and will be extended 5 to 10 ft (1.5 to 3 m) into the bedrock. The well is expected to be approximately 15 ft (4.5 m) deep; a screen will be placed at the top of the water table. The well will be installed and completed as described in Section 7.4.4.2.1. A continuous recording pressure transducer may be installed to obtain water level data for a period of two years. Groundwater samples will be collected semiannually for two years. Samples will be analyzed for the parameters listed in Table 7.4.4-4.*

**Issue Number 5**

*What is the extent of alluvial saturation and water quality in middle Pajarito Canyon upstream from the confluence with Twomile Canyon and downstream of outfalls at TA-6?*

**Importance**

*The surface water and the alluvial groundwater in middle Pajarito Canyon west of TA-18 contains HE compounds. The source of the HE in the surface water and alluvial groundwater is not known. An alluvial monitoring well upstream of the confluence with Twomile Canyon will help identify the source of the contaminants and will provide information about alluvial saturation for determination of water balance in the alluvium in middle Pajarito Canyon. Identification of the location and geological controls where stream loss occurs will aid in the analysis of water budget and potentially aid in the identification of vertical and horizontal flow pathways in the subsurface.*

*Assessment of water quality will better define the relative contributions of outfalls at TA-6 and PRSs at TA-6, TA-40, and former TA-12 with respect to PRSs in upper Pajarito Canyon. Installation of an alluvial monitoring well will allow the determination of alluvial groundwater water quality in Pajarito Canyon upstream of the confluence with Twomile Canyon.*

**Approach**

*One alluvial monitoring well (PCAO-4) will be installed in Pajarito Canyon upstream of the confluence with Twomile Canyon. The well is expected to encounter less than 10 ft (3 m) of alluvium and will be extended 5 to 10 ft (1.5 to 3 m) into the bedrock. The well is expected to be approximately 15 ft (4.5 m) deep; a screen will be placed at the top of the water table. The well will be installed and completed as described in Section 7.4.4.2.1. A continuous recording pressure transducer may be installed to obtain water level data for a period of two years. Groundwater samples will be collected semiannually for two years. Samples will be analyzed for the parameters listed in Table 7.4.4-4.*

**Issue Number 6**

*What is the extent of alluvial saturation and water quality in middle Pajarito Canyon downstream from the confluence with Twomile Canyon?*

**Importance**

*Streamflow data collected from stream gaging station E245 suggest significant stream loss in the section of Pajarito Canyon downstream from the confluence with Twomile Canyon. In 1996 the surface water at gaging station E245 contained the HE compounds HMX (4.4 μg/L) and RDX (1.01 μg/L). HMX concentrations were two orders of magnitude below its former SAL value, but RDX was present in the surface water at stream gage E245 above its former SAL value of 0.61 μg/L. The alluvial groundwater in Pajarito Canyon west of TA-18 also contains HE compounds. The source of the HE in the surface water and alluvial groundwater is not known. An alluvial monitoring well downstream of the confluence with Twomile Canyon will help identify the source of the contaminants and will provide information about alluvial saturation to determine water balance in the alluvium in middle Pajarito Canyon.*

*Identification of the location and geological controls where stream loss occurs will aid in the analysis of water budget and potentially aid in the identification of vertical and horizontal flow pathways in the subsurface. Assessment of water quality will better define the relative contributions of PRSs and outfalls that discharge to Twomile Canyon. Installation of an alluvial monitoring well will allow the determination of alluvial groundwater water quality in middle Pajarito Canyon downstream of the confluence with Twomile Canyon.*

**Approach**

*One alluvial monitoring well (PCAO-5) will be installed in Pajarito Canyon downstream of the confluence with Twomile Canyon. The well is expected to encounter less than 10 ft (3 m) of alluvium and will be extended 5 to 10 ft (1.5 to 3 m) into the bedrock. The well is expected to be approximately 15 ft (4.5 m) deep; a screen will be placed at the top of the water table. The well will be installed and completed as described in Section 7.4.4.2.1. A continuous recording pressure transducer may be installed to obtain water level data for a period of two years. Groundwater samples will be collected semiannually for two years. Samples will be analyzed for the parameters listed in Table 7.4.4-4.*

**Issue Number 7**

*What is the extent of alluvial saturation and water quality in middle Pajarito Canyon near stream gage E245 upstream of TA-18?*

**Importance**

*Streamflow data collected from stream gaging station E245 suggest significant stream loss in the section of Pajarito Canyon downstream from the confluence with Twomile Canyon. Identification of the location and geological controls where stream loss occurs will aid in the analysis of water budget and potentially aid in the identification of vertical and horizontal flow pathways in the subsurface. Assessment of water quality will better define the relative contributions of PRSs and outfalls that discharge to Twomile Canyon. The alluvial groundwater in Pajarito Canyon west of TA-18 also contains HE compounds. The source of the HE in the surface water and alluvial groundwater is not known. Installation of an alluvial monitoring well in middle Pajarito Canyon will help identify the source of the contaminants and will provide information about saturation within the alluvium for determination of water balance in the alluvium in middle Pajarito Canyon.*

**Approach**

*One alluvial monitoring well (PCAO-6) will be installed in middle Pajarito Canyon downstream of stream gage E245 and between the confluence with Twomile Canyon and Threemile Canyon. The well is expected to encounter less than 20 ft (6 m) of alluvium and will be extended 5 to 10 ft (1.5 to 3 m) into the bedrock. The well is expected to be approximately 25 ft (8 m) deep; a screen will be placed at the top of the water table. The well will be installed and completed as described in Section 7.4.4.2.1. A continuous recording pressure transducer may be installed to obtain water level data for a period of two years. Groundwater samples will be collected semiannually for two years. Samples will be analyzed for the parameters listed in Table 7.4.4-4.*

**Issue Number 8**

*What is the extent of alluvial saturation and water quality in lower Pajarito Canyon downstream from the confluence with Threemile Canyon and downstream from PRSs at TA-18?*

**Importance**

*HE compounds have been observed in the alluvial groundwater in Pajarito Canyon in the baseline wells upstream of TA-18 and in the LACEF wells near Kiva 1 at TA-18. RDX has been observed in concentrations more than three times its former SAL value in the alluvial groundwater upstream of TA-18. HMX, other HE compounds, thorium-228, thorium-230, uranium, and 1,2-dichloroethane have been measured in concentrations above former SAL values in the LACEF wells at TA-18. Surface water in Threemile Canyon also contains HE compounds, traces of organic solvents and radionuclides including 0.89 pCi/L thorium-228, 0.62 pCi/L thorium-230, and up to 3.7 μg/L uranium (see Section 3.6.6 in Chapter 3 of this work plan). The differences in geochemistry of the groundwater in Threemile Canyon and the contribution of contaminants to Pajarito Canyon from Threemile Canyon have not been investigated. In addition, the contribution of alluvial groundwater moving from Threemile Canyon to Pajarito Canyon in terms of water balance has not been determined.*

**Approach**

*A transect of three wells (PCAO-7A, PCAO-7B, and PCAO-7C) will be installed across the width of Pajarito Canyon below the confluence with Threemile Canyon east of TA-18. Information derived from sampling core and groundwater will be used to determine the presence, depth, and thickness of potential saturation and to evaluate the chemistry of groundwater encountered. The wells are expected to encounter approximately 45 ft (13.5 m) of alluvium and will be drilled up to 10 ft (3 m) into the bedrock. The wells are expected to be approximately 50 ft (15 m) deep and a screen will be placed at the top of the water table. Continuous recording pressure transducers may be installed to obtain water level data for a period of two years. These wells will be installed and completed as described in Section 7.4.4.2.1. Groundwater samples will be collected semiannually for two years. Samples will be analyzed for the parameters listed in Table 7.4.4-4.*

*Groundwater samples may be collected from selected existing wells in Pajarito Canyon and Threemile Canyon if appropriate samples can be obtained from the wells. Existing wells that will be sampled in Pajarito Canyon include PCO-1, PCO-2, and PCO-3. Existing wells 18-BG-4 and 18-MW-8 may be sampled in Threemile Canyon. Continuous recording pressure transducers may be installed to obtain water level data for a period of two years. Groundwater samples will be collected semiannually for two years. Samples will be analyzed for the parameters listed in Table 7.4.4-4.*

**Issue Number 9**

*What is the extent of alluvial saturation and water quality in Threemile Canyon downstream from firing sites and outfalls at TA-15?*

**Importance**

*Threemile Spring is a seasonal spring that issues from the alluvium in Threemile Canyon. The source of the water is not known, but the water could come from the emergence of alluvial groundwater in Threemile Canyon. Alluvial groundwater has not previously been documented upstream from the confluence with the south fork of Threemile Canyon. Installing an alluvial monitoring well in Threemile Canyon to determine the presence and amount of saturation in the alluvium would also provide information about water quality and could potentially identify the source of the spring water. Threemile Spring water could also come from infiltration of alluvial groundwater in middle Pajarito Canyon moving down-dip in the Bandelier Tuff to Threemile Canyon. In this case, groundwater may not present the alluvium in Threemile Canyon upstream from Threemile Spring.*

*Surface water collected below Threemile Spring contains HE compounds. The source of the HE compounds could be from firing sites upstream in Threemile Canyon or from alluvial groundwater in middle Pajarito Canyon. Installation of an alluvial monitoring well in Threemile Canyon will also provide information for the determination of water balance in the alluvium in this canyon.*

**Approach**

*One alluvial monitoring well (3MAO-1) will be installed in Threemile Canyon upstream of Threemile Spring. The well is expected to encounter less than 20 ft (6 m) of alluvium and will be extended 5 to 10 ft (1.5 to 3 m) into the bedrock. The well is expected to be approximately 25 ft (8 m) deep; a screen will be placed at the top of the water table. The well will be installed and completed as described in Section 7.4.4.2.1. A continuous recording pressure transducer may be installed to obtain water level data for a period of two years. Groundwater samples will be collected semiannually for two years. Samples will be analyzed for the parameters listed in Table 7.4.4-4.*

*One alluvial monitoring well (3MAO-2) will be installed in Threemile Canyon at the confluence with Pajarito Canyon. The well is expected to encounter less than 40 ft (12 m) of alluvium and will be extended 5 to 10 ft (1.5 to 3 m) into the bedrock. The well is expected to be approximately 45 ft (14 m) deep; a screen will be placed at the top of the water table. The well will be installed and completed as described in Section 7.4.4.2.1. A continuous recording pressure transducer may be installed to obtain water level data for a period of two years. Groundwater samples will be collected semiannually for two years. Samples will be analyzed for the parameters listed in Table 7.4.4-4.*

**Issue Number 10**

*What is the extent of saturation in the alluvium in lower Pajarito Canyon, where do the losses occur from the alluvial groundwater, and what is the water quality in lower Pajarito Canyon from TA-18 to the eastern Laboratory boundary?*

**Importance**

*Most of the water added to Pajarito Canyon from storm water runoff, snowmelt runoff, and discharge from springs and outfalls either seeps into subsurface units in middle Pajarito Canyon or moves down canyon* *in the alluvium into lower Pajarito Canyon. Only occasional surface water outflows from lower Pajarito Canyon are recorded during times of appreciable precipitation events. It appears that the majority of the alluvial groundwater in lower Pajarito Canyon is either lost to evaporation, ET, or to seepage into subsurface units. Neither the mechanism nor the location of the water loss from the alluvium is known. Additional data collection and synthesis is required to obtain an understanding of the dynamics of the alluvial groundwater in lower Pajarito Canyon.*

*The alluvial groundwater in lower Pajarito Canyon contains trace levels of HE compounds, apparently from the movement of alluvial groundwater down canyon from middle Pajarito Canyon and possibly from Threemile Canyon. Currently three alluvial monitoring wells (PCO-1, -2, and -3) are sampled annually by ESH-18 personnel as part of the environmental surveillance program. Two additional alluvial monitoring wells (18-MW-17 and -18) were installed in lower Pajarito Canyon as part of the RFI for OU 1093 (see Section 3.7 in Chapter 3 of this work plan for a discussion of the results of the sampling); these RFI wells are not routinely sampled.*

*Additional sampling of the existing wells and installation of new wells is needed to determine the seasonal and annual variations in water quality of the alluvial groundwater. Continuous water level measurements are needed to determine the transient dynamics of the alluvial groundwater and to calculate the water balance of the alluvial system. This information is needed to infer the locations and amounts of water loss from the alluvial groundwater to better understand hydrologic flow paths and the dynamics of the hydrogeology of Pajarito Canyon.*

**Approach**

*The existing monitoring wells (PCO-1, -2, and -3) will be sampled semiannually for two years to determine the presence of contaminants and to determine the seasonal and annual variations in alluvial groundwater chemistry. Samples will be analyzed for the parameters listed in Table 7.4.4-4. These wells and possibly wells 18-MW-17 and -18 may be installed with continuous recording pressure transducers to obtain water level data for a period of two years.*

#### 7.4.4.1.2 Hydrogeological Characterization of the Regional Aquifer

*This section describes the planned hydrogeologic and geochemical characterization of the regional aquifer and perched intermediate zones encountered beneath Pajarito Canyon. The ultimate goal of this effort is to characterize possible contaminants in intermediate-depth and regional aquifer groundwater and to provide the information needed to enhance the Laboratory's groundwater monitoring program, if necessary. The characterization of Pajarito Canyon will be coordinated with the Hydrogeologic Workplan (LANL 1996, 55430). The locations of the planned regional wells discussed in this section are approximate, and final locations will be determined through discussions with the Laboratory's Groundwater Integration Team and state regulators. The number, location, and scope of the regional wells may be affected by information obtained from previous boreholes drilled as part of the Hydrogeologic Workplan. Changes to the scope of the regional aquifer investigations will be discussed with state regulators during quarterly meetings to evaluate the progress of the Hydrogeologic Workplan investigations. Regulator approval of changes to the scope of regional aquifer investigations will be documented in the minutes of the quarterly meetings. These minutes are distributed to holders of the Hydrogeologic Workplan and are considered addenda to that document.*

*Additionally, before drilling each regional aquifer borehole, a field implementation plan (FIP) will be prepared that describes the field procedures that will be implemented for each specific borehole. The FIP* *details the drilling and sampling methods that will be employed at each borehole and further specifies the locations, number, and types of core, cuttings, and groundwater samples that will be collected based on the most recent information derived from previously drilled boreholes. The FIP supplements this work plan by providing the detailed site-specific information needed to implement the drilling of each deep borehole. Since the deep drilling program at the Laboratory began, several different drilling methods have been used to advance the deep boreholes; the FIP specifies the preferred drilling methods for each deep well by incorporating lessons learned from previous drilling efforts and taking into account evolving drilling technologies.*

*Most of the regional aquifer wells planned for Pajarito Canyon are designed to provide information about intermediate-depth perched groundwater systems and the regional aquifer in areas where no data exist. Large areas of the western and central portion of the Laboratory that are within the Pajarito Canyon watershed area have not been previously been the subject of subsurface investigations. Therefore, no information about perched zones of saturation, water quality, recharge potential, movement of groundwater, and the regional aquifer itself is available for a large area in the central portion of the Laboratory where Pajarito Canyon is located.*

**Planned Regional Aquifer Wells and Hydrogeologic and Geochemical Investigations**

*The wells discussed in this section are listed in Table 7.4.3-3 and shown in Figure 7.4.3-2. Methods for analysis of water samples are described in Section 7.4.4.3.1; methods for analysis of borehole core samples are described in Section 7.4.4.3.2.*

*The regional aquifer investigation will evaluate possible groundwater pathways from the surface to the regional aquifer, assess the potential for downward movement of potentially contaminated groundwater, and determine whether perched groundwater or the regional aquifer contain Laboratory-derived contaminants. The characterization effort will involve evaluation of information from an existing well (PM-2) that is completed in the regional aquifer within Pajarito Canyon, selective sampling and analysis of this well, and installation of six new wells (R-17, R-18, R-19, R-20, R-21, and R-22) in accordance with the Hydrogeologic Workplan (LANL 1996, 55430). The activities are listed below in order of priority as determined by the Hydrogeologic Workplan.*

- *Install regional aquifer well R-22 in lower Pajarito Canyon on Laboratory property approximately 500 ft (150 m) west of the Laboratory boundary at state road NM4. Well R-22 will determine the presence and quality of intermediate perched water downgradient of TA-18 and TA-54. Water chemistry data derived from intermediate perched zones and the regional aquifer may be compared with data from springs located in White Rock Canyon to evaluate potential hydraulic connections. This well is downgradient from MDA L and MDA G, and hydrogeological data collected will support the MDA G performance assessment. R-22 will potentially provide a monitoring point at the eastern Laboratory boundary in Pajarito Canyon.*

- *Install regional aquifer well R-18 to obtain information about the presence and water quality of possible intermediate perched zones of saturation and to collect geochemical data for the regional aquifer in an area of the Laboratory whose geological and hydrological characteristics are poorly understood. This well will provide information about the regional aquifer in an area of the western part of the Laboratory not influenced by the Pajarito fault.*

- *Install regional aquifer well R-20 near PM-2 to help define the presence, vertical extent, and water quality of intermediate perched zones and, with R-21, detect potential migration of organic vapor* *from MDA L at TA-54. The well may provide early warning for contaminants approaching PM-2 from MDA L. This well will be located east of TA-18 and approximately 700 ft (210 m) west of PCO-1. Well R-20 will provide hydrogeologic control and a stratigraphic and contaminant monitoring point below TA-18 PRSs in lower Pajarito Canyon.*

- *Install regional aquifer well R-17 to obtain information about the stratigraphy and hydrology of the western part of the Laboratory and to determine hydraulic and geochemical properties of potential intermediate perched zones and the upper portion of the regional aquifer beneath upper Twomile Canyon south of TA-3. Well R-17 will be located on the east end of a finger of Twomile Mesa between Twomile Canyon and the southwest fork of Twomile Canyon. The purpose of this well is to investigate the regional aquifer and intermediate perched zones in an area where such information is lacking. Results from this well will help identify potential pathways of recharge to the regional aquifer and the direction of flow in various groundwater zones by careful complementary design with nearby wells R-6, R-24, and R-25. At the level of the regional aquifer, R-17 is located upgradient from Mortandad Canyon and may provide baseline hydrogeochemical conditions for the regional aquifer with respect to Mortandad Canyon.*

- *Install regional aquifer well R-19 to determine the potential long-term impacts of upgradient PRSs as well as MDA C and former surface impoundments at TA-35. This well will provide hydrogeologic information about possible perched zones of saturation and the regional aquifer in the central portion of the Laboratory. Additionally, this well will determine the presence of perched zones of saturation within possible paleochannels in the Cerro Toledo interval and the Guaje Pumice Bed and will provide additional stratigraphic and structural control for the location of the paleochannels. Well R-19 will be located in Pajarito Canyon northwest of TA-18. This well could also serve as early detection warning for upgradient contaminants approaching PM-2.*

- *Install regional aquifer well R-21 on Mesita del Buey adjacent to MDA L at TA-54 as discussed in the Hydrogeologic Workplan (LANL 1996, 55431). Well R-21 is designed to evaluate and monitor hydrologic and geochemical conditions in the regional aquifer beneath MDA L. An organic vapor plume is present to a depth of at least 500 ft (150 m) beneath MDA L in the Cerros del Rio basalts. A tritium plume is present to a depth of at least 40 ft (12 m) beneath MDA H. Data obtained from this well will be compared with data from well R-20 to evaluate the vertical migration of the organic chemicals and potential movement toward supply well PM-2.*

- *Zonal sampling of PM-2 and analysis for low-detection-limit tritium; chlorate; organic chemicals; HE compounds; dissolved organic carbon; major and minor ions; trace elements; stable isotopes; field-measured parameters; americium-241; carbon-14; cesium-137; plutonium-238; plutonium-239,240; strontium-90; uranium-234; uranium-235; and uranium-238. This sampling and analysis is designed to determine if contaminants from the alluvial groundwater have possibly reached the regional aquifer near TA-18.*

*The six planned new regional aquifer wells, together with other activities, will address specific issues relevant to characterization of the regional aquifer. These issues, their importance, and the planned technical approach to addressing them are detailed below.*

**Issue Number 1**

*Are intermediate perched zones present beneath Pajarito Canyon, and, if so, what is the thickness of the intermediate perched zones? What contaminants, if any, are present in the intermediate perched zones?*

**Importance**

*Intermediate perched zones may have been identified in borehole SHB-4 and municipal supply well PM-2. No information regarding the presence or characterization of intermediate perched zones is currently available for the upper and middle canyons. Hydrogeologic and stratigraphic control points are essential to gathering information that may be used to develop a model for hydraulic pathways between alluvial systems and the regional aquifer.*

*Buried paleochannels in the subsurface may provide collection points and conduits for intermediate perching zones and lateral transport pathways for groundwater (see Section 3.7.2.1 in Chapter 3 of this work plan). Possible locations of buried paleochannels include the following.*

- *The Cerro Toledo interval channel/fluvial deposits may include a major channel system that extends from the upper reaches of Los Alamos Canyon toward the southeast to Potrillo Canyon. This channel system may cross Pajarito Canyon near TA-18.*
- *The pre-Bandelier Tuff surface may locally be the top of the Puye Formation, the top of Tschicoma Formation intermediate volcanic flows, or the top of Cerros del Rio basalt flows. The ancestral Rio Grande channel appears to trend toward the south-southwest across the Pajarito Plateau and cross Pajarito Canyon west of TA-18.*

**Approach**

*Wells R-17, R-18, R-19, R-20, and R-22 will be constructed along the length of Pajarito Canyon to establish stratigraphic and hydrogeologic control points along a longitudinal transect. The wells are designed to provide characterization of water quality, geochemical, and water level data for potential intermediate perched zones (Bandelier Tuff, basalts, and Puye Formation) and the regional aquifer beneath Pajarito Canyon. Borehole advancement and well construction procedures are described in Section 4.1.1.3 in Chapter 4 of the Hydrogeologic Workplan (LANL 1996, 55430).*

*Groundwater and/or pore water samples collected from the Bandelier Tuff, basalts, Puye Formation, and possibly the Santa Fe Group will be processed using careful sampling and/or filtration/centrifugation techniques. Given adequate volumes of pore water, those samples will be analyzed for the parameters listed in Table 7.4.4-6. Groundwater samples will be analyzed for the parameters listed in Table 7.4.4-7. Borehole core samples will be analyzed for the parameters listed in Table 7.4.4-5.*

**Issue Number 2**

*Is groundwater in upper Twomile Canyon affected by Laboratory operations? Is perched groundwater present in upper Twomile Canyon? What is the depth to the regional aquifer in the upper reaches of the canyons? What is the water quality in the regional aquifer in this part of the Laboratory?*

**Importance**

*Currently, no direct hydrogeologic or stratigraphic information is available in the area comprising the upper canyons within the Pajarito Canyon watershed. Subsurface information from drilling is needed to define the stratigraphy, hydrology, and water quality of groundwater near TA-3, -6, -59 and -69. This area is upgradient of the regional aquifer beneath Mortandad Canyon, and R-17 will provide baseline information for the regional aquifer in this area.*

**TABLE 7.4.4-6**

**ANALYTICAL SUITE FOR PORE WATER EXTRACTED FROM BOREHOLE CORE SAMPLES IN THE DEEP UNSATURATED ZONE[a,b]**

| | | | |
|---|---|---|---|
| **Laboratory-Measured Parameters** | | | |
| *Alkalinity* | | *Specific conductance* | |
| *pH* | | *Temperature* | |
| **Major and Minor Ions** | | | |
| *Aluminum* | *Fluoride* | *Phosphate* | |
| *Ammonium* | *Iron* | *Potassium* | |
| *Bromide* | *Magnesium* | *Sodium* | |
| *Calcium* | *Manganese* | *Sulfate* | |
| *Chlorate* | *Nitrate* | | |
| *Chloride* | *Nitrite* | | |
| **Trace Elements** | | | |
| *Aluminum* | *Chromium* | *Silver* | |
| *Antimony* | *Cobalt* | *Thallium* | |
| *Arsenic* | *Copper* | *Titanium* | |
| *Barium* | *Lead* | *Uranium* | |
| *Beryllium* | *Mercury* | *Vanadium* | |
| *Boron* | *Nickel* | *Zinc* | |
| *Cadmium* | *Selenium* | | |
| **Dissolved Organic Carbon (fractionation analysis)** | | | |
| **Total Suspended Solids** | | | |
| **Total Dissolved Solids** | | | |
| **Neutral Species ($SiO_2$)** | | | |
| **Hardness** | | | |
| **Cyanide** | | | |
| **HE** | | | |
| **Stable Isotopes** | | | |
| *Deuterium/hydrogen* | | | |
| *Oxygen-18/oxygen-16* | | | |
| **Radionuclides** | | | |
| *Americium-241* | *Plutonium-239,240* | *Uranium-235* | *Gamma spectroscopy* |
| *Cesium-137* | *Strontium-90* | *Uranium-236* | *Gross-alpha, -beta, and -gamma* |
| *Plutonium-238* | *Uranium-234* | *Uranium-238* | *Tritium (low-detection-limit)* |

a. *Filtered (<0.45 µm) and unfiltered water samples will be collected.*

b. *If sample volume is limited, analyses will focus on major cations, anions, metals, and tritium.*

## TABLE 7.4.4-7

## ANALYTICAL SUITE FOR INTERMEDIATE PERCHED ZONE AND REGIONAL AQUIFER GROUNDWATER SAMPLES*

| | | | |
|---|---|---|---|
| **Field-Measured Parameters** | | | |
| *Alkalinity* | *pH* | *Temperature* | |
| *Dissolved oxygen* | *Specific conductance* | *Turbidity* | |
| **Major and Minor Ions** | | | |
| *Aluminum* | *Fluoride* | *Phosphate* | |
| *Ammonium* | *Iron* | *Potassium* | |
| *Bromide* | *Magnesium* | *Sodium* | |
| *Calcium* | *Manganese* | *Sulfate* | |
| *Chlorate* | *Nitrate* | | |
| *Chloride* | *Nitrite* | | |
| **Trace Elements** | | | |
| *Aluminum* | *Chromium* | *Silver* | |
| *Antimony* | *Cobalt* | *Thallium* | |
| *Arsenic* | *Copper* | *Titanium* | |
| *Barium* | *Lead* | *Uranium* | |
| *Beryllium* | *Mercury* | *Vanadium* | |
| *Boron* | *Nickel* | *Zinc* | |
| *Cadmium* | *Selenium* | | |
| **Organic Chemicals** | | | |
| *VOCs* | | | |
| *SVOCs* | | | |
| *HE* | | | |
| **Dissolved Organic Carbon (fractionation analysis)** | | | |
| **Total Suspended Solids** | | | |
| **Total Dissolved Solids** | | | |
| **Neutral Species ($SiO_2$)** | | | |
| **Hardness** | | | |
| **Cyanide** | | | |
| **Stable and Radiogenic Isotopes** | | | |
| *Carbon-14* | *Chloride-36* | *Oxygen-18/oxygen-16* | |
| *Carbon-13* | *Deuterium/hydrogen* | | |
| **Radionuclides** | | | |
| *Americium-241* | *Plutonium-239,240* | *Uranium-235* | *Gamma spectroscopy* |
| *Cesium-137* | *Strontium-90* | *Uranium-236* | *Gross-alpha, -beta, and -gamma* |
| *Plutonium-238* | *Uranium-234* | *Uranium-238* | *Tritium (low-detection-limit)* |

**Filtered (<0.45 μm) and unfiltered water samples will be collected.*

**Approach**

*Well R-17 will be installed on the east end of a finger of Twomile Mesa located between Twomile Canyon and the southwest fork of Twomile Canyon (see Figure A-1). The purpose of this well is to investigate the regional aquifer and intermediate perched zones in a canyon system where such information is lacking. R-17 is expected to intersect the regional aquifer at approximately 1200 ft (360 m) below ground level and be drilled to a total depth of 1300 ft (390 m). The location of the well and the estimated drill depths of major subsurface units are shown in Figure A-2.*

*Well R-18 will be installed south of middle Pajarito Canyon on Pajarito Mesa (see Figure A-1). This well will provide information about perched groundwater and the regional aquifer in an area where the hydrology and geology of the Laboratory are poorly understood. This well is expected to intersect the regional aquifer at approximately 1200 ft (360 m) and be drilled to a total depth of 1300 ft (390 m). The location of the well and the estimated drill depths of major subsurface units are shown in Figure A-2.*

*Groundwater and/or pore water samples may be collected from the Bandelier Tuff, basalts, Puye Formation, and Santa Fe Group sediments. Samples will be processed using careful sampling and/or filtration/centrifugation techniques. If needed and given adequate volumes of pore water, those samples will be analyzed for the parameters listed in Table 7.4.4-6. Groundwater samples will be analyzed for the parameters listed in Table 7.4.4-7. Borehole core samples will be analyzed for the parameters listed in Table 7.4.4-5.*

**Issue Number 3**

*What is the subsurface stratigraphy and groundwater quality in middle Pajarito Canyon structurally down-dip from MDA C and impoundments at TA-35?*

**Importance**

*Former oil impoundments at TA-35 and the former landfill at MDA C may have potentially impacted groundwater quality downgradient of these sites. The New Mexico Environment Department (NMED) has required that groundwater monitoring be conducted as part of the approval for closure of the oil impoundments at TA-35. The Bandelier Tuff dips toward the southeast at TA-35, and planned regional aquifer wells in middle Pajarito Canyon may be located appropriately to monitor potential impacts to intermediate perched zones or the regional aquifer. If contaminants are present in the regional aquifer, a monitoring well located upgradient of PM-2 is needed to provide early warning of the advance of contaminants.*

*A pre-Bandelier Tuff paleochannel extends across the Pajarito Plateau from north to south and appears to cross Pajarito Canyon west of TA-18. Intermediate zones of perched groundwater are present in the Guaje Pumice Bed at the base of the Bandelier Tuff beneath Los Alamos Canyon. This perched groundwater may move laterally down the pre-Bandelier Tuff paleochannel within the Guaje Pumice Bed and cross beneath Pajarito Canyon near TA-18 (LANL 1996, 55430, p. 4-50). Investigations are needed to better delineate the location of the paleochannel, determine if intermediate perched groundwater is present in the Guaje Pumice Bed, and, if present, characterize the perched groundwater. Adequate characterization of the perched groundwater could determine the source of the water and identify potential flow paths.*

**Approach**

*Install regional aquifer well R-19 in Pajarito Canyon just northwest of TA-18. This well will be located down stratigraphic and structural dip (at the Bandelier Tuff level) from former impoundments at TA-35 and approximately along the axis of the pre-Bandelier Tuff paleochannel. This well is expected to encounter the regional aquifer at approximately 900 ft (270 m) below ground level and is projected to be drilled to a total depth of 1000 ft (300 m).*

*Groundwater and/or pore water samples may be collected from the Bandelier Tuff, basalts, Puye Formation, and Santa Fe Group sediments. Samples will be processed using careful sampling and/or filtration/centrifugation techniques. If needed and given adequate volumes of pore water, those samples will be analyzed for the parameters listed in Table 7.4.4-6. Groundwater samples will be analyzed for the parameters listed in Table 7.4.4-7. Borehole core samples will be analyzed for the parameters listed in Table 7.4.4-5.*

**Issue Number 4**

*Is the organic vapor plume beneath MDA L migrating into Pajarito Canyon and are intermediate perched zones present beneath Pajarito Canyon?*

**Importance**

*Buried contaminants at MDA L (organic solvents) have been observed to have migrated at least 500 ft (150 m) beneath Mesita del Buey. Tritium beneath MDA H at TA-54 has migrated at least 40 ft (12 m) beneath the mesa top. One borehole drilled at an angle beneath MDA L encountered a small zone of possibly perched water within the basalt in the Puye Formation. Investigations to determine the potential impact of the MDAs at TA-54 on intermediate perched zones and the regional aquifer have not been completed. Monitoring of the regional aquifer along the perimeter of TA-54 is needed to fully assess the potential impacts of contaminant migration with depth. If contaminants have reached the regional aquifer, a monitoring well located between PM-2 and MDA L is needed to provide an early warning of the potential movement of contaminants toward the well.*

*During drilling of PM-2, a "show of water" at 335 ft (100 m) was reported (see Section 3.7.4 in Chapter 3 of this work plan). This is interpreted to be within the Otowi Member of the Bandelier Tuff, which has not previously been observed to contain significant saturation. Fracture flow or matric flow of alluvial groundwater beneath Pajarito Canyon could be a source of intermediate perched zones of saturation. Previously unidentified flow paths to the regional aquifer could be present locally. Installation of a monitoring well to the regional aquifer is needed to assess the potential presence of intermediate perched zones of saturation and to determine the geochemistry of potential intermediate zones of saturation.*

**Approach**

*Well R-20 will be located east of PM-2 and approximately 700 ft (210 m) west of PCO-1. Well R-20 will provide hydrogeologic control and a stratigraphic and contaminant monitoring point below TA-18 PRSs in lower Pajarito Canyon. The location of the borehole should confirm or deny the presence of the intermediate perched zone observed at PM-2 and provide control for paleochannel location efforts. Well R-20 would monitor for vapor plume migration from MDA L and may provide early warning for contaminants approaching PM-2.*

*Groundwater and/or pore water samples may be collected from the Bandelier Tuff, basalts, Puye Formation, and Santa Fe Group sediments. Samples will be processed using careful sampling and/or filtration/centrifugation techniques. If needed and given adequate volumes of pore water, those samples will be analyzed for the parameters listed in Table 7.4.4-6. Groundwater samples will be analyzed for the parameters listed in Table 7.4.4-7. Continuous borehole core samples will be collected and analyzed for the parameters listed in Table 7.4.4-5.*

**Issue Number 5**

*Are intermediate perched zones present beneath lower Pajarito Canyon near the Laboratory boundary? What is the depth to the regional aquifer? What is the water quality of the regional aquifer beneath lower Pajarito Canyon?*

**Importance**

*The lower part of Pajarito Canyon near the Laboratory boundary is located downstream from the TA-54 disposal areas and may be downgradient from intermediate zones of saturation. Buried contaminants at MDA L (organic solvents) have been observed to have migrated at least 500 ft (150 m) beneath Mesita del Buey. Tritium beneath MDA H has migrated at least 40 ft (12 m) beneath the mesa top. One borehole drilled at an angle beneath MDA L encountered a small zone of possibly perched water within the basalt in the Puye Formation. Investigations to determine the potential impact of the MDAs at TA-54 on intermediate perched zones and the regional aquifer have not been completed. Monitoring of the regional aquifer along the perimeter of TA-54 is needed to fully assess the potential impacts of contaminant migration with depth. If contaminants have reached the regional aquifer, a monitoring well at the eastern boundary of the Laboratory in Pajarito Canyon is needed to monitor the potential for off-site migration of contaminants. A deep monitoring well southeast of TA-54 is needed to provide pre-Bandelier Tuff stratigraphic information to support the MDA G performance assessment.*

*Alluvial groundwater present in lower Pajarito Canyon potentially provides recharge to subsurface units and possibly the regional aquifer. Since 1950 no boreholes have been drilled in lower Pajarito Canyon to assess the presence of groundwater beneath the canyon. A borehole in lower Pajarito Canyon is needed to assess the impact of alluvial groundwater on deeper units.*

*Hydrogeologic and stratigraphic control and water quality information is needed along the eastern Laboratory boundary. A characterization well in Pajarito Canyon at the eastern boundary will provide water chemistry data from possible intermediate perched zones and from the regional aquifer that can provide comparison with springs in White Rock Canyon. Hydrogeologic information obtained at this location will evaluate potential hydrologic connections between the regional aquifer and springs in White Rock Canyon. If needed, a well at the eastern Laboratory boundary could be used for long-term monitoring of groundwater leaving the Laboratory.*

**Approach**

*Well R-22 will be located in lower Pajarito Canyon approximately 500 ft (150 m) west of the Laboratory boundary at state road NM4. Well R-22 will provide characterization of groundwater at the eastern Laboratory boundary. Well R-22 will determine the presence and quality of intermediate perched water downgradient of the TA-54 disposal areas. Water chemistry data derived from intermediate perched zones and the regional aquifer may be compared with data from springs located in White Rock Canyon to* *evaluate potential hydraulic connections. Pre-Bandelier Tuff geological data may be collected to support the MDA G performance assessment.*

*Groundwater and/or pore water samples may be collected from the Bandelier Tuff, basalts, Puye Formation, and Santa Fe Group sediments if saturation occurs in these different strata. Samples will be processed using careful sampling and/or filtration/centrugation techniques. If needed and given adequate volumes of pore water, those samples will be analyzed for the parameters listed in Table 7.4.4-6. Groundwater samples will be analyzed for the parameters listed in Table 7.4.4-7. Borehole core samples will be analyzed for the parameters listed in Table 7.4.4-5.*

### 7.4.4.2 Core and Water Sampling Methods

*All samples will be collected using applicable ER Project SOPs (Table 7.4.4-8) for the collection, preservation, identification, storage, transport, and documentation of environmental samples. Decontamination of sampling equipment will be performed in accordance with LANL-ER-SOP-01.08, "Field Decontamination of Drilling and Sampling Equipment." Wash water and other wastes generated during the sampling operation will be managed and disposed of in accordance with LANL-ER-SOP-1.06, "Management of RFI Program Wastes."*

**TABLE 7.4.4-8**

**REQUIREMENTS FOR**
**GROUNDWATER AND BOREHOLE CORE SAMPLING METHODS**

| Activity | LANL-ER-SOP No. |
|---|---|
| *Monitoring well construction* | *05.01* |
| *Well development* | *05.02* |
| *Purging of wells for representative sampling* | *06.01* |
| *Pressure transducer measurements* | *07.01* |
| *Fluid level measurements* | *07.02* |
| *Drilling methods and drill site management* | *04.01* |
| *General borehole logging* | *04.04* |
| *Core-barrel sampling for subsurface earth materials* | *06.26* |
| *Field logging, handling, and documenting of borehole samples* | *12.01* |

#### 7.4.4.2.1 Alluvial Borehole Advancement and Well Installation

*Borehole advancement and well installation specifications for Type 1 (alluvial) wells that will be followed in this investigation are discussed in Section 4.1.1.1 in Chapter 4 of the Hydrogeologic Workplan (LANL 1996, 55430, p. 4-16). The only exception to those specifications is that continuous core samples will be collected throughout each alluvial borehole. The boreholes will be drilled through the alluvium and at least 10 ft (3 m) into bedrock to investigate the perching mechanism at the base of the alluvium.*

#### 7.4.4.2.2 Regional Aquifer Borehole Advancement and Well Installation

*Borehole advancement and well installation procedures that will be followed in this investigation are discussed in Section 4.1.1.2 in Chapter 4 of the Hydrogeologic Workplan (LANL 1996, 55430, p. 4-16).*

#### 7.4.4.2.3 General Geophysical Procedures

*Geophysical logging will be conducted on the boreholes for the wells completed in the regional aquifer. The application of logging techniques will complement hydrogeologic data collected from core samples. Cased-hole wireline logging will be conducted on the regional aquifer boreholes and/or wells. Application of the various logging techniques will depend on geologic conditions encountered and will be determined on a well-by-well basis.*

*Portions of the boreholes for the regional aquifer wells may be logged with open-hole logging tools if borehole stability is such that the borehole can be advanced without casing. After logging, casing will be set in this interval, and the borehole will be advanced to a nominal total depth of 100 ft (30 m) into the top of the regional aquifer. Because of the unconsolidated nature of the subsurface strata and use of air-rotary drilling, these boreholes may be cased before open borehole logging can be accomplished. Cased-hole logging will be performed from surface to total depth.*

*Procedures for open-hole and cased-hole geophysical logging are discussed in Section 4.1.6 in Chapter 4 of the Hydrogeologic Workplan (LANL 1996, 55430).*

#### 7.4.4.2.4 General Sampling Guidelines

*The procedures described in this section follow those in Chapter 4 of the Hydrogeologic Workplan (LANL 1996, 55430) (Section 4.1.3 for borehole sampling and Section 4.1.4 for groundwater sampling) with several exceptions. Because of the number of exceptions, the procedures are fully described in this section rather than incorporating the Hydrogeologic Workplan by reference. In general, the following guidelines will apply to sampling the boreholes before installation of the six regional aquifer wells.*

- *Samples of cuttings or core will be collected and analyzed to identify potential contaminants at each borehole location. The uppermost sample in each borehole will be analyzed for a full range of compounds (see Table 7.2.6-3 and Table 7.2.6-4). Deeper samples will be analyzed for major and minor anions, trace elements, and tritium (low- and high-detection-limit) as well as other COPCs appropriate for that location. In addition, selected samples from each borehole will be analyzed for volatile organic compounds (VOCs) and SVOCs.*

- *Each core or cutting interval will be photographically documented and digitally stored as a visual log together with lithologic information and other data such as geophysical logs or sample analyses according to depth.*

- *Core and cutting samples will be field screened for radioactivity using a Geiger-Müller detector and monitored for VOCs using a photoionization detector. Field screening will be conducted at regular intervals during borehole advancement.*

- *For the regional aquifer wells, borehole anemometry testing may be conducted in the Bandelier Tuff at 10 ft (3 m) intervals in selected boreholes.*

- *Retrieved core and cuttings samples will be analyzed for moisture content at 10-ft (3-m) intervals. Samples will be routinely analyzed for moisture content at 50-ft (15-m) intervals in the Puye Formation, basalts, or Tschicoma Formation. Samples will not be analyzed for moisture content where saturation is encountered.*

- *For planning and conceptual design purposes, it has been assumed that four water-bearing zones will be encountered during advancement of each borehole including three intermediate perched zones and the regional aquifer. Four zones were selected for planning purposes because other recent deep wells installed by the ER Project encountered one to five perched zones in addition to the regional aquifer. Groundwater samples will be collected from each water-bearing zone and analyzed for the parameters listed in Table 7.4.4-7 (or Table 7.4.4-6 for core pore water samples). Laboratory analyses for these different analytes will be performed on filtered samples and on unfiltered samples if the water sample is relatively nonturbid (that is, less than 5 turbidity units).*

- *Hydraulic properties analyses will be conducted on core samples in each borehole based on geologic and hydrologic conditions encountered and the need to provide critical parameters for site-wide numerical models evaluating flow and transport.*

- *Samples of cuttings or core will be selected based on geologic conditions encountered and, as appropriate, will be submitted for petrographic, x-ray fluorescence, and x-ray diffraction analyses to characterize the lithologic units penetrated.*

- *Samples may be collected for isotopic dating of basalts or tuff deposits in the Puye Formation to provide correlation with similar volcanic deposits encountered in widespread boreholes.*

*Groundwater from the newly-installed regional aquifer wells will be sampled according to the following general procedures and assumptions.*

- *As the boreholes are being drilled, drilling will be interrupted whenever intermediate perched zone groundwater is encountered and when the top of the regional aquifer is encountered. The casing string may be retracted slightly, as necessary, to ensure representative sampling. The borehole will be bailed to reduce the effect of drilling operations, and the borehole may be rested for up to 12 hours before sampling. Samples will be retained for an appropriate period of time to enable reanalysis, if needed.*

- *After the wells are completed and developed, groundwater samples will be collected from the screened intervals and analyzed for the presence of selected RCRA Appendix VIII and IX constituents and radionuclides.*

- *After the wells are completed, groundwater from two depths will be sampled and analyzed twice at approximately six-month intervals. Then the well may be turned over to ESH-18 for possible use in long-term groundwater monitoring.*

### 7.4.4.3 Analytical Methods

*This section describes the methods for analyzing groundwater samples for organic and inorganic chemicals and radionuclides and the methods for analyzing borehole core samples for inorganic chemicals, radionuclides, and geotechnical parameters. Analysis of groundwater and borehole core samples has two purposes: (1) to detect and measure Laboratory-derived COPCs and (2) to obtain information about the geochemistry of the water-bearing zones.*

#### 7.4.4.3.1 Analysis of Groundwater Samples

*Groundwater samples collected according to the strategy outlined in Section 7.4.4.1 will initially undergo full-suite analyses for organic and inorganic chemicals and radionuclides at ER Project-approved fixed-*

*site laboratories. The analytical suites for analysis of organic and inorganic chemicals and radionuclides are listed in Table 7.4.4-4, Table 7.4.4-5, Table 7.4.4-6, and Table 7.4.4-7. All analyses for organic chemicals will be performed in accordance with EPA SW-846 protocols (EPA 1987, 57589). The detailed analyte lists, EQLs, minimum detectable activities, required QC procedures, and the acceptance criteria are found in the 1995 ER Project analytical services statement of work (LANL 1995, 49738) or the version that is current when this work plan is implemented. The first sample collected from each alluvial and regional aquifer well location will undergo analysis for the full suite of organic and inorganic chemicals and radionuclides. If chemicals are identified as COPCs for a particular sampling location, all subsequent samples from that location will be analyzed for appropriate COPCs. Any analyte reported as not detected may be excluded from subsequent limited-suite analyses.*

*All water samples will be analyzed for inorganic chemicals to identify COPCs and to obtain a better understanding of the baseline geochemistry of surface water and groundwater. The target analytes, conservative EDLs, and analytical methods for inorganic chemicals are listed in Table 7.4.4-9. Water samples collected for inorganic analyses will be filtered at the time of collection to remove particles larger than 0.45 μm. In addition, unfiltered water samples will be collected to evaluate the influence of suspended particles on water chemistry (including suspended solids), if the measured turbidity is less than 5 turbidity units. Analyses of these samples will be supplemented by analyses of unfiltered samples collected for environmental monitoring by ESH-18. Measurements for inorganic chemicals include analyses for 26 trace metals, major anions (bromide, chloride, fluoride, nitrate, sulfate, and field alkalinity), minor anions (chlorate, nitrite, and orthophosphate), dissolved silica, and total cyanide. All analyses for inorganic chemicals will be performed in accordance with EPA SW-846 protocols (EPA 1987, 57589), EPA standard methods (EPA 1983, 56406), or standard methods for chemical analysis of water (Franson 1995, 56405). The required QC procedures and acceptance criteria for the metals and total cyanide analyses are found in the 1995 ER Project analytical services statement of work (LANL 1995, 49738) or the version that is current when this work plan is implemented.*

*The target analytes and their half-lives, detected emission, minimum detectable activities, and analytical methods for radionuclides are listed in Table 7.4.4-10. In addition to measurements of gross-alpha, -beta, and -gamma radioactivity, the radionuclide analytes include americium-241; plutonium-238; plutonium-239,240; strontium-90; tritium; uranium-234; uranium-235; uranium-236; and uranium-238. The analyses for low-detection-limit tritium and uranium-236 will help identify whether recent recharge to an intermediate aquifer and the regional aquifer has occurred.*

*The ER Project analyte list for the gamma spectroscopy analysis (see Table 7.2.6-5) includes the decay series of the naturally occurring radionuclides thorium-232, uranium-235, and uranium-238 as well as fission and activation products and their progeny. Measurements of naturally occurring radionuclides known to be present in Laboratory soils provide an indication of the quality of the gamma spectroscopy measurement. Radionuclides with half-lives less than 365 days are not considered to be COPCs. Data for these short-lived radionuclides can be useful when evaluating values reported for a parent radionuclide because the relative activity concentration of parent and daughter isotopes is a known quantity. The shorter-lived radionuclides are usually included in the analyte list to verify the presence of longer-lived parent isotopes, but they are not evaluated as primary radionuclides because they decay to unmeasurable concentrations within the span of several years or less. The naturally occurring radionuclide is present in Laboratory soils at concentrations ranging from 25 to 40 pCi/g and is always present in the gamma spectra of Laboratory soil samples. The potassium-40 gamma emission peak provides a qualitative indicator of the accuracy and precision of the gamma spectroscopy measurement, but potassium-40 is not considered to be a potential contaminant. The required QC procedures and acceptance criteria for the radiochemical analyses (except low-level tritium and uranium-236) are found in the 1995 ER Project analytical services statement of work (LANL 1995, 49738) or the version that is current when this work plan is implemented.*

## TABLE 7.4.4-9

## ESTIMATED DETECTION LIMITS AND ANALYTICAL METHODS FOR INORGANIC CHEMICALS IN GROUNDWATER SAMPLES[a]

| Analyte | EDL (µg/L) | Analytical Method | Analytical Protocol[b] |
|---|---|---|---|
| **Metals (total and dissolved)** | | | |
| Aluminum | 10 | ICPES | SW-6010B |
| Ammonium | 20 | IC | SW-9056 |
| Antimony | 0.1 | ICPMS | SW-6020 |
| Arsenic | 1 | ETVAA | SW-7060A |
| Barium | 2 | ICPES | SW-6010B |
| Beryllium | 5 | ICPES | SW-6010B |
| Boron | 10 | ICPES | SW-6010B |
| Cadmium | 1 | ICPMS | SW-6020 |
| Calcium | 10 | ICPES | SW-6010B |
| Chromium | 2 | ICPES | SW-6010B |
| Cobalt | 2 | ICPES | SW-6010B |
| Copper | 2 | ICPES | SW-6010B |
| Iron | 10 | ICPES | SW-6010B |
| Lead | 3 | ETVAA or ICPMS | SW-7421 or SW-6020 |
| Magnesium | 10 | ICPES | SW-6010B |
| Manganese | 2 | ICPES | SW-6010B |
| Mercury | 0.2 | CVAA | SW-7470A |
| Nickel | 2 | ICPES | SW-6010B |
| Potassium | 10 | ICPES | SW-6010B |
| Selenium | 0.2 | ETVAA | SW-7740 |
| Silver | 0.2 | ICPES | SW-6010B |
| Sodium | 50 | ICPES | SW-6010B |
| Thallium | 2 | ICPMS | SW-6020 |
| Titanium | 2 | ICPES | SW-6010B |
| Uranium | 1 | ICPMS | SW-6020 |
| Vanadium | 2 | ICPES | SW-6010B |
| Zinc | 10 | ICPES | SW-6010B |
| **Anions (dissolved)** | | | |
| Bromide | 20 | IC | SW-9056 |
| Chlorate | 20 | IC | SW-9056 |
| Chloride | 20 | IC | SW-9056 |
| Fluoride | 20 | IC | SW-9056 |
| Nitrate | 40 | IC | SW-9056 |
| Nitrite | 40 | IC | SW-9056 |
| Orthophosphate | 20 | IC | SW-9056 |
| Sulfate | 100 | IC | SW-9056 |
| **Other Inorganic Chemicals (dissolved)** | | | |
| Silica | 200 | Colorimetry | EPA Method 370.1 |
| Total cyanide | 50 | Colorimetry | SW-9012A |

a. Both unfiltered (total) and filtered (dissolved) water samples will be collected. Water samples will be filtered at the time of collection to remove particles larger than 0.45 µm.

b. EPA SW-846 Method (EPA 1987, 57589) or equivalent

**TABLE 7.4.4-10**

**MINIMUM DETECTABLE ACTIVITY AND ANALYTICAL METHODS FOR RADIONUCLIDES IN GROUNDWATER SAMPLES[a]**

| Analyte | Half-Life (yr) | Detected Emission | Minimum Detectable Activity (pCi/L) | Analytical Method |
|---|---|---|---|---|
| Americium-241 | 432.2 | $\alpha$ | 0.05 | $\alpha$-Spectrometry |
| Plutonium-238 | 87.7 | $\alpha$ | 0.05 | $\alpha$-Spectrometry |
| Plutonium-239,240[b] | $2.411 \times 10^4$ | $\alpha$ | 0.05 | $\alpha$-Spectrometry |
| Strontium-90 | 28.7 | $\beta$ | 1.0 | GPC |
| Tritium | 12.3 | $\beta$ | 250 | LSC |
| Tritium (low level) | 12.3 | $\beta$ | 1 | Electrolytic enrichment/GPC |
| Uranium-234 | $2.46 \times 10^5$ | $\alpha$ | 0.1 | $\alpha$-Spectrometry[c] |
| Uranium-235 | $7.04 \times 10^8$ | $\alpha$ | 0.1 | $\alpha$-Spectrometry[c] |
| Uranium-236 | $2.342 \times 10^7$ | $\alpha$ | 0.1 | TIMS |
| Uranium-238 | $4.47 \times 10^9$ | $\alpha$ | 0.1 | $\alpha$-Spectrometry[c] |
| Gamma spectroscopy[e] | N/A[f] | $\gamma$ | 10[g] | $\gamma$-Spectroscopy |
| Gross-alpha | N/A | $\alpha$ | 1.0 | GPC or LSC |
| Gross-beta | N/A | $\beta$ | 1.0 | GPC or LSC |
| Gross-gamma | N/A | $\gamma$ | 20 | NaI(Tl) or HPGe detection |

a. All water samples will be filtered at the time of collection to remove particles larger than 0.45 µm.
b. The plutonium-239 and plutonium-240 isotopes cannot be distinguished by alpha spectrometry. The half-life of plutonium-239 is given.
c. Radionuclide may also be analyzed by ICPMS.
d. Water sampling for uranium-236 analysis should use clean protocols including EPA 1669 or United States Geological Survey 94-539
e. The gamma spectroscopy analyte list is given in Table 7.2.6-5.
f. N/A = not applicable
g. The minimum detectable activity for cesium-137 is 1.0 pCi/L; the minimum detectable activities for other analytes will vary.

Groundwater samples will also be analyzed for the additional parameters listed in Table 7.4.4-11. To better understand the nature of recharge to an intermediate-depth groundwater zone and the regional aquifer, analysis for carbon-14, chloride-36, and stable isotope ratios deuterium/hydrogen and oxygen-18/oxygen-16 may be performed to estimate the age of water and to help identify specific sources of recharge. Analyses for carbon-13 and dissolved organic carbon (humic acids by fractionation analysis) will be performed to provide a better understanding of the organic geochemistry of the groundwater.

The field measurements listed in Table 7.4.4-12 will be made at the time of sample collection.

**TABLE 7.4.4-11**

**ANALYTICAL METHODS FOR ADDITIONAL PARAMETERS IN GROUNDWATER SAMPLES[a]**

| Analyte | Analytical Method |
|---|---|
| **Stable and Radiogenic Isotopes[b]** | |
| *Carbon-14, carbon-13* | *Accelerator MS* |
| *Deuterium/hydrogen* | *Accelerator MS* |
| *Oxygen-18/oxygen-16* | *MS* |
| *Chloride-36* | *MS* |
| **Organic Chemicals** | |
| *VOCs* | *SW-8260[c]* |
| *SVOCs* | *SW-8270* |
| *HE[e]* | *SW-8330* |
| **Other Analytes** | |
| *Total organic carbon* | *SW-415.1[d]* |
| *Dissolved organic carbon (humic substances)* | *USGS/WRI 79-4* |
| *Hardness (as calcium carbonate)* | *EPA Method 130* |

*a. All water samples will be filtered at the time of collection to remove particles larger than 0.45 µm.*

*b. Stable isotopes will be measured in intermediate-depth and regional aquifer groundwater samples.*

*c. EPA SW-846 Methods (EPA 1987, 57589)*

*d. EPA 1983, 56406*

*e. All alluvial and perched groundwater samples will be analyzed for HE compounds. The initial samples of the regional aquifer will be analyzed for HE compounds, but subsequent samples of the regional aquifer will be analyzed for HE compounds only if detected in the initial samples.*

**TABLE 7.4.4-12**

**FIELD MEASUREMENTS FOR GROUNDWATER SAMPLES**

| Measurement | Precision[a] | Method |
|---|---|---|
| *Alkalinity* | *±1 mg/L calcium carbonate* | *EPA Method 310.1* |
| *Dissolved oxygen* | *±0.1 mg/L* | *LANL-ER-SOP-06.02[b]* |
| *pH* | *±0.02* | *LANL-ER-SOP-06.02* |
| *Specific conductance* | *±1 mmho/cm (µS/cm)* | *LANL-ER-SOP-06.02* |
| *Temperature* | *±1 °C* | *LANL-ER-SOP-06.02* |
| *Turbidity (nephelometric)* | *±1 NTU* | *EPA Method 180.1* |

*a. Precision with which measurement will be recorded*

*b. ER Project SOPs*

### 7.4.4.3.2 Analysis of Borehole Core Samples

*Borehole core samples collected according to the criteria outlined in Section 7.4.3.1.4 will undergo analysis at ER Project-approved laboratories for the organic (HE) and inorganic chemicals and radionuclides listed in Table 7.2.6-3 and Table 7.2.6-4. In addition, TOC or amount of solid organic* *carbon will be measured in borehole core samples containing or potentially containing HE compounds and degradation products. The purpose of the analyses is to identify COPCs and to obtain a better understanding of the baseline geochemistry of the water-bearing zones. The target analytes, EDLs, and analytical methods for inorganic chemicals are listed in Table 7.4.4-13. Measurements for inorganic chemicals include analyses for 26 trace metals, major and trace anions (bromide, chloride, fluoride, and sulfate), and total cyanide. All analyses for inorganic chemicals will be performed according to EPA SW-846 protocols (EPA 1987, 57589) or EPA standard methods for chemical analysis of wastes. Core samples will be processed using EPA SW-846 mineral acid ($HNO_3$) extraction procedures (EPA SW-846 Method SW-3050 [EPA 1987, 57589]) for analysis of trace metals. The anion analyses will be performed on the leachate formed from a deionized water slurry (leaching time is 16 hours) of the homogenized core samples. The required QC procedures and acceptance criteria for the metals and total cyanide analyses are found in the 1995 ER Project analytical services statement of work (LANL 1995, 49738) or the version that is current when this work plan is implemented.*

*Borehole core samples will also be analyzed for the properties identified in Table 7.4.4-14. The geotechnical, geochemical, hydrologic, and geophysical analyses will be performed on selected core samples based on the judgment of the field geologist and the technical team.*

#### 7.4.4.4 Hydrologic and Geochemical Modeling

*Hydrologic and geochemical modeling may be performed as part of data synthesis and evaluation activities and may help to determine additional data needs. One goal of this work plan relates to an understanding and prediction of hydrologic flow paths and an evaluation of geochemical reactions and the resultant movement of solutes in groundwater in Pajarito Canyon. Tools for this purpose include computer models, such as MINTEQA2 (Allison et al. 1991, 49930), and others discussed in Section 5.3.1 in Chapter 5 of the core document (LANL 1997, 55622).*

*Hydrologic modeling may be useful first to describe and verify water-balance estimates. Models used could include MODFLOW and others as outlined in Section 5.4.2.1.2 in Chapter 5 of the core document (LANL 1996, 55622). Movement in the alluvium may be modeled using MODFLOW; unsaturated flow may be modeled using UNSATII, FEHM, or TRACR3D. The regional aquifer will likely require development of a new model (Frenzel 1995, 56028).*

*Hydrologic and geochemical modeling may be applied at any stage of this investigation. In the project design phase, modeling may be used to examine hypotheses relating to the hydrogeologic components of the conceptual model and to determine where additional information is needed. In later phases, hydrologic and geochemical modeling may be used to refine the conceptual model and assess viable techniques to remediate actinide-contaminated sediments and groundwater, as needed. Results of the modeling efforts could provide source term inputs to stochastic human health and ecological risk models for determining relative risks from water exposure pathways now and in the future.*

*As new data are acquired, the data will be continually evaluated to refine the hydrogeologic and geochemical components of the conceptual model. For example, new data collected in Pajarito Canyon may be compared with groundwater flow maps, water chemistry, conceptual hypotheses, and model predictions to assess the level of understanding regarding recharge and discharge areas, groundwater flow directions, geochemical reactions such as adsorption and mineral-solid phase precipitation and interconnections between alluvial groundwater, intermediate perched zones, and the regional aquifer. If there is agreement between the modeled features and the observed features in Pajarito Canyon, it will be possible to incorporate reasonable assumptions into the groundwater and geochemical modeling effort.*

*This type of analysis can determine whether it is necessary to collect additional field data for the groundwater characterization.*

**TABLE 7.4.4-13**

**ESTIMATED DETECTION LIMITS AND ANALYTICAL METHODS FOR INORGANIC CHEMICALS IN BOREHOLE CORE SAMPLES**

| Analyte | EDL (mg/kg) | Analytical Method | Analytical Protocol[a] |
|---|---|---|---|
| **Metals** | | | |
| Aluminum | 40 | ICPES | SW-6010B |
| Ammonium | 0.1 | IC | SW-9056 |
| Antimony | 0.1 | ICPMS | SW-6020 |
| Arsenic | 2 | ETVAA | SW-7060A |
| Barium | 40 | ICPES | SW-6010B |
| Beryllium | 1 | ICPES | SW-6010B |
| Cadmium | 1 | ICPMS | SW-6020 |
| Chromium | 2 | ICPES | SW-6010B |
| Cobalt | 10 | ICPES | SW-6010B |
| Copper | 5 | ICPES | SW-6010B |
| Iron | 20 | ICPES | SW-6010B |
| Lead | 0.6 | ETVAA or ICPMS | SW-7421 or SW-6020 |
| Manganese | 3 | ICPES | SW-6010B |
| Mercury | 0.1 | CVAA | SW-7471A |
| Nickel | 8 | ICPES | SW-6010B |
| Selenium | 1 | ETVAA | SW-7740 |
| Silver | 2 | ICPES | SW-6010B |
| Thallium | 2 | ICPMS | SW-6020 |
| Uranium | 0.5 | ICPMS | SW-6020 |
| Vanadium | 10 | ICPES | SW-6010B |
| Zinc | 4 | ICPES | SW-6010B |
| **Anions[b]** | | | |
| Bromide | 0.1 | IC | SW-9056 |
| Chloride | 0.1 | IC | SW-9056 |
| Fluoride | 0.02 | IC | SW-9056 |
| Nitrate | 0.1 | IC | SW-9056 |
| Sulfate | 0.1 | IC | SW-9056 |
| **Other Organic and Inorganic Chemicals** | | | |
| TOC or amount of organic carbon | 0.001 wt % | Elemental analysis | SW-415.1[c] |
| Total cyanide | 0.05 | Colorimetry | SW-9012A |

a. EPA SW-846 Method (EPA 1987, 57589)

b. Anion analyses will be performed on the leachate formed from a deionized water slurry of the homogenized core sample.

c. EPA 1983, 56406

**TABLE 7.4.4-14**

**GEOTECHNICAL, GEOCHEMICAL, HYDROLOGIC, AND GEOPHYSICAL ANALYSES OF BOREHOLE CORE SAMPLES**

| Analysis | Analytical Method |
|---|---|
| **Geotechnical analyses** | |
| *Bulk density* | *ASTM D 2937-94* |
| *Distribution coefficient ($K_d$)* | *ASTM D 4319-93* |
| *Particle size distribution* | *ASTM D 422-63(90)* |
| *Porosity (calculated total)* | *Calculated from bulk density and specific gravity measurements* |
| *Porosity (effective)* | *ASTM D 425-88(94)* |
| *Specific gravity* | *ASTM D 854-92* |
| **Geochemical analyses** | |
| *Mineralogical composition* | *X-ray diffraction, electron microprobe** |
| **Hydrologic analyses** | |
| *Moisture content* | *ASTM D 2216-92* |
| *Moisture potential* | *Pressure plate extractor (or other techniques)* |
| *Saturated hydraulic conductivity* | *ASTM D 5084-90* |
| **Geophysical analyses** | |
| *Lithological logging* | *TBD* |
| *Natural gamma logging* | *TBD* |
| *Neutron moisture logging* | *TBD* |

**Geochemical analyses are described in the LANL-ER-SOP-09 series.*

*Key steps in refining the Pajarito Canyon conceptual model are as follows.*

1. *Integrate available data for Pajarito Canyon geology, hydrology, and water quality/geochemistry.*

   - *Incorporate hydrologic, stratigraphic, geophysical, and chemical data for Pajarito Canyon into a centralized database (the Facility for Information Management, Analysis, and Display)*

   - *Develop a three-dimensional representation of stratigraphy and geology for Pajarito Canyon*

   - *Model and display data related to geology, geochemistry, boreholes, and observed groundwater*

   - *Extrapolate existing data and estimate uncertainties in resultant models*

   - *Synthesize the existing information to identify areas where data needs are most critical*

2. *Perform preliminary evaluation of hydrologic and geochemical processes for Pajarito Canyon.*

    - *Evaluate existing water quality/geochemistry, vadose zone, and water level data for the various zones of saturation with respect to trends and indications of interconnection*

    - *Develop a canyon-specific model and evaluate data needs with respect to placement of wells for characterization*

3. *Refine the conceptual model and upgrade the groundwater monitoring network for Pajarito Canyon.*

    - *Drill boreholes for subsurface characterization at highest priority locations (that is, the locations with highest risk and most critical data needs)*

    - *Use information as each borehole is drilled to optimize the placement and determine the need for subsequent boreholes*

## 7.5 Air-Particulate Sampling and Analysis Plan

*The Laboratory operates a network of more than 50 environmental air stations (called AIRNET) to sample radionuclides in ambient air. Fifteen of these stations are located within the Pajarito Canyon watershed. These stations are monitored regularly, and the results of the monitoring are reported annually. The 15 stations located within the Pajarito Canyon watershed include 13 stations located on Laboratory property and 2 perimeter stations located in White Rock. Air samples are analyzed for tritium; americium-241; plutonium-238; plutonium-239,249; uranium-234; uranium-235; and uranium-238. A discussion of the Laboratory's air monitoring surveillance program is presented in Section 3.8 in Chapter 3 of this work plan.*

*No contaminant sources in the air resulting from sources in Pajarito Canyon have been identified as a result of the AIRNET monitoring. Existing surface sediment data collected in Pajarito Canyon, as described in Section 3.4 in Chapter 3 of this work plan, do not indicate the presence of a significant source of radioactive contaminants in sediments. Continued monitoring of the AIRNET stations will be provided by ESH-17 personnel and published annually in the Laboratory's annual environmental surveillance reports. These AIRNET stations currently provide site-specific air monitoring data, and no significant long-term trends indicative of an airborne release within the Pajarito Canyon watershed have been identified. Therefore, no additional air monitoring in Pajarito Canyon is proposed as part of this work plan.*

## 7.6 Biological Sampling and Analysis Plan

*As discussed in the core document (LANL 1997, 55622), the approach for evaluating ecological risks is currently being discussed with the NMED, DOE, Laboratory ER Project, and EPA. A draft document has been submitted to NMED and is being reviewed. Based on the results of this process, a sampling plan for Pajarito Canyon will be developed to be consistent with that approach.*

**REFERENCES FOR CHAPTER 7**

*The following list includes all the references cited in this chapter. The parenthetical information following each reference provides the author, publication date, and ER identification (ER ID) number. This information is also included in the citations in the text and can be used to locate the documents.*

*ER ID numbers are assigned by the Laboratory's ER Project to track all material associated with Laboratory PRSs. These numbers can be used to locate copies of the documents at the ER Project's Records-Processing Facility and, where applicable, within the ER Project reference library. The references cited in this work plan can be found in the volumes of the reference library titled Reference Set for Canyons.*

*Copies of the reference library are maintained at the New Mexico Environment Department Hazardous and Radioactive Materials Bureau, the Los Alamos Area Office of DOE, and the ER Project Office. This library is a living document that was developed to ensure that the administrative authority (AA) has all the necessary material to review the decisions and actions proposed in this work plan. However, documents previously submitted to the AA are not included in the reference library.*

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*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 53450)**

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# Appendix A

*Maps*

Appendix A is made up of four oversized maps that are not included in this electronic version:

- Figure A-1, Pajarito Canyon watershed
- Figure A-2, Stream channel profile and cross section of Pajarito Canyon system showing locations of important monitoring wells and well construction information
- Figure A-3, Lateral and other miscellaneous cross sections of the Pajarito Canyon watershed
- Figure A-4, East-west cross section of Pajarito Canyon showing important wells and conceptual water/contaminant flow paths

Copies of the maps may be viewed at the Laboratory's Public Reading Room, located at 1619 Central Avenue, Los Alamos, NM.

# Appendix B

*List and Status of PRSs*

**TABLE B-1**

**PRSs IN THE PAJARITO CANYON WATERSHED**

| PRS No. | Description | HSWA | OU | FU | NFA Status | NFA Criterion* |
|---|---|---|---|---|---|---|
| *03-001(a)* | *<90 day storage* | *Yes* | *1114* | *1* | *Final AA approval of permit modification 12/10/96* | *4* |
| *03-001(b)* | *Satellite storage area* | *Yes* | *1114* | *1* | *Final AA approval of permit modification 12/10/96* | *4* |
| *03-001(c)* | *<90 day storage* | *Yes* | *1114* | *1* | *Final AA approval of permit modification 12/10/96* | *4* |
| *03-001(e)* | *<90 day storage* | *No* | *1114* | *1* | | |
| *03-001(g)* | *Satellite storage area* | *No* | *1114* | *1* | *Proposed in permit modification 9/96* | *3* |
| *03-001(l)* | *<90 day storage* | *No* | *1114* | *1* | *Proposed in permit modification 9/96* | *1* |
| *03-001(s)* | *Satellite storage area* | *No* | *1114* | *1* | *Proposed in permit modification 9/96* | *3* |
| *03-001(t)* | *Satellite storage area* | *No* | *1114* | *1* | *Proposed in permit modification 9/96* | *3* |
| *03-001(u)* | *Satellite storage area* | *No* | *1114* | *1* | *Proposed in permit modification 9/96* | *1* |
| *03-001(w)* | *Satellite storage area* | *No* | *1114* | *1* | *Proposed in permit modification 9/96* | *3* |
| *03-002(d)* | *Container storage area* | *Yes* | *1114* | *1* | *Proposed in permit modification 9/96* | *2* |
| *03-003(a)* | *Storage area* | *Yes* | *1114* | *1* | *Proposed in report/work plan* | *5* |
| *03-003(b)* | *Storage area* | *Yes* | *1114* | *1* | *Proposed in report/work plan* | *5* |
| *03-003(h)* | *Storage area (transformers)* | *No* | *1114* | *1* | *Proposed in work plan or RFI report that received an NOD or disapproval letter from AA* | *4* |
| *03-003(j)* | *Storage area (transformers)* | *No* | *1114* | *1* | *Proposed in work plan or RFI report that received an NOD or disapproval letter from AA* | *4* |
| *03-003(k)* | *Storage area (transformer)* | *No* | *1114* | *1* | *Proposed in work plan or RFI report that received an NOD or disapproval letter from AA* | *4* |
| *03-003(l)* | *Storage area* | *No* | *1114* | *1* | *Proposed in work plan or RFI report that received an NOD or disapproval letter from AA* | *4* |
| *03-003(p)* | *Storage area* | *No* | *1114* | *1* | *Cleanup report submitted* | *5* |
| *03-009(d)* | *Surface disposal site* | *Yes* | *1114* | *1* | *Proposed in permit modification 9/95* | *2* |
| *03-009(f)* | *Surface disposal* | *Yes* | *1114* | *1* | *Final AA approval of permit modification 12/10/96* | *2* |
| *03-009(g)* | *Surface disposal* | *Yes* | *1114* | *1* | *Proposed in permit modification 3/95* | *2* |
| *03-009(j)* | *Surface disposal site* | *Yes* | *1114* | *1* | *Proposed in permit modification 9/96* | *2* |
| *03-010(a)* | *Systematic release site* | *Yes* | *1114* | *1* | *Proposed in report/work plan* | *5* |

*NMED 1998, 57897

## TABLE B-1 (continued)

## PRSs IN THE PAJARITO CANYON WATERSHED

| PRS No. | Description | HSWA | OU | FU | NFA Status | NFA Criterion* |
|---|---|---|---|---|---|---|
| *03-011* | *Systematic product release* | *Yes* | *1114* | *1* | *Proposed in work plan or RFI report that received an NOD or disapproval letter from AA* | *2* |
| *03-013(g)* | *Operational release* | *No* | *1114* | *1* | *Final DOE approval of permit modification* | *2* |
| *03-013(h)* | *Operational release* | *No* | *1114* | *1* | *Final DOE approval of permit modification* | *2* |
| *03-014($a_2$)* | *Waste water treatment facility* | *No* | *1114* | *1* | *Proposed in report/work plan* | *5* |
| *03-014(t)* | *Waste water treatment facility* | *Yes* | *1114* | *1* | *Proposed in report/work plan* | *5* |
| *03-014(z)* | *Waste water treatment facility* | *No* | *1114* | *1* | *Proposed in report/work plan* | *5* |
| *03-016(a)* | *Septic system* | *No* | *1114* | *1* | *Proposed in permit modification 9/96* | *2* |
| *03-018* | *Septic system* | *Yes* | *1114* | *1* | *Final AA approval of permit modification 12/10/96* | *3* |
| *03-019* | *Septic tank* | *Yes* | *1114* | *1* | *Proposed in permit modification 9/96* | *2* |
| *03-022* | *Sump* | *No* | *1114* | *1* | *Cleanup report submitted* | *5* |
| *03-025(b)* | *Tank and/or associated equipment* | *Yes* | *1114* | *1* | *Proposed in work plan or RFI report that received an NOD or disapproval letter from AA* | *3* |
| *03-025(c)* | *Tank and/or associated equipment* | *No* | *1114* | *1* | | |
| *03-026(d)* | *Tank and/or associated equipment* | *Yes* | *1114* | *1* | *AA concurrence for deferral* | |
| *03-033* | *Sump* | *Yes* | *1114* | *1* | *Proposed in report/work plan* | *5* |
| *03-038(e)* | *Waste lines* | *No* | *1114* | *1* | *Proposed in permit modification 9/96* | *2* |
| *03-038(f)* | *Waste lines* | *No* | *1114* | *1* | *Proposed for deferral* | |
| *03-039(c)* | *Silver recovery unit* | *No* | *1114* | *1* | *Final DOE approval of permit modification* | *3* |
| *03-040(a)* | *Storage area* | *No* | *1114* | *1* | *Proposed in permit modification 9/96* | *2* |
| *03-042* | *Sump* | *No* | *1114* | *1* | *Proposed in report/work plan* | *5* |
| *03-043(c)* | *Tank and/or associated equipment* | *Yes* | *1114* | *1* | *Proposed in permit modification 9/96* | *5* |
| 03-043(i) | Aboveground tank | No | 1114 | 1 | Proposed in permit modification 9/96 | 3 |
| 03-044(b) | Container storage | No | 1114 | 1 | Final DOE approval of permit modification | 4 |
| 03-047(j) | Drum storage | No | 1114 | 1 | Proposed in permit modification 9/96 | 3 |
| 03-047(k) | Drum storage | No | 1114 | 1 | Proposed in permit modification 9/96 | 3 |
| 03-050(d) | Exhaust emissions from off-gas scrubber of HEPA filter system | Yes | 1114 | 1 | Proposed in permit modification 9/96 | 5 |

*NMED 1998, 57897

## TABLE B-1 (continued)

### PRSs IN THE PAJARITO CANYON WATERSHED

| PRS No. | Description | HSWA | OU | FU | NFA Status | NFA Criterion * |
|---|---|---|---|---|---|---|
| 03-050(e) | Exhaust emissions from off-gas scrubber of HEPA filter system | Yes | 1114 | 1 | Proposed in permit modification 9/96 | 2 |
| 03-050(f) | *Exhaust emissions from off-gas scrubber of HEPA filter system* | *Yes* | *1114* | *1* | *Proposed in permit modification 9/96* | *5* |
| 03-050(g) | *Exhaust emissions from off-gas scrubber of HEPA filter system* | *Yes* | *1114* | *1* | *Proposed in permit modification 9/96* | *5* |
| 03-051(a) | *Soil contamination (oil from leaking compressor)* | *No* | *1114* | *1* | *Proposed in work plan or RFI report that received an NOD or disapproval letter from AA* | *4* |
| 03-051(b) | *Soil contamination (oil from leaking compressor)* | *No* | *1114* | *1* | *Proposed in work plan or RFI report that received an NOD or disapproval letter from AA* | *4* |
| 03-051(d) | *Soil contamination (oil from leaking compressor)* | *No* | *1114* | *1* | *Proposed in permit modification 9/96* | *3* |
| 03-052(a) | *Storm drainage* | *Yes* | *1114* | *1* | | |
| 03-052(e) | *Storm drainage* | *Yes* | *1114* | *1* | | |
| 03-054(a) | *Outfall* | *Yes* | *1114* | *1* | *Proposed in permit modification 9/96* | *2* |
| 03-054(b) | *Outfall* | *Yes* | *1114* | *1* | | |
| 03-054(d) | *Outfall* | *Yes* | *1114* | *1* | *Proposed in permit modification 9/96* | *2* |
| 03-055(a) | *Outfall* | *Yes* | *1114* | *1* | *Proposed in permit modification 9/96* | *2* |
| 03-055(b) | *Outfall* | *No* | *1114* | *1* | *Final DOE approval of permit modification* | *3* |
| 03-056(f) | *Drum storage* | *No* | *1114* | *1* | *Proposed in permit modification 9/96* | *1* |
| 03-056(g) | *Satellite storage area* | *No* | *1114* | *1* | *Proposed in permit modification 9/96* | *3* |
| 03-056(j) | *Storage area* | *No* | *1114* | *1* | *Proposed in permit modification 9/96* | *2* |
| 03-056(m) | *Drum storage* | *Yes* | *1114* | *1* | *Proposed in permit modification 9/96* | *2* |
| 06-001(a) | *Septic system* | *Yes* | *1111* | *5* | | |
| 06-001(b) | *Septic system* | *Yes* | *1111* | *5* | | |
| 06-002 | *Septic system* | *Yes* | *1111* | *5* | | |
| 06-003(a) | *Firing site* | *Yes* | *1111* | *5* | | |
| 06-003(b) | *Firing site* | *No* | *1111* | *5* | *Final DOE approval of permit modification* | *3* |
| 06-003(c) | *Firing site* | *Yes* | *1111* | *5* | | |

*NMED 1998, 57897

## TABLE B-1 (continued)

## PRSs IN THE PAJARITO CANYON WATERSHED

| PRS No. | Description | HSWA | OU | FU | NFA Status | NFA Criterion* |
|---|---|---|---|---|---|---|
| 06-003(d) | Firing site | Yes | 1111 | 5 | | |
| 06-003(e) | Firing site | Yes | 1111 | 5 | | |
| 06-003(f) | Firing site | Yes | 1111 | 5 | | |
| 06-003(g) | Firing site and building | Yes | 1111 | 5 | | |
| 06-004 | Sump | No | 1111 | 5 | Final DOE approval of permit modification | 1 |
| 06-005 | Firing site (pit) | Yes | 1111 | 5 | | |
| 06-006 | Storage area | Yes | 1111 | 5 | | |
| 06-007(a) | Material disposal area (MDA F) | Yes | 1111 | 5 | | |
| 06-007(f) | Surface disposal | Yes | 1111 | 5 | Cleanup report submitted | 5 |
| 06-007(g) | Building and surface disposal | Yes | 1111 | 5 | | |
| 06-008 | Underground tank | No | 1111 | 5 | | |
| 07-001(a) | Firing site | Yes | 1111 | 5 | | |
| 07-001(b) | Firing site | Yes | 1111 | 5 | | |
| 07-001(c) | Firing site | Yes | 1111 | 5 | | |
| 08-001(a) | Buildings | No | 1157 | 5 | Proposed for deferral | |
| 08-001(b) | Buildings | No | 1157 | 5 | Proposed for deferral | |
| 08-002 | Firing site | Yes | 1157 | 5 | | |
| 08-003(a) | Septic system | Yes | 1157 | 5 | EC report submitted | 5 |
| 08-003(b) | Septic system | Yes | 1157 | 5 | Final AA approval of permit modification 12/10/96 | 2 |
| 08-003(c) | Septic system | Yes | 1157 | 5 | Final AA approval of permit modification 12/10/96 | 2 |
| 08-004(a) | Floor drain | Yes | 1157 | 5 | | |
| 08-004(b) | Drain line | Yes | 1157 | 5 | | |
| 08-004(c) | Floor drain | Yes | 1157 | 5 | | |
| 08-005 | Container storage area | Yes | 1157 | 5 | Cleanup report submitted | 5 |
| 08-006(a) | Material disposal area (MDA Q) | Yes | 1157 | 5 | | |
| 08-006(b) | Landfill (duplicate of 8-006 [a]) | Yes | 1157 | 5 | Final AA approval of permit modification 12/10/96 | 1 |
| 08-007 | Silver recovery unit | Yes | 1157 | 5 | Final AA approval of permit modification 12/10/96 | 3 |

*NMED 1998, 57897

## TABLE B-1 (continued)

## PRSs IN THE PAJARITO CANYON WATERSHED

| PRS No. | Description | HSWA | OU | FU | NFA Status | NFA Criterion* |
|---|---|---|---|---|---|---|
| 08-008(a) | Storage area | No | 1157 | 5 | Final DOE approval of permit modification | 3 |
| 08-008(b) | Storage area | No | 1157 | 5 | Final DOE approval of permit modification | 3 |
| 08-008(d) | Storage area | No | 1157 | 5 | Final DOE approval of permit modification | 3 |
| 08-009(a) | Industrial or sanitary wastewater treatment unit | Yes | 1157 | 5 | | |
| 08-009(b) | Industrial or sanitary wastewater treatment unit | No | 1157 | 5 | Final DOE approval of permit modification | 2 |
| 08-009(c) | Storm drain and outfall | No | 1157 | 5 | | |
| 08-009(d) | Industrial or sanitary wastewater treatment unit | Yes | 1157 | 5 | Proposed in report/work plan | 5 |
| 08-009(e) | Industrial or sanitary wastewater treatment unit | Yes | 1157 | 5 | Proposed in report/work plan | 5 |
| 08-009(f) | Outfall | No | 1157 | 5 | | |
| 08-010(a) | Storage area | No | 1157 | 5 | Final DOE approval of permit modification | 4 |
| 08-010(b) | Storage area | No | 1157 | 5 | Final DOE approval of permit modification | 4 |
| 08-010(c) | Storage area | No | 1157 | 5 | Final DOE approval of permit modification | 4 |
| 08-011(a) | Underground tank | No | 1157 | 5 | Final DOE approval of permit modification | 5 |
| 08-011(b) | Underground tank | No | 1157 | 5 | Final DOE approval of permit modification | 5 |
| 09-001(a) | Firing sites | Yes | 1157 | 5 | Proposed in report/work plan | 5 |
| 09-001(b) | Firing sites | Yes | 1157 | 5 | Proposed in report/work plan | 5 |
| 09-001(c) | Firing sites | Yes | 1157 | 5 | | |
| 09-001(d) | Firing sites | Yes | 1157 | 5 | Proposed in report/work plan | 5 |
| 09-002 | Burn pit | Yes | 1157 | 5 | | |
| 09-003(a) | Settling tank | Yes | 1157 | 5 | | |
| 09-003(b) | Settling tank | Yes | 1157 | 5 | | |
| 09-003(c) | Electric manhole | Yes | 1157 | 5 | Final AA approval of permit modification 12/10/96 | 2 |
| 09-003(d) | Settling tank | Yes | 1157 | 5 | | |
| 09-003(e) | Settling tank | Yes | 1157 | 5 | | |
| 09-003(f) | Settling tank | Yes | 1157 | 5 | Final AA approval of permit modification 12/10/96 | 2 |
| 09-003(g) | Settling tank | Yes | 1157 | 5 | Proposed in report/work plan | 5 |
| 09-003(h) | Settling tank | Yes | 1157 | 5 | Proposed in report/work plan | 5 |

*NMED 1998, 57897

# TABLE B-1 (continued)

## PRSs IN THE PAJARITO CANYON WATERSHED

| PRS No. | Description | HSWA | OU | FU | NFA Status | NFA Criterion* |
|---|---|---|---|---|---|---|
| *09-003(i)* | *Settling tank* | *Yes* | *1157* | *5* | *Proposed in report/work plan* | *5* |
| *09-004(a)* | *Settling tank* | *Yes* | *1157* | *5* | *Proposed for deferral* | |
| *09-004(b)* | *Settling tank* | *Yes* | *1157* | *5* | *Proposed for deferral* | |
| *09-004(c)* | *Settling tank* | *Yes* | *1157* | *5* | *Proposed for deferral* | |
| *09-004(d)* | *Settling tank* | *Yes* | *1157* | *5* | *Proposed for deferral* | |
| *09-004(e)* | *Settling tank* | *Yes* | *1157* | *5* | *Proposed for deferral* | |
| *09-004(f)* | *Settling tank* | *Yes* | *1157* | *5* | *Proposed for deferral* | |
| *09-004(g)* | *Settling tank* | *Yes* | *1157* | *5* | *Proposed for deferral* | |
| *09-004(h)* | *Settling tank* | *Yes* | *1157* | *5* | *Proposed for deferral* | |
| *09-004(i)* | *Settling tank* | *Yes* | *1157* | *5* | *Proposed for deferral* | |
| *09-004(j)* | *Settling tank* | *Yes* | *1157* | *5* | *Proposed for deferral* | |
| *09-004(k)* | *Settling tank* | *Yes* | *1157* | *5* | *Proposed for deferral* | |
| *09-004(l)* | *Settling tank* | *Yes* | *1157* | *5* | *Proposed for deferral* | |
| *09-004(m)* | *Settling tank* | *Yes* | *1157* | *5* | *Proposed for deferral* | |
| *09-004(n)* | *Settling tank* | *Yes* | *1157* | *5* | *Proposed for deferral* | |
| *09-004(o)* | *Settling tank* | *Yes* | *1157* | *5* | *Proposed for deferral* | |
| *09-005(a)* | *Septic system* | *Yes* | *1157* | *5* | *Proposed in report/work plan* | *5* |
| *09-005(b)* | *Septic system* | *Yes* | *1157* | *5* | *Final AA approval of permit modification 12/10/96* | *2* |
| *09-005(c)* | *Septic system* | *Yes* | *1157* | *5* | *Final AA approval of permit modification 12/10/96* | *2* |
| *09-005(d)* | *Septic system* | *Yes* | *1157* | *5* | *Proposed in report/work plan* | *5* |
| *09-005(e)* | *Septic system* | *Yes* | *1157* | *5* | *Final AA approval of permit modification 12/10/96* | *2* |
| *09-005(f)* | *Septic system* | *Yes* | *1157* | *5* | *Final AA approval of permit modification 12/10/96* | *2* |
| *09-005(g)* | *Septic system* | *Yes* | *1157* | *5* | *Proposed in permit modification 3/95* | *2* |
| *09-005(h)* | *Septic system* | *Yes* | *1157* | *5* | *Final AA approval of permit modification 12/10/96* | *2* |
| *09-006* | *Septic system* | *Yes* | *1157* | *5* | | |
| *09-007* | *Basket pit* | *Yes* | *1157* | *5* | *Final AA approval of permit modification 12/10/96* | *2* |
| *09-008(a)* | *Surface impoundment* | *No* | *1157* | *5* | *Final DOE approval of permit modification* | *1* |

*NMED 1998, 57897

**TABLE B-1 (continued)**

**PRSs IN THE PAJARITO CANYON WATERSHED**

| PRS No. | Description | HSWA | OU | FU | NFA Status | NFA Criterion* |
|---|---|---|---|---|---|---|
| 09-008(b) | Surface impoundment | Yes | 1157 | 5 | Proposed in report/work plan | 5 |
| 09-009 | Surface impoundment | Yes | 1157 | 5 | Proposed in report/work plan | 5 |
| 09-010(a) | Storage area | No | 1157 | 5 | Cleanup report submitted | 5 |
| 09-010(b) | Storage area | No | 1157 | 5 | Cleanup report submitted | 5 |
| 09-010(c) | Storage area | No | 1157 | 5 | Final DOE approval of permit modification | 1 |
| 09-011(a) | Storage area | No | 1157 | 5 | Final DOE approval of permit modification | 4 |
| 09-011(b) | Storage area | No | 1157 | 5 | | |
| 09-011(c) | Storage area | No | 1157 | 5 | | |
| 09-012 | Disposal pit | No | 1157 | 5 | | |
| 09-013 | Material disposal area (MDA M) | Yes | 1157 | 5 | Cleanup report submitted | 5 |
| 09-014 | Firing site | No | 1157 | 5 | | |
| 09-015 | Manhole | No | 1157 | 5 | Final DOE approval of permit modification | 2 |
| 09-016 | Underground tank | No | 1157 | 5 | Final DOE approval of permit modification | 5 |
| 12-001(a) | Firing site – steel-lined chamber | Yes | 1085 | 2 | Cleanup report submitted | 5 |
| 12-001(b) | Firing site (former) | Yes | 1085 | 2 | | |
| 12-002 | Open burning ground | Yes | 1085 | 2 | Proposed in permit modification 3/95 | 1 |
| 12-003 | Storage area | No | 1085 | 2 | Final DOE approval of permit modification | 2 |
| 12-004(a) | Radiation test facility | No | 1085 | 2 | Proposed in report/work plan | 5 |
| 12-004(b) | Pipe | No | 1085 | 2 | Proposed in report/work plan | 5 |
| 15-004(a) | Firing site C | Yes | 1086 | 2 | Proposed in report/work plan | 5 |
| 15-004(d) | Firing site C | No | 1086 | 2 | Proposed in report/work plan | 5 |
| 15-004(e) | Mistakenly called firing site (actually manhole bunker) | No | 1086 | 2 | Final DOE approval of permit modification | 1 |
| 15-004(f) | Machine firing site E-F | Yes | 1086 | 2 | | |
| 15-005(c) | Storage area (R-41) | No | 1086 | 2 | Proposed in report/work plan | 5 |
| 15-006(b) | Firing site Ector | Yes | 1086 | 2 | | |
| 15-006(c) | Firing site R-44 | Yes | 1086 | 2 | | |

*NMED 1998, 57897

## TABLE B-1 (continued)

## PRSs IN THE PAJARITO CANYON WATERSHED

| PRS No. | Description | HSWA | OU | FU | NFA Status | NFA Criterion* |
|---|---|---|---|---|---|---|
| 15-006(d) | Firing site R-45 | Yes | 1086 | 2 | Proposed in report/work plan | 5 |
| 15-007(c) | Shaft | Yes | 1086 | 2 | | |
| 15-007(d) | Shaft | Yes | 1086 | 2 | Proposed in permit modification 9/95 | 4 |
| 15-008(b) | Surface disposal | Yes | 1086 | 2 | | |
| 15-008(g) | Surface disposal | No | 1086 | 2 | Proposed in report/work plan | 5 |
| 15-009(b) | Septic system | Yes | 1086 | 2 | Proposed in permit modification 9/95 | 2 |
| 15-009(c) | Septic tank | Yes | 1086 | 2 | Proposed in permit modification 9/95 | 2 |
| 15-009(d) | Septic tank | No | 1086 | 2 | Final DOE approval of permit modification | 2 |
| 15-009(h) | Septic tank | Yes | 1086 | 2 | Proposed in permit modification 9/95 | 2 |
| 15-010(b) | Septic system | Yes | 1086 | 2 | Proposed in report/work plan | 5 |
| 15-014(f) | Industrial or sanitary wastewater treatment unit | No | 1086 | 2 | Final DOE approval of permit modification | 1 |
| 15-014(h) | Outfall | No | 1086 | 2 | Proposed in report/work plan | 5 |
| 15-014(m) | Outfall | Yes | 1086 | 2 | Final AA approval of permit modification 12/10/96 | 4 |
| 18-001(a) | Lagoons | Yes | 1093 | 2 | Cleanup report submitted | 5 |
| 18-001(b) | Sewer lines | Yes | 1093 | 2 | Cleanup report submitted | 5 |
| 18-001(c) | Sump | Yes | 1093 | 2 | Proposed in permit modification 9/96 | 5 |
| 18-002(a) | Firing site | Yes | 1093 | 2 | Proposed in report/work plan | 5 |
| 18-002(b) | Firing site | Yes | 1093 | 2 | Proposed in report/work plan | 5 |
| 18-002(c) | Drop tower | No | 1093 | 2 | Proposed in report/work plan | 5 |
| 18-003(a) | Settling pit | Yes | 1093 | 2 | | |
| 18-003(b) | Septic system | Yes | 1093 | 2 | | |
| 18-003(c) | Septic system | Yes | 1093 | 2 | | |
| 18-003(d) | Septic system | Yes | 1093 | 2 | | |
| 18-003(e) | Septic system | Yes | 1093 | 2 | Cleanup report submitted | 5 |
| 18-003(f) | Septic system | Yes | 1093 | 2 | Proposed in report/work plan | 5 |
| 18-003(g) | Septic system | Yes | 1093 | 2 | | |
| 18-003(h) | Septic system | Yes | 1093 | 2 | Proposed in report/work plan | 5 |

*NMED 1998, 57897

## TABLE B-1 (continued)

## PRSs IN THE PAJARITO CANYON WATERSHED

| PRS No. | Description | HSWA | OU | FU | NFA Status | NFA Criterion* |
|---|---|---|---|---|---|---|
| 18-004(a) | Waste lines containment | Yes | 1093 | 2 | Proposed in report/work plan | 5 |
| 18-004(b) | Pit | Yes | 1093 | 2 | Proposed in report/work plan | 1 |
| 18-005(a) | Storage area/ magazine | Yes | 1093 | 2 | Proposed in report/work plan | 5 |
| 18-006 | Storage pipe for uranium solution | No | 1093 | 2 | | |
| 18-007 | Buried armored vehicle | Yes | 1093 | 2 | Proposed in permit modification 9/96 | 1 |
| 18-008 | Underground storage tank | No | 1093 | 2 | Cleanup report submitted | 5 |
| 18-009(a) | Transformer | No | 1093 | 2 | Final DOE approval of permit modification | 5 |
| 18-009(b) | Transformer | No | 1093 | 2 | Proposed in permit modification 9/96 | 3 |
| 18-009(c) | Transformer | No | 1093 | 2 | Final DOE approval of permit modification | 3 |
| 18-009(d) | Transformer | No | 1093 | 2 | Final DOE approval of permit modification | 3 |
| 18-009(e) | Transformer | No | 1093 | 2 | Final DOE approval of permit modification | 4 |
| 18-010(a) | Outfall | No | 1093 | 2 | Final DOE approval of permit modification | 2 |
| 18-010(b) | Storm drain outfall | No | 1093 | 2 | Proposed in report/work plan | 5 |
| 18-010(c) | Storm drain outfall | No | 1093 | 2 | Proposed in report/work plan | 5 |
| 18-010(d) | Storm drain outfall | No | 1093 | 2 | Proposed in report/work plan | 5 |
| 18-010(e) | Storm drain outfall | No | 1093 | 2 | Proposed in report/work plan | 5 |
| 18-010(f) | Storm drain outfall | No | 1093 | 2 | Proposed in report/work plan | 5 |
| 18-011 | Soil containment | No | 1093 | 2 | Proposed in report/work plan | 5 |
| 18-012(a) | Outfall | Yes | 1093 | 2 | Proposed in report/work plan | 5 |
| 18-012(b) | Outfall | Yes | 1093 | 2 | Proposed in report/work plan | 5 |
| 18-012(c) | Sump and drain lines | No | 1093 | 2 | Proposed in report/work plan | 5 |
| 18-012(d) | Drain line | No | 1093 | 2 | Final DOE approval of permit modification | 1 |
| 18-013 | Waste tank | No | 1093 | 2 | Proposed in report/work plan | 5 |
| 22-001 | Building | No | 1111 | 5 | Final DOE approval of permit modification | 4 |
| 22-003(a) | Satellite storage area | No | 1111 | 5 | Final DOE approval of permit modification | 4 |
| 22-003(b) | Satellite storage area | No | 1111 | 5 | Final DOE approval of permit modification | 4 |
| 22-003(c) | Satellite storage area | No | 1111 | 5 | Final DOE approval of permit modification | 4 |

*NMED 1998, 57897

**TABLE B-1 (continued)**

**PRSs IN THE PAJARITO CANYON WATERSHED**

| PRS No. | Description | HSWA | OU | FU | NFA Status | NFA Criterion* |
|---|---|---|---|---|---|---|
| 22-003(d) | Satellite storage area | No | 1111 | 5 | Final DOE approval of permit modification | 4 |
| 22-003(e) | Satellite storage area | No | 1111 | 5 | Final DOE approval of permit modification | 4 |
| 22-003(f) | Satellite storage area | No | 1111 | 5 | Final DOE approval of permit modification | 4 |
| 22-003(g) | Satellite storage area | No | 1111 | 5 | Final DOE approval of permit modification | 4 |
| 22-010(a) | Septic system | Yes | 1111 | 5 | | |
| 22-010(b) | Septic system | yes | 1111 | 5 | | |
| 22-011 | Disposal pit | Yes | 1111 | 5 | Proposed in permit modification 3/95 | 1 |
| 22-012 | Decontamination facility | Yes | 1111 | 5 | | |
| 22-013 | Liquid waste treatment/storage | No | 1111 | 5 | Final DOE approval of permit modification | 4 |
| 22-014(a) | Industrial or sanitary wastewater treatment unit | Yes | 1111 | 5 | | |
| 22-014(b) | Sump | Yes | 1111 | 5 | | |
| 22-015(a) | Drain lines and dry wells | Yes | 1111 | 5 | | |
| 22-015(b) | Sump and outfall | Yes | 1111 | 5 | | |
| 22-015(c) | Outfall | Yes | 1111 | 5 | Cleanup report submitted | 5 |
| 22-015(d) | Drain line and outfall | Yes | 1111 | 5 | | |
| 22-015(e) | Industrial or sanitary wastewater treatment unit | Yes | 1111 | 5 | | |
| 22-016 | Septic system | Yes | 1111 | 5 | | |
| 27-001 | Buried naval guns | Yes | 1093 | 2 | Proposed in permit modification 9/96 | 1 |
| 27-002 | Firing sites | Yes | 1093 | 2 | Proposed in report/work plan | 5 |
| 27-003 | Bazooka impact area | Yes | 1093 | 2 | Proposed in permit modification 9/96 | 5 |
| 27-004 | Building | No | 1093 | 2 | Final DOE approval of permit modification | 5 |
| 36-002 | Sump | Yes | 1130 | 2 | Proposed in permit modification 9/96 | 5 |
| 36-003(a) | Septic system | Yes | 1130 | 2 | Cleanup report submitted | 5 |
| 36-003(d) | Septic system | No | 1130 | 2 | Final DOE approval of permit modification | 2 |
| 36-004(e) | Firing site | No | 1130 | 2 | | |
| 40-001(a) | Septic system | Yes | 1111 | 5 | Final AA approval of permit modification 12/10/96 | 1 |
| 40-001(b) | Septic system | Yes | 1111 | 5 | | |

*NMED 1998, 57897

**TABLE B-1 (continued)**

**PRSs IN THE PAJARITO CANYON WATERSHED**

| PRS No. | Description | HSWA | OU | FU | NFA Status | NFA Criterion * |
|---|---|---|---|---|---|---|
| 40-001(c) | Septic system | Yes | 1111 | 5 | | |
| 40-002(a) | Container storage area | No | 1111 | 5 | Final DOE approval of permit modification | 4 |
| 40-003(a) | Firing site | Yes | 1111 | 5 | Closure report submitted/additional cleanup required | |
| 40-003(b) | Burning area/open detonation | No | 1111 | 5 | Final DOE approval of permit modification | 4 |
| 40-004 | Operational release | Yes | 1111 | 5 | | |
| 40-005 | Sump | Yes | 1111 | 5 | | |
| 40-006(a) | Firing site | Yes | 1111 | 5 | | |
| 40-006(b) | Firing site | Yes | 1111 | 5 | | |
| 40-006(c) | Firing site | Yes | 1111 | 5 | | |
| 40-007(a) | Storage area | No | 1111 | 5 | | |
| 40-007(b) | Storage area | No | 1111 | 5 | | |
| 40-007(c) | Storage area | No | 1111 | 5 | | |
| 40-007(d) | Storage area | No | 1111 | 5 | | |
| 40-007(e) | Storage area | No | 1111 | 5 | | |
| 40-008 | HE storage area | No | 1111 | 5 | Final DOE approval of permit modification | 4 |
| 40-009 | Landfill | Yes | 1111 | 5 | | |
| 40-010 | Surface disposal site | Yes | 1111 | 5 | | |
| 48-001 | Air exhaust system | No | 1129 | 4 | Proposed in report/work plan | 5 |
| 54-001(f) | Storage area | No | 1148 | 5 | Final DOE approval of permit modification | 2 |
| 54-004 | Material disposal area (MDA H) | Yes | 1148 | 5 | | |
| 54-005 | Material disposal area (MDA J) | Yes | 1148 | 5 | | |
| 54-007(a) | Septic system | Yes | 1148 | 5 | | |
| 54-010 | Underground tank | No | 1148 | 5 | Final DOE approval of permit modification | 2 |
| 54-012(a) | Reduction site | No | 1148 | 5 | | |
| 54-013(b) | Material disposal area (MDA G) disposal pit | Yes | 1148 | 5 | | |
| 54-014(b) | Material disposal area (MDA G) storage pit | Yes | 1148 | 5 | | |
| 54-014(c) | Material disposal area (MDA G) storage shafts | Yes | 1148 | 5 | | |

*NMED 1998, 57897

## TABLE B-1 (continued)

## PRSs IN THE PAJARITO CANYON WATERSHED

| PRS No. | Description | HSWA | OU | FU | NFA Status | NFA Criterion* |
|---|---|---|---|---|---|---|
| *54-014(d)* | *Material disposal area (MDA G) storage trenches* | *Yes* | *1148* | *5* | | |
| *54-015(a)* | *Storage area* | *No* | *1148* | *5* | | |
| *54-015(b)* | *Storage area* | *No* | *1148* | *5* | | |
| *54-015(c)* | *Storage area* | *No* | *1148* | *5* | | |
| *54-015(d)* | *Storage area* | *No* | *1148* | *5* | | |
| *54-015(e)* | *Storage area* | *No* | *1148* | *5* | | |
| *54-015(f)* | *Storage area* | *No* | *1148* | *5* | | |
| *54-015(j)* | *Storage area* | *No* | *1148* | *5* | | |
| *54-015(k)* | *Storage area* | *Yes* | *1148* | *5* | | |
| *54-016(b)* | *Sump* | *No* | *1148* | *5* | | |
| *54-017* | *Material disposal area (MDA G) disposal pits* | *Yes* | *1148* | *5* | | |
| *54-018* | *Material disposal area (MDA G) disposal pits* | *Yes* | *1148* | *5* | | |
| *54-019* | *Material disposal area (MDA G) disposal shafts* | *Yes* | *1148* | *5* | | |
| *54-020* | *Material disposal area (MDA G) disposal shafts* | *Yes* | *1148* | *5* | | |
| *54-021* | *Aboveground oil storage tanks* | *No* | *1148* | *5* | *Final DOE approval of permit modification* | *5* |
| *54-022* | *Transformer spill* | *No* | *1148* | *5* | *Final DOE approval of permit modification* | *5* |
| *55-011(d)* | *Storm drain* | *No* | *1129* | *4* | *Final DOE approval of permit modification* | *4* |
| *59-001* | *Septic system* | *Yes* | *1114* | *1* | *Proposed in permit modification 3/95* | *5* |
| *59-002* | *Container storage area* | *No* | *1114* | *1* | *Final DOE approval of permit modification* | *3* |
| *59-003* | *Sump* | *No* | *1114* | *1* | *Final DOE approval of permit modification* | *2* |
| *59-004* | *Outfall* | *No* | *1114* | *1* | *Proposed in report/work plan* | *5* |
| *64-001* | *Storage area* | *No* | *1114* | *1* | *Final DOE approval of permit modification* | *4* |
| *69-001* | *Incinerator and associated equipment* | *Yes* | *1157* | *5* | | |
| *69-002(a)* | *Septic system* | *No* | *1157* | *5* | *Final DOE approval of permit modification* | *2* |
| *69-002(b)* | *Septic system* | *No* | *1157* | *5* | *Final DOE approval of permit modification* | *2* |
| *C-03-003* | *Stained asphalt* | | | | | |

*NMED 1998, 57897

**TABLE B-1 (continued)**

**PRSs IN THE PAJARITO CANYON WATERSHED**

| PRS No. | Description | HSWA | OU | FU | NFA Status | NFA Criterion * |
|---|---|---|---|---|---|---|
| C-03-010 | Outfall | | | | | |
| C-03-019 | Underground storage tank | | | | | |
| C-03-021 | Underground storage tank | | | | | |
| C-06-001 | Building | | | | | |
| C-06-003 | Building | | | | | |
| C-06-005 | Building | | | | | |
| C-06-006 | Building | | | | | |
| C-06-007 | Building | | | | | |
| C-06-008 | Building | | | | | |
| C-06-009 | Building | | | | | |
| C-06-010 | Building | | | | | |
| C-06-011 | Building | | | | | |
| C-06-012 | Building | | | | | |
| C-06-013 | Building | | | | | |
| C-06-014 | Building | | | | | |
| C-06-015 | Building | | | | | |
| C-06-016 | Building | | | | | |
| C-06-017 | Building | | | | | |
| C-06-018 | Building | | | | | |
| C-06-019 | Building | | | | | |
| C-06-020 | Building | | | | | |
| C-06-021 | Building | | | | | |
| C-08-001 | Building | | | | | |
| C-08-002 | Building | | | | | |
| C-08-003 | Building | | | | | |
| C-08-004 | Building | | | | | |
| C-08-005 | Building | | | | | |

*NMED 1998, 57897

## TABLE B-1 (continued)

### PRSs IN THE PAJARITO CANYON WATERSHED

| PRS No. | Description | HSWA | OU | FU | NFA Status | NFA Criterion* |
|---|---|---|---|---|---|---|
| C-08-006 | Building | | | | | |
| C-08-007 | Building | | | | | |
| C-08-008 | Building | | | | | |
| C-08-009 | Building | | | | | |
| C-08-010 | Building | | | | | |
| C-08-011 | Building | | | | | |
| C-08-012 | Building | | | | | |
| C-08-013 | Building | | | | | |
| C-08-014 | Laboratory | | | | | |
| C-08-015 | Building | | | | | |
| C-08-016 | Building | | | | | |
| C-08-017 | Storage area | | | | | |
| C-08-018 | Storage area | | | | | |
| C-08-019 | Storage area | | | | | |
| C-08-020 | Disposal area | | | | | |
| C-09-001 | Soil contamination | | | | | |
| C-09-002 | Buildings | | | | | |
| C-09-003 | Buildings | | | | | |
| C-09-004 | Building | | | | | |
| C-09-005 | Building | | | | | |
| C-09-006 | Buildings | | | | | |
| C-09-007 | Building | | | | | |
| C-09-008 | Underground tank | | | | | |
| C-09-009 | Unintentional release | | | | | |
| C-09-011 | Burn site | | | | | |
| C-12-001 | Building | No | 1085 | 2 | Proposed in report/work plan, reviewed by AA | 5 |
| C-12-002 | Building | No | 1085 | 2 | Proposed in report/work plan, reviewed by AA | 5 |

*NMED 1998, 57897

## TABLE B-1 (continued)

## PRSs IN THE PAJARITO CANYON WATERSHED

| PRS No. | Description | HSWA | OU | FU | NFA Status | NFA Criterion* |
|---|---|---|---|---|---|---|
| C-12-003 | Building | No | 1085 | 2 | Proposed in report/work plan, reviewed by AA | 5 |
| C-12-004 | Building | No | 1085 | 2 | Proposed in report/work plan | 5 |
| C-12-005 | Building | No | 1085 | 2 | Proposed in report/work plan, reviewed by AA | 5 |
| C-12-006 | Pole (duplicate of 12-004[a]) | No | 1085 | 2 | Final DOE approval of permit modification | 1 |
| C-14-006 | Building | No | 1085 | 2 | Proposed in report/work plan, reviewed by AA | 5 |
| C-15-003 | Surface disposal | No | 1086 | 2 | Final DOE approval of permit modification | 2 |
| C-15-009 | Underground tank | No | 1086 | 2 | Final DOE approval of permit modification | 2 |
| C-18-001 | Laboratory | No | 1093 | 2 | Final DOE approval of permit modification | 5 |
| C-18-002 | Building | No | 1093 | 2 | Final DOE approval of permit modification | 3 |
| C-18-003 | Storage area | No | 1093 | 2 | Final DOE approval of permit modification | 4 |
| C-36-003 | Storm drainages | Yes | 1130 | 2 | | |
| C-40-001 | Usage site | No | 1111 | 5 | Final DOE approval of permit modification | 2 |
| C-59-001 | Capacitors and transformer | No | 1114 | 1 | Proposed in work plan or RFI report that received a NOD or disapproval letter from AA | 4 |

*NMED 1998, 57897

## NO FURTHER ACTION (NFA) PROPOSALS
## CRITERIA

| | |
|---|---|
| *NFA Criterion 1* | *The Solid Waste Management Unit/Area of Concern (SWMU/AOC) cannot be located, does not exist or is a duplicate SWMU/AOC.* |
| *NFA Criterion 2* | *The SWMU/AOC has never been used for the management (i.e., generation, treatment, storage and/or disposal) of Resource Conservation and Recovery Act (RCRA) solid waste or hazardous wastes and/or constituents or other Comprehensive Environmental Response, Conservation and Liability Act (CERCLA) hazardous substances.* |
| *NFA Criterion 3* | *No release to the environment has occurred or is likely to occur in the future from the SWMU/AOC.* |
| *NFA Criterion 4* | *A release from the SWMU/AOC to the environment has occurred, but the SWMU/AOC was characterized and/or remediated under another authority (such as the New Mexico Environment Department's Underground Storage Tank or Ground Water Quality Bureaus), which adequately addressed RCRA corrective action, and documentation, such as a closure letter, is available.* |
| *NFA Criterion 5* | *The SWMU/AOC has been characterized or remediated in accordance with current applicable state or federal regulations, and the available data indicate that contaminants pose an acceptable level of risk under current and projected future land use.* |

# Appendix C

*Data for Wells, Boreholes, and Moisture Access Tubes in Pajarito Canyon*

**TABLE C-1**

**SUMMARY AND STATUS OF PAJARITO CANYON WELLS, BOREHOLES, AND MOISTURE ACCESS TUBES**

| Hole ID | ER ID | Date Completed | Total Depth (ft) | Depth Completed (ft) | Location | Current Status | Well Comment |
|---|---|---|---|---|---|---|---|
| 03-MW-1 | 03-2664 | 9/22/94 | 29 | 28.8 | West of TA-3-30 | Inactive monitor well | Shallow perched groundwater well |
| 18-1136 | 18-1136 | 7/7/94 | 24 | 0 | Pajarito Canyon west of TA-18 | Plugged and abandoned | Plugged monitor well |
| 18-1165 | 18-1165 | 8/8/94 | 12.5 | 0 | Pajarito Canyon at TA-18 | Plugged and abandoned | Plugged monitor well |
| 18-1195 | 18-1195 | 7/5/94 | 10 | 0 | Pajarito Canyon at TA-18 | Plugged and abandoned | Plugged monitor well |
| 18-1196 | 18-1196 | 7/5/94 | 10 | 0 | Pajarito Canyon at TA-18 | Plugged and abandoned | Plugged monitor well |
| 18-1233 | 18-1233 | 7/20/94 | 20 | 0 | Pajarito Canyon at TA-18 | Plugged and abandoned | Plugged monitor well |
| 18-1254 | 18-1254 | 8/10/94 | 15 | 0 | Pajarito Canyon at TA-18 | Plugged and abandoned | Plugged monitor well |
| 18-BG-1 | 18-1060 | 8/1/94 | 37 | 35 | Pajarito Canyon west of TA-18 | Active monitor well | Shallow alluvial monitor well |
| 18-BG-2 | 18-1063 | 8/2/94 | 35 | 0 | Pajarito Canyon west of TA-18 | Plugged and abandoned | Plugged monitor well BG-2 |
| 18-BG-3 | 18-1066 | 8/3/94 | 20 | 0 | Pajarito Canyon west of TA-18 | Inactive monitor hole | Plugged monitor well BG-3 |
| 18-BG-4 | 18-10024 | 2/18/98 | 25 | 6.5 | Threemile Canyon at TA-18 | Active monitor well | Shallow alluvial monitor well |
| 18-MW-1 | 18-2013 | 7/8/90 | 25.6 | 25.6 | Pajarito Canyon at TA-18 | Active monitor well | Shallow alluvial monitor well |
| 18-MW-10 | 18-1255 | 8/10/94 | 22 | 20 | Pajarito Canyon at TA-18 | Active monitor well | Shallow alluvial monitor well |
| 18-MW-11 | 18-1275 | 8/11/94 | 49 | 47 | Pajarito Canyon at TA-18 | Active monitor well | Shallow alluvial monitor well |
| 18-MW-12 | 18-10010 | 11/6/96 | 43.8 | 41 | Pajarito Canyon at TA-18 | Active monitor well | Shallow alluvial monitor well |
| 18-MW-13 | 18-10011 | 11/14/96 | 40.1 | 40 | Pajarito Canyon at TA-18 | Active monitor well | Shallow alluvial monitor well |
| 18-MW-14 | 18-10012 | 11/8/96 | 45 | 43 | Pajarito Canyon at TA-18 | Active monitor well | Shallow alluvial monitor well |
| 18-MW-15 | 18-10013 | 11/12/96 | 48 | 39 | Pajarito Canyon at TA-18 | Active monitor well | Shallow alluvial monitor well |
| 18-MW-16 | 18-10014 | 11/4/96 | 37 | 30.5 | Pajarito Canyon at TA-18 | Active monitor well | Shallow alluvial monitor well |
| 18-MW-17 | 18-1684 | 8/1/95 | 23.8 | 22 | Lower Pajarito Canyon | Active monitor well | Shallow alluvial monitor well |
| 18-MW-18 | 18-1685 | 7/31/95 | 24 | 23 | Lower Pajarito Canyon | Active monitor well | Shallow alluvial monitor well |
| 18-MW-2 | 18-2014 | 7/8/90 | 27.6 | 27.6 | Pajarito Canyon at TA-18 | Active monitor well | Shallow alluvial monitor well |
| 18-MW-3 | 18-2015 | 7/8/90 | 27 | 23.4 | Pajarito Canyon at TA-18 | Active monitor well | Shallow alluvial monitor well |
| 18-MW-4 | 18-2016 | 7/8/90 | 26.2 | 26.2 | Pajarito Canyon at TA-18 | Active monitor well | Shallow alluvial monitor well |
| 18-MW-5 | 18-2023 | 3/7/94 | 30 | 28 | Pajarito Canyon at TA-18 | Active monitor well | Shallow alluvial monitor well |
| 18-MW-6 | 18-2024 | 3/9/94 | 27 | 25 | Pajarito Canyon at TA-18 | Active monitor well | Shallow alluvial monitor well |
| 18-MW-7 | 18-1135 | 7/6/94 | 32 | 30 | Pajarito Canyon at TA-18 | Active monitor well | Shallow alluvial monitor well |

**TABLE C-1 (continued)**

**SUMMARY AND STATUS OF PAJARITO CANYON WELLS, BOREHOLES, AND MOISTURE ACCESS TUBES**

| Hole ID | ER ID | Date Completed | Total Depth (ft) | Depth Completed (ft) | Location | Current Status | Well Comment |
|---|---|---|---|---|---|---|---|
| 18-MW-8 | 18-1166 | 8/4/94 | 40 | 37.9 | Threemile Canyon at TA-18 | Active monitor well | Shallow alluvial monitor well |
| 18-MW-9 | 18-1234 | 7/21/94 | 23 | 21 | Pajarito Canyon at TA-18 | Active monitor well | Shallow alluvial monitor well |
| 18-TH-1 | | 10/22/84 | 28 | 0 | Threemile Canyon at Kiva 2 | Plugged and abandoned | Plugged engineering test hole |
| 18-TH-2 | | 10/22/84 | 23 | 0 | Threemile Canyon at TA-18 | Plugged and abandoned | Plugged engineering test hole |
| 18-TH-3 | | 10/22/84 | 32 | 0 | Pajarito Canyon at Kiva 1 | Plugged and abandoned | Plugged engineering test hole |
| 50-9100 | 50-9100 | 2/5/96 | 316 | 316 | TA-50, MDA C | Active monitor well | MDA C monitor well |
| EGH-LA-1 | | 7/31/79 | 2292 | 0 | Sigma Mesa | Plugged and abandoned | Geothermal test on Sigma Mesa |
| H-19 | | 9/1/49 | 2000 | 0 | Los Alamos Canyon at Ice Rink | Abandoned | Hydrogeologic test hole |
| PCM-1 | | 6/30/85 | 60 | 8 | Lower Pajarito Canyon | Active monitor well | Moisture access tube, open hole |
| PCM-2 | | 6/30/85 | 120 | 7 | Lower Pajarito Canyon | Active monitor well | Moisture access tube, open hole |
| PCM-3 | | 6/30/85 | 60 | 8 | Lower Pajarito Canyon | Active monitor well | Moisture access tube, open hole |
| PCM-4 | | 6/30/85 | 60 | 10 | Lower Pajarito Canyon | Active monitor well | Moisture access tube, open hole |
| PCO-1 | 36-2020 | 6/30/85 | 22 | 12 | Lower Pajarito Canyon | Active monitor well | Shallow alluvial monitor well |
| PCO-2 | 36-2021 | 6/30/85 | 22 | 9.5 | Lower Pajarito Canyon | Active monitor well | Shallow alluvial monitor well |
| PCO-3 | 36-2022 | 6/30/85 | 20 | 17.7 | Lower Pajarito Canyon | Active monitor well | Shallow alluvial monitor well |
| PCTH-5 | | 3/31/50 | 263 | 24 | Lower Pajarito Canyon | Inactive monitor hole | Water test hole |
| PCTH-6 | | 3/31/50 | 300 | 120 | Lower Pajarito Canyon | Inactive monitor hole | Water test hole |
| PM-2 | | 7/15/65 | 2600 | 2300 | Lower Pajarito Canyon | Active production well | Pajarito Mesa production well |
| PM-4 | | 8/15/81 | 2920 | 2874 | Mesita del Buey | Active production well | Pajarito Mesa production well |
| SHB-1 | | 12/15/91 | 700 | 700 | West of TA-55 | 3-in. tubing w/ water | Seismic hazards borehole |
| SHB-2 | | 1/1/92 | 200 | 0 | TA-3 | 3-in. tubing w/ water | Seismic hazards borehole |
| SHB-3 | | 1/1/92 | 860 | 0 | TA-16 | 3-in. tubing w/ water | Seismic hazards borehole |
| SHB-4 | | 1/15/92 | 200 | 0 | TA-18 | 3-in. tubing w/ water | Seismic hazards borehole, tubing dry |

## TABLE C-2

### COORDINATES[a] FOR PAJARITO CANYON WELLS, BOREHOLES, AND MOISTURE ACCESS TUBES

| Site ID | Easting (ft) | Northing (ft) | Elevation (ft) | Land Surface Datum Measuring Point | Coordinate Source | Coordinate Confidence | Coordinate Comment |
|---|---|---|---|---|---|---|---|
| 03-MW-1 | 1616678.92 | 1773314.27 | 7457.70 | GL[b] | LANL 1995, 55638 | Good | |
| 18-1136 | 1634872.22 | 1761758.17 | 6754.01 | GL | LANL 1995, 54615 | Good | Plugged monitor well |
| 18-1165 | 1634723.53 | 1760674.42 | 6747.07 | GL | LANL 1995, 54615 | Good | Plugged monitor well |
| 18-1195 | 1636044.25 | 1760654.89 | 6724.11 | GL | LANL 1995, 54615 | Good | Plugged monitor well |
| 18-1196 | 1636069.88 | 1760642.60 | 6723.34 | GL | LANL 1995, 54615 | Good | Plugged monitor well |
| 18-1233 | 1635931.36 | 1760903.08 | 6730.01 | GL | LANL 1995, 54615 | Good | Plugged monitor well |
| 18-1254 | 1635576.10 | 1761043.68 | 6735.31 | GL | LANL 1995, 54615 | Good | Plugged monitor well |
| 18-BG-1 | 1634152.90 | 1762575.36 | 6776.45 | TOC[c] | LANL 1995, 54615 | Good | ER site 18-1060 |
| 18-BG-2 | 1634119.84 | 1762585.90 | 6774.60 | GL | LANL 1995, 54615 | Good | Plugged monitor well BG-2 |
| 18-BG-3 | 1634060.95 | 1762534.84 | 6776.08 | GL | FIMAD[d] | Good | Plugged monitor well BG-3 |
| 18-BG-4 | 1633600 | 1760750 | 6765 | | Estimate | Moderate | Well not surveyed 4/98 |
| 18-MW-1 | 1634843.70 | 1761930.30 | 6758.80 | GL | LANL 1995, 54615 | Good | ER site 18-2013 |
| 18-MW-10 | 1635610.25 | 1761063.57 | 6735.90 | TOC | LANL 1995, 54615 | Good | ER site 18-1255 |
| 18-MW-11 | 1636001.69 | 1761139.83 | 6740.13 | TOC | LANL 1995, 54615 | Good | ER site 18-1275 |
| 18-MW-12 | 1636139.90 | 1760607.80 | 6725.70 | TOC | LANL 1997, 56417 | Good | ER site 18-10010, Kaiser data |
| 18-MW-13 | 1636092.80 | 1760626.10 | 6727.30 | TOC | LANL 1997, 56417 | Good | ER site 18-10011, Kaiser data |
| 18-MW-14 | 1636093.90 | 1760676.80 | 6725.80 | TOC | LANL 1997, 56417 | Good | ER site 18-10012, Kaiser data |
| 18-MW-15 | 1635995.70 | 1760669.40 | 6727.90 | TOC | LANL 1997, 56417 | Good | ER site 18-10013, Kaiser data |
| 18-MW-16 | 1636040.80 | 1760580.70 | 6727.00 | TOC | LANL 1997, 56417 | Good | ER site 18-10014, Kaiser data |
| 18-MW-17 | 1637778.20 | 1759717.10 | 6695.20 | GL | FIMAD | Good | ER site 18-1684 |
| 18-MW-18 | 1639925.00 | 1758247.20 | 6654.70 | GL | FIMAD | Good | ER site 18-1685 |
| 18-MW-2 | 1634878.40 | 1761868.10 | 6758.50 | TOC | LANL 1995, 54615 | Good | ER site 18-2014 |
| 18-MW-3 | 1634893.60 | 1761864.10 | 6758.30 | TOC | LANL 1995, 54615 | Good | ER site 18-2015 |

a. State Plane Coordinate System, New Mexico Central Zone, 1983 North American Datum
b. GL = ground level
c. TOC = top of casing
d. FIMAD = Facility for Information Management, Analysis, and Display

## TABLE C-2 (continued)

### COORDINATES[a] FOR PAJARITO CANYON WELLS, BOREHOLES, AND MOISTURE ACCESS TUBES

| Site ID | Easting (ft) | Northing (ft) | Elevation (ft) | Land Surface Datum Measuring Point | Coordinate Source | Coordinate Confidence | Coordinate Comment |
|---|---|---|---|---|---|---|---|
| 18-MW-4 | 1634904.50 | 1761878.60 | 6758.30 | TOC[b] | LANL 1995, 54615 | Good | ER site 18-2016 |
| 18-MW-5 | 1635883.20 | 1761021.00 | 6736.70 | TOC | LANL 1995, 54615 | Good | ER site 18-2023 |
| 18-MW-6 | 1635899.60 | 1760916.30 | 6730.10 | TOC | LANL 1995, 54615 | Good | ER site 18-2024 |
| 18-MW-7 | 1634846.28 | 1761791.52 | 6755.50 | TOC | LANL 1995, 54615 | Good | ER site 18-1135 |
| 18-MW-8 | 1634714.26 | 1760658.14 | 6747.79 | TOC | LANL 1995, 54615 | Good | ER site 18-1166 |
| 18-MW-9 | 1635949.81 | 1760893.56 | 6732.91 | TOC | LANL 1995, 54615 | Good | ER site 18-1234 |
| 18-TH-1 | 1634470.00 | 1760660.00 | 6750.00 | GL[c] | Estimate | Moderate | Estimated at Kiva 2 guard tower |
| 18-TH-2 | 1635580.00 | 1760830.00 | 6735.00 | GL | Estimate | Moderate | Estimated at Kiva 3 guard tower |
| 18-TH-3 | 1634860.00 | 1761950.00 | 6760.00 | GL | Estimate | Moderate | Estimated at Kiva 1 guard tower |
| 50-9100 | 1626312.00 | 1768776.00 | 7233.00 | GL | Koch 1998, 58094 | Good | MDA C monitor well |
| EGH-LA-1 | 1628830.00 | 1770620.00 | 7215.00 | | FIMAD[d] map pick | Moderate | |
| H-19 | 1618444.00 | 1775462.10 | 7178.00 | GL | FIMAD | Good | |
| PCM-1 | 1637944.00 | 1760162.00 | 6697.60 | GL | Purtymun 1995, 45344/FIMAD | Good | BH-1288 |
| PCM-2 | 1641844.00 | 1757762.00 | 6640.10 | GL | Purtymun 1995, 45344/FIMAD | Good | BH-1289 |
| PCM-3 | 1643044.00 | 1757162.00 | 6615.00 | GL | Purtymun 1995, 45344/FIMAD | Good | BH-1290 |
| PCM-4 | 1644444.00 | 1756562.00 | 6584.70 | GL | Purtymun 1995, 45344/FIMAD | Good | BH-1291 |
| PCO-1 | 1637919.13 | 1759990.14 | 6687.00 | GL | LANL 1995, 54615 | Good | ER site 36-2020 |
| PCO-2 | 1641699.75 | 1757441.30 | 6618.30 | GL | LANL 1995, 54615 | Good | ER site 36-2021 |
| PCO-3 | 1646085.89 | 1755485.55 | 6546.30 | GL | LANL 1995, 54615 | Good | ER site 36-2022 |
| PCTH-5 | 1643557.00 | 1756580.00 | 6593.20 | GL | Purtymun 1995, 45344/FIMAD | Good | xh pt 112, T-5 (FIMAD designations) |
| PCTH-6 | 1640517.00 | 1757881.00 | 6594.50 | GL | Purtymun 1995, 45344/FIMAD | Good | T-6 (FIMAD designations) |
| PM-2 | 1636786.30 | 1760326.00 | 6715.00 | GL | Purtymun 1995, 45344 | Good | |

a. State Plane Coordinate System, New Mexico Central Zone, 1983 North American Datum

b. TOC = top of casing

c. GL = ground level

d. FIMAD = Facility for Information Management, Analysis, and Display

## TABLE C-2 (continued)

### COORDINATES[a] FOR PAJARITO CANYON WELLS, BOREHOLES, AND MOISTURE ACCESS TUBES

| Site ID | Easting (ft) | Northing (ft) | Elevation (ft) | Land Surface Datum Measuring Point | Coordinate Source | Coordinate Confidence | Coordinate Comment |
|---|---|---|---|---|---|---|---|
| *PM-3* | *1642590.00* | *1769530.00* | *6610.00* | | *FIMAD[b] map pick* | *Moderate* | *New pick from well house* |
| *PM-4* | *1635716.60* | *1764674.10* | *6920.00* | *GL[c]* | *Purtymun 1995, 45344* | | |
| *PM-5* | *1632110.00* | *1767790.00* | *7095.00* | | *FIMAD map pick* | *Moderate* | *New pick from well house* |
| *SHB-1* | *1624052.20* | *1769848.70* | *7314.60* | | *1994 survey* | *Good* | |
| *SHB-2* | *1617643.00* | *1773155.00* | *7436.00* | *GL* | *FIMAD* | *Good* | |
| *SHB-3* | *1609310.00* | *1760990.00* | *7607.00* | *GL* | *FIMAD* | *Good* | |
| *SHB-4* | *1636245.00* | *1761245.00* | *6747.70* | *GL* | *Koch 1998, 58094* | *Good* | |

*a. State Plane Coordinate System, New Mexico Central Zone, 1983 North American Datum*

*b. FIMAD = Facility for Information Management, Analysis, and Display*

*c. GL = ground level*

## TABLE C-3

## CASING CONSTRUCTION INFORMATION FOR PAJARITO CANYON WELLS, BOREHOLES, AND MOISTURE ACCESS TUBES

| Hole ID | Tubing Type | Tubing Diameter (in.) | Top of Tubing (ft) | Measuring Point | Surface Casing Type | Surface Casing Diameter (in.) | Surface Casing Color | Top of Casing (ft) | Casing Source | Top of Casing Confidence | Casing Diameter Source | Casing Diameter Confidence | Casing Comment |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *03-MW-1* | *Steel* | *2* | *-1* | *GL*[a] | | | | | *LANL 1995, 55638* | | | | *Stainless steel* |
| *18-1136* | | *2* | | | | | | | | | | | *Casing removed* |
| *18-1165* | | *2* | | | | | | | | | | | *Casing removed* |
| *18-1195* | | *2* | | | | | | | | | | | *Casing removed* |
| *18-1196* | | *2* | | | | | | | | | | | *Casing removed* |
| *18-1233* | | *2* | | | | | | | | | | | *Casing removed* |
| *18-1254* | | *2* | | | | | | | | | | | *Casing removed* |
| *18-BG-1* | *PVC*[b] | *2* | *5* | | | | | | *LANL 1997, 56356* | *Moderate* | *LANL 1997, 56356* | *Good* | *Riser height ?* |
| *18-BG-2* | | | | | | | | | | | | | *Casing removed* |
| *18-BG-3* | | | | | | | | | | | | | *Casing removed* |
| *18-BG-4* | *PVC* | *4* | | | *Steel* | *6* | | | | | | | *New well 2/98* |
| *18-MW-1* | *PVC* | *2* | *0* | *GL* | *None* | | | | *LATA 1991, 12464* | *Good* | | | |
| *18-MW-10* | *PVC* | *2* | *0* | *GL* | | | | | *LANL 1997, 56356* | *Good* | | | *Well completion record* |
| *18-MW-11* | *PVC* | *2* | *0* | *GL* | | | | | *LANL 1997, 56356* | *Good* | | | |
| *18-MW-12* | *PVC* | *2* | *3* | *TOC*[c] | *Steel* | | | | *LANL 1997, 56417* | *Good* | | | *Well completion record* |
| *18-MW-13* | *PVC* | *2* | *3* | *TOC* | *Steel* | | | | *LANL 1997, 56417* | *Good* | | | *Well completion record* |
| *18-MW-14* | *PVC* | *2* | *2.91* | *TOC* | *Steel* | | | | *LANL 1997, 56417* | *Good* | | | *Well completion record* |
| *18-MW-15* | *PVC* | *2* | *2.38* | *TOC* | *Steel* | | | | *LANL 1997, 56417* | *Good* | | | *Well completion record* |

a. *GL = ground level*

b. *PVC = polyvinyl chloride*

c. *TOC = top of casing*

**TABLE C-3 (continued)**

**CASING CONSTRUCTION INFORMATION FOR PAJARITO CANYON WELLS, BOREHOLES, AND MOISTURE ACCESS TUBES**

| Hole ID | Tubing Type | Tubing Diameter (in.) | Top of Tubing (ft) | Measuring Point | Surface Casing Type | Surface Casing Diameter (in.) | Surface Casing Color | Top of Casing (ft) | Casing Source | Top of Casing Confidence | Casing Diameter Source | Casing Diameter Confidence | Casing Comment |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *18-MW-16* | *PVC*[a] | *2* | *3.06* | *TOC*[b] | *Steel* | | | | *LANL 1997, 56417* | *Good* | | | *Well completion record* |
| *18-MW-17* | *PVC* | *2* | *3.1* | *TOC* | *Steel* | *6* | *Tan* | | *Core log* | *Good* | *Richard Koch (SAIC)* | *Moderate* | *Square surface casing with cap* |
| *18-MW-18* | *PVC* | *2* | *1.75* | *TOC* | *Steel* | *6* | *Tan* | | *Core log* | *Good* | *Richard Koch (SAIC)* | *Moderate* | *Square surface casing with cap* |
| *18-MW-2* | *PVC* | *2* | *0* | *GL*[c] | *None* | | | | *LATA 1991, 12464* | *Good* | | | |
| *18-MW-3* | *PVC* | *2* | *0* | *GL* | *None* | | | | *LATA 1991, 12464* | *Good* | | | |
| *18-MW-4* | *PVC* | *2* | *0* | *GL* | *None* | | | | *LATA 1991, 12464* | *Good* | | | |
| *18-MW-5* | *PVC* | *2* | *1.5* | *GL* | | | | | *LANL 1994, 47113* | *Good* | | | |
| *18-MW-6* | *PVC* | *2* | *0* | *GL* | | | | | *LANL 1994, 47113* | *Good* | | | |
| *18-MW-7* | *PVC* | *2* | *5* | | | | | | *LANL 1997, 56356* | | | | *Well completion record* |
| *18-MW-8* | *PVC* | *2* | *2* | | | | | | *LANL 1997, 56356* | | | | *Well completion record* |
| *18-MW-9* | *PVC* | *2* | *4* | | | | | | *LANL 1997, 56356* | | | | *Well completion record* |
| *18-TH-1* | *None* | | | | | | | | | | | | *Not cased* |
| *18-TH-2* | *None* | | | | | | | | | | | | *Not cased* |
| *18-TH-3* | *None* | | | | | | | | | | | | *Not cased* |
| *50-9100* | | | | | | | | | | | | | *Not cased* |
| *EGH-LA-1* | | | | | | | | | | | | | |

a. *PVC = polyvinyl chloride*

b. *TOC = top of casing*

c. *GL = ground level*

## TABLE C-3 (continued)

### CASING CONSTRUCTION INFORMATION FOR PAJARITO CANYON WELLS, BOREHOLES, AND MOISTURE ACCESS TUBES

| Hole ID | Tubing Type | Tubing Diameter (in.) | Top of Tubing (ft) | Measuring Point | Surface Casing Type | Surface Casing Diameter (in.) | Surface Casing Color | Top of Casing (ft) | Casing Source | Top of Casing Confidence | Casing Diameter Source | Casing Diameter Confidence | Casing Comment |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *H-19* | | | | | *Steel* | *8* | | *1.5* | *USGS*[a] | *Moderate* | *USGS log* | *Moderate* | *Purtymun 1995, 45344 0–10': 12" pulled at comp; USGS: 0–10': 8"* |
| *PCM-1* | *Plastic* | *4* | *0.3* | | *None* | | | | *Purtymun 1995, 45344* | | | | *Casing 0–8 ft, cement 0–8 ft, 8–60 open* |
| *PCM-2* | *Plastic* | *4* | *0.2* | | *None* | | | | *Purtymun 1995, 45344* | | | | *Casing 0–7 ft, cement 0–7 ft, 7–120 open* |
| *PCM-4* | *Plastic* | *4* | *0.2* | | *None* | | | | *Purtymun 1995, 45344* | | | *Casing* | *Casing 0–9.5 ft, cement 0–9.5 ft, 9.5–60 open* |
| *PCO-1* | *Plastic* | *4* | *0.3* | *TOT*[b] | *Steel* | *9* | | *1.3* | *Purtymun 1995, 45344* | | | | *Casing 0–12 ft, cement 0–2 ft* |
| *PCO-2* | *Plastic* | *4* | | | *Steel* | *9* | | *1.3* | *Purtymun 1995, 45344* | | | | *Casing 0–9 ft, cement 0–1 ft* |
| *PCO-3* | *Plastic* | *4* | *0.7* | | *Steel* | *9* | | *1.3* | *Purtymun 1995, 45344* | | | | *Casing 0–17.7 ft, cement 0–2 ft* |
| *PM-2* | *Steel* | *14* | | | *Steel* | *26* | | | *Purtymun 1995, 45344* | | *Purtymun 1995, 45344* | | *Casing 0–504':26"; 0–2300:14"* |
| *PM-3* | *Steel* | *14* | | | *Steel* | *26* | | | | | | | |
| *PM-4* | *Steel* | *16* | | | *Steel* | *42* | | | *Purtymun 1995, 45344* | | *Purtymun 1995, 45344* | | *Casing 0–41':42"; 0–923':28"; 0–2874:16"* |
| *PM-5* | *Steel* | *16* | | | *Steel* | *42* | | | *Purtymun 1995, 45344* | | *Purtymun 1995, 45344* | | *Casing 0–40':42"; 0–1178':28"; 0–3092:16"* |

*a. USGS = United States Geological Survey*

*b. TOT = top of tubing*

## TABLE C-3 (continued)

### CASING CONSTRUCTION INFORMATION FOR PAJARITO CANYON WELLS, BOREHOLES, AND MOISTURE ACCESS TUBES

| Hole ID | Tubing Type | Tubing Diameter (in.) | Top of Tubing (ft) | Measuring Point | Surface Casing Type | Surface Casing Diameter (in.) | Surface Casing Color | Top of Casing (ft) | Casing Source | Top of Casing Confidence | Casing Diameter Source | Casing Diameter Confidence | Casing Comment |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *SHB-1* | *PVC** | *3* | | | *Steel* | *8* | *Tan?* | | | | *Gardner et al. 1993, 12582* | | *3-in. tubing filled with water* |
| *SHB-2* | *PVC* | *3* | | | *Steel* | *8* | *Tan?* | | | | *Gardner et al. 1993, 12582* | | *3-in. tubing filled with water* |
| *SHB-3* | *PVC* | *3* | | | *Steel* | *8* | *Tan?* | | | | *Gardner et al. 1993, 12582* | | *3-in tubing filled with water* |
| *SHB-4* | *PVC* | *3* | | | *Steel* | *8* | *Tan?* | | | | *Gardner et al. 1993, 12582* | | *3-in. tubing filled with water, dry 1997* |
| *PCTH-5* | *None* | | | | *Steel* | *24* | | | *Purtymun 1995, 45344* | | | | *Casing 0–24 ft, open hole 24–263 ft* |
| *PCTH-6* | *None* | | | | *Steel* | *8* | | | *Purtymun 1995, 45344* | | | | *Casing 0–120 ft, open hole 120–300 ft* |

**PVC = polyvinyl chloride*

## TABLE C-4

### SCREEN INTERVAL INFORMATION FOR PAJARITO CANYON WELLS, BOREHOLES, AND MOISTURE ACCESS TUBES

| Hole ID | ER ID | Elevation (ft) | Top of Screen (ft) | Bottom of Screen (ft) | Perforation Size (in.) | Annulus Pack (ft) | Sump Length (ft) | Screen Source | Screen Comment |
|---|---|---|---|---|---|---|---|---|---|
| *03-MW-1* | *03-2664* | *7457.7* | *23* | *28* | | *Sand pack* | *0.83* | *LANL 1995, 55638* | *Wound stainless steel rod* |
| *18-1136* | *18-1136* | *6754.01* | | | | | | | *Casing removed* |
| *18-1165* | *18-1165* | *6747.07* | | | | | | | *Casing removed* |
| *18-1195* | *18-1195* | *6724.11* | | | | | | | *Casing removed* |
| *18-1196* | *18-1196* | *6723.34* | | | | | | | *Casing removed* |
| *18-1233* | *18-1233* | *6730.01* | | | | | | | *Casing removed* |
| *18-1254* | *18-1254* | *6735.31* | | | | | | | *Casing removed* |
| *18-BG-1* | *18-1060* | *6776.45* | *10* | *35* | *0.01* | *Sand pack 10–20* | *0* | *LANL 1997, 56356* | *Top of filter pack at 8 ft* |
| *18-BG-2* | *18-1063* | *6774.60* | | | | | | | *Casing removed* |
| *18-BG-3* | *18-1066* | *6776.08* | | | | | | | *Casing removed* |
| *18-BG-4* | *18-10024* | *6765* | *2.5* | *6.5* | *0.01* | *Sand pack 20–40* | *0.75* | *Catherine Goetz (ICF Kaiser)* | *Polyvinyl chloride* |
| *50-9100* | *50-9100* | *7233.00* | | | | | | | |
| *EGH-LA-1* | | *7215.00* | | | | | | | *Plugged and abandoned* |
| *H-19* | | *7178.00* | | | | *Open hole* | | *Purtymun 1995, 45344* | *No casing, no screen* |
| *PCM-1* | | *6697.60* | | | | *Open hole* | | *Purtymun 1995, 45344* | *Open hole 8–60 ft* |
| *PCM-2* | | *6640.10* | | | | *Open hole* | | *Purtymun 1995, 45344* | *Open hole 7–120 ft* |
| *PCM-3* | | *6615.00* | | | | *Open hole* | | *Purtymun 1995, 45344* | *Open hole 8–60 ft* |
| *PCM-4* | | *6584.70* | | | | *Open hole* | | *Purtymun 1995, 45344* | *Open hole 10–60 ft* |
| *PCMW-1* | *18-2013* | *6758.80* | *5.6* | *25.6* | *0.01* | *Sand pack 10–20* | *0* | *LATA 1991, 12464* | *Top of filter pack at 3 ft* |
| *PCMW-10* | *18-1255* | *6735.90* | *10* | *20* | *0.01* | *Sand pack 10–20* | *0* | *LANL 1997, 56356* | *Top of filter pack at 8 ft* |
| *PCMW-11* | *18-1275* | *6740.13* | *27* | *47* | *0.01* | *Sand pack 10–20* | *0* | *LANL 1997, 56356* | *Top of filter pack at 25 ft* |
| *PCMW-12* | *18-10010* | *6725.70* | *5* | *40* | *0.01* | *Sand pack 10–20* | *1* | *LANL 1997, 55527* | *Top of filter pack at 4.5 ft* |
| *PCMW-13* | *18-10011* | *6727.30* | *6* | *39* | *0.01* | *Sand pack 10–20* | *1* | *LANL 1997, 55527* | *Top of filter pack at 5 ft* |
| *PCMW-14* | *18-10012* | *6725.80* | *7* | *42* | *0.01* | *Sand pack 10–20* | *1* | *LANL 1997, 55527* | *Top of filter pack at 6 ft* |
| *PCMW-15* | *18-10013* | *6727.90* | *5* | *38* | *0.01* | *Sand pack 10–20* | *1* | *LANL 1997, 55527* | *Top of filter pack at 4.5 ft* |

## TABLE C-4 (continued)

## SCREEN INTERVAL INFORMATION FOR PAJARITO CANYON WELLS, BOREHOLES, AND MOISTURE ACCESS TUBES

| Hole ID | ER ID | Elevation (ft) | Top of Screen (ft) | Bottom of Screen (ft) | Perforation Size (in.) | Annulus Pack (ft) | Sump Length (ft) | Screen Source | Screen Comment |
|---|---|---|---|---|---|---|---|---|---|
| *PCMW-16* | *18-10014* | *6727.00* | *6* | *30.5* | *0.01* | *Sand pack 10–20* | *0* | *LANL 1997, 55527* | *Top of filter pack at 5 ft* |
| *PCMW-17* | *18-1684* | *6695.20* | *12* | *22* | *0.01* | *Sand pack 10–20* | *0* | *LANL 1997, 55527* | *Top of filter pack at 9 ft* |
| *PCMW-18* | *18-1685* | *6654.70* | *12.5* | *23* | *0.01* | *Sand pack 10–20* | *0* | *LANL 1997, 55527* | *Top of filter pack at 10.5 ft* |
| *PCMW-2* | *18-2014* | *6758.50* | *7.6* | *27.6* | *0.01* | *Sand pack 10–20* | *0* | *LATA 1991, 12464* | *Top of filter pack at 3 ft* |
| *PCMW-3* | *18-2015* | *6758.30* | *3.4* | *23.4* | *0.01* | *Sand pack 10–20* | *0* | *LATA 1991, 12464* | *Top of filter pack at 3 ft* |
| *PCMW-4* | *18-2016* | *6758.30* | *6.2* | *26.2* | *0.01* | *Sand pack 10–20* | *0* | *LATA 1991, 12464* | *Top of filter pack at 3 ft* |
| *PCMW-5* | *18-2023* | *6736.70* | *3* | *28* | *0.01* | *Sand pack 10–20* | *0* | *LANL 1994, 47113* | *Top of filter pack at 3 ft* |
| *PCMW-6* | *18-2024* | *6730.10* | *5* | *25* | *0.01* | *Sand pack 10–20* | *0* | *LANL 1994, 47113* | *Top of filter pack at 3 ft* |
| *PCMW-7* | *18-1135* | *6755.50* | *10* | *30* | *0.01* | *Sand pack 10–20* | *0* | *LANL 1997, 56356* | *Top of filter pack at 8 ft* |
| *PCMW-8* | *18-1166* | *6747.79* | *8* | *38* | *0.01* | *Sand pack 10–20* | *0* | *LANL 1997, 56356* | *Top of filter pack at 6 ft* |
| *PCMW-9* | *18-1234* | *6732.91* | *6* | *21* | *0.01* | *Sand pack 10–20* | *0* | *LANL 1997, 56356* | *Top of filter pack at 4 ft* |
| *PCO-1* | *36-2020* | *6687.00* | *4* | *12* | *0.25* | *Gravel pack 2–12* | *0* | *Purtymun 1995, 45344* | |
| *PCO-2* | *36-2021* | *6618.30* | *1.5* | *9.5* | *0.25* | *Gravel pack 1–9* | *0* | *Purtymun 1995, 45344* | |
| *PCO-3* | *36-2022* | *6546.30* | *5* | *17* | *0.25* | *Gravel pack 2–18* | *0* | *Purtymun 1995, 45344* | |
| *PM-2* | | *6715.00* | *1004* | *2280* | | *Gravel pack?* | *20* | *Purtymun 1995, 45344* | *Louvers* |
| *PM-4* | | *6920.00* | *1260* | *2854* | | *Gravel pack* | *20* | *Purtymun 1995, 45344* | *Louvers* |
| *SHB-1* | | *7314.60* | | | | | | *Gardner et al. 1993, 12582* | *3-in.-diameter tubing, not screened* |
| *SHB-2* | | *7436.00* | | | | | | *Gardner et al. 1993, 12582* | *3-in.-diameter tubing, not screened* |
| *SHB-3* | | *7607.00* | | | | | | *Gardner et al. 1993, 12582* | *3-in.-diameter tubing, not screened* |
| *SHB-4* | | *6747.70* | | | | | | *Gardner et al. 1993, 12582* | *3-in.-diameter tubing, not screened* |

**TABLE C-5**

**WATER LEVEL MEASUREMENTS IN PAJARITO CANYON MONITOR WELLS**

| Site ID | Hole ID | Measured Depth (ft) | Measured Depth Date | SWL[a] Date | SWL (ft) | GL[b] or MP[c] | SWL Elevation | SWL Source | SWL Confidence | SWL Comment | TOT[d] (ft) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 03-MW-1 | 03-2664 | 29 | 9/22/94 | 9/22/94 | 23 | GL | | LANL 1995, 55638 | Good | | -1 |
| 18-1136 | 18-1136 | 24 | 7/7/94 | 7/7/94 | 17.9 | GL | | LANL 1995, 54615 | Good | | |
| 18-1165 | 18-1165 | 12.5 | 8/8/94 | 8/8/94 | 7.5 | GL | | LANL 1995, 54615 | Good | | |
| 18-1195 | 18-1195 | 10 | 7/5/94 | 7/5/94 | 6.4 | GL | | LANL 1995, 54615 | Good | | |
| 18-1196 | 18-1196 | 10 | 7/5/94 | 7/5/94 | 5.33 | GL | | LANL 1995, 54615 | Good | | |
| 18-1233 | 18-1233 | 20 | 7/20/94 | 7/20/94 | 12 | GL | | LANL 1995, 54615 | Good | | |
| 18-1254 | 18-1254 | 15 | 8/10/94 | 8/10/94 | 9.7 | GL | | LANL 1995, 54615 | Good | | |
| 18-BG-1 | 18-BG-1 | 37 | 8/1/94 | 8/1/94 | 18 | GL | | LANL 1995, 54615 | Good | | 5 |
| 18-BG-1 | 18-BG-1 | | | 11/15/94 | 13.3 | GL | | LANL 1997, 56356 | Good | Well completion form | 5 |
| 18-BG-1 | 18-BG-1 | | | 7/15/95 | 6.69 | GL | 6769.76 | LANL 1996, 55120 | Good | 18-1060 | 5 |
| 18-BG-1 | 18-BG-1 | | | 3/11/97 | 19.18 | TOC[e] | 6757.27 | LANL 1995, 47257 | Good | ? TOC or GL | 5 |
| 18-BG-2 | 18-1063 | 35 | 8/2/94 | 8/2/94 | 12.5 | GL | | LANL 1995, 54615 | Good | | |
| 18-BG-3 | 18-1066 | 20 | 8/5/94 | 8/5/94 | 15.5 | GL | | LANL 1997, 56356 | Good | Core log record | |
| 18-BG-4 | 18-10024 | 7 | 2/18/98 | 2/18/98 | 2.5 | GL | | RFI field notes | Good | Water did not recover after well was drilled; Catherine Goetz (ICF Kaiser) | |
| 18-MW-1 | 18-MW-1 | 25.6 | 7/8/90 | 5/15/93 | 7.33 | GL | | LANL 1995, 54615 | Good | | -0.47 |
| 18-MW-1 | 18-MW-1 | | | 6/15/93 | 9.75 | GL | | LANL 1995, 54615 | Good | | -0.47 |
| 18-MW-1 | 18-MW-1 | 25.4 | 7/12/93 | 7/12/93 | 13 | GL | | LANL 1995, 54615 | Good | | -0.47 |
| 18-MW-1 | 18-MW-1 | | | 8/15/93 | 10.91 | GL | | LANL 1995, 54615 | Good | | -0.47 |
| 18-MW-1 | 18-MW-1 | | | 9/15/93 | 11.95 | GL | | LANL 1995, 54615 | Good | | -0.47 |
| 18-MW-1 | 18-MW-1 | 25.5 | 10/12/93 | 10/12/93 | 13.5 | TOC | | LANL 1997, 56356 | Good | | -0.47 |
| 18-MW-1 | 18-MW-1 | | | 11/15/93 | 16.78 | GL | | LANL 1995, 54615 | Good | | -0.47 |
| 18-MW-1 | 18-MW-1 | 25.4 | 7/12/94 | 7/12/94 | 12.8 | GL | | LANL 1995, 54615 | Good | NOD response notes | -0.47 |
| 18-MW-1 | 18-MW-1 | | | 10/15/94 | 12.4 | GL | | LANL 1995, 54615 | Good | | -0.47 |
| 18-MW-1 | 18-MW-1 | | | 7/15/95 | 8.47 | GL | 6750.33 | LANL 1996, 55120 | Good | | -0.47 |

a. SWL = static water level

b. GL = ground level

c. MP = measuring point

d. TOT = top of tubing

e. TOC = top of casing

**TABLE C-5 (continued)**

**WATER LEVEL MEASUREMENTS IN PAJARITO CANYON MONITOR WELLS**

| Site ID | Hole ID | Measured Depth (ft) | Measured Depth Date | SWL[a] Date | SWL (ft) | GL[b] or MP[c] | SWL Elevation | SWL Source | SWL Confidence | SWL Comment | TOT[d] (ft) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *18-MW-1* | *18-MW-1* | | | *3/11/97* | *16.66* | *TOC[e]* | *6742.14* | *LANL 1995, 47257* | *Good* | *? TOC or GL* | *-0.47* |
| *18-MW-1* | *18-MW-1* | | | *8/15/97* | *13.55* | *GL* | | *RFI field notes* | *Good* | *Karl Maness (ICF Kaiser)* | *-0.47* |
| *18-MW-1* | *18-MW-1* | | | *9/30/97* | *8.28* | *TOC* | | *RFI field notes* | *Good* | *Karl Maness (ICF Kaiser)* | *-0.47* |
| *18-MW-10* | *18-MW-10* | *28.7* | *8/10/94* | *8/10/94* | *9.4* | *GL* | | *LANL 1995, 54615* | *Good* | | *0* |
| *18-MW-10* | *18-MW-10* | *22* | *8/10/94* | *8/10/94* | *16* | *GL* | | *LANL 1997, 56356* | *Good* | *Water level from core log* | *0* |
| *18-MW-10* | *18-MW-10* | | | *11/15/94* | *8.9* | *GL* | | *LANL 1995, 54615* | *Good* | | *0* |
| *18-MW-10* | *18-MW-10* | | | *11/15/94* | *16* | *GL* | | *LANL 1997, 56356* | *Good* | *Well completion form* | *0* |
| *18-MW-10* | *18-MW-10* | | | *7/15/95* | *6.04* | *GL* | *6729.86* | *LANL 1996, 55120* | *Good* | | *0* |
| *18-MW-10* | *18-MW-10* | | | *3/11/97* | *9.31* | *TOC* | *6726.59* | *LANL 1995, 47257* | *Good* | *? TOC or GL* | *0* |
| *18-MW-11* | *18-MW-11* | *49* | *8/11/94* | *8/11/94* | *21* | *GL* | | *LANL 1995, 54615* | *Good* | | *0* |
| *18-MW-11* | *18-MW-11* | | | *9/15/94* | *21* | *GL* | | *LANL 1997, 56356* | *Good* | *Well completion form* | *0* |
| *18-MW-11* | *18-MW-11* | | | *11/15/94* | *16.8* | *GL* | | *LANL 1995, 54615* | *Good* | | *0* |
| *18-MW-11* | *18-MW-11* | | | *7/15/95* | *14.81* | *GL* | *6725.32* | *LANL 1996, 55120* | *Good* | | *0* |
| *18-MW-11* | *18-MW-11* | | | *3/11/97* | *18.65* | *TOC* | *6721.45* | *LANL 1995, 47257* | *Good* | *? TOC or GL* | *0* |
| *18-MW-12* | *18-MW-12* | *43* | *11/6/96* | *11/6/96* | *8.39* | *GL* | | *LANL 1995, 47257* | *Good* | *Initial water level 8.5 ft* | *3.076* |
| *18-MW-12* | *18-MW-12* | | | *11/8/96* | *9.26* | *GL* | | *RFI field notes* | *Good* | | *3.076* |
| *18-MW-12* | *18-MW-12* | | | *11/12/96* | *8.4* | *GL* | | *RFI field notes* | *Good* | | *3.076* |
| *18-MW-12* | *18-MW-12* | | | *11/13/96* | *8.23* | *GL* | | *RFI field notes* | *Good* | *Time: 1615; Karl Maness (ICF Kaiser)* | *3.076* |
| *18-MW-12* | *18-MW-12* | | | *11/13/96* | *8.13* | *GL* | | *RFI field notes* | *Good* | *Time: 0825; Karl Maness (ICF Kaiser)* | *3.076* |
| *18-MW-12* | *18-MW-12* | | | *11/13/96* | *8.41* | *GL* | | *RFI field notes* | *Good* | *Time: 1425; Karl Maness (ICF Kaiser)* | *3.076* |
| *18-MW-12* | *18-MW-12* | | | *11/14/96* | *8.04* | *GL* | | *RFI field notes* | *Good* | *Karl Maness (ICF Kaiser)* | *3.076* |
| *18-MW-12* | *18-MW-12* | | | *11/20/96* | *8.24* | *GL* | | *RFI field notes* | *Good* | *Karl Maness (ICF Kaiser)* | *3.076* |
| *18-MW-12* | *18-MW-12* | | | *11/22/96* | *8.19* | *GL* | | *RFI field notes* | *Good* | *Karl Maness (ICF Kaiser)* | *3.076* |

*a. SWL = static water level*

*b. GL = ground level*

*c. MP = measuring point*

*d. TOT = top of tubing*

*e. TOC = top of casing*

**TABLE C-5 (continued)**

**WATER LEVEL MEASUREMENTS IN PAJARITO CANYON MONITOR WELLS**

| Site ID | Hole ID | Measured Depth (ft) | Measured Depth Date | SWL[a] Date | SWL (ft) | GL[b] or MP[c] | SWL Elevation | SWL Source | SWL Confidence | SWL Comment | TOT[d] (ft) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 18-MW-12 | 18-MW-12 | | | 11/27/96 | 8.31 | GL | | RFI field notes | Good | Karl Maness (ICF Kaiser) | 3.076 |
| 18-MW-12 | 18-MW-12 | | | 12/4/96 | 8.23 | GL | 6714.4 | LANL 1995, 47257 | Fair | From figure | 3.076 |
| 18-MW-12 | 18-MW-12 | 42 | 3/11/97 | 3/11/97 | 9.02 | TOC[e] | 6716.68 | LANL 1995, 47257 | Good | ? TOC or GL | 3.076 |
| 18-MW-12 | 18-MW-12 | 40.725 | 6/10/97 | 6/10/97 | 7.25 | TOC | | RFI field notes | Good | Surface water flowing in stream | 3.076 |
| 18-MW-12 | 18-MW-12 | | | 7/23/97 | 9.14 | TOC | | RFI field notes | Good | Karl Maness (ICF Kaiser) | 3.076 |
| 18-MW-12 | 18-MW-12 | 40.58 | 8/29/97 | 9/29/97 | 7.37 | TOC | | RFI field notes | Good | Karl Maness (ICF Kaiser) | 3.076 |
| 18-MW-12 | 18-MW-12 | 39 | 12/16/97 | 12/16/97 | 9.61 | TOC | | RFI field notes | Good | Karl Maness (ICF Kaiser) | 3.076 |
| 18-MW-13 | 18-MW-13 | 40 | 11/14/96 | 11/14/96 | 8.6 | GL | | LANL 1997, 47257 | Good | Initial water level 10 ft | 2.9 |
| 18-MW-13 | 18-MW-13 | | | 11/20/96 | 8.69 | GL | | RFI field notes | Good | Karl Maness (ICF Kaiser) | 2.9 |
| 18-MW-13 | 18-MW-13 | | | 11/22/96 | 8.8 | GL | | RFI field notes | Good | Karl Maness (ICF Kaiser) | 2.9 |
| 18-MW-13 | 18-MW-13 | | | 11/27/96 | 8.9 | GL | | RFI field notes | Good | Karl Maness (ICF Kaiser) | 2.9 |
| 18-MW-13 | 18-MW-13 | | | 12/4/96 | 8.94 | GL | 6715.5 | LANL 1995, 47257 | Good | Karl Maness (ICF Kaiser) | 2.9 |
| 18-MW-13 | 18-MW-13 | 40 | 3/11/97 | 3/11/97 | 9.57 | TOC | 6717.73 | LANL 1995, 47257 | Good | ? TOC or GL | 2.9 |
| 18-MW-13 | 18-MW-13 | 40.47 | 6/10/97 | 6/10/97 | 8.25 | TOC | | RFI field notes | Good | Karl Maness (ICF Kaiser) | 2.9 |
| 18-MW-13 | 18-MW-13 | | | 7/23/97 | 10.05 | TOC | | RFI field notes | Good | Karl Maness (ICF Kaiser) | 2.9 |
| 18-MW-13 | 18-MW-13 | 40.42 | 9/29/97 | 9/29/97 | 8.37 | TOC | | RFI field notes | Good | Karl Maness (ICF Kaiser) | 2.9 |
| 18-MW-13 | 18-MW-13 | 40 | 12/16/97 | 12/16/97 | 10.47 | TOC | | RFI field notes | Good | Karl Maness (ICF Kaiser) | 2.9 |
| 18-MW-14 | 18-MW-14 | 43 | 11/8/96 | 11/8/96 | 10.4 | GL | | LANL 1995, 47257 | Good | Initial water level 17 ft or 18 ft (see log) | 2.449 |
| 18-MW-14 | 18-MW-14 | | | 11/13/96 | 10.05 | GL | | RFI field notes | Good | Time: 1615; Karl Maness (ICF Kaiser) | 2.449 |
| 18-MW-14 | 18-MW-14 | | | 11/13/96 | 10.86 | GL | | RFI field notes | Good | Time: 0820; Karl Maness (ICF Kaiser) | 2.449 |
| 18-MW-14 | 18-MW-14 | | | 11/13/96 | 10.06 | GL | | RFI field notes | Good | Time: 1425; Karl Maness (ICF Kaiser) | 2.449 |

a. SWL = static water level
b. GL = ground level
c. MP = measuring point
d. TOT = top of tubing
e. TOC = top of casing

**TABLE C-5 (continued)**

**WATER LEVEL MEASUREMENTS IN PAJARITO CANYON MONITOR WELLS**

| Site ID | Hole ID | Measured Depth (ft) | Measured Depth Date | SWL[a] Date | SWL (ft) | GL[b] or MP[c] | SWL Elevation | SWL Source | SWL Confidence | SWL Comment | TOT[d] (ft) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 18-MW-14 | 18-MW-14 | | | 11/14/96 | 9.82 | GL | | RFI field notes | Good | Karl Maness (ICF Kaiser) | 2.449 |
| 18-MW-14 | 18-MW-14 | | | 11/20/96 | 9.47 | GL | | RFI field notes | Good | Karl Maness (ICF Kaiser) | 2.449 |
| 18-MW-14 | 18-MW-14 | | | 11/22/96 | 9.39 | GL | | RFI field notes | Good | Karl Maness (ICF Kaiser) | 2.449 |
| 18-MW-14 | 18-MW-14 | | | 11/27/96 | 9.54 | GL | | RFI field notes | Good | Karl Maness (ICF Kaiser) | 2.449 |
| 18-MW-14 | 18-MW-14 | | | 12/4/96 | 9.27 | GL | 6714.1 | LANL 1995, 47257 | Good | From figure | 2.449 |
| 18-MW-14 | 18-MW-14 | 43 | 3/11/97 | 3/11/97 | 11.15 | TOC[e] | 6714.65 | LANL 1995, 47257 | Good | ? TOC or GL | 2.449 |
| 18-MW-14 | 18-MW-14 | 45.5 | 6/10/97 | 6/10/97 | 9.44 | TOC | | RFI field notes | Good | Karl Maness (ICF Kaiser) | 2.449 |
| 18-MW-14 | 18-MW-14 | | | 7/23/97 | 10.48 | TOC | | RFI field notes | Good | Karl Maness (ICF Kaiser) | 2.449 |
| 18-MW-14 | 18-MW-14 | 44.39 | 9/29/97 | 9/29/97 | 9.25 | TOC | | RFI field notes | Good | Karl Maness (ICF Kaiser) | 2.449 |
| 18-MW-14 | 18-MW-14 | 43 | 12/16/97 | 12/16/97 | 11.15 | TOC | | RFI field notes | Good | Karl Maness (ICF Kaiser) | 2.449 |
| 18-MW-15 | 18-MW-15 | | | 11/22/93 | 8.61 | GL | | RFI field notes | Good | | 2.226 |
| 18-MW-15 | 18-MW-15 | | | 10/4/96 | | | 6716.9 | LANL 1995, 47257 | Fair | From figure | 2.226 |
| 18-MW-15 | 18-MW-15 | 39 | 11/12/96 | 11/12/96 | 8.85 | GL | | LANL 1995, 47257 | Good | Initial water level 9 ft | 2.226 |
| 18-MW-15 | 18-MW-15 | | | 11/13/96 | 6.36 | GL | | RFI field notes | Good | Time: 1425; Karl Maness (ICF Kaiser) | 2.226 |
| 18-MW-15 | 18-MW-15 | | | 11/13/96 | 7.37 | GL | | RFI field notes | Good | Time: 1615; Karl Maness (ICF Kaiser) | 2.226 |
| 18-MW-15 | 18-MW-15 | | | 11/14/96 | 7.71 | GL | | RFI field notes | Good | Karl Maness (ICF Kaiser) | 2.226 |
| 18-MW-15 | 18-MW-15 | | | 11/20/96 | 8.58 | GL | | RFI field notes | Good | Karl Maness (ICF Kaiser) | 2.226 |
| 18-MW-15 | 18-MW-15 | | | 11/27/96 | 8.93 | GL | | RFI field notes | Good | Karl Maness (ICF Kaiser) | 2.226 |
| 18-MW-15 | 18-MW-15 | | | 12/4/96 | 8.82 | GL | | RFI field notes | Good | Karl Maness (ICF Kaiser) | 2.226 |
| 18-MW-15 | 18-MW-15 | 39.89 | 6/10/97 | 6/10/97 | 7.74 | TOC | | RFI field notes | Good | Karl Maness (ICF Kaiser) | 2.226 |
| 18-MW-15 | 18-MW-15 | | | 7/23/97 | 8.82 | TOC | | RFI field notes | Good | Karl Maness (ICF Kaiser) | 2.226 |
| 18-MW-15 | 18-MW-15 | 35 | 9/29/97 | 9/29/97 | 7.83 | TOC | | RFI field notes | Good | Karl Maness (ICF Kaiser); slit in bottom | 2.226 |
| 18-MW-15 | 18-MW-15 | 38 | 12/16/97 | 12/16/97 | 9.03 | TOC | | RFI field notes | Good | Karl Maness (ICF Kaiser) | 2.226 |

a. SWL = static water level

b. GL = ground level

c. MP = measuring point

d. TOT = top of tubing

e. TOC = top of casing

**TABLE C-5 (continued)**

**WATER LEVEL MEASUREMENTS IN PAJARITO CANYON MONITOR WELLS**

| Site ID | Hole ID | Measured Depth (ft) | Measured Depth Date | SWL[a] Date | SWL (ft) | GL[b] or MP[c] | SWL Elevation | SWL Source | SWL Confidence | SWL Comment | TOT[d] (ft) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 18-MW-16 | 18-MW-16 | 30.5 | 11/4/96 | 11/4/96 | 11.13 | GL | | LANL 1995, 47257 | Good | Initial water level 20 ft | 3.025 |
| 18-MW-16 | 18-MW-16 | | | 11/5/96 | 21.01 | GL | | RFI field notes | Good | Time: 1300; Karl Maness (ICF Kaiser) | 3.025 |
| 18-MW-16 | 18-MW-16 | | | 11/5/96 | 18.98 | GL | | RFI field notes | Good | Time: 1510; Karl Maness (ICF Kaiser) | 3.025 |
| 18-MW-16 | 18-MW-16 | | | 11/6/96 | 13.09 | GL | | RFI field notes | Good | Karl Maness (ICF Kaiser) | 3.025 |
| 18-MW-16 | 18-MW-16 | | | 11/7/96 | 12.13 | GL | | RFI field notes | Good | Karl Maness (ICF Kaiser) | 3.025 |
| 18-MW-16 | 18-MW-16 | | | 11/12/96 | 11.92 | GL | | RFI field notes | Good | Karl Maness (ICF Kaiser) | 3.025 |
| 18-MW-16 | 18-MW-16 | | | 11/13/96 | 17.03 | GL | | RFI field notes | Good | Time: 1425; Karl Maness (ICF Kaiser) | 3.025 |
| 18-MW-16 | 18-MW-16 | | | 11/13/96 | 15.46 | GL | | RFI field notes | Good | Time: 1615; Karl Maness (ICF Kaiser) | 3.025 |
| 18-MW-16 | 18-MW-16 | | | 11/14/96 | 12.24 | GL | | RFI field notes | Good | Karl Maness (ICF Kaiser) | 3.025 |
| 18-MW-16 | 18-MW-16 | | | 11/20/96 | 11.17 | GL | | RFI field notes | Good | Karl Maness (ICF Kaiser) | 3.025 |
| 18-MW-16 | 18-MW-16 | | | 11/22/96 | 11.15 | GL | | RFI field notes | Good | Karl Maness (ICF Kaiser) | 3.025 |
| 18-MW-16 | 18-MW-16 | | | 11/27/96 | 11.36 | GL | | RFI field notes | Good | Karl Maness (ICF Kaiser) | 3.025 |
| 18-MW-16 | 18-MW-16 | | | 12/4/96 | 11.14 | GL | | RFI field notes | Good | Karl Maness (ICF Kaiser) | 3.025 |
| 18-MW-16 | 18-MW-16 | 30.5 | 3/11/97 | 3/11/97 | 9.4 | TOC[e] | 6717.6 | LANL 1995, 47257 | Good | ? TOC or GL | 3.025 |
| 18-MW-16 | 18-MW-16 | 33.5 | 6/10/97 | 6/10/97 | 7.63 | TOC | | RFI field notes | Good | Karl Maness (ICF Kaiser) | 3.025 |
| 18-MW-16 | 18-MW-16 | | | 7/23/97 | 9.11 | TOC | | RFI field notes | Good | Karl Maness (ICF Kaiser) | 3.025 |
| 18-MW-16 | 18-MW-16 | | | 9/29/97 | 7.7 | TOC | | RFI field notes | Good | Karl Maness (ICF Kaiser) | 3.025 |
| 18-MW-16 | 18-MW-16 | 30.5 | 12/16/97 | 12/16/97 | 9.35 | TOC | | RFI field notes | Good | Karl Maness (ICF Kaiser) | 3.025 |
| 18-MW-17 | 18-MW-17 | 22 | 8/1/95 | 8/1/95 | 12.5 | GL | | Core log | Good | Information from core log | 3.1 |
| 18-MW-17 | 18-MW-17 | | | 8/24/95 | 14.35 | GL | | RFI field notes | Good | Catherine Goetz (ICF Kaiser) | 3.1 |
| 18-MW-17 | 18-MW-17 | | | 3/11/97 | 18.27 | TOC | | RFI field notes | Good | Karl Maness (ICF Kaiser) | 3.1 |

*a. SWL = static water level*

*b. GL = ground level*

*c. MP = measuring point*

*d. TOT = top of tubing*

*e. TOC = top of casing*

## TABLE C-5 (continued)

### WATER LEVEL MEASUREMENTS IN PAJARITO CANYON MONITOR WELLS

| Site ID | Hole ID | Measured Depth (ft) | Measured Depth Date | SWL[a] Date | SWL (ft) | GL[b] or MP[c] | SWL Elevation | SWL Source | SWL Confidence | SWL Comment | TOT[d] (ft) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *18-MW-18* | *18-MW-18* | *23* | *7/31/95* | *7/31/95* | *12.5* | *GL* | | *Core log* | *Good* | *Information from core log* | *1.75* |
| *18-MW-18* | *18-MW-18* | | | *8/3/95* | *11.8* | *GL* | | *RFI field notes* | *Good* | *Catherine Goetz (ICF Kaiser)* | *1.75* |
| *18-MW-18* | *18-MW-18* | | | *3/11/97* | *13.41* | *TOC[e]* | | *RFI notes - Maness* | *Good* | *Karl Maness (ICF Kaiser)* | *1.75* |
| *18-MW-2* | *18-MW-2* | *27.6* | *7/8/90* | *5/15/93* | *8.27* | *GL* | | *LANL 1995, 54615* | *Good* | | *-0.39* |
| *18-MW-2* | *18-MW-2* | | | *6/15/93* | *9.85* | *GL* | | *LANL 1995, 54615* | *Good* | | *-0.39* |
| *18-MW-2* | *18-MW-2* | | | *8/15/93* | *11.91* | *GL* | | *LANL 1995, 54615* | *Good* | | *-0.39* |
| *18-MW-2* | *18-MW-2* | | | *9/15/93* | *12.83* | *GL* | | *LANL 1995, 54615* | *Good* | | *-0.39* |
| *18-MW-2* | *18-MW-2* | *26.8* | *10/13/93* | *10/13/93* | *15.5* | *TOC* | | *LANL 1997, 56356* | *Good* | | *-0.39* |
| *18-MW-2* | *18-MW-2* | | | *11/15/93* | *17.1* | *GL* | | *LANL 1995, 54615* | *Good* | | *-0.39* |
| *18-MW-2* | *18-MW-2* | *26.7* | *2/24/94* | *2/24/94* | *17.5* | *GL* | *6740.9* | *LANL 1995, 54615* | *Good* | | *-0.39* |
| *18-MW-2* | *18-MW-2* | *26.6* | *7/12/94* | *7/12/94* | *14.5* | *GL* | | *LANL 1995, 54615* | *Good* | *NOD response notes* | *-0.39* |
| *18-MW-2* | *18-MW-2* | *26.6* | *7/12/94* | *7/12/94* | *14.5* | *GL* | | *LANL 1995, 54615* | *Good* | | *-0.39* |
| *18-MW-2* | *18-MW-2* | | | *10/15/94* | *14* | *GL* | | *LANL 1995, 54615* | *Good* | | *-0.39* |
| *18-MW-2* | *18-MW-2* | | | *7/15/95* | *9.35* | *GL* | *6748.95* | *LANL 1996, 55120* | *Good* | | *-0.39* |
| *18-MW-2* | *18-MW-2* | | | *3/11/97* | *16.71* | *TOC* | *6741.59* | *LANL 1995, 47257* | *Good* | *? TOC or GL* | *-0.39* |
| *18-MW-2* | *18-MW-2* | | | *8/15/97* | *15.39* | *GL* | | *LANL 1997, 56356* | *Good* | *RFI field notes – Karl Maness (ICF Kaiser)* | *-0.39* |
| *18-MW-2* | *18-MW-2* | | | *9/30/97* | *9.15* | *TOC* | | *LANL 1997, 56356* | *Good* | *RFI field notes – Karl Maness (ICF Kaiser)* | *-0.39* |
| *18-MW-3* | *18-MW-3* | *23.4* | *7/8/90* | *5/15/93* | *8.26* | *GL* | | *LANL 1995, 54615* | *Good* | | *-0.44* |
| *18-MW-3* | *18-MW-3* | | | *6/15/93* | *9.82* | *GL* | | *LANL 1995, 54615* | *Good* | | *-0.44* |
| *18-MW-3* | *18-MW-3* | | | *8/15/93* | *11.84* | *GL* | | *LANL 1995, 54615* | *Good* | | *-0.44* |
| *18-MW-3* | *18-MW-3* | | | *9/15/93* | *12.74* | *GL* | | *LANL 1995, 54615* | *Good* | | *-0.44* |
| *18-MW-3* | *18-MW-3* | *26.5* | *10/13/93* | *10/13/93* | *15.5* | *TOC* | | *LANL 1997, 56356* | *Good* | | *-0.44* |

*a. SWL = static water level*
*b. GL = ground level*
*c. MP = measuring point*
*d. TOT = top of tubing*
*e. TOC = top of casing*

**TABLE C-5 (continued)**

**WATER LEVEL MEASUREMENTS IN PAJARITO CANYON MONITOR WELLS**

| Site ID | Hole ID | Measured Depth (ft) | Measured Depth Date | SWL[a] Date | SWL (ft) | GL[b] or MP[c] | SWL Elevation | SWL Source | SWL Confidence | SWL Comment | TOT[d] (ft) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 18-MW-3 | 18-MW-3 | | | 11/15/93 | 16.93 | GL | | LANL 1995, 54615 | Good | | -0.44 |
| 18-MW-3 | 18-MW-3 | 23.3 | 2/25/94 | 2/25/94 | 17.4 | GL | 6740.9 | LANL 1995, 54615 | Good | NOD response notes | -0.44 |
| 18-MW-3 | 18-MW-3 | 23.3 | 7/12/94 | 7/12/94 | 14.4 | GL | | LANL 1995, 54615 | Good | NOD response notes | -0.44 |
| 18-MW-3 | 18-MW-3 | | | 10/15/94 | 14 | GL | | LANL 1995, 54615 | Good | | -0.44 |
| 18-MW-3 | 18-MW-3 | | | 7/15/95 | 9.35 | GL | 6748.95 | LANL 1996, 55120 | Good | | -0.44 |
| 18-MW-3 | 18-MW-3 | | | 3/11/97 | 16.6 | TOC[e] | 6741.7 | LANL 1995, 47257 | Good | ? TOC or GL | -0.44 |
| 18-MW-3 | 18-MW-3 | | | 8/15/97 | 15.35 | GL | | LANL 1997, 56356 | Good | RFI field notes – Karl Maness (ICF Kaiser) | -0.44 |
| 18-MW-3 | 18-MW-3 | | | 9/30/97 | 9.08 | TOC | | LANL 1997, 56356 | Good | RFI field notes – Karl Maness (ICF Kaiser) | -0.44 |
| 18-MW-4 | 18-MW-4 | 26.2 | 7/8/90 | 5/15/93 | 8.46 | GL | | LANL 1995, 54615 | Good | | -0.57 |
| 18-MW-4 | 18-MW-4 | | | 6/15/93 | 9.11 | GL | | LANL 1995, 54615 | Good | | -0.57 |
| 18-MW-4 | 18-MW-4 | | | 8/15/93 | 11.5 | GL | | LANL 1995, 54615 | Good | | -0.57 |
| 18-MW-4 | 18-MW-4 | | | 9/15/93 | 12.44 | GL | | LANL 1995, 54615 | Good | | -0.57 |
| 18-MW-4 | 18-MW-4 | 26 | 10/13/93 | 10/13/93 | 14.2 | TOC | | LANL 1997, 56356 | Good | | -0.57 |
| 18-MW-4 | 18-MW-4 | | | 10/21/93 | 14.5 | TOC | | LANL 1997, 56356 | Good | | -0.57 |
| 18-MW-4 | 18-MW-4 | | | 11/15/93 | 16.6 | GL | | LANL 1995, 54615 | Good | | -0.57 |
| 18-MW-4 | 18-MW-4 | 26.1 | 2/25/94 | 2/24/94 | 17.6 | GL | | LANL 1995, 54615 | Good | NOD response notes | -0.57 |
| 18-MW-4 | 18-MW-4 | 25.7 | 7/13/94 | 7/13/94 | 13.5 | GL | | LANL 1995, 54615 | Good | NOD response notes | -0.57 |
| 18-MW-4 | 18-MW-4 | | | 10/15/93 | 13.2 | GL | | LANL 1995, 54615 | Good | | -0.57 |
| 18-MW-4 | 18-MW-4 | | | 7/15/95 | 9.42 | GL | 6749.08 | LANL 1996, 55120 | Good | | -0.57 |
| 18-MW-4 | 18-MW-4 | | | 3/11/97 | 16.37 | TOC | 6742.13 | LANL 1995, 47257 | Good | ? TOC or GL | -0.57 |
| 18-MW-4 | 18-MW-4 | | | 8/15/97 | 14.2 | GL | | LANL 1997, 56356 | Good | RFI field notes – Karl Maness (ICF Kaiser) | -0.57 |
| 18-MW-4 | 18-MW-4 | | | 9/30/97 | 9.21 | TOC | | LANL 1997, 56356 | Good | RFI field notes – Karl Maness (ICF Kaiser) | -0.57 |

a. SWL = static water level

b. GL = ground level

c. MP = measuring point

d. TOT = top of tubing

e. TOC = top of casing

**TABLE C-5 (continued)**

**WATER LEVEL MEASUREMENTS IN PAJARITO CANYON MONITOR WELLS**

| Site ID | Hole ID | Measured Depth (ft) | Measured Depth Date | SWL[a] Date | SWL (ft) | GL[b] or MP[c] | SWL Elevation | SWL Source | SWL Confidence | SWL Comment | TOT[d] (ft) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 18-MW-5 | 18-MW-5 | 29.5 | 3/7/94 | 3/7/94 | 17.5 | TOC[e] | | LANL 1995, 54615 | Good | | 1.5 |
| 18-MW-5 | 18-MW-5 | | | 3/27/94 | 16.5 | TOC | 6718.7 | LANL 1994, 47113 | Good | P. 8 TA-18-PL30 UST | 1.5 |
| 18-MW-5 | 18-MW-5 | 29.6 | 7/7/94 | 7/7/94 | 13 | GL | | LANL 1995, 54615 | Good | NOD response notes | 1.5 |
| 18-MW-5 | 18-MW-5 | | | 10/15/94 | 14.7 | GL | | LANL 1995, 54615 | Good | | 1.5 |
| 18-MW-5 | 18-MW-5 | 27.93 | 4/19/95 | 4/19/95 | 10.83 | GL | | LANL 1997, 56356 | Good | NOD response notes, conv to GL | 1.5 |
| 18-MW-5 | 18-MW-5 | | | 7/15/95 | 12.21 | GL | 6742.49 | LANL 1996, 55120 | Good | | 1.5 |
| 18-MW-5 | 18-MW-5 | | | 3/11/97 | 15.31 | TOC | 6721.39 | LANL 1995, 47257 | Good | ? TOC or GL | 1.5 |
| 18-MW-6 | 18-MW-6 | 25 | 4/9/94 | 4/9/94 | 18 | GL | | LANL 1995, 54615 | Good | | 0 |
| 18-MW-6 | 18-MW-6 | | | 4/27/94 | 11.5 | GL | 6718.6 | LANL 1994, 47113 | Good | P. 8 TA-18-PL30 UST | 0 |
| 18-MW-6 | 18-MW-6 | 25.3 | 7/7/94 | 7/7/94 | 8.9 | GL | | LANL 1995, 54615 | Good | NOD response notes | 0 |
| 18-MW-6 | 18-MW-6 | | | 10/15/94 | 8.5 | GL | | LANL 1995, 54615 | Good | | 0 |
| 18-MW-6 | 18-MW-6 | 25.2 | 4/19/95 | 4/19/95 | 7.5 | TOC | | LANL 1997, 56356 | Good | NOD response notes | 0 |
| 18-MW-6 | 18-MW-6 | | | 7/15/95 | 6.95 | GL | 6723.15 | LANL 1996, 55120 | Good | | 0 |
| 18-MW-6 | 18-MW-6 | | | 3/11/97 | 8.89 | TOC | 6721.21 | LANL 1995, 47257 | Good | ? TOC or GL | 0 |
| 18-MW-7 | 18-MW-7 | 32 | 7/6/94 | 7/6/94 | 12 | GL | | LANL 1995, 54615 | Good | | 5 |
| 18-MW-7 | 18-MW-7 | | | 11/15/94 | 11.5 | GL | | LANL 1997, 56356 | Good | Well completion form | 5 |
| 18-MW-7 | 18-MW-7 | | | 7/15/95 | 7.14 | GL | 6748.36 | LANL 1996, 55120 | Good | | 5 |
| 18-MW-7 | 18-MW-7 | | | 3/11/97 | 15.8 | TOC | 6739.7 | LANL 1995, 47257 | Good | ? TOC or GL | 5 |
| 18-MW-8 | 18-MW-8 | 37.9 | 8/4/94 | 9/15/94 | 7.5 | GL | | LANL 1995, 54615 | Good | | 2 |
| 18-MW-8 | 18-MW-8 | | | 11/15/94 | 7.5 | GL | | LANL 1997, 56356 | Good | Well completion form | 2 |
| 18-MW-8 | 18-MW-8 | | | 7/15/95 | 7.42 | GL | 6740.37 | LANL 1996, 55120 | Good | | 2 |
| 18-MW-8 | 18-MW-8 | | | 3/11/97 | 5.73 | TOC | 6742.07 | LANL 1995, 47257 | Good | ? TOC or GL | 2 |
| 18-MW-9 | 18-MW-9 | 23 | 7/21/94 | 7/21/94 | 13.5 | GL | | LANL 1995, 54615 | Good | | 4 |
| 18-MW-9 | 18-MW-9 | | | 11/15/94 | 12 | GL | | LANL 1997, 56356 | Good | Well completion form | 4 |

a. SWL = static water level
b. GL = ground level
c. MP = measuring point
d. TOT = top of tubing
e. TOC = top of casing

## TABLE C-5 (continued)

### WATER LEVEL MEASUREMENTS IN PAJARITO CANYON MONITOR WELLS

| Site ID | Hole ID | Measured Depth (ft) | Measured Depth Date | SWL[a] Date | SWL (ft) | GL[b] or MP[c] | SWL Elevation | SWL Source | SWL Confidence | SWL Comment | TOT[d] (ft) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *18-MW-9* | *18-MW-9* | | | *11/15/94* | *9.9* | *GL* | | *LANL 1995, 54615* | *Good* | | *4* |
| *18-MW-9* | *18-MW-9* | | | *3/11/97* | *11.83* | *TOC[e]* | *6721.07* | *LANL 1995, 47257* | *Good* | *? TOC or GL* | *4* |
| *50-9100* | *50-9100* | *316* | *2/5/96* | *2/5/96* | *Dry* | *GL* | | *Koch 1998, 58094* | *Good* | | |
| *H-19* | *H-19* | *69.2* | *7/20/92* | | | | | *LANL 1995, 54615* | *Good* | *P. 224, USGS[f] gamma log H-19* | |
| *H-19* | *H-19* | *2000* | *8/1/49* | *8/1/49* | *950* | *GL* | | *LANL 1995, 54615* | *Good* | *P. 217* | |
| *H-19* | *H-19* | *253* | *5/7/60* | *5/7/60* | *5* | *GL* | | *LANL 1995, 54615* | *Good* | *P. 224, USGS gamma log H-19* | |
| *PCM-1* | *PCM-1* | *60* | *6/30/85* | *6/30/85* | *Dry* | *GL* | | *Purtymun 1995, 45344* | *Good* | *P. 120* | *0.3* |
| *PCM-2* | *PCM-2* | *120* | *6/30/85* | *6/30/85* | *Dry* | *GL* | | *Purtymun 1995, 45344* | *Good* | *P. 120* | *0.2* |
| *PCM-3* | *PCM-3* | *60* | *6/30/85* | *6/30/85* | *Dry* | *GL* | | *Purtymun 1995, 45344* | *Good* | *P. 121* | *0.3* |
| *PCM-4* | *PCM-4* | *60* | *6/30/85* | *6/30/85* | *Dry* | *GL* | | *Purtymun 1995, 45344* | *Good* | *P. 121* | *0.2* |
| *PCO-1* | *PCO-1* | *12* | *6/11/85* | *6/11/85* | *1.3* | *GL* | | *Purtymun 1995, 45344* | *Good* | *P. 118* | *0.3* |
| *PCO-1* | *PCO-1* | | | *3/1/86* | *1.81* | *GL* | | *ESH-18 field notes* | *Good* | *Max Maes* | *0.3* |
| *PCO-1* | *PCO-1* | | | *6/1/86* | *1.93* | *GL* | | *ESH-18 field notes* | *Good* | *Max Maes* | *0.3* |
| *PCO-1* | *PCO-1* | | | *10/26/87* | *1.81* | *GL* | | *ESH-18 field notes* | *Good* | *Max Maes* | *0.3* |
| *PCO-1* | *PCO-1* | | | *3/4/88* | *1.63* | *GL* | | *ESH-18 field notes* | *Good* | *Max Maes* | *0.3* |
| *PCO-1* | *PCO-1* | | | *3/17/89* | *1.76* | *GL* | | *ESH-18 field notes* | *Good* | *Max Maes* | *0.3* |
| *PCO-1* | *PCO-1* | | | *4/17/90* | *1.87* | *GL* | | *ESH-18 field notes* | *Good* | *Max Maes* | *0.3* |
| *PCO-1* | *PCO-1* | | | *5/29/91* | *1.93* | *GL* | | *ESH-18 field notes* | *Good* | *Max Maes* | *0.3* |

*a. SWL = static water level*

*b. GL = ground level*

*c. MP = measuring point*

*d. TOT = top of tubing*

*e. TOC = top of casing*

*f. USGS = United States Geological Survey*

## TABLE C-5 (continued)

## WATER LEVEL MEASUREMENTS IN PAJARITO CANYON MONITOR WELLS

| Site ID | Hole ID | Measured Depth (ft) | Measured Depth Date | SWL[a] Date | SWL (ft) | GL[b] or MP[c] | SWL Elevation | SWL Source | SWL Confidence | SWL Comment | TOT[d] (ft) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| PCO-1 | PCO-1 | | | 9/1/92 | 1.91 | GL | | ESH-18 field notes | Good | Max Maes | 0.3 |
| PCO-1 | PCO-1 | | | 4/15/93 | 1.12 | GL | | LANL 1995, 54615 | Good | | 0.3 |
| PCO-1 | PCO-1 | | | 6/15/93 | 1.15 | GL | | LANL 1995, 54615 | Good | | 0.3 |
| PCO-1 | PCO-1 | | | 7/15/93 | 1.3 | GL | | LANL 1995, 54615 | Good | | 0.3 |
| PCO-1 | PCO-1 | | | 8/7/93 | 1.8 | GL | | ESH-18 field notes | Good | Max Maes | 0.3 |
| PCO-1 | PCO-1 | 13 | 11/2/93 | 11/2/93 | 1 | TOC[e] | | LANL 1997, 56356 | Good | | 0.3 |
| PCO-1 | PCO-1 | 13.3 | 2/22/94 | 2/24/94 | 2.7 | GL | 6684.3 | LANL 1995, 54615 | Good | ?1.1 GL; LANL 1994, 47112 | 0.3 |
| PCO-1 | PCO-1 | | | 6/22/94 | 5.1 | GL | | ESH-18 field notes | Good | Max Maes | 0.3 |
| PCO-1 | PCO-1 | 13 | 7/26/94 | 7/26/94 | 1.7 | GL | | LANL 1995, 54615 | Good | NOD response notes | 0.3 |
| PCO-1 | PCO-1 | 13 | 10/20/94 | 10/20/94 | 1 | GL | | LANL 1995, 54615 | Good | NOD response notes | 0.3 |
| PCO-1 | PCO-1 | | | 5/20/95 | 4.69 | GL | | ESH-18 field notes | Good | Max Maes | 0.3 |
| PCO-1 | PCO-1 | | | 7/15/95 | .7 | GL | 6686.3 | LANL 1996, 55120 | Good | | 0.3 |
| PCO-1 | PCO-1 | | | 7/30/96 | 10.1 | GL | | ESH-18 field notes | Good | Max Maes | 0.3 |
| PCO-1 | PCO-1 | | | 3/11/97 | 1.83 | TOC | 6685.2 | LANL 1997, 56417 | Good | ? TOC or GL | 0.3 |
| PCO-1 | PCO-1 | | | 4/10/97 | 1.83 | GL | | LANL 1997, 56356 | Good | RFI field notes – surface water running | 0.3 |
| PCO-2 | PCO-2 | | | 6/11/85 | 6.3 | GL | | ESH-18 field notes | Good | Max Maes | |
| PCO-2 | PCO-2 | 9.5 | 6/11/85 | 6/11/85 | 6.3 | GL | | Purtymun 1995, 45344 | Good | P. 119 | |
| PCO-2 | PCO-2 | | | 8/1/86 | 6.26 | GL | | ESH-18 field notes | Good | Max Maes | |
| PCO-2 | PCO-2 | | | 10/26/87 | 5.92 | GL | | ESH-18 field notes | Good | Max Maes | |
| PCO-2 | PCO-2 | | | 4/4/88 | 5.97 | GL | | ESH-18 field notes | Good | Max Maes | |
| PCO-2 | PCO-2 | | | 3/27/89 | 6.21 | GL | | ESH-18 field notes | Good | Max Maes | |
| PCO-2 | PCO-2 | | | 4/17/90 | 6.46 | GL | | ESH-18 field notes | Good | Max Maes | |
| PCO-2 | PCO-2 | | | 5/29/91 | 6.57 | GL | | ESH-18 field notes | Good | Max Maes | |

*a. SWL = static water level*
*b. GL = ground level*
*c. MP = measuring point*
*d. TOT = top of tubing*
*e. TOC = top of casing*

## TABLE C-5 (continued)

## WATER LEVEL MEASUREMENTS IN PAJARITO CANYON MONITOR WELLS

| Site ID | Hole ID | Measured Depth (ft) | Measured Depth Date | SWL[a] Date | SWL (ft) | GL[b] or MP[c] | SWL Elevation | SWL Source | SWL Confidence | SWL Comment | TOT[d] (ft) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *PCO-2* | *PCO-2* | | | *9/1/92* | *6.68* | *GL* | | *ESH-18 field notes* | *Good* | *Max Maes* | |
| *PCO-2* | *PCO-2* | | | *4/15/93* | *5* | *GL* | | *LANL 1995, 54615* | *Good* | | |
| *PCO-2* | *PCO-2* | | | *6/15/93* | *5.35* | *GL* | | *LANL 1995, 54615* | *Good* | | |
| *PCO-2* | *PCO-2* | | | *7/15/93* | *7.45* | *GL* | | *LANL 1995, 54615* | *Good* | | |
| *PCO-2* | *PCO-2* | | | *8/7/93* | *8.3* | *GL* | | *ESH-18 field notes* | *Good* | *Max Maes* | |
| *PCO-2* | *PCO-2* | *10.5* | *11/2/93* | *11/2/93* | *7.9* | *TOC*[e] | | *LANL 1997, 56356* | *Good* | | |
| *PCO-2* | *PCO-2* | *9.5* | *2/23/94* | *2/23/94* | *9.3* | *TOC* | | *LANL 1997, 56356* | *Good* | *Dry (no sample)* | |
| *PCO-2* | *PCO-2* | | | *5/22/94* | *8.35* | *GL* | | *ESH-18 field notes* | *Good* | *Max Maes* | |
| *PCO-2* | *PCO-2* | *10.2* | *7/26/94* | *7/26/94* | *9* | *TOC* | | *LANL 1995, 54615* | *Good* | *NOD response notes* | |
| *PCO-2* | *PCO-2* | *10.1* | *10/26/94* | *10/26/94* | *6.9* | *GL* | | *LANL 1995, 54615* | *Good* | *NOD response notes* | |
| *PCO-2* | *PCO-2* | | | *5./20/95* | *9.37* | *GL* | | *ESH-18 field notes* | *Good* | *Max Maes* | |
| *PCO-2* | *PCO-2* | | | *4/10/97* | *6.91* | *GL* | | *RFI field notes* | *Good* | *Karl Maness (ICF Kaiser)* | |
| *PCO-3* | *PCO-3* | | | *6/11/85* | *3.1* | *GL* | | *ESH-18 field notes* | *Good* | *Max Maes* | *0.7* |
| *PCO-3* | *PCO-3* | *17* | *6/11/85* | *6/11/85* | *3.1* | *GL* | | *Purtymun 1995, 45344* | *Good* | *P. 119* | *0.7* |
| *PCO-3* | *PCO-3* | | | *3/1/86* | *2.7* | *GL* | | *ESH-18 field notes* | *Good* | *Max Maes* | *0.7* |
| *PCO-3* | *PCO-3* | | | *10/26/87* | *2.8* | *GL* | | *ESH-18 field notes* | *Good* | *Max Maes* | *0.7* |
| *PCO-3* | *PCO-3* | | | *4/4/88* | *3.1* | *GL* | | *ESH-18 field notes* | *Good* | *Max Maes* | *0.7* |
| *PCO-3* | *PCO-3* | | | *3/27/89* | *3.02* | *GL* | | *ESH-18 field notes* | *Good* | *Max Maes* | *0.7* |
| *PCO-3* | *PCO-3* | | | *4/17/90* | *3.22* | *GL* | | *ESH-18 field notes* | *Good* | *Max Maes* | *0.7* |
| *PCO-3* | *PCO-3* | | | *5/29/91* | *3.31* | *GL* | | *ESH-18 field notes* | *Good* | *Max Maes* | *0.7* |
| *PCO-3* | *PCO-3* | | | *9/1/92* | *3.64* | *GL* | | *ESH-18 field notes* | *Good* | *Max Maes* | *0.7* |
| *PCO-3* | *PCO-3* | | | *4/15/93* | *3.25* | *GL* | | *LANL 1995, 54615* | *Good* | | *0.7* |
| *PCO-3* | *PCO-3* | | | *6/7/93* | *5.4* | *GL* | | *ESH-18 field notes* | *Good* | *Max Maes* | *0.7* |
| *PCO-3* | *PCO-3* | | | *6/15/93* | *3.63* | *GL* | | *LANL 1995, 54615* | *Good* | | *0.7* |

*a. SWL = static water level*

*b. GL = ground level*

*c. MP = measuring point*

*d. TOT = top of tubing*

*e. TOC = top of casing*

**TABLE C-5 (continued)**

**WATER LEVEL MEASUREMENTS IN PAJARITO CANYON MONITOR WELLS**

| Site ID | Hole ID | Measured Depth (ft) | Measured Depth Date | SWL[a] Date | SWL (ft) | GL[b] or MP[c] | SWL Elevation | SWL Source | SWL Confidence | SWL Comment | TOT[d] (ft) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| PCO-3 | PCO-3 | 18.9 | 11/3/93 | 11/3/93 | 4.2 | TOC[e] | | LANL 1997, 56356 | Good | Skunk water | 0.7 |
| PCO-3 | PCO-3 | 18.9 | 2/23/94 | 2/23/94 | 3.9 | TOC | | LANL 1997, 56356 | Good | NOD response notes | 0.7 |
| PCO-3 | PCO-3 | | | 6/12/94 | 4.25 | GL | | ESH-18 field notes | Good | Max Maes | 0.7 |
| PCO-3 | PCO-3 | | | 7/26/94 | Dry | GL | | LANL 1995, 54615 | ????? | Probably wrong hole – Max Maes | 0.7 |
| PCO-3 | PCO-3 | 19.1 | 10/25/94 | 10/25/94 | 3.7 | GL | | LANL 1995, 54615 | Good | NOD response notes | 0.7 |
| PCO-3 | PCO-3 | | | 5/20/95 | 4.73 | GL | | ESH-18 field notes | Good | Max Maes | 0.7 |
| PCO-3 | PCO-3 | | | 4/10/97 | 4.59 | GL | | RFI field notes | Good | Karl Maness (ICF Kaiser) static water standing | 0.7 |
| SHB-1 | SHB-1 | 700 | 12/15/91 | 12/15/91 | Dry | | | Gardner et al. 1993, 12582 | Good | Borehole dry | |
| SHB-2 | SHB-2 | 200 | 12/15/91 | 12/15/91 | Dry | | | Gardner et al. 1993, 12582 | Good | Borehole dry | |
| SHB-3 | SHB-3 | 860 | 1/15/92 | 1/15/92 | 346 | GL | | Gardner et al. 1993, 12582 | Approx | Calculated water depth approximate | |
| SHB-4 | SHB-4 | 200 | 1/31/92 | 1/31/92 | 125 | GL | | Gardner et al. 1993, 12582 | Approx | 125–145 ft wet | |

a. SWL = static water level

b. GL = ground level

c. MP = measuring point

d. TOT = top of tubing

e. TOC = top of casing

## TABLE C-6

## STRATIGRAPHIC INFORMATION FROM PAJARITO CANYON WELLS, BOREHOLES, AND MOISTURE ACCESS TUBES

| Hole ID | Date Completed | Depth Drilled (ft) | Depth Completed (ft) | Formation | Purtymun 1995 Data | | Revised Model | | Start Elev (ft) | End Elev (ft) | Land Surface Dadum (ft) | Stratigraphic Source | Stratigraphic Pick Comment |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Start Depth (ft) | End Depth (ft) | Start Depth (ft) | End Depth (ft) | | | | | |
| 18-1165 | 8/8/94 | 12.5 | 0 | Alluvium | 0 | 12.5 | | | 6747.1 | 6734.6 | 6747.1 | LANL 1997, 56356 | |
| 18-1195 | 7/5/94 | 10 | 0 | Alluvium | 0 | 10 | | | 6724.1 | 6714.1 | 6724.1 | LANL 1997, 56356 | |
| 18-1196 | 7/5/94 | 10 | 0 | Alluvium | 0 | 10 | | | 6723.3 | 6713.3 | 6723.3 | LANL 1997, 56356 | |
| 18-1233 | 7/20/94 | 20 | 0 | Alluvium | 0 | 20 | | | 6730 | 6710 | 6730 | LANL 1997, 56356 | |
| 18-1254 | 8/10/94 | 15 | 0 | Alluvium | 0 | 15 | | | 6735.3 | 6720.3 | 6735.3 | LANL 1997, 56356 | |
| 18-BG-1 | 8/1/94 | 37 | 35 | Alluvium | 0 | 37 | 0 | 30 | 6771.5 | 6741.5 | 6771.5 | LANL 1997, 56356 | Possible tuff contact at 30 ft |
| 18-BG-1 | 8/1/94 | 37 | 35 | Tuff | 37 | 37 | 30 | 37 | 6741.5 | 6734.5 | 6771.5 | LANL 1997, 56356 | |
| 18-BG-2 | 8/2/94 | 35 | 0 | Alluvium | 0 | 37 | | | 6774.6 | 6737.6 | 6774.6 | LANL 1997, 56356 | No lithologic description deeper than 26 ft |
| 18-BG-2 | 8/2/94 | 35 | 0 | Tuff | 37 | 37 | | | 6737.6 | 6737.6 | 6774.6 | LANL 1997, 56356 | |
| 18-BG-3 | 8/3/94 | 20 | 0 | Alluvium | 0 | 20 | | | 6776.1 | 6756.1 | 6776.1 | LANL 1997, 56356 | |
| 18-BG-4 | 2/18/98 | 25 | 6.5 | Alluvium | 0 | 6.5 | | | 6765 | 6758.5 | 6765 | C. Goetz | |
| 18-BG-4 | 2/18/98 | 25 | 6.5 | Tuff | 6.5 | 25 | | | 6758.5 | 6740 | 6765 | C. Goetz | |
| 18-MW-1 | 7/8/90 | 25.6 | 25.6 | Alluvium | 0 | 25.6 | | | 6758.8 | 6733.2 | 6758.8 | LANL 1997, 56356 | |
| 18-MW-10 | 8/10/94 | 22 | 20 | Alluvium | 0 | 22 | | | 6735.9 | 6713.9 | 6735.9 | LANL 1997, 56356 | |
| 18-MW-11 | 8/11/94 | 49 | 47 | Alluvium | 0 | 47 | 0 | 39 | 6740.1 | 6701.1 | 6740.1 | LANL 1997, 56356 | Possible tuff contact at 39 ft |
| 18-MW-11 | 8/11/94 | 49 | 47 | Tuff | | | 39 | 47 | 6701.1 | 6693.1 | 6740.1 | LANL 1997, 56356 | |
| 18-MW-12 | 11/6/96 | 43.8 | 41 | Alluvium | 0 | 43.8 | 0 | 42 | 6722.7 | 6680.7 | 6722.7 | LANL 1997, 56356 | Possible tuff contact at 42 ft |
| 18-MW-12 | 11/6/96 | 43.8 | 41 | Tuff | | | 42 | 43.8 | 6680.7 | 6678.9 | 6722.7 | LANL 1997, 56356 | |
| 18-MW-13 | 11/14/96 | 40.1 | 40 | Alluvium | 0 | 40.1 | | | 6724.3 | 6684.2 | 6724.3 | LANL 1997, 56356 | |
| 18-MW-14 | 11/8/96 | 45 | 43 | Alluvium | 0 | 42 | | | 6722.9 | 6680.9 | 6722.9 | LANL 1997, 56356 | |
| 18-MW-14 | 11/8/96 | 45 | 43 | Tuff | 42 | 45 | | | 6680.9 | 6677.9 | 6722.9 | LANL 1997, 56356 | |
| 18-MW-15 | 11/12/96 | 48 | 39 | Alluvium | 0 | 48 | | | 6723.4 | 6675.4 | 6723.4 | LANL 1997, 56356 | |
| 18-MW-16 | 11/4/96 | 37 | 30.5 | Alluvium | 0 | 30 | | | 6724 | 6694 | 6724 | LANL 1997, 56356 | |
| 18-MW-17 | 8/1/95 | 23.8 | 22 | Alluvium | 0 | 23.8 | | | 6692.1 | 6668.3 | 6692.1 | LANL 1997, 56356 | |
| 18-MW-16 | 11/4/96 | 37 | 30.5 | Tuff | 30 | 37 | | | 6694 | 6687 | 6724 | LANL 1997, 56356 | |

## TABLE C-6 (continued)

### STRATIGRAPHIC INFORMATION FROM PAJARITO CANYON WELLS, BOREHOLES, AND MOISTURE ACCESS TUBES

| Hole ID | Date Completed | Depth Drilled (ft) | Depth Completed (ft) | Formation | Purtymun 1995 Data Start Depth (ft) | Purtymun 1995 Data End Depth (ft) | Revised Model Start Depth (ft) | Revised Model End Depth (ft) | Start Elev (ft) | End Elev (ft) | Land Surface Dadum (ft) | Stratigraphic Source | Stratigraphic Pick Comment |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 18-MW-18 | 7/31/95 | 24 | 23 | Alluvium | 0 | 24 | | | 6653 | 6629 | 6653 | LANL 1997, 56356 | |
| 18-MW-2 | 7/8/90 | 27.6 | 27.6 | Alluvium | 0 | 27.6 | | | 6758.5 | 6730.9 | 6758.5 | LANL 1997, 56356 | |
| 18-MW-3 | 7/8/90 | 27 | 23.4 | Alluvium | 0 | 27 | | | 6758.3 | 6731.3 | 6758.3 | LANL 1997, 56356 | |
| 18-MW-4 | 7/8/90 | 26.2 | 26.2 | Alluvium | 0 | 26.2 | | | 6758.3 | 6732.1 | 6758.3 | LANL 1997, 56356 | |
| 18-MW-5 | 3/7/94 | 30 | 28 | Alluvium | 0 | 28 | | | 6735.2 | 6707.2 | 6735.2 | LANL 1997, 56356 | |
| 18-MW-6 | 3/9/94 | 27 | 25 | Alluvium | 0 | 27 | | | 6730.1 | 6703.1 | 6730.1 | LANL 1997, 56356 | |
| 18-MW-7 | 7/14/94 | 32 | 30 | Alluvium | 0 | 32 | | | 6750.5 | 6718.5 | 6750.5 | LANL 1997, 56356 | Drill log |
| 18-MW-7 | 7/14/94 | 32 | 30 | Tuff | 32 | 32 | | | 6718.5 | 6718.5 | 6750.5 | LANL 1997, 56356 | Drill log |
| 18-MW-8 | 8/4/94 | 40 | 37.9 | Alluvium | 0 | 40 | 0 | 10 | 6745.8 | 6735.8 | 6745.8 | LANL 1997, 56356 | Possible tuff contact at 10 ft |
| 18-MW-8 | 8/4/94 | 40 | 37.9 | Tuff | 40 | 40 | 10 | 40 | 6735.8 | 6705.8 | 6745.8 | LANL 1997, 56356 | |
| 18-MW-9 | 7/21/94 | 23 | 21 | Alluvium | 0 | 23 | | | 6728.9 | 6705.9 | 6728.9 | LANL 1997, 56356 | |
| H-19 | Sep-49 | 2000 | | Alluvium | 0 | 27 | | | 7178 | 7151 | 7178 | Purtymun 1995, 45344 | |
| H-19 | Sep-49 | 2000 | | Tshirege | 27 | 200 | | | 7151 | 6978 | 7178 | Purtymun 1995, 45344 | |
| H-19 | Sep-49 | 2000 | | Otowi | 200 | 415 | | | 6978 | 6763 | 7178 | Purtymun 1995, 45344 | |
| H-19 | Sep-49 | 2000 | | Guaje | 415 | 472 | | | 6763 | 6706 | 7178 | Purtymun 1995, 45344 | |
| H-19 | Sep-49 | 2000 | | Tschicoma | 472 | 819 | | | 6706 | 6359 | 7178 | Purtymun 1995, 45344 | |
| H-19 | Sep-49 | 2000 | | Puye | 819 | 1210 | | | 6359 | 5968 | 7178 | Purtymun 1995, 45344 | |
| H-19 | Sep-49 | 2000 | | Tschicoma | 1210 | 1480 | | | 5968 | 5698 | 7178 | Purtymun 1995, 45344 | |
| H-19 | Sep-49 | 2000 | | Tschicoma | 1490 | 2000 | | | 5688 | 5178 | 7178 | Purtymun 1995, 45344 | |
| H-19 | Sep-49 | 2000 | | Totavi | 1480 | 1490 | | | 5698 | 5688 | 7178 | Purtymun 1995, 45344 | |
| PCM-1 | 6/30/85 | 60 | | Alluvium | 0 | 8 | | | 6697.6 | 6689.6 | 6697.6 | Purtymun 1995, 45344 | |

## TABLE C-6 (continued)

### STRATIGRAPHIC INFORMATION FROM PAJARITO CANYON WELLS, BOREHOLES, AND MOISTURE ACCESS TUBES

| Hole ID | Date Completed | Depth Drilled (ft) | Depth Completed (ft) | Formation | Purtymun 1995 Data | | Revised Model | | Start Elev (ft) | End Elev (ft) | Land Surface Dadum (ft) | Stratigraphic Source | Stratigraphic Pick Comment |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Start Depth (ft) | End Depth (ft) | Start Depth (ft) | End Depth (ft) | | | | | |
| *PCM-1* | *6/30/85* | *60* | | *Tuff* | *8* | *60* | | | *6689.6* | *6637.6* | *6697.6* | *Purtymun 1995, 45344* | |
| *PCM-2* | *6/30/85* | *120* | | *Alluvium* | *0* | *6* | | | *6640.1* | *6634.1* | *6640.1* | *Purtymun 1995, 45344* | |
| *PCM-2* | *6/30/85* | *120* | | *Tuff* | *6* | *120* | | | *6634.1* | *6520.1* | *6640.1* | *Purtymun 1995, 45344* | |
| *PCM-3* | *6/30/85* | *60* | | *Alluvium* | *0* | *8* | | | *6615* | *6607* | *6615* | *Purtymun 1995, 45344* | |
| *PCM-3* | *6/30/85* | *60* | | *Tuff* | *8* | *60* | | | *6607* | *6555* | *6615* | *Purtymun 1995, 45344* | |
| *PCM-4* | *6/30/85* | *60* | | *Alluvium* | *0* | *1* | | | *6584.7* | *6583.7* | *6584.7* | *Purtymun 1995, 45344* | |
| *PCM-4* | *6/30/85* | *60* | | *Tuff* | *1* | *60* | | | *6583.7* | *6524.7* | *6584.7* | *Purtymun 1995, 45344* | |
| *PCO-1* | *6/30/85* | *22* | *12* | *Alluvium* | *0* | *11* | | | *6687* | *6676* | *6687* | *Purtymun 1995, 45344* | |
| *PCO-1* | *6/30/85* | *22* | *12* | *Tuff* | *11* | *22* | | | *6676* | *6665* | *6687* | *Purtymun 1995, 45344* | |
| *PCO-2* | *6/30/85* | *22* | *9.5* | *Alluvium* | *0* | *9* | | | *6618.3* | *6609.3* | *6618.3* | *Purtymun 1995, 45344* | |
| *PCO-2* | *6/30/85* | *22* | *9.5* | *Tuff* | *9* | *22* | | | *6609.3* | *6596.3* | *6618.3* | *Purtymun 1995, 45344* | |
| *PCO-3* | *6/30/85* | *20* | *17.7* | *Alluvium* | *0* | *12* | | | *6546.3* | *6534.3* | *6546.3* | *Purtymun 1995, 45344* | |
| *PCO-3* | *6/30/85* | *20* | *17.7* | *Tuff* | *12* | *20* | | | *6534.3* | *6526.3* | *6546.3* | *Purtymun 1995, 45344* | |
| *PM-2* | *7/15/65* | *2600* | *2300* | *Alluvium* | *0* | *30* | | | *6715* | *6685* | *6715* | *Purtymun 1995, 45344* | |
| *PM-2* | *7/15/65* | *2600* | *2300* | *Tshirege* | | | *30* | *100* | *6685* | *6615* | *6715* | *Gardner et al. 1993, 12582* | *Revised based on geologic model* |
| *PM-2* | *7/15/65* | *2600* | *2300* | *Cerro Toledo* | | | *100* | *170* | *6615* | *6545* | *6715* | *Gardner et al. 1993, 12582* | *Revised based on geologic model* |

## TABLE C-6 (continued)

### STRATIGRAPHIC INFORMATION FROM PAJARITO CANYON WELLS, BOREHOLES, AND MOISTURE ACCESS TUBES

| Hole ID | Date Completed | Depth Drilled (ft) | Depth Completed (ft) | Formation | Purtymun 1995 Data | | Revised Model | | Start Elev (ft) | End Elev (ft) | Land Surface Dadum (ft) | Stratigraphic Source | Stratigraphic Pick Comment |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Start Depth (ft) | End Depth (ft) | Start Depth (ft) | End Depth (ft) | | | | | |
| *PM-2* | *7/15/65* | *2600* | *2300* | *Otowi* | *30* | *405* | *170* | *405* | *6545* | *6310* | *6715* | *Purtymun 1995, 45344* | |
| *PM-2* | *7/15/65* | *2600* | *2300* | *Guaje* | *405* | *432* | | | *6310* | *6283* | *6715* | *Purtymun 1995, 45344* | |
| *PM-2* | *7/15/65* | *2600* | *2300* | *Basalt Unit 2* | *432* | *2312* | | | *6283* | *4403* | *6715* | *Purtymun 1995, 45344* | |
| *PM-2* | *7/15/65* | *2600* | *2300* | *Puye-Fanglomerate* | *700* | *1340* | | | *6015* | *5375* | *6715* | *Purtymun 1995, 45344* | |
| *PM-2* | *7/15/65* | *2600* | *2300* | *Puye-Totavi Lentil* | *1340* | *1410* | | | *5375* | *5305* | *6715* | *Purtymun 1995, 45344* | |
| *PM-2* | *7/15/65* | *2600* | *2300* | *Puye-Chaquehui* | *1410* | *2370* | | | *5305* | *4345* | *6715* | *Purtymun 1995, 45344* | |
| *PM-2* | *7/15/65* | *2600* | *2300* | *Chamita* | *2370* | *2410* | | | *4345* | *4305* | *6715* | *Purtymun 1995, 45344* | |
| *PM-2* | *7/15/65* | *2600* | *2300* | *Tesuque* | *2410* | *2600* | | | *4305* | *4115* | *6715* | *Purtymun 1995, 45344* | |
| *PM-4* | *8/15/81* | *2920* | *2875* | *Tshirege* | *0* | *220* | *0* | *150* | *6920* | *6770* | *6920* | *Purtymun 1995, 45344* | |
| *PM-4* | *8/15/81* | *2920* | *2875* | *Cerro Toledo* | | | *150* | *220* | *6770* | *6700* | *6920* | *Koch 1998, 58094* | *Revised based on geologic model* |
| *PM-4* | *8/15/81* | *2920* | *2875* | *Otowi* | *220* | *540* | | | *6700* | *6380* | *6920* | *Purtymun 1995, 45344* | |
| *PM-4* | *8/15/81* | *2920* | *2875* | *Guaje* | *540* | *600* | | | *6380* | *6320* | *6920* | *Purtymun 1995, 45344* | |
| *PM-4* | *8/15/81* | *2920* | *2875* | *Basalt Unit 2* | *600* | *1100* | | | *6320* | *5820* | *6920* | *Purtymun 1995, 45344* | |
| *PM-4* | *8/15/81* | *2920* | *2875* | *Puye-Fanglomerate* | *1100* | *1300* | | | *5820* | *5620* | *6920* | *Purtymun 1995, 45344* | |
| *PM-4* | *8/15/81* | *2920* | *2875* | *Puye-Totavi Lentil* | *1300* | *1420* | | | *5620* | *5500* | *6920* | *Purtymun 1995, 45344* | |
| *PM-4* | *8/15/81* | *2920* | *2875* | *Puye-Chaquehui* | *1420* | *2920* | | | *5500* | *4000* | *6920* | *Purtymun 1995, 45344* | |

**TABLE C-6 (continued)**

**STRATIGRAPHIC INFORMATION FROM PAJARITO CANYON WELLS, BOREHOLES, AND MOISTURE ACCESS TUBES**

| Hole ID | Date Completed | Depth Drilled (ft) | Depth Completed (ft) | Formation | Purtymun 1995 Data | | Revised Model | | Start Elev (ft) | End Elev (ft) | Land Surface Dadum (ft) | Stratigraphic Source | Stratigraphic Pick Comment |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Start Depth (ft) | End Depth (ft) | Start Depth (ft) | End Depth (ft) | | | | | |
| *PM-4* | *8/15/81* | *2920* | *2875* | *Basalt Unit 1* | *1950* | *2430* | | | *4970* | *4490* | *6920* | *Purtymun 1995, 45344* | |
| *PM-5* | *9/15/82* | *3120* | *3092* | *Tshirege* | *0* | *335* | | | *7095* | *6760* | *7095* | *Purtymun 1995, 45344* | |
| *PM-5* | *9/15/82* | *3120* | *3092* | *Otowi* | *335* | *710* | | | *6760* | *6385* | *7095* | *Purtymun 1995, 45344* | |
| *PM-5* | *9/15/82* | *3120* | *3092* | *Guaje* | *710* | *740* | | | *6385* | *6355* | *7095* | *Purtymun 1995, 45344* | |
| *PM-5* | *9/15/82* | *3120* | *3092* | *Basalt Unit 2* | *740* | *1145* | | | *6355* | *5950* | *7095* | *Purtymun 1995, 45344* | |
| *PM-5* | *9/15/82* | *3120* | *3092* | *Puye-Fanglomerate* | *760* | *1470* | | | *6335* | *5625* | *7095* | *Purtymun 1995, 45344* | |
| *PM-5* | *9/15/82* | *3120* | *3092* | *Puye-Totavi Lentil* | *1470* | *1550* | | | *5625* | *5545* | *7095* | *Purtymun 1995, 45344* | |
| *PM-5* | *9/15/82* | *3120* | *3092* | *Puye-Chaquehui* | *1550* | *2780* | | | *5545* | *4315* | *7095* | *Purtymun 1995, 45344* | |
| *PM-5* | *9/15/82* | *3120* | *3092* | *Basalt Unit 1* | *1765* | *2740* | | | *5330* | *4355* | *7095* | *Purtymun 1995, 45344* | |
| *PM-5* | *9/15/82* | *3120* | *3092* | *Chamita* | *2780* | *2860* | | | *4315* | *4235* | *7095* | *Purtymun 1995, 45344* | |
| *PM-5* | *9/15/82* | *3120* | *3092* | *Tesuque* | *2860* | *3120* | | | *4235* | *3975* | *7095* | *Purtymun 1995, 45344* | |
| *SHB-1* | *12/15/91* | *700* | | *Tshirege* | *0* | *306* | | | *7315* | *7009* | *7314.6* | *Gardner et al. 1993, 12582* | |
| *SHB-1* | *12/15/91* | *700* | | *Cerro Toledo?* | *306* | *445* | | | *7009* | *6870* | *7314.6* | *Gardner et al. 1993, 12582* | *Revised based on geologic model* |
| *SHB-1* | *12/15/91* | *700* | | *Otowi* | *445* | *631* | | | *6870* | *6684* | *7314.6* | *Gardner et al. 1993, 12582* | |
| *SHB-1* | *12/15/91* | *700* | | *Sedimentary Interval* | *631* | *644* | | | *6684* | *6671* | *7314.6* | *Gardner et al. 1993, 12582* | |
| *SHB-1* | *12/15/91* | *700* | | *Basalt* | *644* | *700* | | | *6671* | *6615* | *7314.6* | *Gardner et al. 1993, 12582* | |

**TABLE C-6 (continued)**

**STRATIGRAPHIC INFORMATION FROM PAJARITO CANYON WELLS, BOREHOLES, AND MOISTURE ACCESS TUBES**

| Hole ID | Date Completed | Depth Drilled (ft) | Depth Completed (ft) | Formation | Purtymun 1995 Data | | Revised Model | | Start Elev (ft) | End Elev (ft) | Land Surface Dadum (ft) | Stratigraphic Source | Stratigraphic Pick Comment |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Start Depth (ft) | End Depth (ft) | Start Depth (ft) | End Depth (ft) | | | | | |
| *SHB-2* | *12/15/91* | *200* | | *Tshirege* | *0* | *200* | | | *7436* | *7236* | *7436* | *Gardner et al. 1993, 12582* | |
| *SHB-3* | *12/30/91* | *860* | | *Tshirege* | *0* | *335* | | | *7607* | *7272* | *7607* | *Gardner et al. 1993, 12582* | |
| *SHB-3* | *12/30/91* | *860* | | *Cerro Toledo* | *335* | *424* | | | *7272* | *7183* | *7607* | *Gardner et al. 1993, 12582* | *Probably "Sedimentary interval"* |
| *SHB-3* | *12/30/91* | *860* | | *Otowi* | *424* | *839* | | | *7183* | *6768* | *7607* | *Gardner et al. 1993, 12582* | |
| *SHB-3* | *12/30/91* | *860* | | *Puye* | *839* | *860* | | | *6768* | *6747* | *7607* | *Gardner et al. 1993, 12582* | |
| *SHB-4* | *1/15/92* | *200* | | *Tshirege* | *0* | *125* | *0* | *117* | *6730* | *6613* | *6730* | *Gardner et al. 1993, 12582* | |
| *SHB-4* | *1/15/92* | *200* | | *Tsankawi* | | | *117* | *120* | *6613* | *6610* | *6730* | *Gardner et al. 1993, 12582* | *Revised based on lithology* |
| *SHB-4* | *1/15/92* | *200* | | *Cerro Toledo* | | | *120* | *200* | *6610* | *6530* | *6730* | *Gardner et al. 1993, 12582* | *Revised based on lithology* |
| *SHB-4* | *1/15/92* | *200* | | *Otowi* | *125* | *200* | | | *6730* | *6730* | *6730* | *Gardner et al. 1993, 12582* | *Revised based on lithology* |
| *PCTH-5* | *3/31/50* | *263* | *24* | *Alluvium* | *0* | *23* | | | *6591.6* | *6591.6* | *6591.6* | *Purtymun 1995, 45344* | |
| *PCTH-5* | *3/31/50* | *263* | *24* | *Tshirege* | *23* | *40* | | | *6591.6* | *6591.6* | *6591.6* | *Purtymun 1995, 45344* | |
| *PCTH-5* | *3/31/50* | *263* | *24* | *Cerro Toledo* | | | *40* | *70* | *6551.6* | *6521.6* | *6591.6* | | *Revised based on geologic model* |
| *PCTH-5* | *3/31/50* | *263* | *24* | *Otowi* | *40* | *160* | *70* | *160* | *6521.6* | *6431.6* | *6591.6* | *Purtymun 1995, 45344* | *Revised based on geologic model* |
| *PCTH-5* | *3/31/50* | *263* | *24* | *Guaje* | *160* | *171* | | | *6591.6* | *6591.6* | *6591.6* | *Purtymun 1995, 45344* | |
| *PCTH-5* | *3/31/50* | *263* | *24* | *Basalt Unit 2* | *171* | *263* | | | *6591.6* | *6591.6* | *6591.6* | *Purtymun 1995, 45344* | |
| *PCTH-6* | *3/31/50* | *300* | *120* | *Alluvium* | *0* | *25* | | | *6642.1* | *6642.1* | *6642.1* | *Purtymun 1995, 45344* | |

## TABLE C-6 (continued)

## STRATIGRAPHIC INFORMATION FROM PAJARITO CANYON WELLS, BOREHOLES, AND MOISTURE ACCESS TUBES

| Hole ID | Date Completed | Depth Drilled (ft) | Depth Completed (ft) | Formation | Purtymun 1995 Data | | Revised Model | | Start Elev (ft) | End Elev (ft) | Land Surface Dadum (ft) | Stratigraphic Source | Stratigraphic Pick Comment |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Start Depth (ft) | End Depth (ft) | Start Depth (ft) | End Depth (ft) | | | | | |
| *PCTH-6* | *3/31/50* | *300* | *120* | *Tshirege* | *25* | *85* | | | *6642.1* | *6642.1* | *6642.1* | *Purtymun 1995, 45344* | |
| *PCTH-6* | *3/31/50* | *300* | *120* | *Cerro Toledo* | | | *85* | *125* | *6557.1* | *6517.1* | *6642.1* | | *Revised based on geologic model* |
| *PCTH-6* | *3/31/50* | *300* | *120* | *Otowi* | *85* | *265* | *125* | *265* | *6517.1* | *6377.1* | *6642.1* | *Purtymun 1995, 45344* | *Revised based on geologic model* |
| *PCTH-6* | *3/31/50* | *300* | *120* | *Guaje* | *265* | *285* | | | *6642.1* | *6642.1* | *6642.1* | *Purtymun 1995, 45344* | |
| *PCTH-6* | *3/31/50* | *300* | *120* | *Puye* | *285* | *300* | | | *6642.1* | *6642.1* | *6642.1* | *Purtymun 1995, 45344* | |

# Appendix D

*Stratigraphic Information Used to Construct Cross Sections*

## TABLE D-1

## STRATIGRAPHIC INFORMATION USED TO CONSTRUCT CROSS SECTIONS

| Point | Unit Name | Easting (ft) | Northing (ft) | Elevation (ft) | Depth to Base of Unit (ft) |
|---|---|---|---|---|---|
| 1 | surface | 1645640 | 1754250 | 6586.09 | 0 |
| 1 | qbt2 | 1645640 | 1754250 | 6572.45 | 13.64 |
| 1 | qbt1v | 1645640 | 1754250 | 6545.7 | 40.39 |
| 1 | qbt1g | 1645640 | 1754250 | 6552.13 | 33.96 |
| 1 | qbtt | 1645640 | 1754250 | 6548.8 | 37.29 |
| 1 | qct | 1645640 | 1754250 | 6539.82 | 46.27 |
| 1 | qbof | 1645640 | 1754250 | 6535.47 | 50.62 |
| 1 | qbog | 1645640 | 1754250 | 6520.38 | 65.71 |
| 1 | tpf | 1645640 | 1754250 | 5506.9 | 1079.19 |
| 1 | tpt | 1645640 | 1754250 | 5459.51 | 1126.58 |
| 1 | water_tab | 1645640 | 1754250 | 5762.11 | 823.98 |
| 2 | surface | 1646560 | 1756830 | 6621.75 | 0 |
| 2 | qbt3 | 1646560 | 1756830 | 6619.24 | 2.51 |
| 2 | qbt2 | 1646560 | 1756830 | 6597.25 | 24.5 |
| 2 | qbt1v | 1646560 | 1756830 | 6562.4 | 59.35 |
| 2 | qbt1g | 1646560 | 1756830 | 6558.68 | 63.07 |
| 2 | qbtt | 1646560 | 1756830 | 6555.42 | 66.33 |
| 2 | qct | 1646560 | 1756830 | 6545.62 | 76.13 |
| 2 | qbof | 1646560 | 1756830 | 6528.98 | 92.77 |
| 2 | qbog | 1646560 | 1756830 | 6512.7 | 109.05 |
| 2 | tpf | 1646560 | 1756830 | 5555.14 | 1066.61 |
| 2 | tpt | 1646560 | 1756830 | 5476.99 | 1144.76 |
| 2 | water_tab | 1646560 | 1756830 | 5763.03 | 858.72 |
| 3 | surface | 1643850 | 1755070 | 6653.28 | 0 |
| 3 | qbt2 | 1643850 | 1755070 | 6608.54 | 44.74 |
| 3 | qbt1v | 1643850 | 1755070 | 6570.77 | 82.51 |
| 3 | qbt1g | 1643850 | 1755070 | 6537.25 | 116.03 |
| 3 | qbtt | 1643850 | 1755070 | 6533.97 | 119.31 |
| 3 | qct | 1643850 | 1755070 | 6518.62 | 134.66 |
| 3 | qbof | 1643850 | 1755070 | 6476.21 | 177.07 |
| 3 | qbog | 1643850 | 1755070 | 6460.46 | 192.82 |
| 3 | tpf | 1643850 | 1755070 | 5480.55 | 1172.73 |
| 3 | tpt | 1643850 | 1755070 | 5429.18 | 1224.1 |
| 3 | tsfuv | 1643850 | 1755070 | 5410.29 | 1242.99 |
| 3 | water_tab | 1643850 | 1755070 | 5790.16 | 863.12 |
| 4 | surface | 1644760 | 1757060 | 6660.51 | 0 |
| 4 | qbt2 | 1644760 | 1757060 | 6632.23 | 28.28 |
| 4 | qbt1v | 1644760 | 1757060 | 6587.78 | 72.73 |
| 4 | qbt1g | 1644760 | 1757060 | 6553.39 | 107.12 |
| 4 | qbtt | 1644760 | 1757060 | 6550.15 | 110.36 |

**TABLE D-1 (continued)**

**STRATIGRAPHIC INFORMATION USED TO CONSTRUCT CROSS SECTIONS**

| Point | Unit Name | Easting (ft) | Northing (ft) | Elevation (ft) | Depth to Base of Unit (ft) |
|---|---|---|---|---|---|
| *4* | *qct* | *1644760* | *1757060* | *6534.47* | *126.04* |
| 4 | qbof | 1644760 | 1757060 | 6469.92 | 190.59 |
| 4 | qbog | 1644760 | 1757060 | 6453.29 | 207.22 |
| 4 | tpf | 1644760 | 1757060 | 5516.03 | 1144.48 |
| 4 | tpt | 1644760 | 1757060 | 5445.59 | 1214.92 |
| 4 | tsfuv | 1644760 | 1757060 | 5395.96 | 1264.55 |
| 4 | water_tab | 1644760 | 1757060 | 5788.27 | 872.24 |
| 5 | surface | 1641480 | 1756750 | 6711.71 | 0 |
| 5 | qbt2 | 1641480 | 1756750 | 6677.3 | 34.41 |
| 5 | qbt1v | 1641480 | 1756750 | 6614.31 | 97.4 |
| 5 | qbt1g | 1641480 | 1756750 | 6529.38 | 182.33 |
| 5 | qbtt | 1641480 | 1756750 | 6526.14 | 185.57 |
| 5 | qct | 1641480 | 1756750 | 6500.95 | 210.76 |
| 5 | qbof | 1641480 | 1756750 | 6403.92 | 307.79 |
| 5 | qbog | 1641480 | 1756750 | 6387.33 | 324.38 |
| 5 | tpf | 1641480 | 1756750 | 5443.87 | 1267.84 |
| 5 | tpt | 1641480 | 1756750 | 5387.78 | 1323.93 |
| 5 | tsfuv | 1641480 | 1756750 | 5052.98 | 1658.73 |
| 5 | water_tab | 1641480 | 1756750 | 5812.48 | 899.23 |
| 6 | surface | 1639600 | 1757600 | 6765.94 | 0 |
| 6 | qbt2 | 1639600 | 1757600 | 6719.22 | 46.72 |
| 6 | qbt1v | 1639600 | 1757600 | 6639.46 | 126.48 |
| 6 | qbt1g | 1639600 | 1757600 | 6527.75 | 238.19 |
| 6 | qbtt | 1639600 | 1757600 | 6524.51 | 241.43 |
| 6 | qct | 1639600 | 1757600 | 6494 | 271.94 |
| 6 | qbof | 1639600 | 1757600 | 6360.12 | 405.82 |
| 6 | qbog | 1639600 | 1757600 | 6343 | 422.94 |
| 6 | tpf | 1639600 | 1757600 | 5416.02 | 1349.92 |
| 6 | tpt | 1639600 | 1757600 | 5355.72 | 1410.22 |
| 6 | tsfuv | 1639600 | 1757600 | 4803.45 | 1962.49 |
| 6 | water_tab | 1639600 | 1757600 | 5830.18 | 935.76 |
| 7 | surface | 1637630 | 1759300 | 6822.09 | 0 |
| 7 | qbt2 | 1637630 | 1759300 | 6781.84 | 40.25 |
| 7 | qbt1v | 1637630 | 1759300 | 6680.39 | 141.7 |
| 7 | qbt1g | 1637630 | 1759300 | 6581.1 | 240.99 |
| 7 | qbtt | 1637630 | 1759300 | 6577.83 | 244.26 |
| 7 | qct | 1637630 | 1759300 | 6543.65 | 278.44 |
| 7 | qbof | 1637630 | 1759300 | 6318.15 | 503.94 |
| 7 | qbog | 1637630 | 1759300 | 6299.87 | 522.22 |
| *7* | *tpf* | *1637630* | *1759300* | *5385.19* | *1436.9* |
| *7* | *tpt* | *1637630* | *1759300* | *5321.33* | *1500.76* |
| *7* | *tsfuv* | *1637630* | *1759300* | *4489.31* | *2332.78* |

**TABLE D-1 (continued)**

**STRATIGRAPHIC INFORMATION USED TO CONSTRUCT CROSS SECTIONS**

| Point | Unit Name | Easting (ft) | Northing (ft) | Elevation (ft) | Depth to Base of Unit (ft) |
|---|---|---|---|---|---|
| 7 | water_tab | 1637630 | 1759300 | 5850.02 | 972.07 |
| 8 | surface | 1638030 | 1760300 | 6828.86 | 0 |
| 8 | qbt2 | 1638030 | 1760300 | 6798.54 | 30.32 |
| 8 | qbt1v | 1638030 | 1760300 | 6692.15 | 136.71 |
| 8 | qbt1g | 1638030 | 1760300 | 6586.01 | 242.85 |
| 8 | qbtt | 1638030 | 1760300 | 6582.72 | 246.14 |
| 8 | qct | 1638030 | 1760300 | 6549.11 | 279.75 |
| 8 | qbof | 1638030 | 1760300 | 6350.01 | 478.85 |
| 8 | qbog | 1638030 | 1760300 | 6331.1 | 497.76 |
| 8 | tpf | 1638030 | 1760300 | 5401.27 | 1427.59 |
| 8 | tpt | 1638030 | 1760300 | 5331.14 | 1497.72 |
| 8 | tsfuv | 1638030 | 1760300 | 4474.75 | 2354.11 |
| 8 | water_tab | 1638030 | 1760300 | 5845.9 | 982.96 |
| 9 | surface | 1635960 | 1760240 | 6794.37 | 0 |
| 9 | qbt1v | 1635960 | 1760240 | 6710.32 | 84.05 |
| 9 | qbt1g | 1635960 | 1760240 | 6619.77 | 174.6 |
| 9 | qbtt | 1635960 | 1760240 | 6616.42 | 177.95 |
| 9 | qct | 1635960 | 1760240 | 6578.59 | 215.78 |
| 9 | qbof | 1635960 | 1760240 | 6291.97 | 502.4 |
| 9 | qbog | 1635960 | 1760240 | 6272.95 | 521.42 |
| 9 | tpf | 1635960 | 1760240 | 5422.53 | 1371.84 |
| 9 | tpt | 1635960 | 1760240 | 5357.53 | 1436.84 |
| 9 | tsfuv | 1635960 | 1760240 | 4395.89 | 2398.48 |
| 9 | water_tab | 1635960 | 1760240 | 5867.72 | 926.65 |
| 10 | surface | 1635970 | 1761520 | 6864.33 | 0 |
| 10 | qbt2 | 1635970 | 1761520 | 6843.1 | 21.23 |
| 10 | qbt1v | 1635970 | 1761520 | 6729.65 | 134.68 |
| 10 | qbt1g | 1635970 | 1761520 | 6640.35 | 223.98 |
| 10 | qbtt | 1635970 | 1761520 | 6636.95 | 227.38 |
| 10 | qct | 1635970 | 1761520 | 6598.49 | 265.84 |
| 10 | qbof | 1635970 | 1761520 | 6306.32 | 558.01 |
| 10 | qbog | 1635970 | 1761520 | 6286.4 | 577.93 |
| 10 | tpf | 1635970 | 1761520 | 5474.02 | 1390.31 |
| 10 | tpt | 1635970 | 1761520 | 5409.02 | 1455.31 |
| 10 | tsfuv | 1635970 | 1761520 | 4342.82 | 2521.51 |
| 10 | water_tab | 1635970 | 1761520 | 5868.38 | 995.95 |
| 11 | surface | 1634720 | 1760320 | 6866.66 | 0 |
| 11 | qbt2 | 1634720 | 1760320 | 6833.77 | 32.89 |
| 11 | qbt1v | 1634720 | 1760320 | 6724.24 | 142.42 |
| 11 | qbt1g | 1634720 | 1760320 | 6622.91 | 243.75 |

**TABLE D-1 (continued)**

**STRATIGRAPHIC INFORMATION USED TO CONSTRUCT CROSS SECTIONS**

| Point | Unit Name | Easting (ft) | Northing (ft) | Elevation (ft) | Depth to Base of Unit (ft) |
|---|---|---|---|---|---|
| 11 | qbtt | 1634720 | 1760320 | 6619.5 | 247.16 |
| 11 | qct | 1634720 | 1760320 | 6578.12 | 288.54 |
| 11 | qbof | 1634720 | 1760320 | 6284.27 | 582.39 |
| 11 | qbog | 1634720 | 1760320 | 6265.08 | 601.58 |
| 11 | tpf | 1634720 | 1760320 | 5510.52 | 1356.14 |
| 11 | tpt | 1634720 | 1760320 | 5445.52 | 1421.14 |
| 11 | tsfuv | 1634720 | 1760320 | 4495.96 | 2370.7 |
| 11 | water_tab | 1634720 | 1760320 | 5883.02 | 983.64 |
| 12 | surface | 1634700 | 1761030 | 6874.93 | 0 |
| 12 | qbt2 | 1634700 | 1761030 | 6848.08 | 26.85 |
| 12 | qbt1v | 1634700 | 1761030 | 6734.52 | 140.41 |
| 12 | qbt1g | 1634700 | 1761030 | 6639.55 | 235.38 |
| 12 | qbtt | 1634700 | 1761030 | 6636.11 | 238.82 |
| 12 | qct | 1634700 | 1761030 | 6593.98 | 280.95 |
| 12 | qbof | 1634700 | 1761030 | 6292.91 | 582.02 |
| 12 | qbog | 1634700 | 1761030 | 6273.24 | 601.69 |
| 12 | tpf | 1634700 | 1761030 | 5538.24 | 1336.69 |
| 12 | tpt | 1634700 | 1761030 | 5473.24 | 1401.69 |
| 12 | tsfuv | 1634700 | 1761030 | 4482.61 | 2392.32 |
| 12 | water_tab | 1634700 | 1761030 | 5883.92 | 991.01 |
| 13 | surface | 1634470 | 1761520 | 6881.25 | 0 |
| 13 | qbt2 | 1634470 | 1761520 | 6860.85 | 20.4 |
| 13 | qbt1v | 1634470 | 1761520 | 6744.14 | 137.11 |
| 13 | qbt1g | 1634470 | 1761520 | 6653.83 | 227.42 |
| 13 | qbtt | 1634470 | 1761520 | 6650.36 | 230.89 |
| 13 | qct | 1634470 | 1761520 | 6606.87 | 274.38 |
| 13 | qbof | 1634470 | 1761520 | 6297.32 | 583.93 |
| 13 | qbog | 1634470 | 1761520 | 6277.26 | 603.99 |
| 13 | tpf | 1634470 | 1761520 | 5574.84 | 1306.41 |
| 13 | tpt | 1634470 | 1761520 | 5509.84 | 1371.41 |
| 13 | tsfuv | 1634470 | 1761520 | 4475.16 | 2406.09 |
| 13 | water_tab | 1634470 | 1761520 | 5887.86 | 993.39 |
| 14 | surface | 1635220 | 1762140 | 6883.67 | 0 |
| 14 | qbt2 | 1635220 | 1762140 | 6863.5 | 20.17 |
| 14 | qbt1v | 1635220 | 1762140 | 6746.03 | 137.64 |
| 14 | qbt1g | 1635220 | 1762140 | 6661.68 | 221.99 |
| 14 | qbtt | 1635220 | 1762140 | 6658.21 | 225.46 |
| 14 | qct | 1635220 | 1762140 | 6617.13 | 266.54 |
| 14 | qbof | 1635220 | 1762140 | 6308.22 | 575.45 |
| 14 | qbog | 1635220 | 1762140 | 6287.75 | 595.92 |

**TABLE D-1 (continued)**

**STRATIGRAPHIC INFORMATION USED TO CONSTRUCT CROSS SECTIONS**

| Point | Unit Name | Easting (ft) | Northing (ft) | Elevation (ft) | Depth to Base of Unit (ft) |
|---|---|---|---|---|---|
| 14 | tpf | 1635220 | 1762140 | 5548.19 | 1335.48 |
| 14 | tpt | 1635220 | 1762140 | 5483.19 | 1400.48 |
| 14 | tsfuv | 1635220 | 1762140 | 4373.59 | 2510.08 |
| 14 | water_tab | 1635220 | 1762140 | 5878.73 | 1004.94 |
| 15 | surface | 1633740 | 1762240 | 6903.44 | 0 |
| 15 | qbt2 | 1633740 | 1762240 | 6881.89 | 21.55 |
| 15 | qbt1v | 1633740 | 1762240 | 6761.02 | 142.42 |
| 15 | qbt1g | 1633740 | 1762240 | 6677.38 | 226.06 |
| 15 | qbtt | 1633740 | 1762240 | 6673.82 | 229.62 |
| 15 | qct | 1633740 | 1762240 | 6626.66 | 276.78 |
| 15 | qbof | 1633740 | 1762240 | 6300.76 | 602.68 |
| 15 | qbog | 1633740 | 1762240 | 6280 | 623.44 |
| 15 | tpf | 1633740 | 1762240 | 5628.83 | 1274.61 |
| 15 | tpt | 1633740 | 1762240 | 5563.83 | 1339.61 |
| 15 | tsfuv | 1633740 | 1762240 | 4500.03 | 2403.41 |
| 15 | water_tab | 1633740 | 1762240 | 5897.44 | 1006 |
| 16 | surface | 1628200 | 1762600 | 7110.17 | 0 |
| 16 | qbt3 | 1628200 | 1762600 | 7008.69 | 101.48 |
| 16 | qbt2 | 1628200 | 1762600 | 6930.57 | 179.6 |
| 16 | qbt1g | 1628200 | 1762600 | 6735.85 | 374.32 |
| 16 | qbtt | 1628200 | 1762600 | 6731.86 | 378.31 |
| 16 | qct | 1628200 | 1762600 | 6660.97 | 449.2 |
| 16 | qbof | 1628200 | 1762600 | 6413.87 | 696.3 |
| 16 | qbog | 1628200 | 1762600 | 6391.72 | 718.45 |
| 16 | tpf | 1628200 | 1762600 | 5706.66 | 1403.51 |
| 16 | tpt | 1628200 | 1762600 | 5641.66 | 1468.51 |
| 16 | tsfuv | 1628200 | 1762600 | 4961.68 | 2148.49 |
| 16 | water_tab | 1628200 | 1762600 | 5973.6 | 1136.57 |
| 17 | surface | 1614970 | 1769700 | 7532.35 | 0 |
| 17 | qbt5 | 1614970 | 1769700 | 7493.3 | 39.05 |
| 17 | qbt4 | 1614970 | 1769700 | 7456.17 | 76.18 |
| 17 | qbt3 | 1614970 | 1769700 | 7396.87 | 135.48 |
| 17 | qbt1g | 1614970 | 1769700 | 7230.75 | 301.6 |
| 17 | qbtt | 1614970 | 1769700 | 7225.38 | 306.97 |
| 17 | qct | 1614970 | 1769700 | 7165.81 | 366.54 |
| 17 | qbof | 1614970 | 1769700 | 6881.62 | 650.73 |
| 17 | qbog | 1614970 | 1769700 | 6846.37 | 685.98 |
| 17 | tpf | 1614970 | 1769700 | 5901.69 | 1630.66 |
| 17 | tpt | 1614970 | 1769700 | 5836.69 | 1695.66 |
| 18 | surface | 1622300 | 1767600 | 7286.31 | 0 |

**TABLE D-1 (continued)**

**STRATIGRAPHIC INFORMATION USED TO CONSTRUCT CROSS SECTIONS**

| Point | Unit Name | Easting (ft) | Northing (ft) | Elevation (ft) | Depth to Base of Unit (ft) |
|---|---|---|---|---|---|
| 18 | qbt3 | 1622300 | 1767600 | 7184.82 | 101.49 |
| 18 | qbt2 | 1622300 | 1767600 | 7097.01 | 189.3 |
| 18 | qbt1g | 1622300 | 1767600 | 7011.04 | 275.27 |
| 18 | qbtt | 1622300 | 1767600 | 7006.17 | 280.14 |
| 18 | qct | 1622300 | 1767600 | 6915.34 | 370.97 |
| 18 | qbof | 1622300 | 1767600 | 6689.39 | 596.92 |
| 18 | qbog | 1622300 | 1767600 | 6659.11 | 627.2 |
| 18 | tpf | 1622300 | 1767600 | 5805.8 | 1480.51 |
| 18 | tpt | 1622300 | 1767600 | 5740.8 | 1545.51 |
| 18 | tsfuv | 1622300 | 1767600 | 5659.07 | 1627.24 |
| 18 | water_tab | 1622300 | 1767600 | 6143.97 | 1142.34 |
| 19 | surface | 1634220 | 1760220 | 6885.28 | 0 |
| 19 | qbt3 | 1634220 | 1760220 | 6885.02 | 0.26 |
| 19 | qbt2 | 1634220 | 1760220 | 6836.43 | 48.85 |
| 19 | qbt1v | 1634220 | 1760220 | 6726.92 | 158.36 |
| 19 | qbt1g | 1634220 | 1760220 | 6624.67 | 260.61 |
| 19 | qbtt | 1634220 | 1760220 | 6621.24 | 264.04 |
| 19 | qct | 1634220 | 1760220 | 6578.44 | 306.84 |
| 19 | qbof | 1634220 | 1760220 | 6279.47 | 605.81 |
| 19 | qbog | 1634220 | 1760220 | 6260.29 | 624.99 |
| 19 | tpf | 1634220 | 1760220 | 5540.17 | 1345.11 |
| 19 | tpt | 1634220 | 1760220 | 5475.16 | 1410.12 |
| 19 | tsfuv | 1634220 | 1760220 | 4526.66 | 2358.62 |
| 19 | water_tab | 1634220 | 1760220 | 5889.12 | 996.16 |
| 20 | surface | 1634220 | 1760920 | 6853.92 | 0 |
| 20 | qbt2 | 1634220 | 1760920 | 6850.96 | 2.96 |
| 20 | qbt1v | 1634220 | 1760920 | 6737.53 | 116.39 |
| 20 | qbt1g | 1634220 | 1760920 | 6641.56 | 212.36 |
| 20 | qbtt | 1634220 | 1760920 | 6638.1 | 215.82 |
| 20 | qct | 1634220 | 1760920 | 6594.36 | 259.56 |
| 20 | qbof | 1634220 | 1760920 | 6288.09 | 565.83 |
| 20 | qbog | 1634220 | 1760920 | 6268.46 | 585.46 |
| 20 | tpf | 1634220 | 1760920 | 5567.89 | 1286.03 |
| 20 | tpt | 1634220 | 1760920 | 5502.89 | 1351.03 |
| 20 | tsfuv | 1634220 | 1760920 | 4532.63 | 2321.29 |
| 20 | water_tab | 1634220 | 1760920 | 5890.23 | 963.69 |
| 21 | surface | 1634550 | 1762880 | 6906.29 | 0 |
| 21 | qbt2 | 1634550 | 1762880 | 6884.28 | 22.01 |
| 21 | qbt1v | 1634550 | 1762880 | 6763.71 | 142.58 |
| 21 | qbt1g | 1634550 | 1762880 | 6685.54 | 220.75 |

**TABLE D-1 (continued)**

**STRATIGRAPHIC INFORMATION USED TO CONSTRUCT CROSS SECTIONS**

| Point | Unit Name | Easting (ft) | Northing (ft) | Elevation (ft) | Depth to Base of Unit (ft) |
|---|---|---|---|---|---|
| 21 | qbtt | 1634550 | 1762880 | 6682 | 224.29 |
| 21 | qct | 1634550 | 1762880 | 6638.19 | 268.1 |
| 21 | qbof | 1634550 | 1762880 | 6312.23 | 594.06 |
| 21 | qbog | 1634550 | 1762880 | 6290.99 | 615.3 |
| 21 | tpf | 1634550 | 1762880 | 5621.58 | 1284.71 |
| 21 | tpt | 1634550 | 1762880 | 5556.58 | 1349.71 |
| 21 | tsfuv | 1634550 | 1762880 | 4386.68 | 2519.61 |
| 21 | water_tab | 1634550 | 1762880 | 5888.23 | 1018.06 |
| 22 | surface | 1630000 | 1764200 | 7077.23 | 0 |
| 22 | qbt3 | 1630000 | 1764200 | 6997.53 | 79.7 |
| 22 | qbt2 | 1630000 | 1764200 | 6936.54 | 140.69 |
| 22 | qbt1v | 1630000 | 1764200 | 6834.53 | 242.7 |
| 22 | qbt1g | 1630000 | 1764200 | 6758.51 | 318.72 |
| 22 | qbtt | 1630000 | 1764200 | 6754.57 | 322.66 |
| 22 | qct | 1630000 | 1764200 | 6687.31 | 389.92 |
| 22 | qbof | 1630000 | 1764200 | 6410.95 | 666.28 |
| 22 | qbog | 1630000 | 1764200 | 6387.39 | 689.84 |
| 22 | tpf | 1630000 | 1764200 | 5648.46 | 1428.77 |
| 22 | tpt | 1630000 | 1764200 | 5583.46 | 1493.77 |
| 22 | tsfuv | 1630000 | 1764200 | 4708.46 | 2368.77 |
| 22 | water_tab | 1630000 | 1764200 | 5948.17 | 1129.06 |
| 23 | surface | 1630000 | 1765400 | 7095.43 | 0 |
| 23 | qbt3 | 1630000 | 1765400 | 7015.04 | 80.39 |
| 23 | qbt2 | 1630000 | 1765400 | 6953.57 | 141.86 |
| 23 | qbt1v | 1630000 | 1765400 | 6859.87 | 235.56 |
| 23 | qbt1g | 1630000 | 1765400 | 6787.5 | 307.93 |
| 23 | qbtt | 1630000 | 1765400 | 6783.48 | 311.95 |
| 23 | qct | 1630000 | 1765400 | 6713.48 | 381.95 |
| 23 | qbof | 1630000 | 1765400 | 6427.55 | 667.88 |
| 23 | qbog | 1630000 | 1765400 | 6402.58 | 692.85 |
| 23 | tpf | 1630000 | 1765400 | 5678.6 | 1416.83 |
| 23 | tpt | 1630000 | 1765400 | 5613.6 | 1481.83 |
| 23 | tsfuv | 1630000 | 1765400 | 4637.65 | 2457.78 |
| 23 | water_tab | 1630000 | 1765400 | 5951.43 | 1144 |
| 24 | surface | 1631400 | 1760600 | 7009.14 | 0 |
| 24 | qbt3 | 1631400 | 1760600 | 6929.11 | 80.03 |
| 24 | qbt2 | 1631400 | 1760600 | 6864.75 | 144.39 |
| 24 | qbt1v | 1631400 | 1760600 | 6754.93 | 254.21 |
| 24 | qbt1g | 1631400 | 1760600 | 6659.15 | 349.99 |
| 24 | qbtt | 1631400 | 1760600 | 6655.51 | 353.63 |

**TABLE D-1 (continued)**

**STRATIGRAPHIC INFORMATION USED TO CONSTRUCT CROSS SECTIONS**

| Point | Unit Name | Easting (ft) | Northing (ft) | Elevation (ft) | Depth to Base of Unit (ft) |
|---|---|---|---|---|---|
| 24 | qct | 1631400 | 1760600 | 6602.55 | 406.59 |
| 24 | qbof | 1631400 | 1760600 | 6288.84 | 720.3 |
| 24 | qbog | 1631400 | 1760600 | 6269.2 | 739.94 |
| 24 | tpf | 1631400 | 1760600 | 5641.07 | 1368.07 |
| 24 | tpt | 1631400 | 1760600 | 5576.07 | 1433.07 |
| 24 | tsfuv | 1631400 | 1760600 | 4757.01 | 2252.13 |
| 24 | water_tab | 1631400 | 1760600 | 5920.86 | 1088.28 |
| 25 | surface | 1631750 | 1761300 | 6925.72 | 0 |
| 25 | qbt2 | 1631750 | 1761300 | 6874.37 | 51.35 |
| 25 | qbt1v | 1631750 | 1761300 | 6763.18 | 162.54 |
| 25 | qbt1g | 1631750 | 1761300 | 6672.94 | 252.78 |
| 25 | qbtt | 1631750 | 1761300 | 6669.3 | 256.42 |
| 25 | qct | 1631750 | 1761300 | 6615.63 | 310.09 |
| 25 | qbof | 1631750 | 1761300 | 6300.71 | 625.01 |
| 25 | qbog | 1631750 | 1761300 | 6280.53 | 645.19 |
| 25 | tpf | 1631750 | 1761300 | 5638.29 | 1287.43 |
| 25 | tpt | 1631750 | 1761300 | 5573.29 | 1352.43 |
| 25 | tsfuv | 1631750 | 1761300 | 4725.18 | 2200.54 |
| 25 | water_tab | 1631750 | 1761300 | 5916.66 | 1009.06 |
| 26 | surface | 1632200 | 1762200 | 7018.02 | 0 |
| 26 | qbt3 | 1632200 | 1762200 | 6939.12 | 78.9 |
| 26 | qbt2 | 1632200 | 1762200 | 6888.34 | 129.68 |
| 26 | qbt1v | 1632200 | 1762200 | 6773.12 | 244.9 |
| 26 | qbt1g | 1632200 | 1762200 | 6690.68 | 327.34 |
| 26 | qbtt | 1632200 | 1762200 | 6687.02 | 331 |
| 26 | qct | 1632200 | 1762200 | 6633.17 | 384.85 |
| 26 | qbof | 1632200 | 1762200 | 6300.25 | 717.77 |
| 26 | qbog | 1632200 | 1762200 | 6279.26 | 738.76 |
| 26 | tpf | 1632200 | 1762200 | 5634.72 | 1383.3 |
| 26 | tpt | 1632200 | 1762200 | 5569.72 | 1448.3 |
| 26 | tsfuv | 1632200 | 1762200 | 4632.37 | 2385.65 |
| 26 | water_tab | 1632200 | 1762200 | 5912.4 | 1105.62 |
| 27 | surface | 1633400 | 1764500 | 7040.09 | 0 |
| 27 | qbt3 | 1633400 | 1764500 | 6951.39 | 88.7 |
| 27 | qbt2 | 1633400 | 1764500 | 6905.8 | 134.29 |
| 27 | qbt1v | 1633400 | 1764500 | 6799.46 | 240.63 |
| 27 | qbt1g | 1633400 | 1764500 | 6732.53 | 307.56 |
| 27 | qbtt | 1633400 | 1764500 | 6728.83 | 311.26 |
| 27 | qct | 1633400 | 1764500 | 6679.44 | 360.65 |
| 27 | qbof | 1633400 | 1764500 | 6332.45 | 707.64 |

**TABLE D-1 (continued)**

**STRATIGRAPHIC INFORMATION USED TO CONSTRUCT CROSS SECTIONS**

| Point | Unit Name | Easting (ft) | Northing (ft) | Elevation (ft) | Depth to Base of Unit (ft) |
|---|---|---|---|---|---|
| 27 | qbog | 1633400 | 1764500 | 6309.4 | 730.69 |
| 27 | tpf | 1633400 | 1764500 | 5625.39 | 1414.7 |
| 27 | tpt | 1633400 | 1764500 | 5560.39 | 1479.7 |
| 27 | tsfuv | 1633400 | 1764500 | 4390.78 | 2649.31 |
| 27 | water_tab | 1633400 | 1764500 | 5901.94 | 1138.15 |
| 28 | surface | 1640000 | 1754400 | 6717.27 | 0 |
| 28 | qbt2 | 1640000 | 1754400 | 6652.25 | 65.02 |
| 28 | qbt1v | 1640000 | 1754400 | 6583.22 | 134.05 |
| 28 | qbt1g | 1640000 | 1754400 | 6514.53 | 202.74 |
| 28 | qbtt | 1640000 | 1754400 | 6511.24 | 206.03 |
| 28 | qct | 1640000 | 1754400 | 6485.97 | 231.3 |
| 28 | qbof | 1640000 | 1754400 | 6411.51 | 305.76 |
| 28 | qbog | 1640000 | 1754400 | 6396.2 | 321.07 |
| 28 | tpf | 1640000 | 1754400 | 5424.79 | 1292.48 |
| 28 | tpt | 1640000 | 1754400 | 5361.63 | 1355.64 |
| 28 | tsfuv | 1640000 | 1754400 | 5001.93 | 1715.34 |
| 28 | water_tab | 1640000 | 1754400 | 5821.19 | 896.08 |
| 29 | surface | 1648500 | 1753000 | 6526.21 | 0 |
| 29 | qbt2 | 1648500 | 1753000 | 6510.91 | 15.3 |
| 29 | qbt1v | 1648500 | 1753000 | 6495.86 | 30.35 |
| 29 | qbof | 1648500 | 1753000 | 6525.22 | 0.99 |
| 29 | tpf | 1648500 | 1753000 | 5550.49 | 975.72 |
| 29 | tpt | 1648500 | 1753000 | 5509.79 | 1016.42 |
| 29 | water_tab | 1648500 | 1753000 | 5709.39 | 816.82 |
| 30 | surface | 1648500 | 1755200 | 6523.67 | 0 |
| 30 | qbt1v | 1648500 | 1755200 | 6519.16 | 4.51 |
| 30 | qbof | 1648500 | 1755200 | 6523.62 | 0.05 |
| 30 | tpf | 1648500 | 1755200 | 5579.17 | 944.5 |
| 30 | tpt | 1648500 | 1755200 | 5510.54 | 1013.13 |
| 30 | water_tab | 1648500 | 1755200 | 5722.34 | 801.33 |
| 31 | surface | 1625180 | 1762200 | 7235.3 | 0 |
| 31 | qbt4 | 1625180 | 1762200 | 7173.53 | 61.77 |
| 31 | qbt3 | 1625180 | 1762200 | 7055.47 | 179.83 |
| 31 | qbt2 | 1625180 | 1762200 | 6966.92 | 268.38 |
| 31 | qbt1g | 1625180 | 1762200 | 6781.74 | 453.56 |
| 31 | qbtt | 1625180 | 1762200 | 6777.51 | 457.79 |
| 31 | qct | 1625180 | 1762200 | 6694.69 | 540.61 |
| 31 | qbof | 1625180 | 1762200 | 6459.31 | 775.99 |
| 31 | qbog | 1625180 | 1762200 | 6437.06 | 798.23 |
| 31 | tpf | 1625180 | 1762200 | 5743.44 | 1491.86 |

**TABLE D-1 (continued)**

**STRATIGRAPHIC INFORMATION USED TO CONSTRUCT CROSS SECTIONS**

| Point | Unit Name | Easting (ft) | Northing (ft) | Elevation (ft) | Depth to Base of Unit (ft) |
|---|---|---|---|---|---|
| 31 | tpt | 1625180 | 1762200 | 5678.44 | 1556.86 |
| 31 | tsfuv | 1625180 | 1762200 | 5254.37 | 1980.93 |
| 31 | water_tab | 1625180 | 1762200 | 6020.27 | 1215.03 |
| 32 | surface | 1625800 | 1763500 | 7178.83 | 0 |
| 32 | qbt4 | 1625800 | 1763500 | 7175.71 | 3.12 |
| 32 | qbt3 | 1625800 | 1763500 | 7065.17 | 113.66 |
| 32 | qbt2 | 1625800 | 1763500 | 6977.15 | 201.69 |
| 32 | qbt1g | 1625800 | 1763500 | 6802.86 | 375.97 |
| 32 | qbtt | 1625800 | 1763500 | 6798.59 | 380.24 |
| 32 | qct | 1625800 | 1763500 | 6712.28 | 466.55 |
| 32 | qbof | 1625800 | 1763500 | 6487.14 | 691.69 |
| 32 | qbog | 1625800 | 1763500 | 6463.4 | 715.43 |
| 32 | tpf | 1625800 | 1763500 | 5764.78 | 1414.05 |
| 32 | tpt | 1625800 | 1763500 | 5699.78 | 1479.05 |
| 32 | tsfuv | 1625800 | 1763500 | 5120.32 | 2058.51 |
| 32 | water_tab | 1625800 | 1763500 | 6015.11 | 1163.72 |
| 33 | surface | 1626200 | 1764300 | 7081.53 | 0 |
| 33 | qbt3 | 1626200 | 1764300 | 7070.05 | 11.48 |
| 33 | qbt2 | 1626200 | 1764300 | 6983.59 | 97.94 |
| 33 | qbt1g | 1626200 | 1764300 | 6815.85 | 265.68 |
| 33 | qbtt | 1626200 | 1764300 | 6811.57 | 269.96 |
| 33 | qct | 1626200 | 1764300 | 6723.62 | 357.91 |
| 33 | qbof | 1626200 | 1764300 | 6504.28 | 577.25 |
| 33 | qbog | 1626200 | 1764300 | 6479.6 | 601.93 |
| 33 | tpf | 1626200 | 1764300 | 5777.92 | 1303.61 |
| 33 | tpt | 1626200 | 1764300 | 5712.92 | 1368.61 |
| 33 | tsfuv | 1626200 | 1764300 | 5037.82 | 2043.71 |
| 33 | water_tab | 1626200 | 1764300 | 6010.01 | 1071.52 |
| 34 | surface | 1626700 | 1765200 | 7184.43 | 0 |
| 34 | qbt4 | 1626700 | 1765200 | 7180.26 | 4.17 |
| 34 | qbt3 | 1626700 | 1765200 | 7073.82 | 110.61 |
| 34 | qbt2 | 1626700 | 1765200 | 6989.87 | 194.56 |
| 34 | qbt1g | 1626700 | 1765200 | 6829.42 | 355.01 |
| 34 | qbtt | 1626700 | 1765200 | 6825.12 | 359.31 |
| 34 | qct | 1626700 | 1765200 | 6736.76 | 447.67 |
| 34 | qbof | 1626700 | 1765200 | 6522.61 | 661.82 |
| 34 | qbog | 1626700 | 1765200 | 6496.89 | 687.54 |
| 34 | tpf | 1626700 | 1765200 | 5793.31 | 1391.12 |
| 34 | tpt | 1626700 | 1765200 | 5728.31 | 1456.12 |
| 34 | tsfuv | 1626700 | 1765200 | 4940.6 | 2243.83 |

**TABLE D-1 (continued)**

**STRATIGRAPHIC INFORMATION USED TO CONSTRUCT CROSS SECTIONS**

| Point | Unit Name | Easting (ft) | Northing (ft) | Elevation (ft) | Depth to Base of Unit (ft) |
|---|---|---|---|---|---|
| 34 | water_tab | 1626700 | 1765200 | 6004.52 | 1179.91 |
| 35 | surface | 1627560 | 1766860 | 7192.67 | 0 |
| 35 | qbt4 | 1627560 | 1766860 | 7188.82 | 3.85 |
| 35 | qbt3 | 1627560 | 1766860 | 7082.72 | 109.95 |
| 35 | qbt2 | 1627560 | 1766860 | 7000.49 | 192.18 |
| 35 | qbt1g | 1627560 | 1766860 | 6855.71 | 336.96 |
| 35 | qbtt | 1627560 | 1766860 | 6851.36 | 341.31 |
| 35 | qct | 1627560 | 1766860 | 6763.44 | 429.23 |
| 35 | qbof | 1627560 | 1766860 | 6540.77 | 651.9 |
| 35 | qbog | 1627560 | 1766860 | 6513.16 | 679.51 |
| 35 | tpf | 1627560 | 1766860 | 5820.71 | 1371.96 |
| 35 | tpt | 1627560 | 1766860 | 5755.71 | 1436.96 |
| 35 | tsfuv | 1627560 | 1766860 | 4868.83 | 2323.84 |
| 35 | water_tab | 1627560 | 1766860 | 5997.2 | 1195.47 |
| 36 | surface | 1619580 | 1762600 | 7297.22 | 0 |
| 36 | qbt3 | 1619580 | 1762600 | 7186.61 | 110.61 |
| 36 | qbt2 | 1619580 | 1762600 | 7069.06 | 228.16 |
| 36 | qbt1g | 1619580 | 1762600 | 6976.89 | 320.33 |
| 36 | qbtt | 1619580 | 1762600 | 6972.21 | 325.01 |
| 36 | qct | 1619580 | 1762600 | 6880.82 | 416.4 |
| 36 | qbof | 1619580 | 1762600 | 6600.59 | 696.63 |
| 36 | qbog | 1619580 | 1762600 | 6577.04 | 720.18 |
| 36 | tpf | 1619580 | 1762600 | 5798.04 | 1499.18 |
| 36 | tpt | 1619580 | 1762600 | 5733.04 | 1564.18 |
| 36 | tsfuv | 1619580 | 1762600 | 5712.28 | 1584.94 |
| 36 | water_tab | 1619580 | 1762600 | 6188.81 | 1108.41 |
| 37 | surface | 1613000 | 1765300 | 7556.01 | 0 |
| 37 | qbt5 | 1613000 | 1765300 | 7499.72 | 56.29 |
| 37 | qbt4 | 1613000 | 1765300 | 7502.94 | 53.07 |
| 37 | qbt1g | 1613000 | 1765300 | 7209.45 | 346.56 |
| 37 | qbtt | 1613000 | 1765300 | 7204.21 | 351.8 |
| 37 | qct | 1613000 | 1765300 | 7109.23 | 446.78 |
| 37 | qbof | 1613000 | 1765300 | 6775.25 | 780.76 |
| 37 | qbog | 1613000 | 1765300 | 6747.67 | 808.34 |
| 37 | tpf | 1613000 | 1765300 | 5895.55 | 1660.46 |
| 37 | tpt | 1613000 | 1765300 | 5830.55 | 1725.46 |
| 38 | surface | 1613700 | 1767560 | 7534.63 | 0 |
| 38 | qbt5 | 1613700 | 1767560 | 7515.43 | 19.2 |
| 38 | qbt4 | 1613700 | 1767560 | 7488.14 | 46.49 |
| 38 | qbt1g | 1613700 | 1767560 | 7185.91 | 348.72 |

**TABLE D-1 (continued)**

**STRATIGRAPHIC INFORMATION USED TO CONSTRUCT CROSS SECTIONS**

| Point | Unit Name | Easting (ft) | Northing (ft) | Elevation (ft) | Depth to Base of Unit (ft) |
|---|---|---|---|---|---|
| 38 | qbtt | 1613700 | 1767560 | 7180.59 | 354.04 |
| 38 | qct | 1613700 | 1767560 | 7102.22 | 432.41 |
| 38 | qbof | 1613700 | 1767560 | 6763.62 | 771.01 |
| 38 | qbog | 1613700 | 1767560 | 6732.47 | 802.16 |
| 38 | tpf | 1613700 | 1767560 | 5905.29 | 1629.34 |
| 38 | tpt | 1613700 | 1767560 | 5840.29 | 1694.34 |
| 39 | surface | 1614470 | 1769900 | 7551.65 | 0 |
| 39 | qbt5 | 1614470 | 1769900 | 7503.01 | 48.64 |
| 39 | qbt4 | 1614470 | 1769900 | 7476.94 | 74.71 |
| 39 | qbt3 | 1614470 | 1769900 | 7429.81 | 121.84 |
| 39 | qbt1g | 1614470 | 1769900 | 7250.67 | 300.98 |
| 39 | qbtt | 1614470 | 1769900 | 7245.26 | 306.39 |
| 39 | qct | 1614470 | 1769900 | 7187.23 | 364.42 |
| 39 | qbof | 1614470 | 1769900 | 6905.24 | 646.41 |
| 39 | qbog | 1614470 | 1769900 | 6869.61 | 682.04 |
| 39 | tpf | 1614470 | 1769900 | 5905.67 | 1645.98 |
| 39 | tpt | 1614470 | 1769900 | 5840.67 | 1710.98 |
| 40 | surface | 1615310 | 1771600 | 7490.57 | 0 |
| 40 | qbt5 | 1615310 | 1771600 | 7482.74 | 7.83 |
| 40 | qbt4 | 1615310 | 1771600 | 7461.42 | 29.15 |
| 40 | qbt3 | 1615310 | 1771600 | 7390.69 | 99.88 |
| 40 | qbt2 | 1615310 | 1771600 | 7338.27 | 152.3 |
| 40 | qbt1g | 1615310 | 1771600 | 7271.52 | 219.05 |
| 40 | qbtt | 1615310 | 1771600 | 7266.07 | 224.5 |
| 40 | qct | 1615310 | 1771600 | 7206.37 | 284.2 |
| 40 | qbof | 1615310 | 1771600 | 6979.23 | 511.34 |
| 40 | qbog | 1615310 | 1771600 | 6940.25 | 550.32 |
| 40 | tpf | 1615310 | 1771600 | 5902.96 | 1587.61 |
| 40 | tpt | 1615310 | 1771600 | 5837.96 | 1652.61 |
| 41 | surface | 1615800 | 1772850 | 7523.99 | 0 |
| 41 | qbt5 | 1615800 | 1772850 | 7477.48 | 46.51 |
| 41 | qbt4 | 1615800 | 1772850 | 7446.61 | 77.38 |
| 41 | qbt3 | 1615800 | 1772850 | 7358.83 | 165.16 |
| 41 | qbt2 | 1615800 | 1772850 | 7350.06 | 173.93 |
| 41 | qbt1g | 1615800 | 1772850 | 7218.44 | 305.55 |
| 41 | qbtt | 1615800 | 1772850 | 7212.94 | 311.05 |
| 41 | qct | 1615800 | 1772850 | 7143.82 | 380.17 |
| 41 | qbof | 1615800 | 1772850 | 6932.51 | 591.48 |
| 41 | qbog | 1615800 | 1772850 | 6892.54 | 631.45 |
| 41 | tpf | 1615800 | 1772850 | 5904.79 | 1619.2 |

## TABLE D-1 (continued)

## STRATIGRAPHIC INFORMATION USED TO CONSTRUCT CROSS SECTIONS

| Point | Unit Name | Easting (ft) | Northing (ft) | Elevation (ft) | Depth to Base of Unit (ft) |
|---|---|---|---|---|---|
| 41 | tpt | 1615800 | 1772850 | 5839.79 | 1684.2 |
| 42 | surface | 1616800 | 1774750 | 7409.3 | 0 |
| 42 | qbt4 | 1616800 | 1774750 | 7367.03 | 42.27 |
| 42 | qbt3 | 1616800 | 1774750 | 7292.19 | 117.11 |
| 42 | qbt2 | 1616800 | 1774750 | 7364.69 | 44.6 |
| 42 | qbt1g | 1616800 | 1774750 | 7237.43 | 171.87 |
| 42 | qbtt | 1616800 | 1774750 | 7231.87 | 177.43 |
| 42 | qct | 1616800 | 1774750 | 7142.73 | 266.57 |
| 42 | qbof | 1616800 | 1774750 | 6870.29 | 539.01 |
| 42 | qbog | 1616800 | 1774750 | 6829.64 | 579.66 |
| 42 | tpf | 1616800 | 1774750 | 5947.68 | 1461.62 |
| 42 | tpt | 1616800 | 1774750 | 5882.68 | 1526.62 |
| 43 | surface | 1625100 | 1767600 | 7124.65 | 0 |
| 43 | qbt2 | 1625100 | 1767600 | 7050.42 | 74.23 |
| 43 | qbt1g | 1625100 | 1767600 | 6927.56 | 197.09 |
| 43 | qbtt | 1625100 | 1767600 | 6922.93 | 201.72 |
| 43 | qct | 1625100 | 1767600 | 6830.62 | 294.03 |
| 43 | qbof | 1625100 | 1767600 | 6627.35 | 497.3 |
| 43 | qbog | 1625100 | 1767600 | 6598.01 | 526.64 |
| 43 | tpf | 1625100 | 1767600 | 5797.95 | 1326.7 |
| 43 | tpt | 1625100 | 1767600 | 5732.95 | 1391.7 |
| 43 | tsfuv | 1625100 | 1767600 | 5270.31 | 1854.34 |
| 43 | water_tab | 1625100 | 1767600 | 6062.65 | 1062 |
| 44 | surface | 1618110 | 1765460 | 7420.01 | 0 |
| 44 | qbt4 | 1618110 | 1765460 | 7359.05 | 60.96 |
| 44 | qbt3 | 1618110 | 1765460 | 7250.06 | 169.95 |
| 44 | qbt2 | 1618110 | 1765460 | 7156.15 | 263.86 |
| 44 | qbt1g | 1618110 | 1765460 | 7096.91 | 323.1 |
| 44 | qbtt | 1618110 | 1765460 | 7091.96 | 328.05 |
| 44 | qct | 1618110 | 1765460 | 7003.63 | 416.38 |
| 44 | qbof | 1618110 | 1765460 | 6721.84 | 698.17 |
| 44 | qbog | 1618110 | 1765460 | 6694.18 | 725.83 |
| 44 | tpf | 1618110 | 1765460 | 5837.51 | 1582.5 |

Source: Data from the site-wide geologic model provided by Greg Cole (EES-1)

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# Appendix E

*List of Contributors*

| Name and Affiliation | Education and Expertise | Function |
|---|---|---|
| *Roy Bohn (EM/ER)* | *B.S. Biology<br>18 years experience in environmental monitoring and regulatory compliance* | *Regulatory compliance support* |
| *David Broxton (EES-1)* | *M.S. Geology<br>20 years experience conducting field investigations in geology, geologic disposal of high-level nuclear waste, and project management* | *Canyons technical team leader and technical lead for geology* |
| *Karen Burkheimer (Los Alamos Technical Associates, Inc.)* | *A.S. Business Management<br>9 years experience in records management; 4 years experience in document control and archival retrieval* | *Archival research and document production support* |
| *Fran Chapman (Los Alamos Technical Associates, Inc.)* | *16 years experience in business<br>2 years in protocol; 3 years in purchasing; 9 years in word processing, data entry, and document production; and 2 years in law* | *Document production support* |
| *Leslie Dale (Science Applications International Corporation)* | *M.S. Geology<br>6 years experience in site characterization and remediation, waste management, and regulatory compliance* | *Technical support for geology, archival research, and technical author* |
| *Michael Dale (NMED DOE OB)* | *M.S. Geology with emphasis on hydrogeology<br>6 years experience* | *Provided oversight input for hydrologic processes* |
| *Alison Dorries (EES-13)* | *Ph.D. Chemistry/M.P.H. Public Health<br>9 years experience in toxicology, pulmonary health research, regulation development, and human health risk assessment* | *Analysis and assessment focus area leader* |
| *Christy Fläming (Los Alamos Technical Associates, Inc.)* | *25 years experience in graphics, illustration, printing, and document production* | *Artist/designer and graphics team leader* |
| *Teralene Foxx (ESH-20)* | *M.S. Biology<br>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 and support* |
| *Bruce Gallaher (ESH-18)* | *M.S. Hydrology<br>15 years experience in waste management and contaminant hydrology* | *Principal investigator for hydrology* |
| *Catherine Goetz (ICF Kaiser Engineers)* | | *Technical support for TA-18 RFI data* |
| *Bob Gray (Daniel B. Stephens & Associates)* | *M.S. Earth and Planetary Sciences with emphasis on hydrogeology<br>16 years experience in minerals exploration and development, geologic characterization, and project management; 3 years experience in hydrologic research and as a staff and project-level hydrogeologist in the environmental consulting business* | *Technical lead for surface water hydrology* |
| *Marcia Jones (FIMAD)* | *7 years experience in the geographical information system specializing in cartography* | *Produced large maps* |
| *Richard Kelley (Los Alamos Technical Associates, Inc.)* | *B.S. Geology<br>18 years experience in geologic and petroleum geologic exploration including 8 years of environmental and hydrological specialization* | *GIS mapping consultant* |
| *Richard Koch (Science Applications International Corporation)* | *M.S. Geology<br>23 years experience in conducting field investigations and integrating and analyzing geologic, hydrologic, geophysical, and geochemical data* | *Document lead and technical support for geology, hydrogeology, and geochemistry* |

| Name and Affiliation | Education and Expertise | Function |
|---|---|---|
| *Patrick Longmire (CST-7)* | *Ph.D. Aqueous Geochemistry 19 years experience in field hydrogeochemistry and soil chemistry regulatory oversight, the UMTRA project, and RCRA/CERCLA remediation* | *Technical lead for aqueous geochemistry* |
| *Max Maes (ESH-18)* | *Environmental surveillance* | *Provided water level data* |
| *Pamela Maestas (Los Alamos Technical Associates, Inc.)* | *B.A. Human Resources Management 2 years experience as an electronic publications specialist; 3 years experience in word processing, data entry, and various software* | *Electronic publications specialist* |
| *Karl Maness (ICF Kaiser Engineers)* | *B.S. Rangeland Ecology and Management (emphasis in landscape restoration and natural resource management) 2-1/2 years experience in HSWA site investigation and remediation* | *Technical support for TA-18 RFI data* |
| *Sandy Martinez (Los Alamos Technical Associates, Inc.)* | *7 years experience in the Yucca Mountain Project* | *Document production support* |
| *Steve McLin (ESH-18)* | *Ph.D. Hydrology* | *Technical support* |
| *Joe Mose (DOE)* | | *DOE liaison* |
| *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* | *Ecological risk assessment support* |
| *Maureen Oakes (CIC-1)* | *B.S. Biology 7 years experience writing and editing technical documents, including environment, safety, and health and environmental restoration documentation* | *Technical writer/editor* |
| *Allyn Pratt (EES-13)* | *B.S. Environmental Science/M.B.A. 19 years experience in natural resource management, project management, and environmental management* | *Canyons focus team 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* |
| *David Rogers (ESH-18)* | *Ph.D. Earth Sciences (Hydrogeology) 25 years experience in geosciences including 11 years as a geophysicist; 6 years experience in hydrological investigations, modeling of groundwater flow and contaminant transport, and geochemistry* | *Technical support* |
| *David Shaull (ESH-18)* | *33 years experience in all phases of hydrologic data collection and analysis* | *Provided gaging station data* |
| *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 and development of conceptual model* |
| *Mark Tardiff (Neptune and Company, Inc.)* | | *Risk assessment support* |