Work Plan
for
Mortandad Canyon

Environmental
Restoration
Project

September 1997

A Department of Energy
Environmental Cleanup Program

Los Alamos
NATIONAL LABORATORY

LA-UR-97-3291

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EXECUTIVE SUMMARY

Purpose

This Resource Conservation and Recovery Act (RCRA) facility investigation (RFI) work plan establishes the technical approach and methodology for environmental investigation of the Mortandad Canyon system at Los Alamos National Laboratory (hereafter "the Laboratory"). Specifically, 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

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

This work plan presents a technical approach that will be applied to the investigation of the Mortandad Canyon system that is, or may have been, affected by Laboratory operations. This work plan provides information specific to the Mortandad Canyon system regarding historical land uses and Laboratory operations; environmental setting; conceptual model for contaminant occurrence, transport, and exposure route (hereafter "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 for Canyons Investigations (hereafter "the core document").

The groundwater investigations outlined in this work plan were developed in cooperation with other Laboratory investigators who are also responsible for groundwater issues. As a result of these consultations, Mortandad Canyon groundwater investigations are an integral part of the Laboratory's Hydrogeologic Workplan, which was initially developed for the Groundwater Protection Management Program Plan. In addition, the Mortandad Canyon investigation will include supplemental characterization of three potential release sites (PRSs) located in or adjacent to the main canyon and tributaries.

Response to Regulatory Requirements

The Laboratory Environmental Restoration (ER) Project addresses the requirements of Module VIII of the Laboratory's Hazardous Waste Facility Permit (the Hazardous and Solid Waste Amendments [HSWA] Module) (modification dated May 19, 1994), which was issued by the Environmental Protection Agency (EPA) to address corrective actions at the Laboratory. The New Mexico Environment Department (NMED) is the administrative authority for the HSWA Module. This 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 Mortandad 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 solid waste management units (SWMUs). The Mortandad Canyon pathway crosses American Indian and private land and eventually contributes sediments, surface water, and groundwater to the Rio Grande. Because the Mortandad Canyon system and the associated transport processes, rather than distinct SWMUs, are identified as the focus, the Mortandad Canyon investigation is different from SWMU-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 SWMUs although supplemental characterization of three PRSs is included in the proposed 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.

Background

Description of Field Unit 4

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

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

Conceptual Model and Technical Approach

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

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

The Mortandad Canyon characterization activities, presented in Chapter 7 of this work plan, are designed to collect data for risk assessment based on present-day contaminant levels, to evaluate the potential impact of contaminant transport into and within the watershed and, subsequently, to transition to a long-term monitoring program. The conceptual model of contaminant transport and the framework for investigations of human or ecological risk at future times need to be refined before studies of future risk can be undertaken. Transferring ongoing characterization activities to the Laboratory's long-term monitoring program ensures that later, when more detailed regulatory guidance and conceptual (and numerical) models are available, studies of current and future risk can be performed.

Sampling and Analysis Strategy

Characterization activities in the Mortandad Canyon investigation are presented in detail in Chapter 7 of this work plan and will include

- *detailed mapping and description of the geomorphology of selected canyon reaches;*
- *drilling and coring of boreholes to elucidate details on the hydrogeologic structure of the Pajarito Plateau;*
- *sampling and analysis of surface and near-surface sediments on the canyon floors to evaluate surface exposure pathways, historic contaminant transport, and potential sources for migration to groundwater;*
- *sampling and analysis of surface and groundwater to assess the transport pathways and potential impacts on the different zones of saturation; and*
- *supplemental characterization of three PRSs located in or adjacent to the main canyon and tributaries.*

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

For example, sediment sampling and analysis will largely be restricted to post-1942 canyon deposits in both the active channels and the floodplains if pre-1943 deposits are not contaminated. Furthermore, activities will focus on identifying areas most likely to contain contaminants, determining the geomorphic settings where the greatest contaminant inventories could occur (post-1942 sediments), and assessing the susceptibility of the contaminants to redistribution in sediments and dust. Mesa tops, alluvial and colluvial deposits on canyon walls, and drainages of canyon walls may contain contaminants from individual

PRSs. These sites have been or will be characterized as part of RFIs conducted by other ER Project field units, and preliminary RFIs have been performed at all PRSs proposed herein for supplemental characterization.

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

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

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

Schedule and Reporting

Annex I of the core document contains a preliminary schedule for conducting the Mortandad Canyon investigation. The schedule is subject to change based on future DOE funding.

The Laboratory, DOE, NMED, EPA, and the stakeholders have not produced a final definition of the types and schedule of reports for the efforts in executing this work plan and sampling and analysis plan. Because Mortandad Canyon and tributaries contain three PRSs proposed herein for supplemental characterization (the Technical Area 50 Radioactive Liquid Waste Treatment Facility outfall [PRS No. 50-006(d)], contamination associated with a release [PRS No. 50-006(a)], and the sediment traps [PRS No. 00-001]), reporting schedules pertinent to the HSWA Module are directly applicable.

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.

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 Mortandad Canyon and its tributaries and summarizes available data germane to the current investigation.

Chapter 4 develops the conceptual model for the Mortandad Canyon system and its 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 Mortandad Canyon and describes more fully the implementation of the reach concept for investigations. Elements of the quality assurance project plan are included; groundwater investigations are described in detail.

Appendixes

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

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

Appendix C contains the analytical results for sediment samples collected at PRS No. 50-006(d).

Appendix D contains drilling and well completion data for wells, boreholes, and moisture access tubes in the Mortandad Canyon system.

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

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ACRONYMS AND ABBREVIATIONS

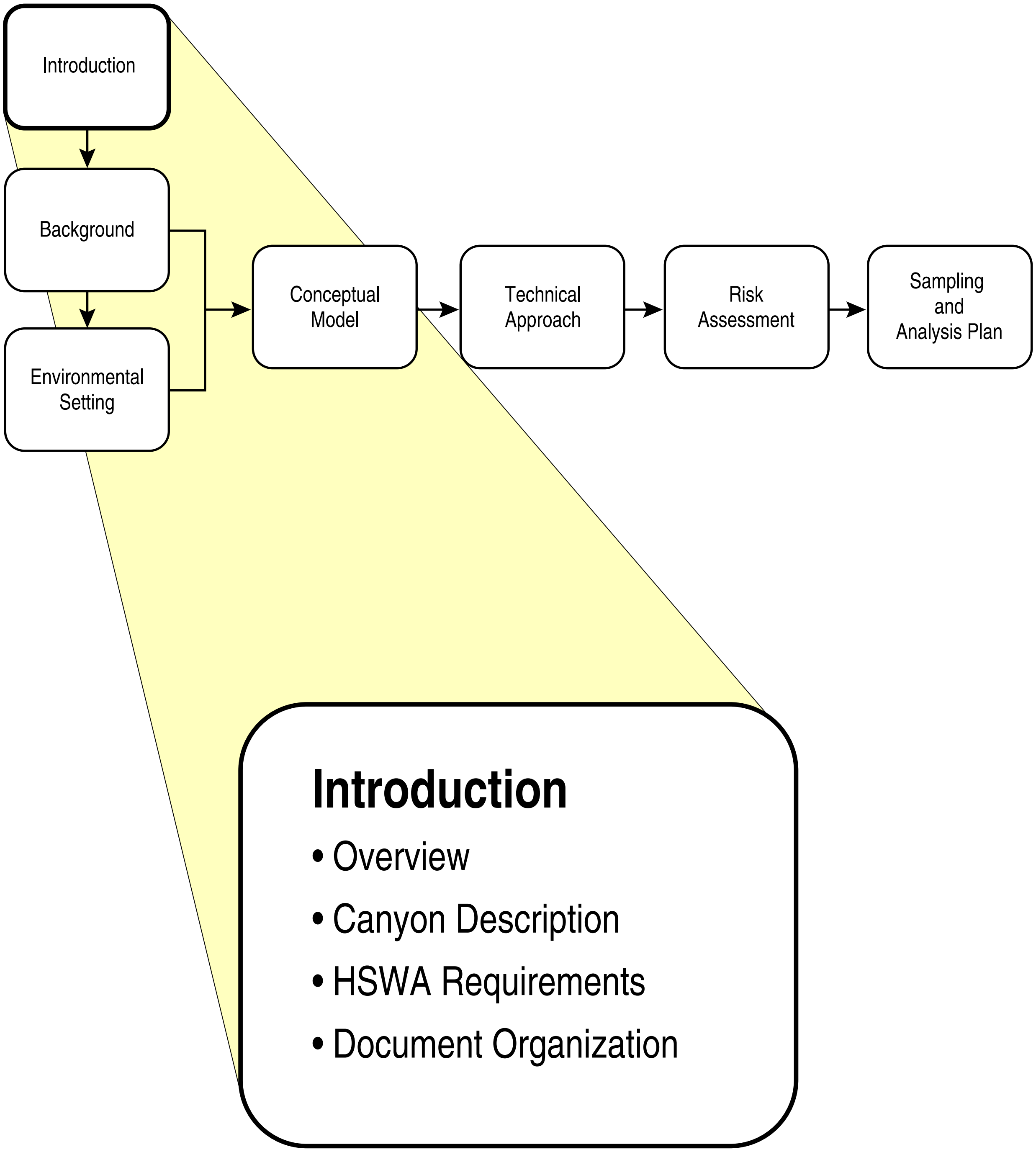
AA	*administrative authority*
AEC	*Atomic Energy Commission*
AGL	*above ground level*
API	*American Petroleum Institute*
ASTM	*American Society for Testing and Materials*
BDL	*below detection limit*
BSV	*background screening value*
BT	*Bandelier Tuff*
C/CH	*core hole, not completed*
CEARP	*Comprehensive Environmental Assessment and Response Program*
CEDE	*committed effective dose equipment*
cfs	*cubic feet per second*
COPC	*chemical of potential concern*
cpm	*counts per minute*
CT	*Cerro Toledo (interval)*
CVAA	*cold vapor atomic absorption*
CWA	*Clean Water Act*
DCG	*derived concentration guide*
D&D	*decontamination and decommissioning*
DOC	*dissolved organic carbon*
DOE	*Department of Energy*
DQO	*data quality objective*
EC	*expedited cleanup*
ECD	*electron capture detector*
EDL	*estimated detection limit*
EPA	*Environmental Protection Agency*
EQL	*estimated quantitation limit*
ER	*Environmental Restoration*
ESAL	*ecotoxicological screening action level*
ESG	*Environmental Surveillance Group*
ESH	*Environment, Safety, and Health (Laboratory Division)*
ET	*evapotranspiration*
ETVAA	*electrothermal vaporization atomic absorption*
FIDLER	*field instrument for detecting low-energy radiation*
FIMAD	*Facility for Information Management, Analysis, and Display*
FU	*field unit*
FY	*fiscal year*
GC	*gas chromatography*

GC/ECD	*gas chromatography/electron capture detector*
GC/MS	*gas chromatography/mass spectrometry*
GFAA	*graphite furnace atomic absorption*
GL	*ground level*
GPC	*gas proportional counter*
gpd	*gallons per day*
gpm	*gallons per minute*
GS	*gaging station*
HEPA	*high-efficiency particulate air*
HPGe	*high-purity germanium*
HSWA	*Hazardous and Solid Waste Amendments*
HTO	*tritiated water*
IA	*interim action*
IC	*ion chromatography*
ICPES	*inductively coupled plasma emission spectroscopy*
ICPMS	*inductively coupled plasma mass spectrometry*
IWP	*Installation Work Plan*
K_d	*distribution coefficient*
LAMPRE	*Los Alamos molten plutonium reactor experiment*
LAPRE	*Los Alamos power reactor experiment*
LEHPGe	*low energy, high-purity germanium*
LSC	*liquid scintillation counting*
LSD MP	*land surface datum measuring point*
M	*moisture access hole*
Ma	*million years ago*
MC	*Mortandad Canyon*
MCL	*maximum contaminant level*
MCO	*Mortandad Canyon observation*
MDA	*material disposal area*
MDA	*minimum detectable activity*
MOU	*memorandum of understanding*
MP	*measuring point*
MS	*mass spectrometry*
MSL	*mean sea level*
n/a	*location has not been surveyed*
NA	*not analyzed*
N/A	*not applicable*
N.A.	*not available*
NaI(Tl)	*thallium doped sodium iodide*
NFA	*no further action*

NM	New Mexico
NMED	New Mexico Environment Department
NMED OB	New Mexico Environment Department Oversight Bureau
NMWQCC	New Mexico Water Quality Control Commission
NOD	notice of deficiency
NPDES	National Pollutant Discharge Elimination System
NR	not reported
NTS	Nevada Test Site
NTU	nephelometric turbidity unit
O	observation (well)
OI	observation intermediate (well)
OU	operable unit
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
PDL	public dose limit
ppm	parts per million
PRS	potential release site
PTD	proposed total depth
PVC	polyvinyl chloride
Qbo	Otowi Member of the Bandelier Tuff
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 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
QC	quality control
R	regional aquifer
RCRA	Resource Conservation and Recovery Act
RFI	RCRA facility investigation
RLWTF	Radioactive Liquid Waste Treatment Facility
RP	report pending
SAL	screening action level
SF	Santa Fe
SI	saturation index
SOP	standard operating procedure
SVOC	semivolatile organic compound
SWL	static water level (below measuring point)
SWSC	Sanitary Wastewater Systems Consolidation
TA	technical area
TBD	to be determined

TD	*total depth*
TDS	*total dissolved solids*
TEDE	*total effective dose equivalent*
TI	*thermal ionization*
TIMS	*thermal ionization mass spectrometry*
TPH	*total petroleum hydrocarbons*
TSC	*Ten Site Canyon*
TW	*test well*
UHTREX	*ultra-high-temperature reactor experiment*
Unc	*uncertainty in counting statistics*
US	*United States*
USGS	*United States Geological Survey*
USRADS	*Ultrasonic Ranging and Data System*
UST	*underground storage tank*
UTL	*upper tolerance limit*
VCA	*voluntary corrective action*
VOC	*volatile organic compound*
WB	*water balance*

Chapter 1


Introduction
Background
Environmental Setting
Conceptual Model
Technical Approach
Risk Assessment
Sampling and Analysis Plan
Introduction
• Overview
• Canyon Description
• HSWA Requirements
• Document Organization

1.0 INTRODUCTION

This Resource Conservation and Recovery Act (RCRA) facility investigation (RFI) work plan describes investigations to be conducted in the Mortandad Canyon system as part of the Environmental Restoration (ER) Project at Los Alamos National Laboratory (hereafter "the Laboratory"). These investigations are being conducted by Field Unit 4 personnel. This work plan includes a summary and evaluation of previous hydrogeologic and contaminant studies in the Mortandad 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 Ten Site Canyon and Effluent Canyon; both are tributaries to Mortandad Canyon.

1.1 Purpose

The purpose of the Mortandad 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

- *determine the extent to which the stream channel and active floodplain sediments, and underlying groundwater in Mortandad Canyon have been affected by Laboratory releases;*
- *determine contaminant transport pathways and mechanisms specific to the canyon system and refine the conceptual model for contaminant occurrence, transport, and exposure routes (hereafter "the conceptual model");*
- *assess the potential for interconnections between groundwater in alluvium, intermediate perched zones, and the regional aquifer;*
- *assess present-day risk to human health and ecological systems and evaluate the potential for transport of contaminants to cause human health and ecological risks in the future;*
- *provide supplemental characterization of three potential release sites (PRSs) located in or adjacent to 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 Mortandad 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 Field Unit 4 and other ER Project field units. Results of field investigations conducted by other field units have been included in the planning and implementation of investigations conducted in the Mortandad Canyon system.

1.2 Relationship to Other Documents

This work plan is tiered to the Core Document for Canyons Investigations (hereafter "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, a discussion of the canyon's history, summaries of the environmental setting and previous investigations conducted in Mortandad Canyon, canyon-specific details on the investigation objectives and technical approach, and a comprehensive sampling and analysis plan.

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 Mortandad 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 investigations will follow an iterative approach in which information obtained from each successive borehole and well 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 boreholes and wells. In accordance with the approach discussed in the Hydrogeologic Workplan, changes in the scope of groundwater investigations will be negotiated annually with the regulators.

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

1.3 Location and Environmental Setting

Mortandad Canyon is located on the Pajarito Plateau in the north-central part of the Laboratory (Figure 1.3-1). The canyon heads near the CMR Building (Technical Area [TA] -3, SM-29) at an elevation of about 7417 ft (2261 m) and trends east-southeast across the Laboratory and San Ildefonso Pueblo land. It empties into the Rio Grande in White Rock Canyon at an elevation of 5611 ft (1710 m). The main channel is about 9.8 mi (15.8 km) long, and the total watershed area is approximately 6.0 mi^2 (15.5 km^2). In addition, Cañada del Buey, a major tributary that joins with Mortandad Canyon approximately 0.5 mi (0.8 km) upstream of the Rio Grande, has a total watershed area of 4.3 mi^2 (11.1 km^2) (LANL 1997, 55622).

Radioactive wastewater has been discharged into the Mortandad Canyon system since 1951. Currently, effluent from the Laboratory's Radioactive Liquid Waste Treatment Facility (RLWTF) at TA-50 is the main source of liquid discharges to Mortandad Canyon. The concentrations of selected contaminants in the discharge are regulated under the National Pollutant Discharge Elimination System (NPDES) as NPDES outfall 051. The concentrations of radionuclides not subject to NPDES regulations are targeted for control at levels equal to or less than the Department of Energy (DOE) derived concentration guides for uncontrolled areas in accordance with DOE Order 5400.5 (DOE 1990, 0080). In August 1996 the Laboratory submitted an application for a groundwater discharge plan to the New Mexico Environment Department (NMED) (LANL 1996, 55688). The plan provides for projected discharges ranging from 2.17 to 8.69 million gal. (8213 to 32,890 m^3) per year. The TA-50 RLWTF discharged 5.5 million gal. (20,818 m^3) in 1994 and 4.6 million gal. (17,411 m^3) in 1995 into Mortandad Canyon. Chapter 2 of this work plan contains a more detailed discussion of past and present discharges.

Other significant sources of water into Mortandad Canyon include cooling water tower discharges at TA-48 and TA-35 and storm water runoff from TAs -3, -35, -48, -50, -52, -55, -60, and -63. These discharges are also regulated by NPDES.

PRSs within the Mortandad Canyon watershed are located at TA-3 and TA-60 (Sigma Mesa) (associated with former Operable Unit [OU] 1114); former TA-4, TAs -5, -35, and -48, former TA-42, TAs -52, -55, and -63 (associated with former OU 1129); and TA-50 and material disposal area C (associated with former OU 1147) (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. Three PRSs are located within the area designated herein for investigation, that is, in or adjacent to the main canyon and tributaries: the TA 50 RLWTF outfall (PRS No. 50-006[d]), contamination associated with a release (PRS No. 50-006[a]), and the sediment traps (PRS No. 00-001). The investigations proposed herein include characterization to supplement preliminary RFIs conducted previously at these PRSs.

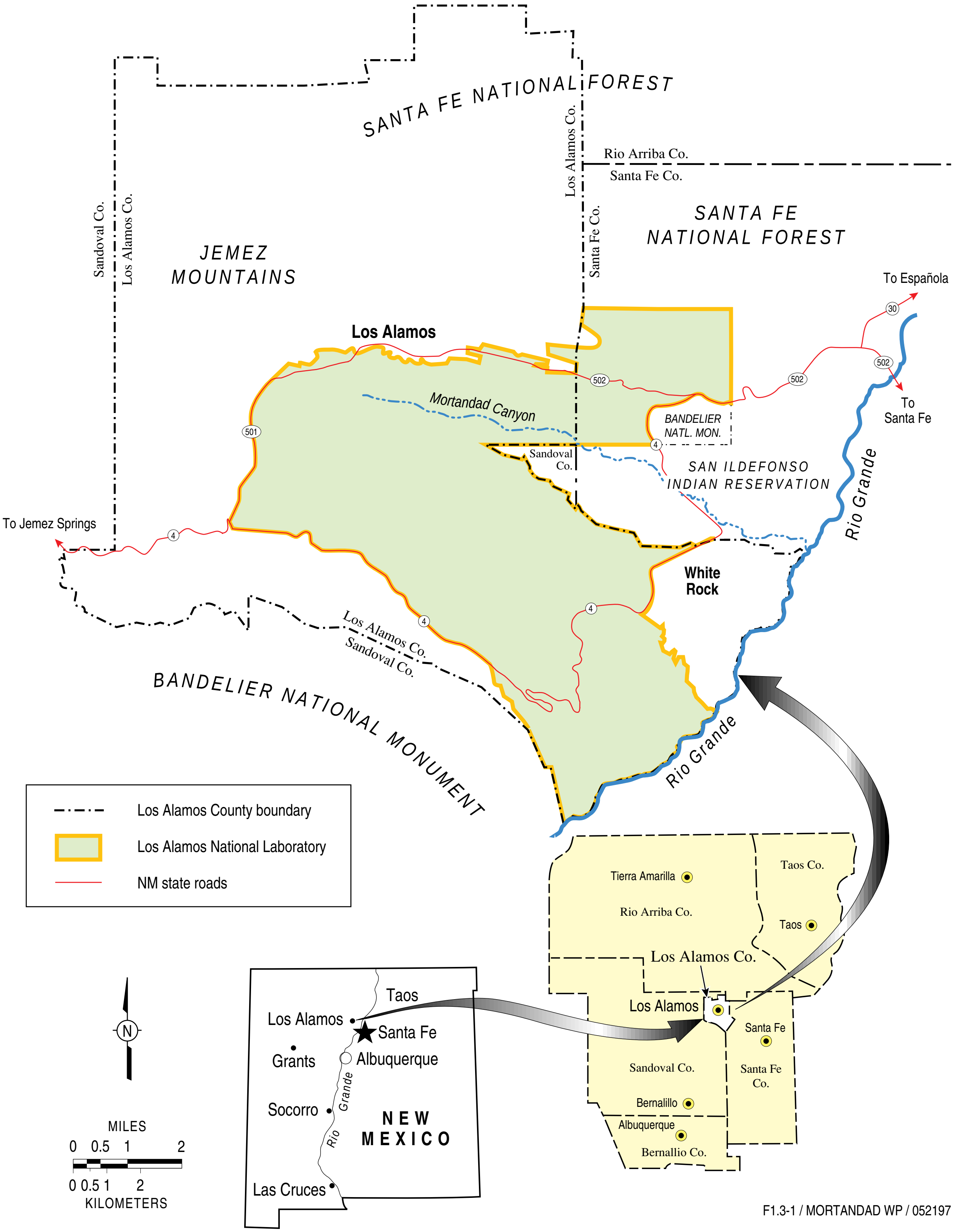


Figure 1.3-1. Location of Mortandad Canyon.

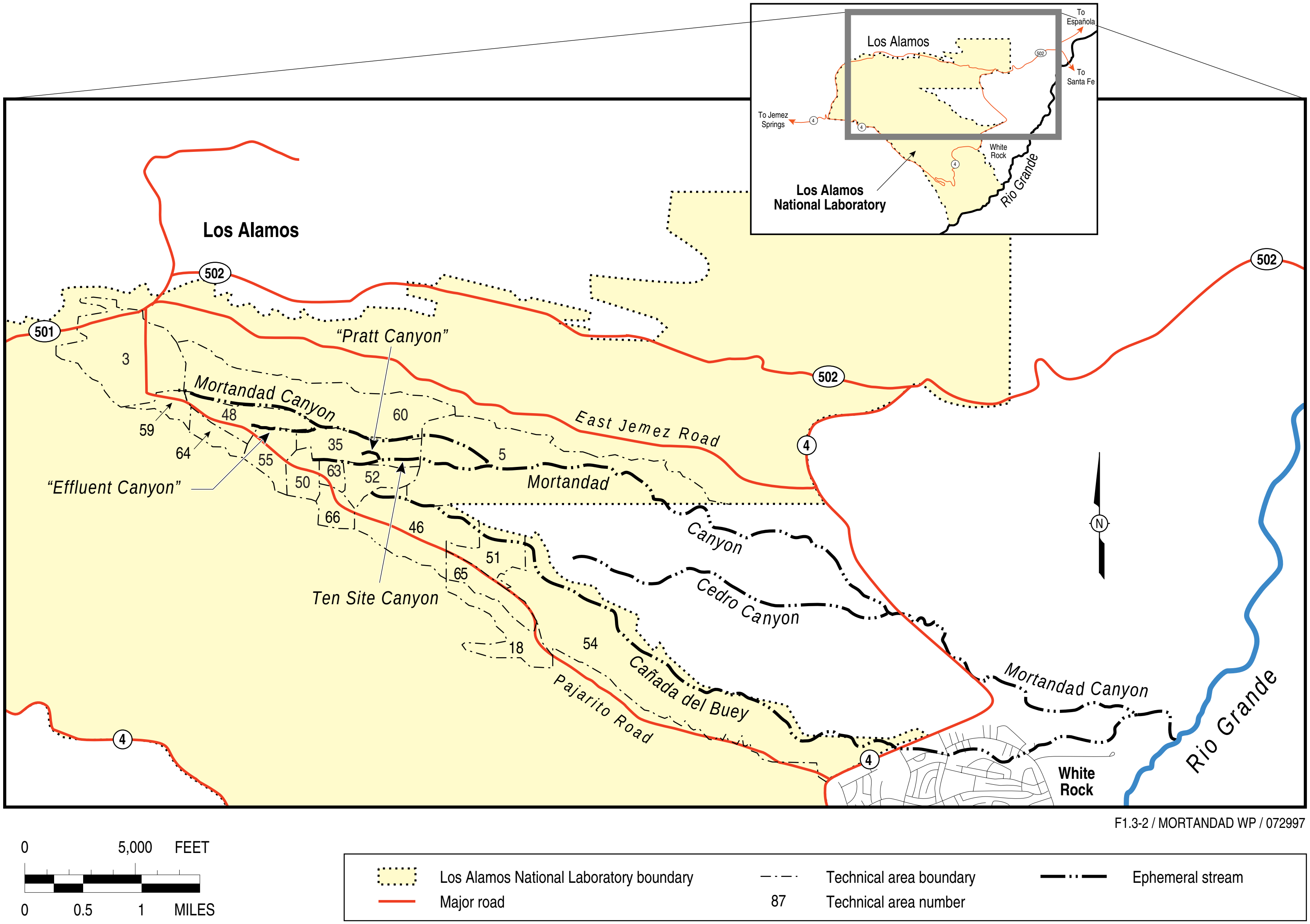


Figure 1.3-2. Laboratory technical areas adjacent to Mortandad Canyon.

1.4 Organization of this Work Plan

Following this introductory chapter, Chapter 2 provides background information on Mortandad Canyon and its tributaries on Laboratory property (Ten Site Canyon and Effluent Canyon), including a description and history of the area and the potential sources of contamination; 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) and in the Glossary of Geology (Bates and Jackson 1987, 50287).

1.5 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

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EPA (US Environmental Protection Agency), April 10, 1990. Module VIII of RCRA Permit No. NM0890010515, EPA Region VI, issued to Los Alamos National Laboratory, Los Alamos, New Mexico, effective May 23, 1990, EPA Region VI, Hazardous Waste Management Division, Dallas, Texas. **(EPA 1990, ER ID Number 1585)**

LANL (Los Alamos National Laboratory), October 25, 1995. "Groundwater Protection Management Program Plan" (draft), Revision 2.0, Los Alamos, New Mexico. **(LANL 1995, ER ID Number 50124)**

LANL (Los Alamos National Laboratory), August 16, 1996. "Ground Water Discharge Plan Application for the TA-50 Radioactive Liquid Waste Treatment Facility," Los Alamos, New Mexico. **(LANL 1996, ER ID Number 55688)**

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 Number 55574)**

LANL (Los Alamos National Laboratory), December 6, 1996. "Hydrogeologic Workplan" (draft), Revision 1.0, Los Alamos, New Mexico. **(LANL 1996, ER ID Number 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 Number 55622)**

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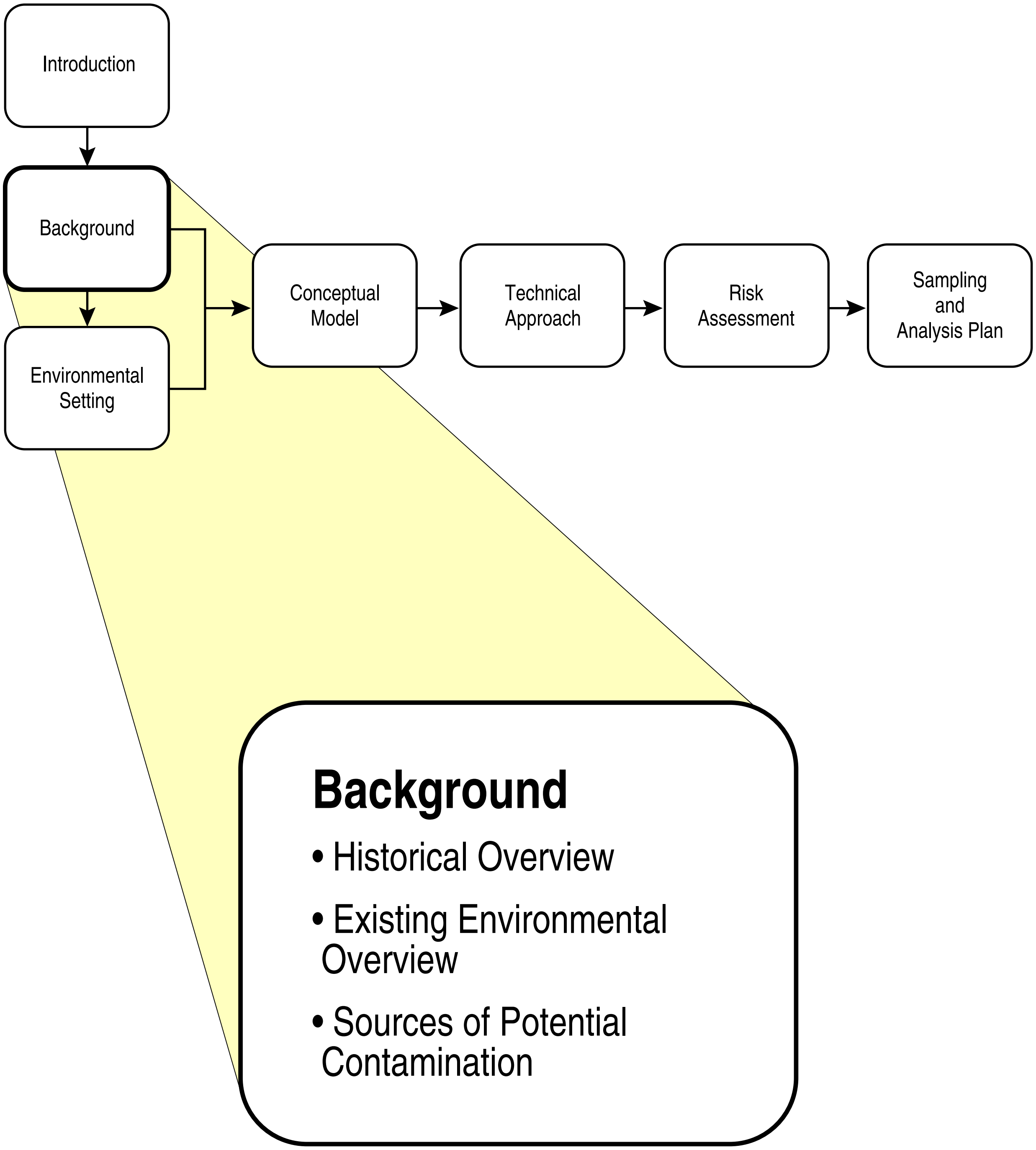
Chapter 2



Background

- Historical Overview
- Existing Environmental Overview
- Sources of Potential Contamination

2.0 BACKGROUND

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

2.1 History of Mortandad Canyon

2.1.1 Prehistoric Use

Habitation and possible use of lower Mortandad Canyon for farming are evidenced by the presence of caves possibly from the Prehistoric Indian Pueblo Period (LANL 1997, 55622 pp. 2–4) in the canyon on Los Alamos National Laboratory (hereafter "the Laboratory") property. Numerous cave habitation sites and a deer trap are present along the north wall of lower Mortandad Canyon. Several caves retain inscriptions and petroglyphs, and one cave, called Cave Kiva, contains well-preserved petroglyphs. This cave has been fitted with access controls to prevent vandalism. To preserve the integrity of the cave sites, they have not been shown on the accompanying maps. The lower canyon floor is broad and was possibly used for garden plots, but no prehistoric structures are known to exist there.

2.1.2 Pre-Laboratory Historic Use

The remains of a homestead are present on the south side of lower Mortandad Canyon on Laboratory property, where a 7-ft-diameter (2.1-m-diameter) cistern and scattered remains of a corrugated tin metal roof and other artifacts are present. An archeological survey of the site performed in 1982 concluded that the artifact assemblage represented limited use during the period circa 1920 to 1940 (Purtymun 1994, 52951). Aerial photographs of the site taken in 1935 show that Mortandad Canyon east of the present-day sediment trap area was cleared and cultivated for crops. The old homestead building was used as a temporary shelter by mounted security patrols during the 1940s and 1950s. The building reportedly burned sometime in the 1950s when it was accidentally ignited by a security patrol preparing coffee.

Sigma Mesa, located north of upper Mortandad Canyon, was also an agricultural site before 1943 (LANL 1993, 51977). The 1935 aerial photographs show that the mesa tops south of Mortandad Canyon in the areas of Technical Areas (TAs) -35, -50, -55, and -63 were also cleared and cultivated for crops.

An old, breached, earthen dam is present in upper Mortandad Canyon. The age of the dam is not known, but it may have been built by the homesteaders to collect surface water runoff for livestock.

2.1.3 Laboratory Operational Use

The primary Laboratory use of Mortandad Canyon has been for liquid waste disposal. Mortandad Canyon and its tributaries have received liquid waste from various Laboratory operations possibly since the Laboratory began operation in 1943. These early discharges were probably limited to outfalls from buildings associated with firing sites located at TA-4 and TA-5 (see Section 2.4.2 and Section 2.4.3). However, the first recorded discharges into Mortandad Canyon and its tributaries occurred coincident with construction of Ten Site, which is now TA-35 on Ten Site Mesa. Sanitary septic systems and the TA-35 wastewater treatment plant began discharging circa 1951. With the continued expansion of Laboratory operations to new sites in the 1950s and 1960s, specifically at TAs -48, -50, and -60, additional discharges began.

Beginning in 1963, radioactive liquid wastes from Laboratory operations have been collected and treated at the Radioactive Liquid Waste Treatment Facility (RLWTF) at TA-50 using classical but effective chemical and physical treatment technology (LANL 1996, 55688). The TA-50 RLWTF has operated continually with periodic upgrades being made to the treatment process. Major upgrades to meet new National Pollutant Discharge Elimination System (NPDES) requirements and the Department of Energy (DOE) derived concentration guides for radionuclides in water in uncontrolled areas (DOE 1990) are being implemented in 1997 and 1998. The discharge has been regulated as NPDES outfall 051 since 1990 and contains typically low levels of radionuclides and other chemical constituents (see Section 2.4.6 for additional information about the TA-50 RLWTF). The discharge flows a short distance downstream in Mortandad Canyon, infiltrates into the alluvium, into a shallow body of perched groundwater in middle Mortandad Canyon.

The Laboratory has installed numerous wells in the canyon alluvium and the hydrogeologic unit immediately below and routinely monitors the groundwater and sediment in the canyon. Monitoring data are reported annually in environmental surveillance reports (for example, Environmental Protection Group 1996, 54769). Evaluation of the monitoring data has shown that most of the radionuclides (fission products and actinides) discharged are adsorbed to the sediments; to date the inventory of transuranic radionuclides (about 400 mCi) discharged to the canyon has been shown to be largely contained within Laboratory boundaries (Stoker et al. 1991, 7530).

Because most of the radionuclides are associated with the sediments, three sediment traps were constructed about 2 mi (3.2 km) downstream from the TA-50 RLWTF outfall in middle Mortandad Canyon. The sediment traps dissipate the energy of major runoff events and capture transported sediments, thus eliminating or reducing radionuclide transport downstream. Two sediment traps were constructed in 1976, and a third was constructed in 1980. The sediment traps have been rebuilt several times, most recently in 1986 to their current configuration (LANL 1996, 55574). Section 2.3.1 provides details on the history and management of the sediment traps. The sediment traps are monitored in accordance with the requirements of Section C.3 of Hazardous and Solid Waste Amendments (HSWA) Module VIII (EPA 1990, 1585) of the Laboratory's Hazardous Waste Facility Permit (hereafter "the HSWA Module") (LANL 1995, 50124).

Environmental Restoration (ER) Project personnel have identified various industrial and sanitary waste outfalls that currently discharge, or discharged in the past, to Mortandad Canyon and its tributaries as potential release sites (PRSs). The PRSs are documented in the Resource Conservation and Recovery Act (RCRA) facility investigation (RFI) work plans for Operable Unit (OU) 1114 (LANL 1993, 51977), OU 1129 (LANL 1992, 7666), and OU 1147 (LANL 1992, 7672). These PRSs are shown in Figure A-1 in Appendix A and listed with current status in Appendix B of this work plan, and are discussed further in this chapter.

The data from routine monitoring and special studies that have been conducted for three decades in the Mortandad Canyon system are voluminous. The results of relevant investigations and monitoring data are discussed in Chapter 3.

2.1.4 Current Recreational Use

The Mortandad Canyon system encompasses land managed by the Laboratory and land owned by San Ildefonso Pueblo (Figure 1.3-2). Currently, hiking trails provide recreational access to the portion of the canyon on Laboratory land. Local residents use a portion of the canyon for activities such as biking, jogging, bird watching, and viewing archaeological sites. The Prehistoric Indian Pueblo Period sites, including Cave Kiva, are popular hiking destinations. The portion of Mortandad Canyon on San Ildefonso Pueblo land is not open to recreational use, and public access is restricted by fences and signs.

In upper Mortandad Canyon Laboratory discharges provide sufficient moisture to support plant communities that are rare in the general environs. Berries, such as strawberries and raspberries, and other edible plants are abundant and may be gathered or consumed by people using the canyon as well as by foraging animals and birds. In middle Mortandad Canyon firewood is collected by area residents.

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 the history of environmental monitoring in Mortandad Canyon is provided in this section, and a discussion of the results of the historical environmental monitoring is provided in Chapter 3.

2.2.1 Historical Environmental Monitoring

From 1951 to 1963 the Laboratory's wastewater treatment plant was operated at TA-35. Routine and accidental discharges from the wastewater treatment plant into Ten Site Canyon and a small tributary known locally as "Pratt Canyon" (a name used herein for convenience only) were monitored sporadically. Some surveillance activities occurred, but the Laboratory's formal environmental surveillance program, which was initiated in 1970, had not yet been implemented. Since 1988 a formal environmental surveillance program has been required under DOE Order 5400.1 (DOE 1988).

In 1960 the United States Geological Survey (USGS) began hydrologic monitoring and studies in Mortandad Canyon to provide information supporting the selection of a site for discharging treated low-level radioactive liquid waste (Baltz et al. 1963, 8402). The existing wastewater treatment plant at TA-35 was not considered adequate to handle the increasing volume of liquid radioactive wastes associated with expanding Laboratory operations; therefore, the Laboratory and USGS conducted investigations to select the site of the new RLWTF and the canyon into which low-level liquid wastes could best be discharged. Mortandad Canyon was selected for discharge based on the following criteria (Baltz et al. 1963, 8402):

- *relatively isolated location on the Pajarito Plateau,*
- *relatively small drainage area, and*
- *large amount of alluvium.*

After the RLWTF began operations at TA-50 in 1963, monitoring of the alluvial groundwater and of contaminants in the groundwater and the sediments continued (Purtymun 1964, 11822; Purtymun 1967, 8987; Purtymun and Kunkler 1967, 8888; Purtymun 1974, 5476; Purtymun 1983, 6407; Nyhan et al. 1982, 7164; Environmental Protection Group 1996, 54769). The discharges provided a unique opportunity to study the mechanisms of radionuclide transport in sediments and groundwater; the results of several studies were reported within three to five years after the TA-50 RLWTF began operations. The Environmental Surveillance Group began systematic monitoring in the canyons in 1970; data are reported in the Laboratory's annual environmental surveillance reports and other special reports (for example, ESG 1990, 6995; Elder and Knoell 1986, 6670; Montoya 1991, 6997).

2.2.2 Current and Proposed Environmental Monitoring

Groundwater monitoring and protection efforts at the Laboratory have evolved from the early programs initiated by the USGS to present efforts that include the ER Project, the Groundwater Protection Management Program Plan (LANL 1995, 50124), environmental surveillance, the Decommissioning

Project, and emergency management and response programs. Other protection efforts include those required by various state of New Mexico regulations, the Clean Water Act (CWA), NPDES, and the RCRA Part B permit and the HSWA Module. Table 2.2.2-1 summarizes some the existing environmental monitoring and surveillance programs that are being implemented in Mortandad Canyon.

TABLE 2.2.2-1

SUMMARY OF LABORATORY ENVIRONMENTAL PROGRAMS RELATED TO MORTANDAD CANYON

Environmental Program	Date Implemented	Approved Activity	Regulatory Agency	Comment
RCRA Permit	*November 1989*	*Hazardous waste storage, treatment, and disposal*	*EPA* *NMED*	*Compliance by ESH-19*
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	*January 30, 1990 (revised August 1994)*	*Discharge of industrial and sanitary liquid effluents*	*EPA* *NMED*	*Compliance by ESH-19*
NPDES Storm Water Permit, CWA	*General permit August 25, 1993*	*Storm water associated with industrial activities*	*EPA* *NMED*	*Compliance by ESH-19*
Groundwater Protection Management Program (Hydrogeologic Workplan and RLWTF Discharge Plan)	*Pending regulatory approval*	*Groundwater monitoring, discharge from the RLWTF*	*NMED*	*RLWTF discharge plan submitted August 1996* *Groundwater monitoring plan submitted December 1996*
Annual environmental surveillance	*Circa 1970*	*DOE orders compliance*	*DOE*	*Annual surveillance reports*

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 (NMWQCC) regulations. The programs include the Sanitary Waste Water Consolidation Plant; Storm Water Pollution Prevention Plan; 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).

Additional monitoring specific to Mortandad Canyon is required by the NMWQCC for discharges that may affect groundwater. The discharge from the TA-50 RLWTF is subject to these requirements. As required by NMWQCC regulations (New Mexico Water Quality Control Commission 1995, 54406), a Ground Water Discharge Plan Application for the TA-50 Radioactive Liquid Waste Treatment Facility was submitted to the New Mexico Environment Department (NMED) (LANL 1996, 55688). This plan (which is pending approval) addresses discharges into Mortandad Canyon and will provide the monitoring of surface water and groundwater that is required. This program will be coordinated with other monitoring efforts described above and in the core document.

The alluvial groundwater wells used for environmental surveillance in Mortandad Canyon are listed in Table 2.2.2-2. One test well (TW-8) provides water level and water quality information on the regional aquifer. Five shallow alluvial groundwater wells, also called "observation" wells, (MCO-4, MCO-5, MCO-6, MCO-7, and MCO-7.5) are routinely sampled. These wells are located in the middle canyon along approximately a 2-mi (3.2-km) section that corresponds to the known extent of alluvial groundwater. Well MCO-7.5 is located downstream of the Mortandad Canyon sediment traps (LANL 1995, 50124). Numerous other wells have been installed in Mortandad Canyon for various purposes. These wells are discussed further in Chapter 3 of this work plan.

2.2.3 HSWA Module Requirements

Section C.1 of the HSWA Module (EPA 1990, 1585) includes a requirement for special monitoring of the saturated alluvium in Mortandad Canyon. In 1990 three wells (MCO-4B, MCO-6B, and MCO-7A) were installed near existing wells MCO-4, MCO-6, and MCO-7, as required. These wells were sampled and analyzed for 10 standard radionuclides, metals, general inorganic chemicals, and organic chemicals; the results were reported by Stoker et al. (1991, 7530).

Section C.3 of the HSWA Module (EPA 1990, 1585) requires the maintenance and operation of the sediment traps in Mortandad Canyon to "ensure containment of all residual sediment contamination within the facility boundary." The sediment traps were cleaned out and enlarged in 1992 to maintain the capability for intercepting surface water and trapping sediments (Environmental Protection Group 1994, 45363). Additional information about the sediment traps is provided in Section 2.3.1 and Section 3.4.4.2.4 in Chapter 3 of this work plan.

A subsurface investigation of saturation below the alluvium in Mortandad Canyon was required in Section C.6 of the HSWA Module. The prescribed data included cores collected through the alluvium into the underlying bedrock. In May 1991 four boreholes (for moisture access tubes MCM-5.1, MCM-5.9A, and MCC-8.2 and well SIMO) were drilled through the alluvium into bedrock tuff; the findings were reported by Stoker et al. (1991, 7530) and are summarized in Chapter 3 of this work plan.

As discussed in Section 2.3 of the core document (LANL 1997, 55622), monitoring of groundwater in wells and springs on San Ildefonso Pueblo land is conducted by the Laboratory under a Memorandum of Understanding (MOU). The MOU also covers investigations of soils, sediments, and foodstuffs that are potential contaminant exposure pathways. In accordance with the MOU, a special investigation of Mortandad Canyon sediments was performed. The results were reported in the annual environmental surveillance report for 1992 (Environmental Protection Group 1994, 45363) and are summarized in Chapter 3 of this work plan.

2.3 Sources of Potential Contamination within Mortandad Canyon

Potential contamination sources (as PRSs) within the Mortandad Canyon watershed and their current regulatory status are listed in Appendix B of this work plan. The locations of PRSs that are discussed in this section are shown on Figure A-1 in Appendix A of this work plan.

2.3.1 Mortandad Canyon Sediment Traps

PRS No. 00-001 comprises the area of the old and current sediment traps in Mortandad Canyon (Figure 2.3.1-1). The site is approximately 900 ft (274 m) long and a maximum of 200 ft (61 m) wide along the Mortandad Canyon stream channel downstream from the confluence of Mortandad Canyon and Ten Site Canyon. The sediment traps are located approximately 1.75 mi (2.82 km) downstream from the TA-50

RLWTF outfall and approximately 1.4 mi (2.3 km) upstream from the Laboratory boundary (Purtymun 1994, 52951). Personnel from Field Unit 4 of the ER Project studied this site in 1995 as part of the preliminary site characterization; the findings are discussed in Section 3.4.4.2.

TABLE 2.2.2-2

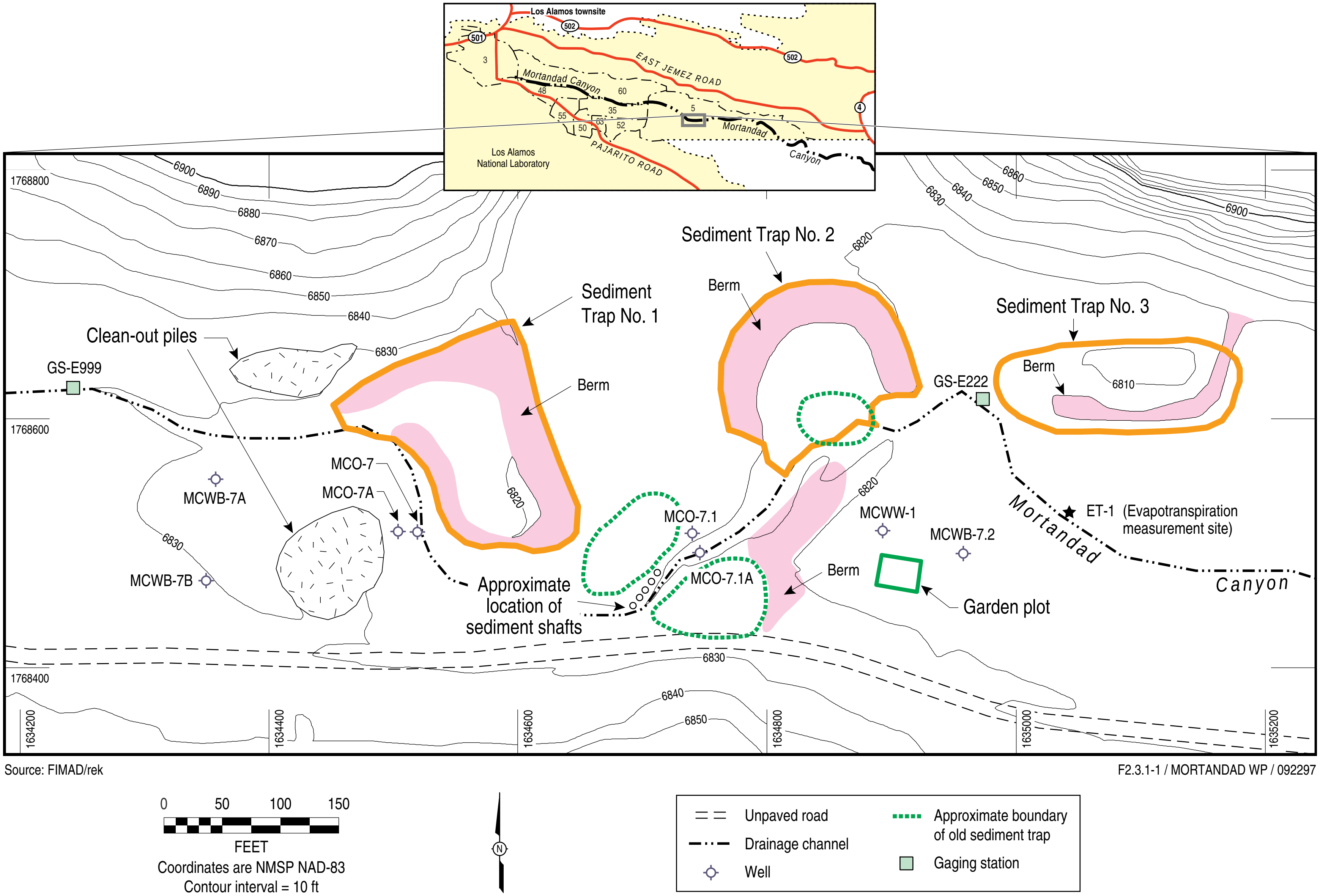
ENVIRONMENTAL SURVEILLANCE GROUNDWATER MONITORING WELLS IN MORTANDAD CANYON

Well	Date Installed	Ground Elevation (ft)	Depth of Casing (ft)	Screened Interval (ft)	Purpose	Comment
MCO-2	1960	7137	9	2–7	Alluvial observation	a
MCO-3	1967	7053	12	2–12	Alluvial observation	a Temporarily out of service
MCO-4	1963	6900	19	14–19	Alluvial observation	a Temporarily out of service, replaced by MCO-4B
MCO-4A	1989	6888	19.4	9.4–19.4	Alluvial observation	b
MCO-4B	1990	6888	33.9	8.9–28.9	Alluvial observation	b
MCO-5	1965	6876	46	21–46	Alluvial observation	a
MCO-6	1974	6850	47	27–47	Alluvial observation	Replacement for original MCO-6 drilled in 1960
MCO-6A	1989	6850	36	22.7–32.7	Alluvial observation	b
MCO-6B	1990	6850	47.1	22–42	Alluvial observation	b
MCO-7	1960	6827	69	39–69	Alluvial observation	a
MCO-7A	1989	6828	44.8	34.8–44.8	Alluvial observation	a
MCO-7.5	1961	6809	60	35–60	Alluvial observation	a
MCO-8	1960	6797	84	64–84	Alluvial observation	a Damaged and out of service since 1978
MCO-8A	1960	6797	50	40–50	Alluvial observation	a
MCO-8.2	1961	6782	70		Alluvial observation	a
MCO-9	1960	6750	55	45–55	Alluvial observation	a
MCO-12	1971	6697	108	88–108	Alluvial observation	a
MCO-13	1970	6674	107	87–107	Alluvial observation	a
MT-1	1988	6812	69		Alluvial observation	a
MT-2	1988	6796	64	44–54	Alluvial observation	a
MT-3	1988	6797	74		Alluvial observation	a
MT-4	1988	6784	74	54–64	Alluvial observation	a
SIMO	1990	6651	104	50–60, 80–90	Alluvial observation	b
TW-8	1960	6878	1065	953–1065	Regional aquifer well	a

a. *Observation well for baseline environmental surveillance monitoring and sampling*

b. *HSWA Special Permit wells sampled in 1990, results reported in Stoker et al. (1991, 7530); resampled in 1995, results pending*

Source: LANL 1995, 50124



Source: FIMAD/rek

F2.3.1-1 / MORTANDAD WP / 092297

Figure 2.3.1-1. Locations of the sediment traps and sediment shafts in Mortandad Canyon.

To ensure containment of sediments transported by major runoff events within the Laboratory boundaries, a series of sediment traps was installed in Mortandad Canyon between 1974 and 1986. In 1974 five shafts (12 in. [30.5 cm] in diameter and 20 ft [6.1 m] deep) were constructed in the stream channel east of well MCO-7. These shafts were filled with coarse gravel that trapped surface runoff and acted as an infiltration gallery to promote infiltration into the alluvium. Two wells (MCO-7.1 and MCO-7.1A) were constructed downgradient from the shafts to monitor the effects of the infiltration gallery. However, runoff events in 1974 and 1975 filled the shafts with fine sediments, which rendered the infiltration gallery ineffective; the project (including the wells) was abandoned. Figure 2.3.1-1 shows the approximate locations of the sediment shafts.

In 1976 the first two sediment traps were constructed in the stream channel. They were simple pits (approximately 25 ft [7.6 m] long, 15 ft [4.6 m] wide, and 7 ft [2.1 m] deep), which were excavated below the prevailing grade of the stream channel. The capacity of each of these two sediment traps was approximately 20,000 gal. (75.7 m^3*). In 1980 a third sediment trap (80 ft [24.4 m] in diameter and 6 ft [1.8 m] deep) was constructed east of the first two traps. It had a capacity of approximately 225,000 gal. (852* m^3*). By September 1983 the first two sediment traps had filled with sediment, and the third sediment trap was about half full. By the spring of 1986 the third sediment trap was full.*

In 1986 the current sediment trap configuration was constructed on and adjacent to the old sediment traps. The current sediment traps consist of large excavated basins surrounded by U-shaped berms that were built from the excavated alluvium (Purtymun 1994, 52951). Sediment Trap No. 1 is the upstream basin that was originally 55 ft (16.8 m) long by 45 ft (13.7 m) wide and ranged in depth from approximately 4.5 to 10 ft (1.4 to 3.0 m); it had a capacity of approximately 118,000 gal. (447 m^3*). Sediment Trap No. 2, the next one downstream, was originally 105 ft (32 m) long, 8 ft (2.4 m) wide, and 10 ft (3.0 m) deep with a capacity of approximately 628,000 gal. (2377* m^3*). The trap farthest downstream, Sediment Trap No. 3, was 150 ft (46 m) long by 32 ft (9.8 m) wide and ranged in depth from 6 to 10 ft (1.8 to 3.0 m); it had a capacity of approximately 87,000 gal. (329* m^3*). The total capacity of the three sediment traps was originally 833,000 gal. (3153* m^3*).*

Discharge from the TA-50 RLWTF normally infiltrates into the alluvium before reaching the sediment traps. Occasionally during periods of heavy precipitation, storm water runoff (possibly mixed with the TA-50 RLWTF discharge) flows into the sediment traps and is temporarily retained, which allows the sediments to settle out and the water to infiltrate into the alluvium. When one sediment trap is full, the water flows into the next sediment trap, which allows additional settlement and infiltration. In 1987 a storm runoff event filled all three sediment traps to capacity and overflowed the berm at Sediment Trap No. 3. This event created a breach in the berm, which was subsequently repaired. At that time, the capacity of Sediment Trap No. 1 was expanded by approximately 167,000 gal. (632 m^3*), bringing the total capacity of the three sediment traps to approximately 1.2 million gal. (4542* m^3*). In 1992 all three sediment traps were cleaned out and re-excavated to their current total retention capacity of 1.2 million gal. (4542* m^3*) (Environmental Protection Group 1994, 45363). Most of the removed sediments were from Sediment Trap No. 1. The sediments were placed in clean-out piles upslope and away from the stream channel (see Figure 2.3.1-1) to minimize the chance for remobilization.*

2.3.2 Mortandad Canyon Garden Plot

The Mortandad Canyon garden plot (PRS No. 00-005) is a small fenced area located approximately 100 ft (30.5 m) southeast of Sediment Trap No. 2 (Figure 2.3.1-1). From 1976 through the early 1980s the area was used as a garden plot to study the transport of radioactive particulates from the ground surface to tomato plants as a result of rain splash (LANL 1990, 7511). Soil collected from within the fenced area was placed in 55-gal. drums and transported to TA-50. Four radionuclides, all with half-lives of 115 days or less

(^{182}Ta [115 days], ^{141}Ce [33 days], ^{124}Sb [60 days], and ^{46}Sc [84 days]), were mixed into the soil by rotating the drums. Then the contaminated soil was returned to the enclosure for the tests (LANL 1992, 7667).

Sometime during the mid 1970s a 3-in.-diameter (7.6-cm-diameter) polyvinyl chloride well (MCWW-1) (see Figure 2.3.1-1) was installed into the alluvium approximately 20 ft (6.1 m) north of the garden plot. The well was intended to supply water for the test vegetables, but it was never used. The well is still present; however, the casing is cracked at the ground surface rendering the well unusable.

Because the experiments were discontinued in the early 1980s, the radionuclides involved have long since decayed to negligible levels of radioactivity. Therefore, the fenced area does not contain any materials that would pose a threat to human health or the environment. Additionally, the empty drums that had been used to transport the contaminated soil and were still present at the site in the early 1980s posed no hazard. No further action (NFA) at the site was recommended in the RFI Work Plan for Operable Unit 1071 (LANL 1992, 7667). PRS No. 00-005 has subsequently been accepted for NFA by NMED (NMED 1996, 55815).

2.4 Mesa-Top Sources of Potential Contamination

Potential contamination sources (as PRSs) within the Mortandad Canyon watershed and their current regulatory status are listed in Appendix B of this work plan. The locations of potential contamination sources on mesa tops within the watershed are shown on Figure A-1 in Appendix A of this work plan.

2.4.1 Technical Area 3 and Technical Area 60

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. A small portion of the southern part of TA-3, mainly near the CMR Building (TA-3-29) and the Materials Science Laboratory (TA-3-1698), is located in the upper reaches of the Mortandad Canyon watershed. That area is almost completely developed with buildings, roads, large paved parking lots, and landscaped unpaved areas.

TA-60, which contains Laboratory support and maintenance operations and contractor service operations, is located east of TA-3 on Sigma Mesa, a finger-like mesa, located between Sandia Canyon to the north and Mortandad Canyon to the south. Most of TA-60 is undeveloped mesa top. The mesa was an agricultural area during the homestead days before 1943 and is presently covered mainly with low, invasive shrubs. Large pines are present at the edges of the mesa, and a few young pines are present on the mesa top. The Nevada Test Site (NTS) test fabrication building (TA-60-17) and the NTS test tower (TA-60-19) are located at the western end of the site adjacent to TA-3. Several small, abandoned experimental areas, including a test solar evaporation pond and a geothermal test borehole (EGH-LA-1), are located on the eastern end of Sigma Mesa. Storage areas on Sigma Mesa contain excess equipment, topsoil, concrete, excavated underground storage tanks (USTs), and recyclable asphalt (LANL 1996, 52930).

PRSs located within the Mortandad Canyon watershed at TA-3 and TA-60 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). Most were recommended for NFA in the work plan, and others were investigated and subsequently recommended for NFA in the RFI report for TA-3 and TA-60 (LANL 1996, 52930).

In addition to the PRSs at TA-3 and TA-60, other historical releases from TA-3 and TA-60 into Mortandad Canyon have been documented. Six releases of cooling water from building TA-3-66 (known locally as the New Sigma Building) occurred before 1975 (Purtymun 1964, 11822; Purtymun 1975, 11787). It is likely that this water was used for once-through cooling and contained no added contaminants; however, the absence of contaminants cannot be confirmed. The releases each lasted from 2 to 6 weeks with total volumes of 4.8 *million gal. (18,168 m^3) in 1962, 9.8 million gal. (37,093 m^3) in 1963, 5 million gal. (18,925 m^3) in 1964, 4.8 million gal. (18,168 m^3) in 1965, and 12.7 million gal. (48,070 m^3) in 1969. The average annual flow from runoff and the cooling water combined entering Mortandad Canyon from 1962 through 1972 was estimated to have ranged from 6.9 million gal. (26,117 m^3) to 33 million gal. (124,905 m^3); the average was approximately 16.6 million gal. (62,831 m^3). No information was reported regarding possible contamination associated with the cooling water (Purtymun 1964, 11822).*

During the summer of 1974, two accidental releases from a radioactive liquid-waste line (at TA-3 near the CMR building and near TA-59) resulted in radioactive contamination of soil near the leaks (Smith et al. 1977, 5579). The waste contained predominantly ^{238}Pu, with lesser concentrations of ^{137}Cs, ^{239}Pu, ^{89}Sr, and ^{90}Sr. The leak near TA-59 was discovered in July 1974 at a cleanout riser in the line north of Pajarito Road. Repairs were made, and 476 yd^3 (364 m^3) of contaminated soil was removed from the area. Contaminated soil was found at depths up to approximately 3 ft (0.9 m) near the leak and for approximately 350 ft (107 m) down the slope on the south wall of Mortandad Canyon. Based on the amount of soil removed and the concentrations of radioactivity in the soil, estimates of the amount of contamination released ranged from 150 to 300 mCi (Smith et al. 1977, 5579).

During pressure-testing of the repaired waste line, radioactive liquid waste was accidentally discharged from a manhole near the CMR building. The waste flowed along the curb on the west side of Diamond Drive to a storm drain that discharged through a culvert to the head of Mortandad Canyon. The waste flowed approximately 160 ft (49 m) downstream on the canyon floor to an earthen containment dam that was constructed to stop the flow. Bentonite was used to adsorb the liquid that ponded in the canyon, and the soil and bentonite that were contaminated above background radioactivity levels were subsequently removed using a backhoe and a front-end loader. A total of approximately 250 yd^3 (191 m^3) of contaminated soil was removed. The soil and asphalt around the manhole, the asphalt road, the curb, and the gutter contacted by the liquid waste were also replaced (Smith et al. 1977, 5579).

Beginning in July 1984, follow-up investigations were performed in three phases at the location. The first phase involved drilling 10 boreholes along a 180-ft-long (55-m-long) transect perpendicular to the waste line on 20-ft (6.1-m) centers to an average depth of 12.5 ft (3.8 m). A total of 52 soil samples were collected. All samples were reported to contain background levels of radioactivity except those collected from the 7.0- to 7.5-ft (2.1- to 2.3-m) depth at the location of the former cleanout riser, which contained 165 pCi/g ^{238}Pu. This location was then remediated to background levels.

The second phase involved drilling six boreholes along a 120-ft-long (37-m-long) line parallel to the waste line to a depth of 12.5 ft (3.8 m). A total of 30 soil samples were collected. All soil samples were reported to contain background levels of radioactivity.

The third and final phase, conducted in October 1984, involved a 200-ft-long (61-m-long) trench dug to a depth of 6 ft (1.8 m) across the location of the former cleanout riser. A total of 21 samples were collected from the bottom of the trench. All samples were reported to contain background levels of radioactivity.

These spill sites were not identified as PRSs or areas of concern by the ER Project; therefore, they were not investigated as part of the RFI for OU 1114 (Field Unit 1), which included TA-3 and TA-59 (LANL 1993, 51977; LANL 1995, 51981). A reach proposed for sediment investigations in Chapter 7 of this work plan encompasses the canyon area affected by these accidental releases.

2.4.2 Former Technical Area 4

Former TA-4, also known as Alpha Site, was established in May 1944 as a test firing site for small conventional explosive charges. The site was abandoned in 1946, and most of the structures associated with the site underwent decontamination and decommissioning (D&D) in the 1950s. Building TA-4-1 was demolished in 1985, and the site was leveled and contoured to the existing terrain. The area of former TA-4 is currently within the boundaries of TA-52 and TA-63. The PRSs are identified as being part of former TA-4 although all are located within the boundary of TA-52. The PRSs were addressed by Field Unit 4 in the RFI Work Plan for Operable Unit 1129 (LANL 1992, 7666).

There were no NPDES-permitted discharges at former TA-4 because the site was abandoned before NPDES became effective. Photographic-processing laboratory effluent was discharged onto the mesa top on the south side of the laboratory building (former TA-4-7). Although effluent was not discharged directly into Ten Site Canyon, it is possible that contaminants (photographic-processing chemicals and uranium) may have been washed into Cañada del Buey by storm water. The site is designated as PRS No. 4-003(a). In 1955 beta activity was detected in the photographic-processing darkroom at levels of up to 2 mR/h. At that time portions of the darkroom floor were removed.

A drain connected to the former laboratory control building (TA-4-3) discharged into a 6-in.-diameter (15.2-cm-diameter) vitrified clay pipe that directed the effluent northward 20 ft (6.1 m) into Ten Site Canyon (LANL 1992, 7666). The site is designated as PRS No. 4-003(b). No radioactivity was detected at the site during surveys that were conducted in 1953 and 1985.

In 1995 an RFI was conducted at the TA-4 PRSs according to the RFI Work Plan for Operable Unit 1129 (LANL 1992, 7666). The RFI report is expected to be completed in 1998.

2.4.3 Technical Area 5

TA-5, also known as Beta Site, was established in 1944 as a test firing site and was used until 1947. After firing activities were completed, the site was used for a variety of experiments, primarily during the 1950s. Beta Site was officially abandoned in 1959, although the site was used periodically for experiments until 1979. The site underwent D&D in 1985.

One outfall at TA-5 is known to have discharged into Mortandad Canyon. PRS No. 5-005(a) is the site where a former French drain that carried effluent from the control building (TA-5-4) to an outfall on the southern edge of Mortandad Canyon. The control building was removed in 1960, and the French drain and affected soil were removed in 1985. The type of waste introduced from the control building into the French drain is unknown (LANL 1992, 7666).

Additionally, two former outfalls discharged to an unnamed canyon tributary to Mortandad Canyon on the south side of TA-5. At PRS No. 5-005(b), potential contamination is associated with an outfall from former building TA-5-5, which was used as a darkroom, shop, and calibration laboratory (PRS No. 5-006[c]). Presumably the outfall operated from 1944 to 1959 when the building was reported to be contaminated with high explosives and was burned (DOE 1987, 8663; LANL 1992, 7666). PRS No. 5-004 is a former septic system (TA-5-13) that was connected to former building TA-5-1. The septic system discharged southward to the unnamed canyon. The septic system operated for about 10 years, was abandoned in 1959, and was removed in 1985 (LANL 1992, 7666).

In 1995 an RFI was conducted at the TA-5 PRSs according to the RFI Work Plan for Operable Unit 1129 (LANL 1992, 7666). The RFI report is expected to be completed in 1998.

2.4.4 Technical Area 35

TA-35, formerly called Ten Site, is located on a finger-like mesa (Ten Site Mesa) between Mortandad Canyon and Ten Site Canyon. Historically TA-35 has been one of the primary contributors of storm water runoff, wastewater discharge, and possible contaminants into Mortandad Canyon. It is one of the most developed technical areas at the Laboratory with approximately 300 designated structures, many of which are storage tanks, manholes, transportable buildings, and mobile office trailers. Various Laboratory groups currently use the several experimental laboratories located at TA-35, and the site has been used since the original Ten Site Laboratory and office building (TA-35-2) was constructed in 1951. This building has housed two experimental reactors (Los Alamos power reactor experiment [LAPRE] -I and -2 and Los Alamos molten plutonium reactor experiment [LAMPRE]), a hot cell used for preparing kilocurie sources of radioactive lanthanum (^{140}La), plutonium research laboratories, and a laboratory at which lithium tritide components were developed and handled (LANL 1992, 7666).

Table 2.4.4-1 lists the chemicals of potential concern (COPCs) associated with each PRS. These PRSs are being addressed by an RFI in progress (LANL 1992, 7666).

The Air Filter Building (TA-35-7) housed the air-filtration components and ion-exchange columns associated with the TA-35 wastewater treatment plant that operated from 1951 until 1963 when the TA-50 RLWTF became operational. The wastewater treatment plant discharged batches of treated wastewater routinely but irregularly as needed. Unplanned releases of highly contaminated liquids and sludge also occurred during the period of operation, as discussed below.

2.4.4.1 Former Wastewater Treatment Plant Outfall

From 1951 to 1963 treated wastewater containing radionuclides was discharged from the Ten Site Laboratory (TA-35-2) into Pratt Canyon. This wastewater originated in the operation of hot cells used to prepare kilocurie sources of radioactive lanthanum (^{140}La) and barium (^{140}Ba), waste from experimental reactors (LAPRE-1 and -2 and LAMPRE), plutonium research laboratories, and a tritium laboratory. It is believed that no releases occurred before September 1951 (Aeby 1954, 742). From 1951 to 1955 the treated wastewater was stored in concrete tanks for approximately six months to allow the ^{140}La to decay. The water was either allowed to evaporate or was used to wash air-cleaning filters (Emelity 1958, 793). If the incoming waste volumes were greater than losses through evaporation, the stored water was released to Pratt Canyon.

In 1953 assays of the storage tanks indicated the presence of waste components with half-lives greater than those expected for the ^{140}Ba and ^{140}La (Buckland 1953, 770). These components were primarily ^{89}Sr and ^{90}Sr, which were present in the ^{140}Ba and ^{140}La shipments (Meyer 1954, 874). Additional treatment of the wastes was required to ensure that the activity of the treated wastewater discharged to Pratt Canyon did not exceed allowable limits (Meyer 1954, 874). In 1955 an experimental treatment system, consisting of a cation-exchange column, was installed to remove the radioactive strontium and the treated wastewater recirculated. This pilot plant was in operation from January 24, 1956, through March 13, 1957. During this period, more wastewater was recirculated than was discharged to the canyon. Results of this operation were promising, and the system was expanded to include two ion-exchange columns as well as chemical treatment of the wastewater. After additional modifications, the "New Ten Site" wastewater treatment plant went into operation on June 13, 1960, and continued operating in that mode until operation ceased in 1963. The treatment process is discussed further below.

TABLE 2.4.4-1

TA-35 PRSs AND CHEMICALS OF POTENTIAL CONCERN

PRS No.	Description	Chemicals of Potential Concern
35-001	Material disposal area (MDA W)	Liquid sodium (approximately 30 gal.), ^{239}Pu, possible fission products
35-002	Material disposal area (MDA X)	$^{235}UO_2$/phosphoric acid , fission products, ^{152}Eu, ^{137}Cs
35-003(a–q)	Wastewater treatment plant	^{140}La, ^{140}Ba, ^{89}Sr and ^{90}Sr, ^{90}Y, ^{137}Cs, ^{106}Ru, ^{238}Pu, ^{239,240}Pu, caustic, acid, sodium carbonate, strontium nitrate, iron sulfate, dielectric oil, unknown chemicals
35-003(r)	Wastewater treatment plant waste-receiving canyon	Same as above
35-004(a–o)	Container storage	Radionuclides, volatile organic compounds (VOCs), semivolatile organic compounds (SVOCs), metals
35-005(a and b)	Former oil impoundments	Hydrocarbons, SVOCs
35-006	Surface impoundment	Hydrocarbons, SVOCs
35-007	Waste oil treatment	Hydrocarbons, dielectric oil
35-008	Surface disposal	Industrial solid wastes
35-009(a–d)	Septic systems	Sanitary wastes, possible industrial wastes, radionuclides, unknown chemicals
35-010(a–e)	Surface impoundments, sanitary lagoons, sand filters, and former NPDES outfall	Sanitary wastes; photographic processing wastes; industrial wastes; laboratory chemicals: acids, bases, solvents; radionuclides
35-011(a–d)	Underground storage tanks	SVOCs, hydrocarbons
35-012(a–b)	Inactive storage tanks	Waste oils, solvents, chemicals
35-013(a–d)	Sumps and drains	Various possible contaminants
35-014(a–g_3)	Soil stained by oil spills	Oil (hydrocarbons), metals, SVOCs, VOCs, alpha emitters, gamma emitters, possible polychlorinated biphenyls (PCBs)
35-015(a–b)	Decommissioned waste oil treatment	Unidentified contaminants
35-016(a–q)	Drains and outfalls	Noncontact cooling water, photographic processing waste, storm runoff, wastewater, gamma emitters, alpha emitters, metals, SVOCs, PCBs
35-017	Soil contaminated from reactor operations	Enriched ^{235}U, uranium trioxide, phosphoric acid, uranium enriched “soup,” uranium dioxide, alpha emitters, beta emitters, gamma emitters, fission products, sodium coolant, nickel, plutonium
35-018(a and b)	Leaking transformers	PCBs

Source: LANL 1992, 7666

On July 26, 1963, treatment operations were transferred to the TA-50 RLWTF. The TA-35 wastewater treatment plant underwent D&D in 1984 and 1985 when most of the underground pipelines, tanks, and outbuildings were removed (Elder et al. 1986, 3089). In 1995 and 1996 the remaining structures, including the phase separator pit (TA-35-3) (PRS No. 35-003[n]); the underground storage tanks (TA-35-3, TA-35-4, and TA-35-5) (PRS Nos. 35-003[a, b, and c]); TA-35-7 (PRS No. 35-003[p]) underwent D&D (LANL 1995, 53455).

During the operation of the TA-35 wastewater treatment plant, 130 separate batches of wastewater were processed. Table 2.4.4-2 contains a summary of the annual volume, gross-beta activity, and radioactive strontium discharges from the TA-35 wastewater treatment plant. Approximately 2.7 x 10^6 gal. (10,220 m^3) of water were discharged to Pratt Canyon. The total activity discharged was about 20 Ci gross-beta activity and 1.4 Ci of ^{89}Sr and ^{90}Sr. The gross-beta activity consisted of a combination of ^{140}Ba, ^{140}La, ^{89}Sr, ^{90}Sr, and trace amounts of ^{137}Cs, ^{106}Ru, plutonium, ^{99}Tc, and uranium (Emelity 1958, 793). No data for possible discharges of other contaminants are available. The RFI for TA-35 (LANL 1992, 7666) is in progress; that report will be released in 1998.

TABLE 2.4.4-2

TOTAL ANNUAL DISCHARGES FROM THE TA-35 WASTEWATER TREATMENT PLANT TO PRATT CANYON[a]

Year	Number of Runs	Volume of Wastewater Treated (gal.)			Gross Beta Activity[b] to Canyon (Ci)	Total Sr Activity[b] to Canyon (Ci)	^{90}Sr Activity[b] to Canyon (Ci)	^{89}Sr Activity[b] to Canyon (Ci)
		Treated	Discharged	Recirculated				
1951	1	Unknown	Unknown	Unknown	0.00500	0.00020	0.00003	0.00017
1952	3	Unknown	52,500	Unknown	1.92200	0.07680	0.01160	0.06540
1953	3	Unknown	Unknown	Unknown	0.16700	0.00670	0.00100	0.00570
1954	1	Unknown	Unknown	Unknown	0.16000	0.00640	0.00097	0.00542
1955	10	52,890	46,850	9,040	0.15142	0.04902	0.00738	0.04164
1956	59	410,900	193,970	238,130	7.36369	0.83700	0.15400	0.68300
1957	16	480,550	446,380	34,440	1.76401	0.22487	0.03373	0.19114
1958	9	370,755	367,485	3,270	1.39311	0.11383	0.01707	0.09675
1959	10	560,234	560,234	0	3.64135	0.02803	0.00420	0.02383
1960	11	572,220	308,635	263,585	1.72937	0.03729	0.00559	0.03170
1961	3	342,497	342,497	0	1.39997	0.01097	0.00165	0.00932
1962	3	318,582	318,582	0	0.90934	0.01643	0.00246	0.01397
1963	1	105,532	105,532	0	0.10802	0.00227	0.00034	0.00193
Total	130	3,214,160	2,690,165	548,465	20.71428	1.40981	0.24002	1.16997

a. Release data were obtained from the Ten Site Treatment Plant Daily Operation Logs (Emelity 1958, 793; Aeby 1954, 742; Christenson 1956, 775).

b. Activities are not corrected for radioactive decay.

During the first four years of operation, the volumes treated and discharged and the radionuclide contents were not routinely recorded in daily operation logs for the treatment plant; these parameters are listed as unknown in Table 2.4.4-2. Because recirculation began in 1955, the volume recirculated during the first four years was probably nil. Information on the discharges for 1951 and 1952 was obtained from Aeby (1954, 742). Discharge data for 1955 through 1963 were obtained from the daily operation logs.

Reports indicate that there were two unplanned releases in which the gross-beta activity exceeded 1 Ci. The first release occurred on September 6, 1952, when wastewater containing 1.8 Ci gross-beta activity and approximately 70 mCi of ^{89}Sr and ^{90}Sr was released because of a malfunctioning solenoid valve (Aeby 1952, 741; Aeby 1954, 742). Another unplanned release occurred during the weekend of February 11 and 12, 1956. In this case a leaking pipe caused 21,200 gal. (80.2 m^3) of water and a quantity of sludge to be pumped into the canyon. Based on activities measured earlier that week, it was estimated that approximately 7 Ci gross-beta activity and 0.7 Ci of ^{89}Sr and ^{90}Sr were released. These estimated volumes and activities in the unplanned releases are included in the data in Table 2.4.4-2.

The total gross-beta activity discharged in 1953 (0.167 Ci) and the strontium concentration were estimated in documentation by Matthews (1954, 55686) based on the total volume of waste treated in 1953 and two samples collected from the concrete holding tanks in February and April 1954. Keenan (1975, 845) projected that the estimate of discharges for 1953 may also be used to estimate the discharges in 1954.

To estimate the radioactivity remaining in the Mortandad Canyon system from these discharges, the appropriate decay correction was applied to each annual estimate listed in Table 2.4.4-2. The calculations assumed that the only radionuclides released were ^{140}*Ba,* ^{140}*La,* ^{89}*Sr, and* ^{90}*Sr. The calculations indicate that approximately 0.2 Ci of only* ^{90}*Sr remains in the Ten Site Canyon/Mortandad Canyon drainage system from the historic releases at TA-35 (as of 1996). All other radionuclides included in the calculations have decayed to daughter products of insignificant activities.*

Plutonium and other radionuclides probably became components in the TA-35 waste stream sometime in the mid 1950s (Christenson 1956, 776), although apparently no records of discharged amounts were maintained. Also, little historic information has been found regarding possible hazardous constituents in the TA-35 wastewater treatment plant effluent.

The following list includes chemicals known to have been associated with the wastewater or used to treat the wastewater before discharge (LANL 1992, 7666).

- HNO_3 *(nitric acid)*
- *NaOH (sodium hydroxide)*
- *Nalcite HCR resin*
- *Octyl alcohol*
- *Iron sulfate* $[Fe_2(SO_4)_3]$
- *Sodium carbonate* (Na_2CO_3)
- *Calcium chloride* ($CaCl_2$)
- *Strontium nitrate* $[Sr(NO_3)_2]$
- *Isopropyl alcohol*
- *Ferric chloride* ($FeCl_3$)

These chemicals were used in treatment described below. As noted earlier, from 1951 to 1955 workers became concerned about the activities of ^{89}*Sr and* ^{90}*Sr being discharged; in March 1955 they implemented an ion exchange treatment (Nalcite HCR resin) to reduce the concentrations. During the last quarter of 1957 the treatment was supplemented with a chemical coagulation pretreatment step involving additions of* $FeCl_3$, $Fe_2\ (SO_4)_3$, Na_2CO_3, $CaCl_2$, *and NaOH to the wastestream to precipitate ferric hydroxides and alkali metal carbonates and coprecipitate radionuclides. This pretreatment was continued as needed until operations were transferred to the TA-50 RLWTF. Nitric acid* (HNO_3) *was used to regenerate the ion exchange resin, and isopropyl and octyl alcohol were used as defoaming agents in the ion exchange column. Spent regenerant from the column was treated similarly and strontium nitrate* $[Sr(NO_3)_2]$ *was added to aid precipitation of strontium as the solid carbonate (Emelity circa 1994, 56039).*

2.4.4.2 Surface Impoundments

PRS Nos. 35-005(a and b) and 35-006 are associated with two decommissioned surface-oil impoundments. PRS Nos. 35-005(a) and 35-006 are located near building TA-35-85. PRS No. 35-005(a) is a gunite-lined surface impoundment that replaced a previously decommissioned surface impoundment (PRS No. 35-006) in 1985. PRS No. 35-005(b) is a gunite-lined surface impoundment located near building TA-35-125.

Closure plans for these surface impoundments were submitted to NMED in October 1988; the state subsequently gave verbal approval to proceed with closure activities (LANL 1992, 7666).

In 1989 the contents of the impoundments and all obviously contaminated soil were removed and disposed of as hazardous waste. In October 1989 sampling and analysis were performed to verify the removal of contaminants from the area. Preliminary results indicated that the criteria for clean closure had been met. The impoundments were then backfilled and revegetated. After the final analytical results were received, it was discovered that the allowed sample holding times had been exceeded; therefore, the data could not be verified. The closure plan was modified to reflect the field work and to include borehole sampling and analysis for the final verification of clean closure. Borehole sampling and analysis performed in December 1990 showed that the levels of contamination remaining after the cleanup did not exceed Environmental Protection Agency (EPA) risk-based cleanup levels (Environmental Surveillance Program 1996, 55333).

The initial closure report and closure certification letters for PRS No. 35-005(b) were submitted to NMED in August 1991. In July 1992 NMED sent a notice of deficiency (NOD) to DOE and denied approval of clean closure for the PRS. An amended closure plan was submitted to NMED on September 4, 1992. In September 1993 the Laboratory received final regulatory approval from NMED on the amended closure report. No further action is required for this surface impoundment; therefore, PRS No. 35-005(b) has been recommended for NFA (LANL 1992, 7666).

The initial closure report and closure certification letters for the impoundment at TA-35-85 (PRS Nos. 35-005[a] and 35-006) were submitted to NMED on December 20, 1991; an amended closure plan was submitted to NMED for approval on November 1, 1993. Potential oil spills and soil contamination associated with PRS No. 35-005(a) are identified as PRS No. 35-014(e_2). Previous investigations performed at PRS No. 35-005(a) and the results of the 1994 RFI at PRS No. 35-014(e_2) are summarized in the RFI report for PRS No. 35-014(e_2) (LANL 1996, 54402). This RFI report states

> *. . . the concentrations of contaminants observed at these biased sample locations do not indicate a potential human health threat, although TPH [total petroleum hydrocarbons] and elevated metal concentrations were observed. However, TPH and metals may be found at higher concentrations on the mesa edge or the slope below. The extent of TPH and metal contamination at this site will be determined under a separate investigation, as stated below.*
>
> *On June 21, 1993, the New Mexico Environment Department (NMED) denied closure of TSL-85 (also known as PRS Nos. 35-005[a] and 35-014[e_2]) and required that the area of the impoundment be resampled as part of the TA-35 RFI (NMED 1996, 53924). Previous samples collected at the site were rejected by NMED because surrogate recovery results for VOC and SVOC analysis were outside EPA limits and missed EPA-allowable holding times . . .*

The amended closure plan also stated that additional samples must be collected near the impoundment and on the mesa edge along the Mortandad Canyon spill path. The closure plan approval requires that the extent of contamination be determined and that contamination be removed as part of the closure effort. Because the site is mandated for closure by NMED under a different authority (Closure Plan Approval, EPA Identification Number: NM0890010515), PRS No. 35-014(e_2) was recommended for NFA in the RFI report (LANL 1996, 54402).

2.4.4.3 Outfalls

Existing and former outfalls located at TA-35 are listed in Table 2.4.4-3. From 1951 until 1975, four sanitary septic systems at TA-35 discharged to Mortandad Canyon and Ten Site Canyon (LANL 1992, 7666). These septic systems were investigated as PRS Nos. 35-009(a, b, c, and d) and were recommended for NFA in the

RFI report (LANL 1996, 54402) because no release of contaminants to the environment was documented. In 1996 voluntary corrective actions (VCAs) were completed at each of the septic systems to prevent any future environmental problems associated with the septic systems (LANL 1996, 55630; LANL 1996, 54967).

TABLE 2.4.4-3

FORMER OUTFALLS AND EXISTING NPDES-PERMITTED OUTFALLS AT TA-35

PRS No.	NPDES Permit No.	Discharge	Comments
35-009(a)	*N/A (septic tank and system)*	*Inactive*	*Sanitary waste from TA-35-2 to Ten Site Canyon VCA in 1996*
35-009(b)	*N/A (septic tank and system)*	*Inactive*	*Sanitary waste from TA-35-67 to Ten Site Canyon VCA in 1996*
35-009(c)	*N/A (septic tank and system)*	*Inactive*	*Sanitary waste from TA-35-2 to Mortandad Canyon VCA in 1996*
35-009(d)	*N/A (septic tank and system)*	*Inactive*	*Sanitary waste from TA-35-27 to Mortandad Canyon VCA in 1996*
35-010(e)	*Former sanitary outfall (10S)*	*Inactive*	*Sanitary waste from TAs -35, -50, -55, -48, and -64 to Ten Site Canyon*
35-016(a)	*Former 04A-089*	*Inactive*	*Noncontact cooling water from TA-35-34 to Ten Site Canyon*
35-016(b)	*06A-132*	*Up to 3,000 gal. per day*	*Photographic waste discharge from TA-35-87 to Ten Site Canyon*
35-016(c)	*Former 04A-088 and former 04A-012*	*Inactive*	*Noncontact cooling water from TA-35-67 to Ten Site Canyon*
35-016(d)	*Former 04A-087*	*Inactive*	*Noncontact cooling water from TA-35-46 to Ten Site Canyon*
35-016(e)	*Former 04A-090*	*Inactive*	*Noncontact cooling water from TA-35-85 to Mortandad Canyon*
35-016(g)	*04A-127*	*12 gal. per minute*	*Noncontact cooling water from TA-35-213, Room 29, to Mortandad Canyon*
35-016(k)	*Former 04A-116*	*Inactive*	*Noncontact cooling water from TA-35-29 to Ten Site Canyon*
35-016(m)	*Former 03A-039*	*Inactive*	*Treated cooling water from TA-35-33 to Mortandad Canyon*
35-016(p)	*Nonpermitted*	*Inactive*	*Cooling water from TA-35-27 to Mortandad Canyon*
Not a PRS	*03A-160*	*14,000 gal. per day*	*Treated cooling water from TA-35-124 to Ten Site Canyon*

The TA-35 sanitary septic sewage lagoons operated in Ten Site Canyon from 1975 until 1992 when the new sanitary waste treatment plant at TA-46 became operational. Daily discharge records from 1987 through 1992 show that an average of approximately 45,000 gal. (170 m^3) were discharged daily from the sand filter beds to the NPDES-permitted outfall (10S) into Ten Site Canyon. Presumably, this volume of effluent (minus infiltration) flowed downstream in Ten Site Canyon into Mortandad Canyon from 1975 through 1992; however, no surface water flow in lower Ten Site Canyon has been documented.

The sewage lagoons and the associated sand filter beds were investigated as PRS Nos. 35-010(a, b, c, and d) according to the RFI Work Plan for Operable Unit 1129 (LANL 1992, 7666). The Phase I RFI sampling and analysis were conducted in 1994, but problems with the analyses occurred. A supplemental sampling and analysis plan was prepared (LANL 1997, 55326); resampling is scheduled to be completed in 1997.

The Phase I RFI for the other TA-35 outfalls (PRS Nos. 35-016[a through p]) was performed in 1994 and 1995 according to the RFI Work Plan for Operable Unit 1129 (LANL 1992, 7666) and the addendum to the work plan (Pratt, 1994, 43475). PRS Nos. 35-016(e, f, and i) were recommended for NFA in the RFI report *for these PRSs (LANL 1996, 54402); PRS Nos. 35-016(b, j, n, and q) were recommended for NFA in the RFI report for these PRSs (LANL 1996, 54763). PRS Nos. 35-016(a, c, d, m, and p) were also recommended for NFA in the RFI report for these PRSs (LANL 1996, 55075).*

At PRS No. 35-016(g) chromium was identified as a COPC in the screening assessment after Phase I sampling and analysis were performed; therefore, this PRS has been recommended for additional sampling and analysis, which are planned during 1997 (LANL 1996, 54422). At PRS No. 35-016(h) it was determined that the Phase I sampling and analysis did not adequately characterize the outfall; therefore, additional archival research, sampling, and analysis have been recommended (LANL 1996, 54422). Additionally, supplemental RFI sampling and analysis are planned during 1997 for PRS Nos. 35-016(k, l, and o) (LANL 1997, 55687).

2.4.5 Technical Area 48

TA-48, the Radiochemistry Site, is located northwest of TA-55 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 NTS 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; discharges to Mortandad Canyon from TA-48 are believed to have begun at about that time.

Several discharges to Mortandad Canyon were identified during the Comprehensive Environmental Assessment and Response Program (CEARP 1986, 8657) and are monitored by Laboratory group ESH-18. Approximately 35 x 10^6 *gal. (132,500* m^3*) of water per year were discharged to the canyon from these outfalls at the time (CEARP Phase I October 1987); since then, two outfalls have been discontinued, and the others are scheduled to be discontinued. The outfalls handle once-through cooling water and cooling tower blowdown. Some of the discharge lines included other small wastewater sources that may have contributed other contaminants. The PRSs that were identified at TA-48 during the RFI are listed in Appendix B, and a summary of the TA-48 outfalls and their respective NPDES permit numbers and PRS numbers are listed in Table 2.4.5-1. NPDES outfalls 03A-045 and 04A-153 together support a wetland of approximately 0.29 acres. Outfall 04A-016 supports a 1.9-acre wetland, and outfall 04A-131 supports a wetland of approximately 0.1 acres.*

The air exhaust system at TA-48 (PRS No. 48-001) is another source of possible contamination into Mortandad 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 (CEARP 1986, 8657; LANL 1992, 7666).

TABLE 2.4.5-1

NPDES-PERMITTED OUTFALLS AT TA-48

PRS No.	NPDES Permit No.	Discharge	Comments
48-007(a)	*03A-045*	*2 gal. per minute*	*Treated cooling water blowdown from TA-48-1 to surface impoundment east of TA-48*
48-007(b)	*04A-016*	*12 gal. per minute*	*Noncontact cooling water from TA-48-1 to Mortandad Canyon*
48-007(c)	*04A-131*	*2,600 gal. per day*	*Noncontact cooling water from TA-48-1 to Mortandad Canyon*
48-007(d)	*04A-153*	*6 gal. per minute*	*Noncontact cooling water from TA-48-1 to surface impoundment east of TA-48*
48-007(e)	*Former 04A-126*	*Inactive 1995*	*Noncontact cooling water from TA-48-8 to Mortandad Canyon*
48-007(f)	*Former 04A-137*	*Inactive 1995*	*Noncontact cooling water from TA-48-46 to Mortandad Canyon*
Not a PRS	*04A-152*	*11,000 gal. per day*	*Noncontact cooling water from TA-48-28 to Mortandad Canyon*

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 TA-48 (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 the following PRSs: 48-001, 48-002(e), 48-003, 48-007(a, b, c, d, and f), and 48-010. Therefore, these PRSs were recommended for NFA (LANL 1995, 50295). An NOD for the TA-48 RFI report was received from NMED in March 1996 (LANL 1996, 53810). Most concerns were related to analytical procedures and data quality. A response to the NOD (LANL 1996, 54448) and a supplemental sampling and analysis plan (LANL 1997, 55326) were prepared for resampling PRSs at TA-48. Supplemental samples were collected and analyzed in early 1997; the results are pending.

2.4.6 Technical Area 50

The Laboratory's RLWTF located at TA-50 began operations on July 26, 1963 and discharged treated wastewater to Mortandad Canyon via Effluent Canyon through an outfall that is currently permitted as NPDES outfall 051 (see Figure A-1 in Appendix A of this work plan).

Table 2.4.6-1 and Figure 2.4.6-1 contain summaries of the annual volumes of radioactive and inorganic constituents discharged from the TA-50 RLWTF. Sludge from the RLWTF is transported to TA-54, Area G for disposal (LANL 1996, 55688).

Radioactive liquid waste is treated in TA-50-1 at the RLWTF and transferred to one of two 20,885-gal. (79-m^3) holding tanks located in TA-50-2. When one of these tanks is full, the contents are discharged. Before discharge, the treated wastewater is sampled and tested for radiological and nonradiological constituents. The wastewater is recycled through the treatment plant until the parameters in the NPDES permit are met (including standard physical and chemical parameters, radium, and trace metals) and the gross-alpha activity is less than 1000 cpm/L. The holding tank discharges at an average flow of 720 gal. (2.73 m^3) per minute for about 30 minutes to discharge a batch. Since 1990 an average of about one batch per working day has been discharged from the TA-50 RLWTF (LANL 1996, 55688). Samples of the treated wastewater are analyzed daily, weekly, and annually according to the NPDES permit requirements.

TABLE 2.4.6-1

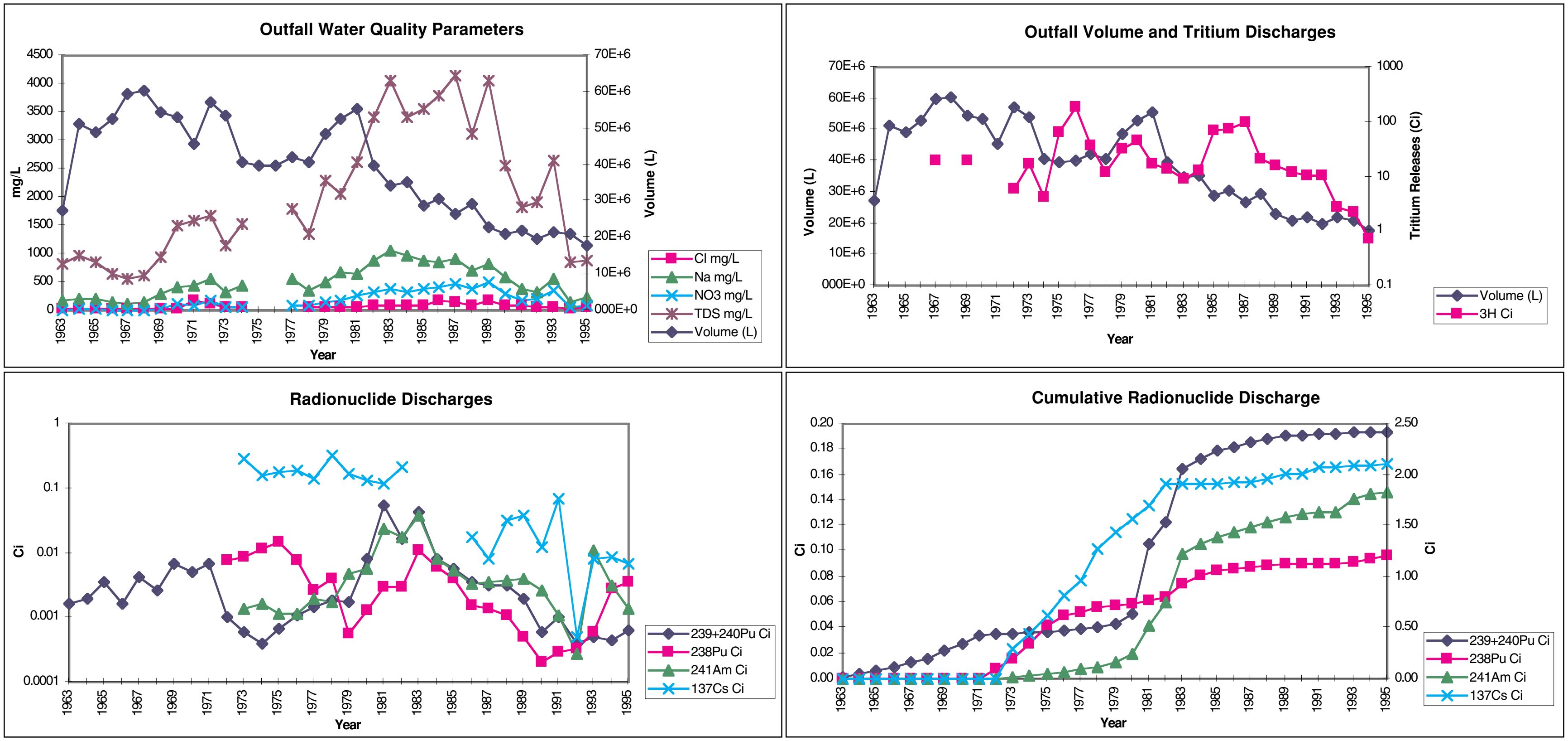
SUMMARY OF VOLUMES AND RADIONUCLIDES DISCHARGED IN TREATED WASTEWATER FROM THE RLWTF[a]

Year	Volume (L)	^{241}Am (Ci)	^{137}Cs (Ci)	Gross Alpha (Ci)	Gross Beta/ Gamma (Ci)	^{238}Pu (Ci)	^{239,240}Pu (Ci)	^{89}Sr (Ci)	^{90}Sr (Ci)	Tritium (Ci)
1963	27,380,000	b	b	0.00371	0.15940	b	0.00160	0.14860	0.03970	b
1964	51,390,000	b	b	0.00120	2.52500	b	0.00194	0.06074	0.08865	b
1965	48,990,000	b	b	0.00189	0.70840	b	0.00349	0.04229	0.06177	b
1966	52,800,000	b	b	0.00209	0.33820	b	0.00162	0.02436	0.03558	b
1967	59,670,000	b	b	0.00342	0.30910	b	0.00422	0.05350	0.01340	20
1968	60,280,000	b	b	0.00257	0.28580	b	0.00259	0.03260	0.00082	b
1969	54,470,000	b	b	0.00660	0.28930	b	0.00678	0.05460	0.01310	20
1970	53,170,000	b	b	0.00330	0.16140	b	0.00498	0.01360	0.01980	b
1971	45,670,000	b	b	0.00394	1.84900	b	0.00691	0.01253	0.03159	b
1972	57,070,000	b	b	0.00513	0.37470	0.00769	0.00102	0.00352	0.00550	5.97
1973	53,720,000	0.00136	0.29270	0.00424	0.95860	0.00839	0.00058	0.00455	0.00710	17.47
1974	40,600,000	0.00166	0.15600	b	0.18100	0.01140	0.00039	0.00287	0.01590	4.05
1975	39,720,000	0.00113	0.17400	b	0.12000	0.01480	0.00067	0.00170	0.00544	66.00
1976	39,890,000	0.00114	0.19300	b	0.01550	0.00748	0.00105	0.00092	0.00417	187.00
1977	42,090,000	0.00193	0.14200	b	0.07630	0.00257	0.00147	0.00226	0.03040	36.50
1978	40,540,000	0.00173	0.31700	b	0.09630	0.00405	0.00183	0.00264	0.01040	12.30
1979	48,580,000	0.00468	0.17000	b	0.07070	0.00055	0.00171	0.00607	0.01420	32.70
1980	52,830,000	0.00570	0.13200	b	b	0.00130	0.00820	0.04090	0.01800	44.90
1981	55,330,000	0.02300	0.12000	b	b	0.00290	0.05500	0.04200	0.02300	17.00
1982	39,760,000	0.01780	0.20900	b	b	0.00300	0.01660	0.01180	0.01280	14.20
1983	34,500,000	0.03800	b	b	b	0.01100	0.04200	0.05700	0.00230	8.70
1984	35,030,000	0.00820	b	b	b	0.00610	0.00810	0.26000	0.00680	13.00
1985	28,600,000	0.00542	b	b	b	0.00393	0.00575	0.00904	0.00125	69.40
1986	30,500,000	0.00324	0.01800	b	b	0.00150	0.00355	0.00920	0.00069	72.50
1987	26,600,000	0.00360	0.00810	b	b	0.00140	0.00320	0.06400	0.00100	100.00
1988	29,300,000	0.00370	0.03100	b	b	0.00110	0.00320	0.08100	0.00020	21.00
1989	22,800,000	0.00410	0.03900	b	b	0.00051	0.00200	0.01800	0.00110	16.00
1990	21,100,000	0.00270	0.01250	b	b	0.00020	0.00060	b	b	12.00
1991	21,900,000	0.00110	0.06700	b	b	0.00030	0.00100	b	b	10.60
1992	19,900,000	0.00027	0.00050	b	b	0.00032	0.00039	b	b	10.63
1993	21,700,000	0.0112	0.00817	0.01240	0.02310	0.00058	0.00049	0.00263	0.00263	2.66
1994	20,841,691	0.00306	0.00851	0.00523	0.08510	0.00281	0.00046	0.00196	0.000285	2.23
1995	17,600,000	0.0034	0.00662	0.00531	0.02348	0.0034	0.0006	0.00012	0.000651	0.731
Total	1.294E+09	0.14612	2.1051	0.06102	8.51870	0.09732	0.19401	1.065	0.469	817.542

a. Amended with data from annual environmental surveillance reports; Purtymun 1975, 11787; and TA-50 annual reports

b. Blank cells are unknown values

Source: LANL 1992, 11705



F2.4.6-1 / MORTANDAD WP / 061097

Figure 2.4.6-1. Summary of TA-50 RLWTF water quality parameters and radionuclides discharged.

DOE Order 5400.5 (DOE 1990) requires that best available technology be employed, as needed, to comply with derived concentration guides (DCGs) for radionuclides in uncontrolled areas. The TA-50 RLWTF discharge occasionally exceeds the DCGs for ^{241}Am, ^{137}Cs, ^{239}Pu, and ^{90}Sr. To achieve complete compliance with the DCGs, the Laboratory is installing ultrafiltration and reverse osmosis units, which are expected to be operational in January 1998. In addition, further source controls and treatment will be implemented to meet a new NPDES discharge standard for NO_3-N of 10 mg/L, which is expected to be imposed in 1998.

From 1963 through 1995, a total of 342 million gal. (1,294,500 m^3) of treated wastewater were discharged. The maximum annual discharge was 15.8 million gal. (59,800 m^3) in 1968. In recent years discharges have declined, and since 1990 discharges have averaged 5.5 million gal. (20,800 m^3) per year. In 1995 4.6 million gal. (17,400 m^3) were discharged.

From 1963 through 1995, a total of approximately 0.15 Ci of ^{241}Am, more than 2 Ci of ^{137}Cs, 0.10 Ci ^{238}Pu, nearly 0.2 Ci of ^{239,240}Pu, approximately 1.5 Ci of ^{89,90}Sr, and approximately 818 Ci of tritium have been discharged. Most of the radionuclides ^{241}Am, ^{137}Cs, ^{238}Pu, and ^{239,240}Pu were discharged between 1972 and 1983.

The ratio of ^{239,240}Pu to ^{238}Pu in the TA-50 RLWTF discharge has varied based on the types of waste treated. This ratio can be used to identify the source or time period of a given source of plutonium contamination in sediments in Mortandad Canyon. Before 1979 the ratio ranged from 0.03 to 0.57. From 1979 through 1993 the ratio typically ranged between 2 and 3; however, it has been as high as 18. In 1994 the ratio was 0.16, and in 1995 it was 0.176, which reverses the recent trend. The ^{239,240}Pu/^{238}Pu ratio is discussed further in Section 3.8.3 of this work plan.

Some of the water quality parameters (Na^+, Cl^-, NO_3^-, and total dissolved solids [TDS]) of the TA-50 RLWTF discharge are also summarized in Figure 2.4.6-1. The average concentrations of Na^+ and Cl^- released are 441 and 62 mg/L, respectively, with maximum concentrations reaching 1063 mg/L sodium in 1983 and 182 mg/L chloride in 1989. Nitrate (as NO_3^-) annual average concentration has been 217 mg/L with a maximum of 766 mg/L in 1972. TDS averages 1810 mg/L with a maximum of 4150 mg/L in 1987. In general, as the volume of discharges decreased after 1981, the concentrations of water quality parameters, especially NO_3^- and Cl^-, increased notably during the 1980s. Since 1990 the concentrations have generally decreased.

Before 1975, outfalls at TA-50 (other than the RLWTF outfall) discharged into the head of Ten Site Canyon via drain lines 55 and 67, which originated in buildings TA-50-1 and TA-50-2, respectively. In 1974 two unplanned releases of untreated wastes occurred due to overflow of a sump in TA-50-2. The activities that were released are unknown. Drain line 67 was sealed with a flexible plug in February 1975.

Both drain lines were completely removed in 1981. Contaminants encountered during the removal were primarily ^{137}Cs, ^{239}Pu, ^{106}Ru, ^{89}Sr, ^{90}Sr, and ^{90}Y. Soil samples collected near the outfalls in 1976 contained up to 50,000 pCi/g gross-alpha activity. However, in Ten Site Canyon only 1 of 27 samples contained gross-alpha activity greater than 20 pCi/g. When the area was partially decontaminated in 1981, approximately 70 m^3 of soil was removed from the outfall locations. After decontamination, the maximum soil activities observed near the outfall were 400 pCi/g gross-alpha and 40 pCi/g gross-beta (Elder et al. 1986, 3089).

An RFI was performed for PRS No. 50-006(a), the former Ten Site Canyon outfalls, as part of OU 1147. In 1993 soil samples were collected near the outfalls of the two former drain lines, on both banks of the drainage channel, and in the canyon drainage channel at regular intervals to about 1300 ft (396 m) downstream from the TA-50 boundary. Contaminants identified as COPCs after background and screening action level (SAL) comparisons and multiple chemical risk evaluation were Aroclor 1254 and Aroclor 1260, the polycyclic aromatic hydrocarbons (PAHs) benz[a]anthracene, benzo[a]pyrene, benzo[b]fluoranthene, benzo[k]fluoranthene, and the radionuclides ^{241}Am, ^{60}Co, ^{137}Cs, ^{40}K, ^{238}Pu, ^{239,240}Pu, ^{226}Ra, ^{90}Sr, and ^{232}Th. The

PAHs were eliminated from the COPC list because they probably originated from runoff from asphalt surfaces in areas adjacent to Ten Site Canyon (LANL 1995, 49925).

A small hummock of soil, which is located on the south side of the drainage channel about 325 ft (99 m) downstream from the outfalls, contained concentrations of ^{137}*Cs,* ^{238}*Pu,* ^{239,240}*Pu, and* ^{90}*Sr above soil SAL values. Supplemental soil samples collected around the hummock did not contain contaminants above SAL values (LANL 1995, 49925). This small area of soil contamination was the subject of an interim action corrective measure in 1996. According to Field Unit 5 personnel, several cubic yards of material were removed and placed into 55-gal. drums for disposal.*

PRS No. 50-006(a) was not recommended for NFA based on the screening assessment presented in the RFI report (LANL 1995, 49925). Because material disposal area (MDA) C is adjacent to Ten Site Canyon, which at the time of the RFI report had not been fully investigated, recommendation for further study of Ten Site Canyon was deferred until analysis of the drilling investigation at MDA C was completed. However, preliminary results indicate that Ten Site Canyon has not been impacted by contaminants from MDA C.

An RFI was performed for the current TA-50 RLWTF outfall into Effluent Canyon (PRS No. 50-006[d]) according to the RFI Work Plan for Operable Unit 1147 (LANL 1992, 7672). Soil samples were collected in nine transect lines perpendicular to the drainage channel from about 20 ft (6.1 m) downstream of the outfall and at intervals of approximately 100 ft (30.5 m) for a distance of approximately 900 ft (274 m) downstream. Each transect line comprised 3 sampling locations approximately 5 ft (1.5 m) apart: 1 or 2 sampling locations in the drainage channel and 1 or 2 sampling locations on the adjacent bank. A total of 57 samples (including duplicates) were collected from 27 locations from the following depth intervals: 0 to 0.5 ft, 1.5 to 2.5 ft, and 3 to 4 ft (0 to 15 cm, 45 to 76 cm, and 0.91 to 1.22 m). Table 2.4.6-2 summarizes the RFI sampling at PRS No. 50-006(d) and the radiological screening measurements of each sample. Additional information and discussion of the results of the RFI sampling at this PRS are presented in Section 3.4.4.2 in Chapter 3 of this work plan. Because PRS No. 50-006(d) is located within Mortandad Canyon, additional investigation of this PRS was deferred until the Mortandad Canyon investigation and is included as part of this work plan.

2.4.7 Technical Area 52

TA-52 is located on an unnamed mesa and occupies the central portion of former TA-4, which is discussed above. TA-52 was established in the mid 1960s to house the ultra-high-temperature reactor experiment (UHTREX). The reactor was shut down in February 1970 and was removed in 1990.

The reactor was housed in building TA-52-1. An outfall associated with TA-52-1 is believed to have discharged noncontact cooling water, but the location of the outfall is uncertain. PRS No. 52-001(d) includes the former sump pump room, ducts, and hot cells located within TA-52-1. Inactive septic systems are present and are included in PRS Nos. 52-002(a through g). PRS No. 52-002(a) is the original septic system for the UHTREX building. Overflow from the septic tank flowed to a 300-ft-long (91-m-long) tile drain field trench that runs east to west near the mesa edge bordering Ten Site Canyon. The septic system may have received solvents, chemicals, and radionuclides as well as sanitary waste.

The other septic systems at TA-52 were installed after 1982 and served only offices; the septic systems did not discharge into Ten Site Canyon. All of these septic systems were inactive by 1993 when the new sanitary wastewater treatment plant at TA-46 became operational. No other outfalls that might contribute to contamination in Mortandad Canyon are associated with TA-52.

TABLE 2.4.6-2

SUMMARY OF SAMPLES COLLECTED AT PRS No. 50-006(d)

Site ID	Depth (ft)	Sample Type	Sample ID	Sample Date	Alpha[a] (pCi/g)	Beta[a] (pCi/g)	Gamma[a] (pCi/g)
50-6000	0–0.5	Reg	AAA2492	6/9/93	10.3	19.2	3.96
50-6001	0–0.5	Reg	AAA2493	6/9/93	60.4	26.3	7.71
50-6002	0–0.5	Reg	AAA2494	6/9/93	8.22	29.4	4.21
50-6002	1.5–2.5	Reg	AAA2750	6/9/93	22.1	43.4	13.03
50-6002	3–4	Reg	AAA2752	6/9/93	31.2	112.7	104.4
50-6003	0–0.5	Reg	AAA2495	6/9/93	18.2	40.6	4.04
50-6004	0–0.5	Reg	AAA2496	6/9/93	2.61	20.5	1.1
50-6005	0–0.5	Reg	AAA2497	6/9/93	BDL[b]	15.9	0.6
50-6005	3–4	Reg	AAA2753	6/9/93	6.96	13.0	1.08
50-6006	0–0.5	Reg	AAA2498	6/9/93	35.5	34.9	17.23
50-6007	0–0.5	Reg	AAA2499	6/9/93	35.8	15.1	16.54
50-6007	1.5–2.5	Reg	AAA2749	6/9/93	59.9	36.1	31.44
50-6008	0–0.5	Reg	AAA2500	6/9/93	12.1	31.3	2.05
50-6008	1.5–2.5	Reg	AAA2748	6/9/93	4.49	14.5	1.44
50-6008	3–4	Reg	AAA2751	6/9/93	1.86	40.5	1.34
50-6009	0–0.5	Reg	AAA2501	6/7/93	18.8	43.7	1.92
50-6009	3–4	Reg	AAA2739	6/7/93	9.65	29.0	0.63
50-6010	0–0.5	Reg	AAA2502	6/7/93	22.1	41.3	133.75
50-6011	0–0.5	Reg	AAA2503	6/7/93	17.9	53.0	9.03
50-6011	0–0.5	Dup	AAA2742	6/7/93	17.8	45.4	8.13
50-6012	0–0.5	Reg	AAA2504	6/7/93	5.76	21.7	10.3
50-6012	1.5–2.5	Reg	AAA2743	6/7/93	1.64	21.1	16.72
50-6012	1.5–2.5	Dup	AAA2745	6/7/93	BDL	9.93	22.98
50-6013	0–0.5	Reg	AAA2505	6/7/93	10.7	45.9	41.99
50-6014	0–0.5	Reg	AAA2506	6/7/93	BDL	9.69	0.83
50-6014	1.5–2.5	Reg	AAA2725	6/7/93	6.74	10.1	1.19
50-6015	0–0.5	Reg	AAA2507	6/7/93	8.33	62.1	4.5
50-6015	3–4	Reg	AAA2747	6/7/93	10.1	29.6	20.24
50-6016	0–0.5	Reg	AAA2508	6/7/93	17.9	29.3	31.65
50-6016	1.5–2.5	Reg	AAA2744	6/7/93	6.29	29.4	38.97
50-6017	0–0.5	Reg	AAA2509	6/7/93	9.9	33.1	1.96
50-6017	3–4	Reg	AAA2735	6/7/93	4.27	31.9	0.88
50-6017	3–4	Dup	AAA2746	6/7/93	3.28	18.5	0.85
50-6018	0–0.5	Reg	AAA2510	6/3/93	45.5	40.9	27.41
50-6018	1.5–2.5	Reg	AAA2728	6/3/93	44.4	62.9	31.39
50-6018	3–4	Reg	AAA2736	6/3/93	19.5	55.8	34.27
50-6019	0–0.5	Reg	AAA2511	6/3/93	4.26	20.9	1.79
50-6019	1.5–2.5	Reg	AAA2726	6/3/93	4.86	21.6	1.15
50-6019	3–4	Reg	AAA2733	6/3/93	9.71	17.8	0.95

[a] *Alpha, beta, and gamma values from radiological screening of samples*

[b] *BDL = below detection limit*

TABLE 2.4.6-2 (continued)

SUMMARY OF SAMPLES COLLECTED AT PRS No. 50-006(d)

Site ID	Depth (ft)	Sample Type	Sample ID	Sample Date	Alpha[a] (pCi/g)	Beta[a] (pCi/g)	Gamma[a] (pCi/g)
50-6020	*0–0.5*	*Reg*	*AAA2512*	*6/3/93*	*6.96*	*21.0*	*1.22*
50-6020	*1.5–2.5*	*Reg*	*AAA2732*	*6/3/93*	*9.21*	*28.2*	*0.9*
50-6020	*3–4*	*Reg*	*AAA2740*	*6/3/93*	*9.54*	*19.4*	*0.93*
50-6021	*0–0.5*	*Reg*	*AAA2513*	*6/3/93*	*23.0*	*57.0*	*76.61*
50-6021	*1.5–2.5*	*Reg*	*AAA2727*	*6/3/93*	*28.3*	*157.3*	*176.96*
50-6021	*3–4*	*Reg*	*AAA2738*	*6/3/93*	*33.3*	*128.6*	*101.36*
50-6022	*0–0.5*	*Reg*	*AAA2514*	*6/3/93*	*14.2*	*20.9*	*22.8*
50-6022	*1.5–2.5*	*Reg*	*AAA2731*	*6/3/93*	*38.0*	*72.2*	*122.9*
50-6022	*3–4*	*Reg*	*AAA2741*	*6/3/93*	*30.0*	*247.2*	*341.04*
50-6023	*0–0.5*	*Reg*	*AAA2515*	*6/3/93*	*21.4*	*53.3*	*40.49*
50-6023	*1.5–2.5*	*Reg*	*AAA2729*	*6/3/93*	*4.86*	*39.3*	*8.89*
50-6023	*3–4*	*Reg*	*AAA2734*	*6/3/93*	*7.84*	*90.4*	*42.0*
50-6024	*0–0.5*	*Reg*	*AAA2516*	*6/3/93*	*16.4*	*25.5*	*5.68*
50-6024	*1.5–2.5*	*Reg*	*AAA2724*	*6/3/93*	*42.8*	*46.1*	*19.94*
50-6025	*0–0.5*	*Reg*	*AAA2517*	*6/3/93*	*35.6*	*64.3*	*37.62*
50-6026	*0–0.5*	*Reg*	*AAA2518*	*6/3/93*	*39.4*	*53.2*	*22.26*
50-6026	*1.5–2.5*	*Reg*	*AAA2730*	*6/3/93*	*130.7*	*139.7*	*104.43*
50-6026	*3–4*	*Reg*	*AAA2737*	*6/3/93*	*83.5*	*132.2*	*128.08*
				Minimum	*1.64*	*9.69*	*0.6*
				Maximum	*130.7*	*247.2*	*341.04*
				Geometric Mean	*14.18*	*35.62*	*9.20*
				Average	*21.93*	*46.91*	*33.47*

a. Alpha, beta, and gamma values from radiological screening of samples

b. BDL = below detection limit

In 1995 an RFI was conducted at the TA-52 PRSs according to the RFI Work Plan for Operable Unit 1129 (LANL 1992, 7666). The RFI report is expected to be completed in 1998.

2.4.8 Technical Area 55 and Former Technical Area 42

TA-55 is located on an unnamed mesa between Mortandad Canyon to the north and Twomile Canyon to the south; it encompasses the area of former TA-42, which is discussed below.

2.4.8.1 Technical Area 55

TA-55 was established in 1973 for the plutonium-processing laboratory. Operations include fabrication of plutonium metal components, processing of plutonium, and basic research on transuranic materials.

Four PRSs at TA-55 are associated with storm water from building TA-55-4, which is collected in catch basins equipped with storm drains that discharge to Mortandad Canyon. PRS No. 55-011(a) discharges storm water collected from the northwest side of TA-55-4; PRS Nos. 55-011(b, c, and e) discharge storm water from the northeast side of TA-55-4. PRS No. 55-010 is associated with potential soil contamination from solvents *used during painting when building TA-55-1 was constructed. No RFI has been performed at the PRSs in this technical area, and no data on known or suspected contaminants are available.*

2.4.8.2 Former Technical Area 42

Former TA-42, the Incinerator Site, was located at the north side of what is now TA-55, on the south edge of Effluent Canyon. The incinerator was designed to burn radionuclide-contaminated wastes generated at the Laboratory, thereby reducing the volume. The incinerator was completed in 1951 and operated for a short time in 1951 and 1952. Because of poor performance and operational problems, very little waste was actually incinerated (Harper and Garde 1981, 6286).

From 1957 until 1969 the site was used to store and decontaminate equipment (for example, dry boxes and vehicles). In 1969 an unsuccessful attempt was made to reactivate the incinerator to burn uncontaminated classified wastes, but by 1970 all operations were discontinued and all combustibles were removed from the building (Harper and Garde 1981, 6286; DOE 1987, 8663). In 1978 the incinerator, including all structures, debris, and contaminated soils, was removed and disposed of at TA-54, Area G. The site was recontoured and revegetated (Harper and Garde 1981, 6286; LANL 1992, 7666).

The following four PRSs were identified at the former TA-42 site.

PRS Nos. 42-001(a through c)	*Incinerator complex*
PRS Nos. 42-002(a and b)	*Decontamination area*
PRS No. 42-003	*Septic system*
PRS No. 42-004	*Canyon disposal*

These PRSs are described in the RFI Work Plan for Operable Unit 1129 (LANL 1992, 7666). In 1993 an RFI for these PRSs was conducted, and the results were reported in the RFI report (Pratt et al. 1994, 41204; LANL 1995, 50056). Concentrations of contaminants above SAL values were not detected, and all PRSs were recommended for NFA.

2.4.9 Technical Area 63

TA-63, which is located south of TA-35 on an unnamed mesa, currently houses an engineering section office and several supporting office trailers. In 1989 TA-63 was created from the western portion of the original TA-52 when the Laboratory redefined the technical area boundaries. The area was part of TA-4 in the 1950s and TA-0 during the 1960s and 1970s. The area has been occupied only by office trailers, storage sheds, and maintenance shops throughout its history.

PRSs associated with TA-63 are listed in Appendix B of this work plan and are shown in Figure A-1 in Appendix A of this work plan. No outfalls are associated with TA-63; however, two septic systems served TA-63 before 1992. These septic systems have been designated as PRS Nos. 63-001(a and b). No surface effluent was discharged from these systems because they were designed with seepage pits. In 1992 the septic systems were disconnected from the building they served and removed from service. The sanitary waste lines were connected to the sanitary sewer system for the TA-46 wastewater treatment plant.

In 1995 an RFI was conducted at the TA-63 PRSs according to the RFI Work Plan for Operable Unit 1129 (LANL 1992, 7666). Four boreholes were drilled at each of the septic systems, and soil samples were collected at depth to characterize the septic systems. Field screening during sample collection did not indicate the presence of radioactive constituents above background levels or the presence of VOCs. The RFI report is expected to be completed in 1998.

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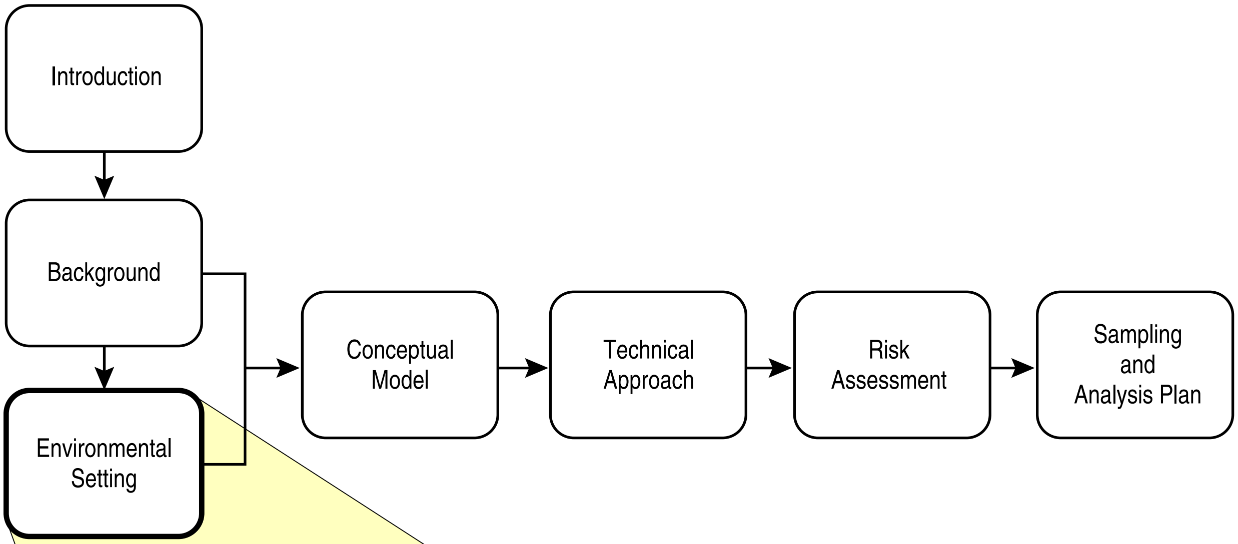
Chapter 3



Environmental Setting

- Environmental Overview
- Geology, Hydrology, and Hydrogeology
- Geochemistry
- Biological Setting
- Radiological Exposure

3.0 ENVIRONMENTAL SETTING

This chapter describes the environmental setting of Mortandad Canyon and Ten Site Canyon and their main tributaries, Effluent Canyon and Pratt Canyon, respectively. The regional environmental setting of the Laboratory is presented in Chapter 3 of the Core Document for Canyons Investigations (hereafter "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 Mortandad 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.

Throughout the years, numerous boreholes have been drilled and either completed for some purpose, left open and uncompleted, or abandoned. The boreholes and completions have been designated by letters and numbers. The first two or three letters designate the canyon or mesa (for example, MC = Mortandad Canyon, TSC = Ten Site Canyon, PM = Pajarito Mesa), 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*
OI	*Observation intermediate; completed in an intermediate perched zone*
M	*Moisture access tube; borehole cased with 2-in.-diameter plastic pipe with a plug in the bottom, intended for logging with a neutron moisture/density gauge*
C/CH	*Core hole; not completed as a well*
WB	*Water-balance; well completed in alluvium intended for water level measurement only*

Each letter is typically followed by a number, which indicates the downstream sequence of installation. The letters after the numbers indicate multiple installations at approximately the same locations as transects, replacements, or multiple depths (for example, MCM-8A through MCM-8F).

Exceptions include the following. Water supply wells are designated by the location of the well field (for example, LA = Los Alamos Canyon, PM = Pajarito Mesa, G = Guaje Canyon, O = Otowi); test wells, typically 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, designated MT for Mortandad test, were completed as wells in the alluvium.

The letter and number/letter designations for these installations also are used as locations on various maps provided in this work plan.

In addition, sediment sampling locations used in the 1960s and 1970s were designated MCS and TSCS followed by a number. The locations are adjacent to the observation wells designated by MCO or TSCO followed by the downstream sequence number. Recently sediment sampling locations have been *designated by the nearby well number (for example, Mortandad at MCO-9 [see Figure A-2 in Appendix A of 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, Mortandad 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 discussed in this work plan are provided by Purtymun (1995, 45344).

3.1 Location, Topography, and Surface Drainage

3.1.1 Mortandad Canyon

Mortandad Canyon is a narrow, east/southeast-trending canyon that heads on the central part of the Pajarito Plateau at an elevation of 7417 ft (2261 m). The watershed extends from the southern part of Technical Area (TA) -3 east/southeast for about 5 mi (8.1 km) on Laboratory property and another 4.5 mi (7.2 km) on San Ildefonso Pueblo land to the confluence with the Rio Grande. The drainage area of Mortandad Canyon on Laboratory property is about 2 mi^2 (5.2 km^2). Figure A-2 in Appendix A of this work plan shows the location of Mortandad Canyon within the Laboratory boundary and the area of the watershed.

Shortly downstream from TA-3 Mortandad Canyon forms a deep, narrow, relatively straight drainage channel. The upper canyon is incised approximately 100 ft (30.5 m) into the Tshirege Member of the Bandelier Tuff. The canyon borders TA-48 on the north approximately 0.7 mi (1.1 km) from the head of the canyon; at this location it is between 700 and 800 ft (213 and 244 m) wide at the rim and approximately 100 ft (30.5 m) deep.

Mortandad Canyon contains a stream that is entirely ephemeral; neither perennial springs nor natural perennial reaches occur. Snowmelt runoff and stormwater runoff from seasonal snow and rain storms flow for a limited distance in the upper canyon and occasionally as far as the sediment traps. Upstream of TA-48, snowmelt and stormwater runoff and cooling water discharges are the sources of flow into Mortandad Canyon. Stormwater runoff into the canyon has likely increased in volume during the past 30 years because of construction of paved parking lots, roads, and buildings at the Laboratory, which increase the imperviousness of the watershed. Surface water flows from the National Pollutant Discharge Elimination System (NPDES) -permitted outfall 051 at the Laboratory's TA-50 Radioactive Liquid Waste Treatment Facility (RLWTF) and from NPDES-permitted cooling tower outfalls at TA-3 and TA-48. Surface flow that results from all outfalls typically extends less than 1 mi (1.6 km) downstream of outfall 051 (LANL 1997, 55622).

For discussion purposes, Mortandad Canyon is divided into upper, middle, lower, and lower off-site sections, similar to those described in earlier reports (for example, Stoker et al. 1991, 7530) except that the designations herein encompass the entire canyon from TA-3 to the Rio Grande.

The **upper canyon** *is the steep narrow upper portion of the canyon that extends from near TA-3 (CMR Building) for about 1.4 mi (2.3 km) eastward to the confluence with Effluent Canyon.*

The **middle canyon** *is the deep narrow portion of the canyon that extends from the confluence of Effluent Canyon about 1.1 mi (1.8 km) eastward to near Test Well (TW) -8 and Mortandad Canyon observation (MCO) well MCO-5.*

The **lower canyon** *is the wider portion of the canyon that extends from near TW-8 about 2 mi (3.2 km) to the Laboratory boundary. This portion of the canyon contains the largest volume of alluvial material, the sediment traps, and most of the alluvial groundwater.*

The **lower off-site canyon** *is the remaining portion of the canyon that extends from the Laboratory boundary about 5 mi (8.1 km) on San Ildefonso Pueblo land to the Rio Grande.*

3.1.2 Ten Site Canyon

Ten Site Canyon is the major tributary to Mortandad Canyon on Laboratory property; it lies south of Mortandad Canyon and extends parallel to Mortandad Canyon for about 1.5 mi (2.4 km). Ten Site Canyon heads at the south side of TA-50 at an elevation of about 7250 ft (2210 m) and joins Mortandad Canyon in the lower canyon. A small tributary of Ten Site Canyon, recently referred to as "Pratt Canyon" (LANL 1996, 54422), received discharges of liquid and sludge waste from the TA-35 wastewater treatment plant that operated from 1951 to 1963. Earlier reports (for example, Aeby 1952, 741) generally referred to Pratt Canyon and Ten Site Canyon as Mortandad Canyon.

3.1.3 Effluent Canyon

Another small tributary to Mortandad Canyon, called "Effluent Canyon," is located east of TA-48 and north of TA-55. Effluent Canyon enters from the south approximately 1.4 mi (2.3 km) downstream of the head of the canyon. Effluent Canyon heads at the east side of TA-48 at an elevation of approximately 7300 ft (2225 m). At the confluence with Effluent Canyon, Mortandad Canyon is approximately 1000 ft (305 m) across, rim to rim, and approximately 150 ft (46 m) deep. A small wetland east of TA-48 has formed from cooling water discharges into Effluent Canyon. Stormwater runoff from the west, south, and east sides of TA-48, the north part of TA-55, and the western part of TA-35 also drain into Effluent Canyon.

This small tributary canyon receives discharge from the TA-50 RLWTF. This outfall has been used since 1963 and is the primary reason why Mortandad Canyon has been the subject of vigorous environmental monitoring since 1960. As many as four noncontact cooling water systems at TA-48 and TA-55 also discharged into Effluent Canyon as of 1990; many of these systems have been discontinued or are expected to be discontinued. Discharges from TA-48 support small wetlands in Effluent Canyon between TA-48 and the TA-50 RLWTF outfall (Figure A-1 in Appendix A of this work plan).

3.1.4 Cedro Canyon

Cedro Canyon, another major tributary, is located entirely on San Ildefonso Pueblo land; it extends for about 3 mi (4.8 km) and joins Mortandad Canyon at state road NM4 north of White Rock about 3 mi (4.8 km) upstream of the Rio Grande. The stream of Cedro Canyon is entirely ephemeral (McLin 1992, 12014).

3.1.5 Cañada del Buey

Cañada del Buey, another major tributary, heads on Laboratory property near TA-52, extends about 7 mi (11.2 km) to the southeast along the north side of TA-54 through the north part of White Rock, and joins Mortandad Canyon about 0.5 mi (0.8 km) upstream of the Rio Grande. Cañada del Buey will be addressed in a separate canyons investigation work plan.

3.2 Climate

The climate of the Pajarito Plateau and the vicinity of Mortandad Canyon is discussed in the core document (LANL 1997, 55622) and is briefly discussed in this section. However, the Laboratory has no meteorological stations in Mortandad Canyon; therefore, canyon-specific data are not available.

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) and Chapter 2 of the IWP (LANL 1996, 55574). It is also discussed in detail by Bowen (1990, 6899).

Past investigations of the hydrology of Mortandad Canyon have mentioned evapotranspiration (ET) as a process for removing shallow alluvial groundwater (for example, Baltz et al. 1963, 8402; Purtymun 1974, 5476; Purtymun et al. 1983, 6407). Canyon-specific ET data are not available; however, three ET monitoring stations have recently been installed in the canyon by the Laboratory Water Quality and Hydrology group (ESH-18). These stations are designated as ET-1, ET-2, and ET-3 and are located near wells MCO-7.5, MCO-6, and MCO-5, respectively (see Figure A-2 in Appendix A of this work plan).

3.3 Geology

Detailed 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). The following discussion uses the core document as the point of departure and provides detail that is specific to the Mortandad Canyon system. Unless otherwise noted, locations of wells and boreholes mentioned herein are shown in Figure A-2 in Appendix A of this work plan. Some locations are off the scale of Figure A-2; 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 Mortandad Canyon area is shown on geologic maps prepared by Baltz et al.(1963, 8402) and Rogers (1995, 54419). The subsurface geology has been investigated by a number of deep boreholes including those for wells TW-8 (Baltz et al. 1963, 8402); PM-3 located in Sandia Canyon to the north (Purtymun 1967, 11829; Purtymun 1995, 45344); PM-4 located in Cañada del Buey to the south (Purtymun 1995, 45344); PM-5 (Purtymun 1995, 45344); SHB-1 (Gardner et al. 1993, 12582); and EGH-LA-1 (Purtymun 1995, 45344). Numerous shallow boreholes in the floor of Mortandad Canyon have penetrated alluvium and upper bedrock units. The distribution of geologic units in the Mortandad Canyon area is illustrated by Rogers (1995, 54419).

3.3.1 Stratigraphy

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

- *Santa Fe Group: 4 to 21 Ma (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*
- *Tshirege Member of the Bandelier Tuff: ca 1.22 Ma (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.

3.3.1.1 Santa Fe Group

In the general area of Mortandad Canyon, the Santa Fe Group was penetrated by water supply wells PM-3, PM-4, and PM-5 and by borehole EGH-LA-1. Based on borehole lithological and geophysical logs, Purtymun (1995, 45344) divided the Santa Fe Group into three formations, which include (in ascending order) the Tesuque Formation, the Chamita Formation, and the “Chaquehui Formation.”

3.3.1.1.1 Tesuque Formation

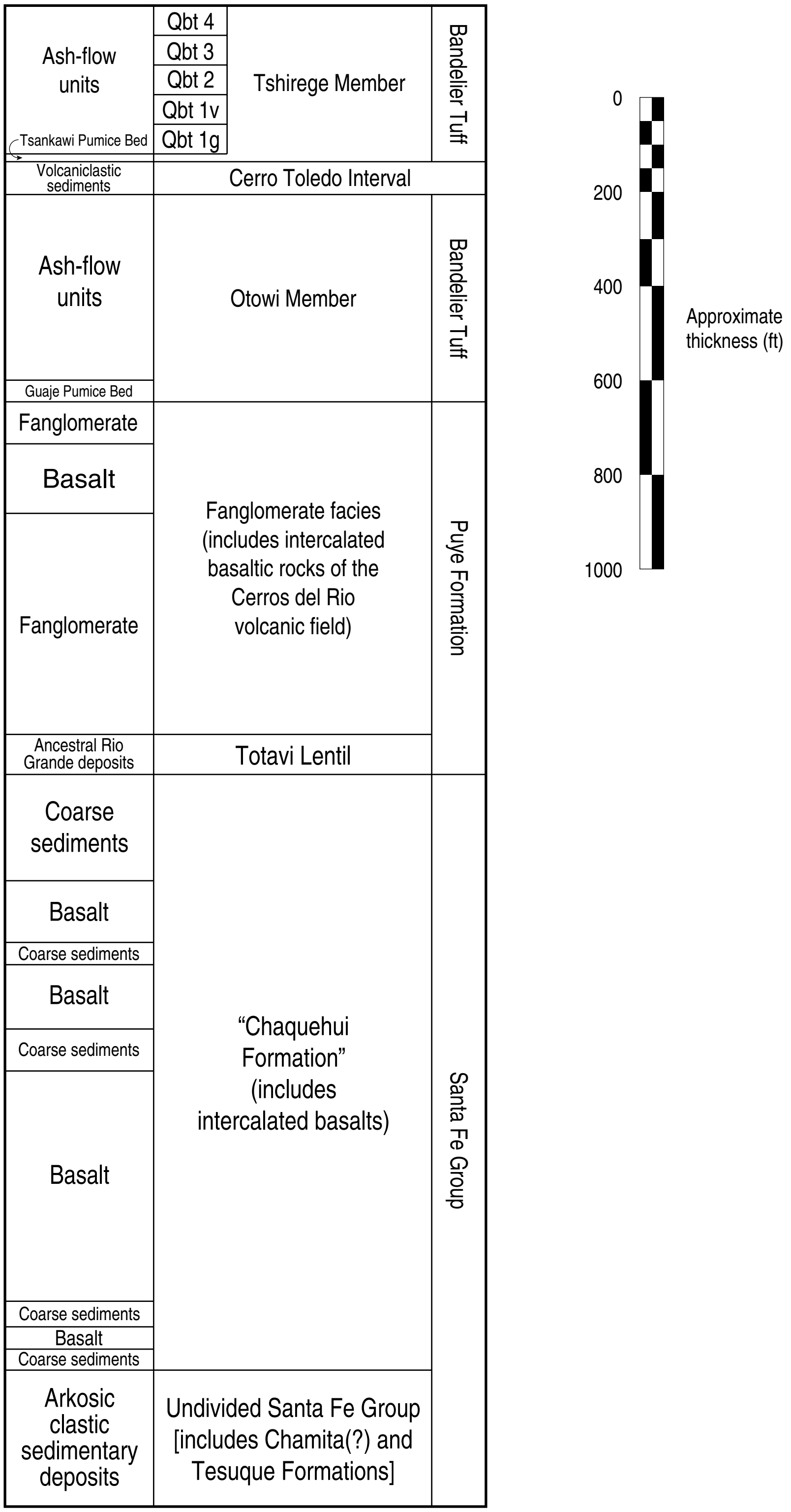
In PM-4 the Tesuque Formation consists of poorly-consolidated, light pinkish brown, silty sandstone, siltstone, and claystone (Purtymun 1967, 11829). The sandstones are predominately fine- to medium-grained, and the sand grains are subrounded to well rounded. Although not described in the Mortandad Canyon area, the Tesuque Formation also contains subordinate gravel and cobble layers in boreholes for wells that are located in other parts of the Pajarito Plateau.

3.3.1.1.2 Chamita Formation

The Chamita Formation is 80 ft (24 m) thick in PM-5 but is absent in PM-3 (Purtymun 1995, 45344). It is similar in appearance to the Tesuque Formation, but the former reportedly contains a larger proportion of volcanic and granitic clasts in its gravel layers (Galusha and Blick 1971, 21526) 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). 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 Tesuque Formation deposits is often difficult, particularly in borehole investigations.

3.3.1.1.3 “Chaquehui Formation”

Purtymun (1995, 45344) calls a distinctive group of coarse-grained sediments at the top of the Santa Fe Group the “Chaquehui Formation.” The name “Chaquehui Formation” is used here in an informal and provisional sense because the type section in Chaquehui Canyon is much younger than the “Chaquehui Formation” identified in boreholes on the Pajarito Plateau. In PM-3 the “Chaquehui Formation” consists of medium- to coarse-grained sandstone, conglomerate, and siltstone (Purtymun 1967, 11829). Because of its high permeability characteristics, it is an important aquifer for the development of high-yield, low-drawdown municipal and industrial water supply wells.



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

F3.3.1-1 / MORTANDAD WP / 090597

Figure 3.3.1-1. Bedrock geologic units near middle Mortandad Canyon.

All the deep boreholes in the Mortandad Canyon area encountered basaltic lava flows that are interbedded with the sedimentary deposits of the "Chaquehui Formation." 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 (Purtymun 1967, 11829).

The "Chaquehui Formation" 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 across the Pajarito Plateau (see Figure 2-4 in the Hydrogeologic Workplan [LANL 1996, 55430]). This trough is filled with up to 1500 ft (457 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 Mortandad Canyon near state road NM4. The western margin of the trough is not well constrained but probably lies west of the headwaters of Mortandad Canyon.

3.3.1.2 Puye Formation

The Puye Formation is a fanglomerate deposit generally consisting of poorly-sorted boulders, cobbles, and coarse sands. In PM-3 the clasts are composed of latite, rhyolite, and fragments of basalt and pumice (Purtymun 1967, 11829). In TW-8 the fanglomerate consists predominately of fine- to coarse-grained sands and interbedded clay, silt, and gravel (Baltz et al. 1963, 8402). The lower part of the fanglomerate includes more than 95 ft (29 m) of light tan to light gray tuff and tuffaceous sand. Confined groundwater representing the top of the regional aquifer was found in these tuffs and tuffaceous sands between the depths of 985 and 990 ft (300 and 302 m) during drilling of the borehole for TW-8 (Baltz et al. 1963, 8402). The water rose in the borehole to a depth of 962.5 ft (293.4 m) below ground surface, which indicates confined conditions. The nature of the confining beds could not be determined from drill cuttings, but Baltz et al. (1963, 8402) believed that the beds were clay.

In TW-8 a sequence of brown and gray basaltic lava flows split the fanglomerate into the main lower part and a thin upper part (Baltz et al. 1963, 8402) (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 stratigraphically equivalent to the basaltic rocks of the Cerros del Rio volcanic field, and they probably represent an extension of that volcanic field beneath the Pajarito Plateau. Dacite, presumably representing the distal edge of a Tschicoma Formation lava flow, was found in the upper part of the fanglomerate in borehole SHB-1. Similar dacite flows may underlie the headwaters of Mortandad Canyon.

The lower part of the Puye Formation includes the "Totavi Lentil" of Griggs (1964, 8795), which is an axial deposit of the ancestral Rio Grande. In PM-3 this deposit is composed of gravel and boulders of latite, rhyolite, and quartzite (Purtymun 1967, 11829). The thickness of the "Totavi Lentil" varies from 40 ft (12 m) in PM-4 to 70 ft (21 m) in PM-5 (Purtymun 1995, 45344). The "Totavi Lentil" interfingers with the fanglomerates of the Puye Formation and basaltic rocks of the Cerros del Rio volcanic field in White Rock Canyon.

3.3.1.3 Otowi Member of the Bandelier Tuff

The Otowi Member is a nonwelded, poorly-consolidated ignimbrite sheet made up 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 borehole 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 (see Figure 5 in Broxton and Reneau [1996, 55429]). The Otowi Member thins eastward against a north-trending basaltic highland that crosses Mortandad Canyon near state road NM4. The Otowi Member is absent in lower Mortandad Canyon where it either was not deposited or was removed by erosion before the Tshirege Member was deposited.*

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 middle and upper Mortandad Canyon (Purtymun 1995, 45344).

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). This unit includes well-stratified tuffaceous sandstones and siltstones, primary ash-fall and pumice-fall deposits, and dacite-rich gravels and boulder deposits. The Cerro Toledo deposits, which vary in thickness from 0 to more than 100 ft (30 m), were deposited partly in erosional channels developed on top of the Otowi Member before deposition of the Tshirege Member and partly on paleotopographic drainage divides. Erosion of the Cerro Toledo interval may have occurred in places before deposition of the Tshirege Qbt 1 unit, which created locally variable thickness. The Cerro Toledo interval is approximately 140 ft (43 m) thick in borehole SHB-1 (Gardner et al. 1993, 12582) and approximately 80 ft (24 m) thick in borehole 35-2028 located in Pratt Canyon (LANL 1996, 54422). The Cerro Toledo interval was not previously identified in any boreholes drilled for wells in Mortandad Canyon; however, it is probably present but was not recognized as a separate unit by geologists who tended to combine these deposits with the Tsankawi Pumice Bed of the Tshirege Member. During preparation of this work plan, borehole logs were reinterpreted to identify probable Cerro Toledo deposits beneath Mortandad Canyon based on the expected thickness of the Tshirege Qbt 1g unit and the Tsankawi Pumice Bed in this area.

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 Mortandad 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. Both Baltz et al. (1963, 8402) and Rogers (1995, 54419) applied different systems of stratigraphic nomenclature to subunits of the Tshirege Member. This work plan follows the nomenclature of Broxton and Reneau (1995, 49726), which was adopted for use as a standard by the Laboratory Environmental Restoration (ER) Project. Correlations among these different systems of nomenclature are shown in Figure 3-8 of the core document (LANL 1997, 55622).

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

- *The Tsankawi Pumice Bed 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 exposed at the surface in areas of Mortandad Canyon east of state road NM4.*

- *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 west of the sediment traps and lower parts of cliff walls in the middle and the upper sections of lower Mortandad Canyon.*

- *Qbt 1v is a series of cliff- and slope-forming outcrops composed of porous, nonwelded, devitrified ignimbrite. 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 widespread mappable marker horizon throughout lower Mortandad 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 Mortandad Canyon and subcrops beneath the canyon floor west of TW-8.*

- *Qbt 2 forms a distinctive, medium brown, vertical cliff that stands out in marked contrast to the slope-forming, lighter-colored tuffs above and below. This unit is the zone of greatest welding in the Tshirege Member and underlies the canyon floor in the steep, narrow parts of middle Ten Site Canyon and upper Mortandad Canyon. Qbt 2 forms the resistant caprock on mesa tops in lower Mortandad Canyon.*

- *Qbt 3 is a nonwelded to partially welded, vapor-phase altered 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 Mortandad Canyon. The upper part of Qbt 3 is a partially welded tuff that forms the caprock of mesas adjacent to middle and upper Mortandad Canyon.*

- *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 in the western part of upper Mortandad Canyon.*

3.3.1.6 Alluvium

Alluvium of Pleistocene and Holocene age rests unconformably on the Bandelier Tuff and the Cerro Toledo interval in Mortandad Canyon west of state road NM4. The alluvium consists mostly of detritus eroded from the Tshirege Member of the Bandelier Tuff, which forms the steep walls of the canyon. The alluvium also contains detritus eroded from eolian deposits and fallout pumice deposits. In the upper canyon, the alluvium is thin and consists of boulders, cobbles, and pebbles of tuff intermixed with sand, silt, and clay. The sand consists mainly of fine- to coarse-grained crystal fragments of quartz and sanidine and is relatively thin, ranging from a few inches up to about 18 ft (5.5 m) thick at well MCO-4.

In middle and lower Mortandad Canyon, the alluvium is generally composed of finer-grained materials, including sand, silt, and clay. The alluvium is significantly thicker and wider in this part of the canyon, ranging from 18 ft (5.5 m) thick at well MCO-4 to 36 ft (11 m) thick at well MCO-6 and to about 60 ft (18 m) thick at well MCO-8.

Figure A-3 in Appendix A of this work plan shows the longitudinal cross section along the axis of the Mortandad Canyon drainage channel and the main tributary canyons, including Ten Site Canyon, its tributary, Pratt Canyon, and Effluent Canyon. The figure contains information from the important boreholes in Mortandad Canyon and information from deep boreholes near the canyon, which are projected into the line of cross section. Also shown on the figure are multiple cross sections perpendicular to the axis of the channel, which show the approximate configuration and shape of the canyon and the thickness and width of the alluvial sediments. The vertical scale exaggeration shown is 10 times the horizontal scale; therefore, changes in the channel gradient are obvious on the cross section. The approximate base of the alluvium, as obtained from borehole logs for the deepest part of the alluvial channel in each section of the canyon, is also shown on the cross section.

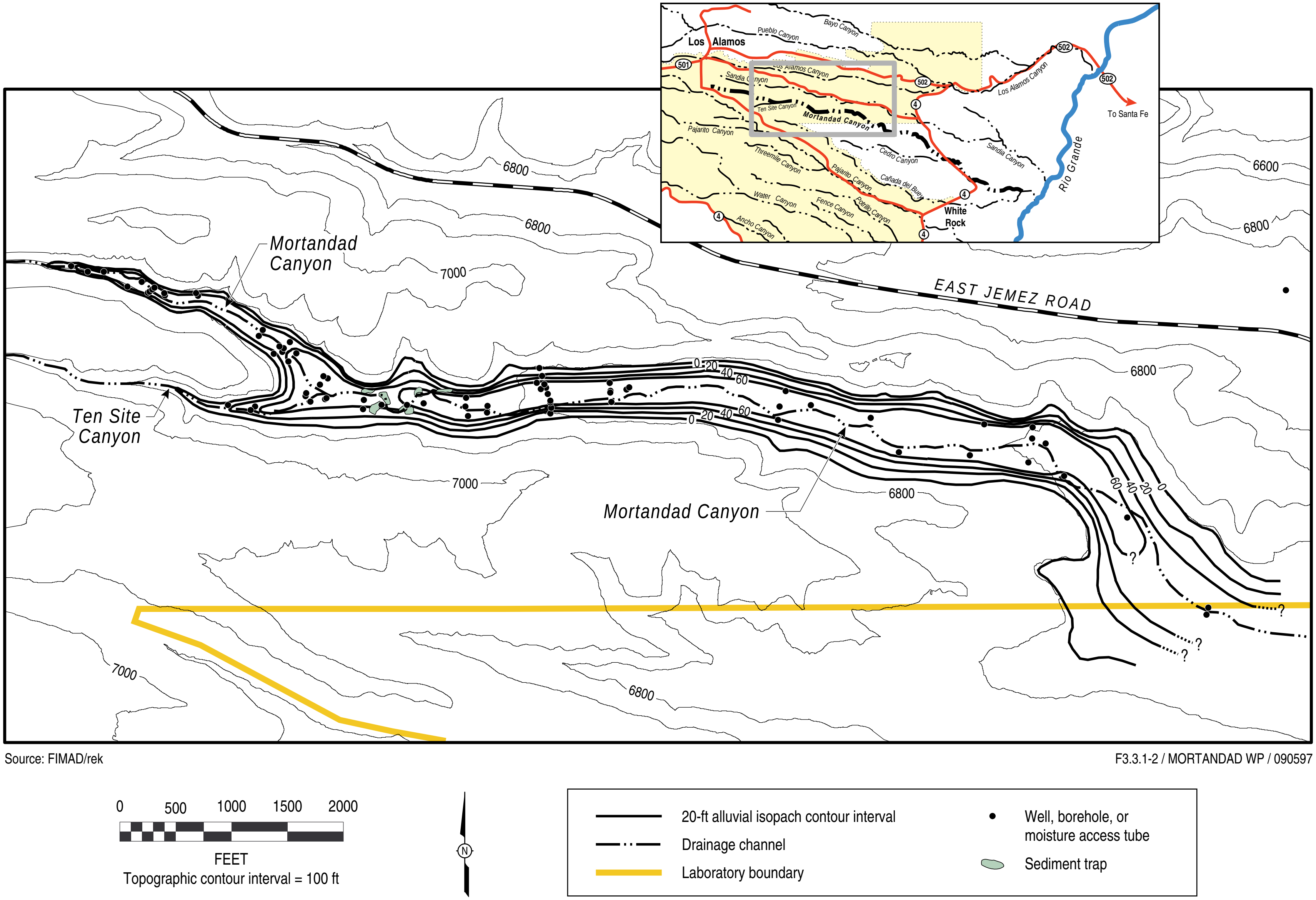
Where available, gamma log traces have been added to the figure adjacent to their respective boreholes to provide visual information about subsurface stratigraphy. The gamma logs were obtained in 1960 during installation of the wells (Purtymun 1964, 11822) and provide general information about natural radiometric variation of the sediments. In general, the gamma logs show the relative abundance of ^{40}K in the sediments. Finer-grained materials such as clays contain higher concentrations of ^{40}K, whereas coarser-grained sands and gravels contain lower concentrations.

The alluvium thickens downstream to near the MCO-8 line of wells. Stratigraphic markers observed on the gamma logs were used to correlate possible horizons within the alluvium. Upper horizons within the alluvium show thickening in the area from the sediment traps to near well MCO-8, probably due to sediment deposition during stormwater runoff (see Section 3.6). The location of the base of the alluvium is difficult to determine in the lower canyon where the Cerro Toledo interval subcrops beneath the alluvium.

The alluvium in the middle canyon is composed of two distinct zones (Baltz et al. 1963, 8402; Stoker et al. 1991, 7530). The lower portion of the alluvium is primarily brown silt and clay with interspersed sand lenses, and the upper part of the alluvium is composed of coarse-grained crystal fragment sand and tuff detritus gravels with a few interspersed lenses of silt and clay. Generally, the alluvium is thickest near the axial part of the canyon and becomes thinner toward the edges. The upper part of the alluvium is about 18 ft (5.5 m) thick at MCO-4 and about 30 ft (9.1 m) thick at MCO-8.

The source of the alluvium in Mortandad Canyon is mostly from physical and chemical weathering of the steep canyon walls that are formed from Tshirege units Qbt 1, Qbt 2, Qbt 3, and Qbt 4. The alluvium is composed of gravels, sands, silts, and clays that have been deposited in the canyon and have subsequently weathered in place. The sands consist mainly of fine- to coarse-grained crystal fragments of quartz and sanidine (Baltz et al. 1963, 8402). Figure 3.3.1-2 is a preliminary isopach map of the alluvium in Mortandad Canyon. The data points were derived from information provided from previous boreholes for wells in the canyon (for example, Purtymun 1995, 45344) and from recent reinterpretation of borehole logs.

The bedrock 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 about 20 ft (6.1 m). In the lower canyon, the Cerro Toledo interval may subcrop beneath the alluvium. Distinguishing sediments of the Cerro Toledo interval from alluvium in borehole cuttings may have been difficult; therefore, identification of this unit in the Mortandad Canyon area has not been previously documented.



Source: FIMAD/rek

F3.3.1-2 / MORTANDAD WP / 090597

Figure 3.3.1-2. Preliminary isopach map of the alluvium in lower Mortandad Canyon.

3.3.2 Geomorphology

Mortandad Canyon has several geomorphically distinct sections between its headwaters in TA-3 and its 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 canyon is relatively steep and narrow where the stream incises through Tshirege units Qbt 1v through Qbt 4. In this section, 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 floor occur upstream of resistant units in the tuff, particularly west of where the channel begins incising through unit Qbt 2, which provides opportunities for sediment storage. Ten Site Canyon has a similar gentle reach upstream of unit Qbt 2. 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.

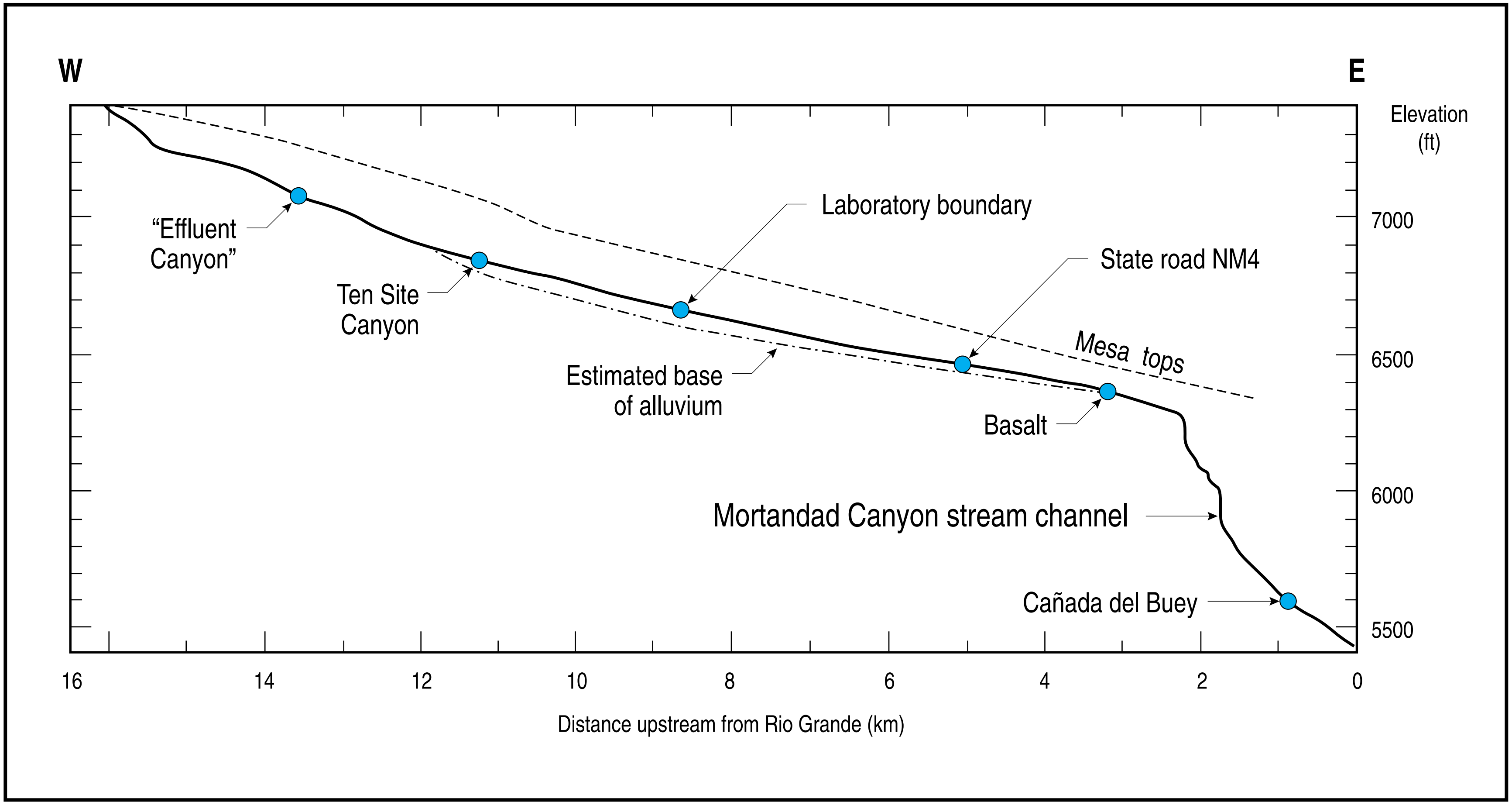
The canyon floor begins widening and the channel gradient decreases where the channel reaches the nonwelded tuff of Tshirege unit Qbt 1g about 4 km (2.5 mi) east of Diamond Drive and 12 km (7.5 mi) west of the Rio Grande, which provides greater opportunity for sediment deposition and long-term sediment storage (Figure 3.3.2-1). The channel gradient slowly decreases from about 0.022 m/m (2.2%, 1.3°) near Ten Site Canyon to a minimum of about 0.014 m/m (0.8°) near state road NM4. The alluvium is dominated by sand and thickens downstream to at least well MCO-8, where it is approximately 18.3 m (60 ft) thick. The combination of decreasing channel gradient, widening canyon floor, and a thick section of permeable, sandy alluvium all contribute to allowing surface water to infiltrate and sediment to be deposited; this occurs primarily in lower Mortandad Canyon between MCO-5 and MCO-12. Downstream of state road NM4 the channel gradually steepens, and the alluvium pinches out where basalt is first exposed in the canyon floor, 3 km (1.9 mi) west of the Rio Grande.

Limited examination of core from several boreholes and radiocarbon analyses of two samples of charcoal indicate that most of the alluvium in lower Mortandad Canyon has been deposited in the past 10,000 years. Charcoal from a depth of 11.7 m (38.4 ft) in the borehole for well MCWB-6.5C yielded an age of 7260 ± 50 radiocarbon years before present (Reneau et al. 1996, 55539), and charcoal from a depth of 10.1 m (33.1 ft) in the borehole for well TSWB-6.4 yielded an age of 7770 ± 50 years before present. Some boreholes have also penetrated the 50,000- to 60,000-year-old El Cajete pumice bed (Figure 3.3.2-2), which indicates a much greater age for some of the alluvium and the potential for significant stratigraphic variability that could affect groundwater flow.

In lower off-site Mortandad Canyon, downstream of state road NM4, the channel steepens and drops through a narrow slot cut into basalt and into underlying Tertiary sediments. This part of the channel is much more rocky than the upstream part, and cobble- to boulder-size basalt clasts are common. The channel gradient progressively decreases between the basalt and the Rio Grande, although the gradient remains relatively high (>0.05 m/m) to the river. Near the Rio Grande, the canyon is a rocky alluvial fan that borders the Rio Grande floodplain.

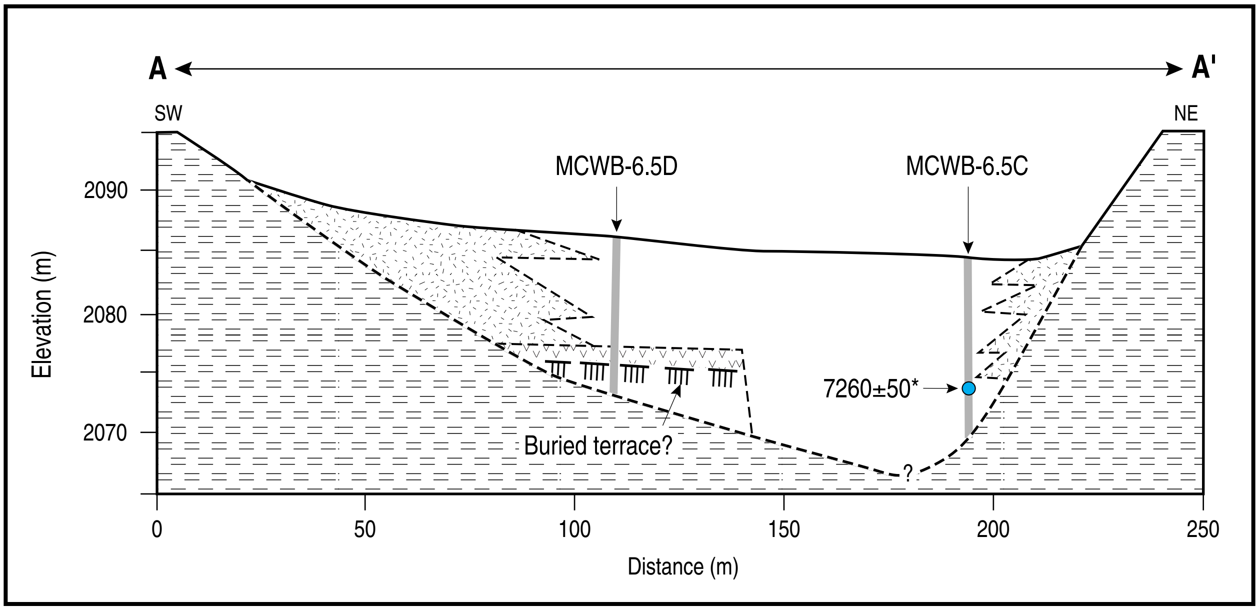
3.3.3 Geological Structure

Baltz et al. (1963, 8402, Figure 2) present a structure contour map for the top of the Tshirege Qbt 1g unit. This map shows that subunits of the Tshirege Member dip gently eastward in the Mortandad Canyon area. The eastward dip of these tuffs is probably the primary initial dip, mainly resulting from the burial of an east-dipping paleotopographic surface and thinning of subunits away from the volcanic source to the west.



F3.3.2-1 / MORTANDAD WP / 081597

Figure 3.3.2-1. Schematic longitudinal profile of the Mortandad Canyon stream channel.



Source: Reneau et al. 1996, 55539

F3.3.2-2 / MORTANDAD WP / 081597

☐ Alluvium

▨ Colluvium

▨ El Cajete pumice

▤ Tshirege Member, Bandelier Tuff

* = radiocarbon years before present

NOTE: See Figure A-2, Inset I-2 in Appendix A of this work plan for the location of the cross section.

Figure 3.3.2-2. Schematic cross section of Mortandad Canyon near Ten Site Canyon.

The paleotopography of the pre-Tshirege surface may strongly influence the direction of groundwater flow in the Cerro Toledo interval beneath Mortandad Canyon. Available data are not sufficient to precisely define this paleotopographic surface, although the data indicate that the pre-Tshirege surface beneath Mortandad Canyon between moisture access tube MCM-5.1 and well SIMO may slope to the east/southeast roughly parallel to the present canyon and between two major paleodrainages that headed in the Sierra de Los Valles (Broxton and Reneau 1996, 55429). However, either southerly or northerly components of flow in this area are possible. In addition, the confluence of Effluent Canyon and Mortandad Canyon is relatively close to the inferred location of a major southeast-draining paleodrainage in the Cerro Toledo interval, which suggests that the Cerro Toledo interval stratigraphy may have a more southerly component to the west.

Paleotopography of the pre-Otowi surface may also influence the direction of flow of potential perched groundwater in the Mortandad 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), which are declining over time, suggesting the passage of a tritiated groundwater plume (Longmire et al. 1996, 54168). Although this perched groundwater has been found only in the area beneath Los Alamos Canyon, structure contour maps (Broxton and Reneau 1996, 55429; Davis et al. 1996, 55446) 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 downgradient along the axis of a large pre-Otowi paleodrainage toward the south, beneath Mortandad Canyon. The location of the axis of this paleodrainage cannot be constrained precisely, but the available data suggest that it crosses beneath Mortandad Canyon near borehole MCC-8.2 about 0.75 mi. (1.2 km) downstream of TW-8. Groundwater infiltrating to and potentially perching in the Guaje Pumice Bed from Mortandad Canyon would tend to migrate toward the axis of this paleodrainage and then flow toward the south or southwest.

Faults and fractures may play a role as infiltration pathways if they become saturated, particularly in the canyon floor. Baltz et al. (1963, 8402) and Rogers (1995, 54419) did not identify any faults that displaced the Bandelier Tuff in the Mortandad Canyon area. However, faults with pre-Bandelier displacement may occur in the subsurface, although none have been identified with certainty to date.

Baltz et al. (1963, 8402) performed a preliminary study of joints (fractures) in the Bandelier Tuff on the walls of Mortandad Canyon. The principal conclusions of this study were as follows.

- *Many of the joints in Mortandad Canyon can be classified as master joints (that is, joints that are numerically predominant and most persistent in length and pass through several groups of beds).*
- *Most master joints are vertical or dip no more than 85° and are generally perpendicular to layering of the Tshirege Member.*
- *The master joints can be traced vertically across two or more subunits of the Tshirege Member and, in places, across all subunits.*
- *The overall trends of the master joints are relatively straight, but most joints are curved slightly along part or all of their length; some of the shorter joints have pronounced local curvature.*
- *Other joints dipping at angles from about 40° to 70° are especially common in the Tshirege Qbt 1v unit, but generally they are not as persistent as the master joints.*
- *Although measurements of joint orientations were not sufficient to establish the fracture pattern with certainty, the available data suggest grouping of sets of nearly parallel joints that form conjugate patterns separated by 60°.*
- *Many of the master joints in the Tshirege Member were probably produced by tensional stresses during cooling of the tuffs.*
- *Runoff from snowmelt was observed to infiltrate joints in the Bandelier Tuff on a topographic bench north of Ten Site (TA-35).*

Personnel from Field Unit 4 of the ER Project are conducting a more detailed investigation of fractures in Mortandad Canyon. The field portion of this study is nearly completed, and the data will be analyzed in the near future.

3.3.4 Data Requirements

Data needed in the geologic investigations in the Mortandad Canyon system to resolve uncertainties in the conceptual model for the canyon, particularly those that relate to potential contaminant pathways, include

- *the geologic nature and distribution of perching layers in alluvial and intermediate-depth groundwaters,*

- *the axis and downgradient direction for pre-Tshirege and pre-Otowi paleodrainages,*
- *areas of faulting and high fracture densities in Mortandad Canyon, and*
- *the geometry and distribution of geologic units below Mortandad Canyon.*

3.4 Surface Sediments

3.4.1 Natural Background Conditions

Sediments in the Mortandad Canyon system are derived from erosion of the Bandelier Tuff and of soils that have developed in the watershed, the latter including 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 Mortandad 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 Field Unit 4 personnel in 1996 (McDonald et al. 1997, 04-0328). These background data will provide the basis for evaluating the nature of contamination in Mortandad Canyon sediments.

3.4.2 Historic Channel Changes

Changes are known to have occurred in the Mortandad Canyon channel since Laboratory operations began in 1943. Although these changes have been only partially defined, they affect the horizontal and vertical distribution of contaminants in the alluvium. The changes include both aggradation that has locally raised the level of the stream bed and degradation that has locally caused incision of the stream bed.

Progressive aggradation upstream of Ten Site Canyon apparently caused repeated flooding of the dirt road; the channel was diverted to the north side of the canyon after the 1987 floods (see Section 3.6). The former channel (now an “inactive channel”) can be traced downstream to the confluence with Ten Site Canyon. Channel aggradation elsewhere is indicated by trees that are partially buried by sediment, both in Mortandad Canyon and in the upper part of Ten Site Canyon. An example of channel incision is provided at gaging station (GS) -2, which was installed circa 1974 on the stream bed but is now perched about 3 ft (0.91 m) above the active channel.

Major channel changes were imposed beginning in 1974 with the construction of the first sediment traps in Mortandad Canyon downstream from Ten Site Canyon and subsequent diversion of the channel near the sediment traps (see Section 2.3.1 in Chapter 2 of this work plan and Section 3.6.1). These traps quickly filled with sediment and became ineffective; new, larger traps were excavated in 1986. These traps have been effective at enhancing sediment deposition in this area and limiting the downstream extent of floods. The traps are periodically cleaned out after they fill with sediment to restore their storage capacity.

3.4.3 Previous Field Screening and Sediment Analyses in Ten Site Canyon

No systematic screening or analyses of sediments along the length of Ten Site Canyon has been conducted; prior investigations have dealt with specific discharge areas from TA-35 into Pratt Canyon and *from TA-50 into the head of Ten Site Canyon. These prior studies provide some data on the types and concentrations of contaminants present in sediments in the Ten Site Canyon watershed.*

The earliest documented discharges into the Mortandad Canyon watershed were from TA-35 into Pratt Canyon (Ten Site Canyon was referred to as "Mortandad Canyon" in early reports). After an accidental discharge of "very hot water" from the former wastewater treatment plant at TA-35 in August 1952, a survey found elevated activity on the sediments 3 mi (4.8 km) from TA-35, extending downstream in Ten Site Canyon and into Mortandad Canyon (Aeby 1952, 741). Elevated activity was reported as far downstream as state road NM4 (Stoker and Koch 1996, 56027), although no written reports are available on the level of activity in the sediments. Surveys from 1953 to 1955 documented elevated beta-gamma activity in Pratt Canyon and downstream in Ten Site Canyon; the level of radioactivity decreased downstream from the outfall (Dodd 1956, 4695; Purtymun 1975, 11787). Most of the radioactivity was due primarily to radionuclides with short half-lives, which completely decayed in less than a year; ^{90}*Sr (half-life of 28.6 years) was also found in the waste stream (see Section 2.4.4.1 in Chapter 2 of this work plan). Monitoring continued until 1962, at which time field sites more than 500 ft (152 m) from the former outfall were at or near background levels for gross-beta activity. Figure 3.4.3-1 shows the sediment sampling sites in Pratt Canyon; Figure 3.4.3-2 shows the results of the early sediment analysis for radioactivity. Field measurements from a radiation grid survey in 1994 showed similar results; elevated beta activity remained on the hillslopes in upper Pratt Canyon, but radioactivity had decreased to at or near background levels at distances greater than 500 ft (152 m) from the outfall (LANL 1996, 54422).*

The Resource Conservation and Recovery Act (RCRA) facility investigation (RFI) report that evaluated discharges from the former TA-35 wastewater treatment plant (Potential Release Site [PRS] No. 35-003[r]) identified a series of chemicals of potential concern (COPCs) in the human health screening assessment including benz[a]anthracene, benzo[a]pyrene, benzo[b]fluoranthene, dibenz[a,h]anthracene, fluorene, indeno[1,2,3-cd]pyrene, benzo[k]fluoranthene, chromium, and dieldrin (LANL 1996, 54422). These analytes, in addition to ^{90}*Sr and possibly other radionuclides, may be present downstream in Ten Site Canyon. Supplemental RFI sampling and analysis of PRS No. 35-003(r) was performed in early 1997; results are pending (LANL 1997, 56175).*

Discharges into Ten Site Canyon from sources other than the RLWTF occurred from TA-50 beginning before 1975 and ending by 1981 when drain lines 55 and 67 were removed (see Section 2.4.6 in Chapter 2 of this work plan). Accidental discharges of untreated radioactive wastes and other chemicals also occurred in 1974. Samples collected in 1993 from the active channel and adjacent inactive channels and/or floodplains for a distance of approximately 1300 ft (396 m) downstream from the outfalls showed a variety of contaminants present above background concentrations including ^{241}*Am,* ^{60}*Co,* ^{137}*Cs,* ^{40}*K,* ^{238}*Pu,* ^{239,240}*Pu,* ^{226}*Ra,* ^{90}*Sr,* ^{232}*Th,* ^{234}*U,* ^{235}*U,* ^{238}*U, lead, mercury, nickel, silver, thallium, tritium, polycyclic aromatic hydrocarbons (PAHs), and polychlorinated biphenyls (LANL, 1995, 49925). Analytes reported above screening action levels (SALs) included* ^{238}*Pu (maximum of 5190 pCi/g),* ^{239,240}*Pu (453 pCi/g),* ^{137}*Cs (73 pCi/g), and* ^{90}*Sr (58 pCi/g). The highest concentrations were restricted to one small area in the canyon floor, which was excavated as part of an interim action in 1996; results of analyses from other areas showed much lower concentrations. Samples from the inactive channel and floodplain showed elevated levels of radionuclides to depths of at least 3 to 4 ft (0.91 to 1.2 m), which probably indicate a large amount of recent sediment deposition and possibly suggest the presence of a large volume of contaminated sediments in the upper part of Ten Site Canyon.*

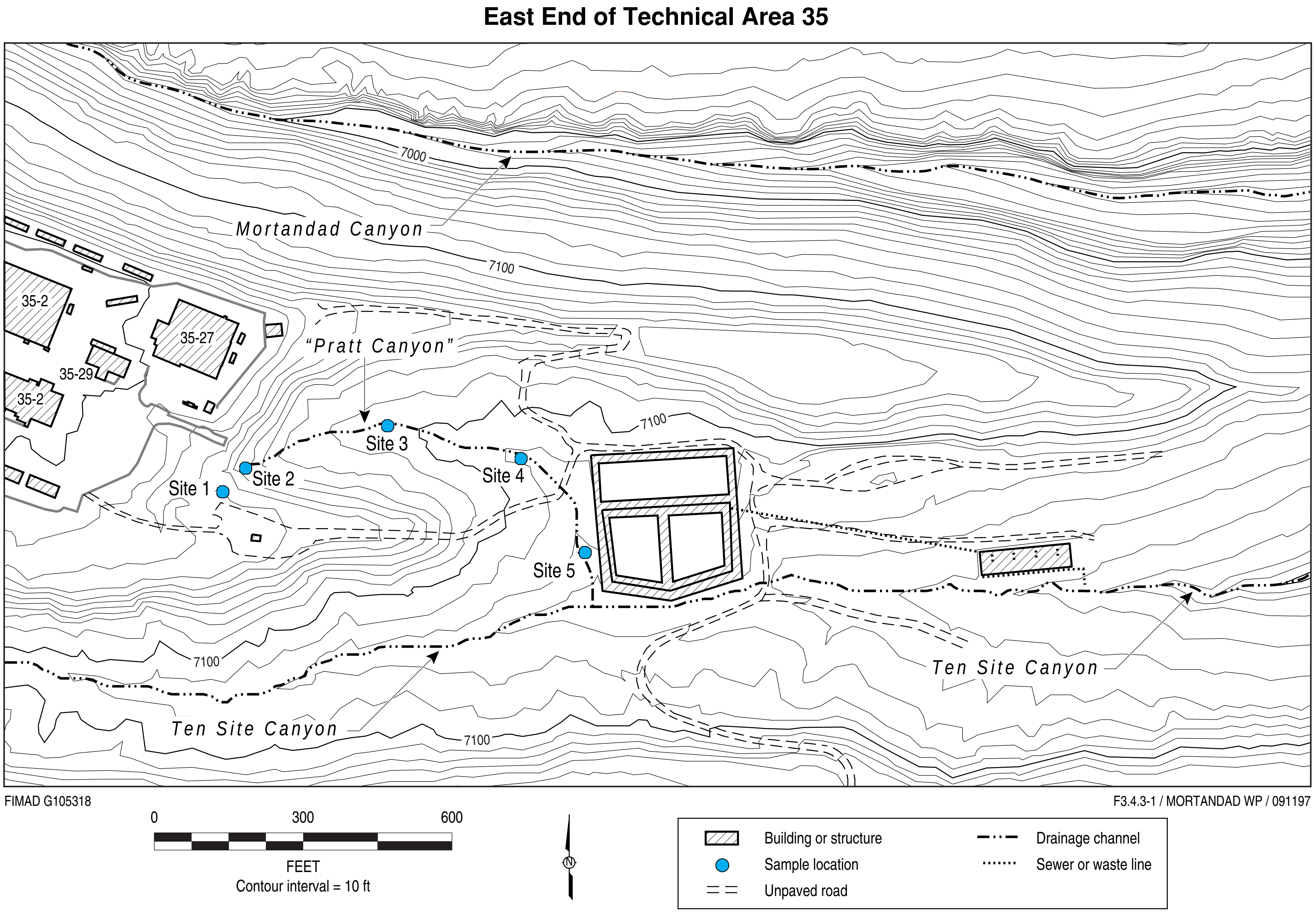
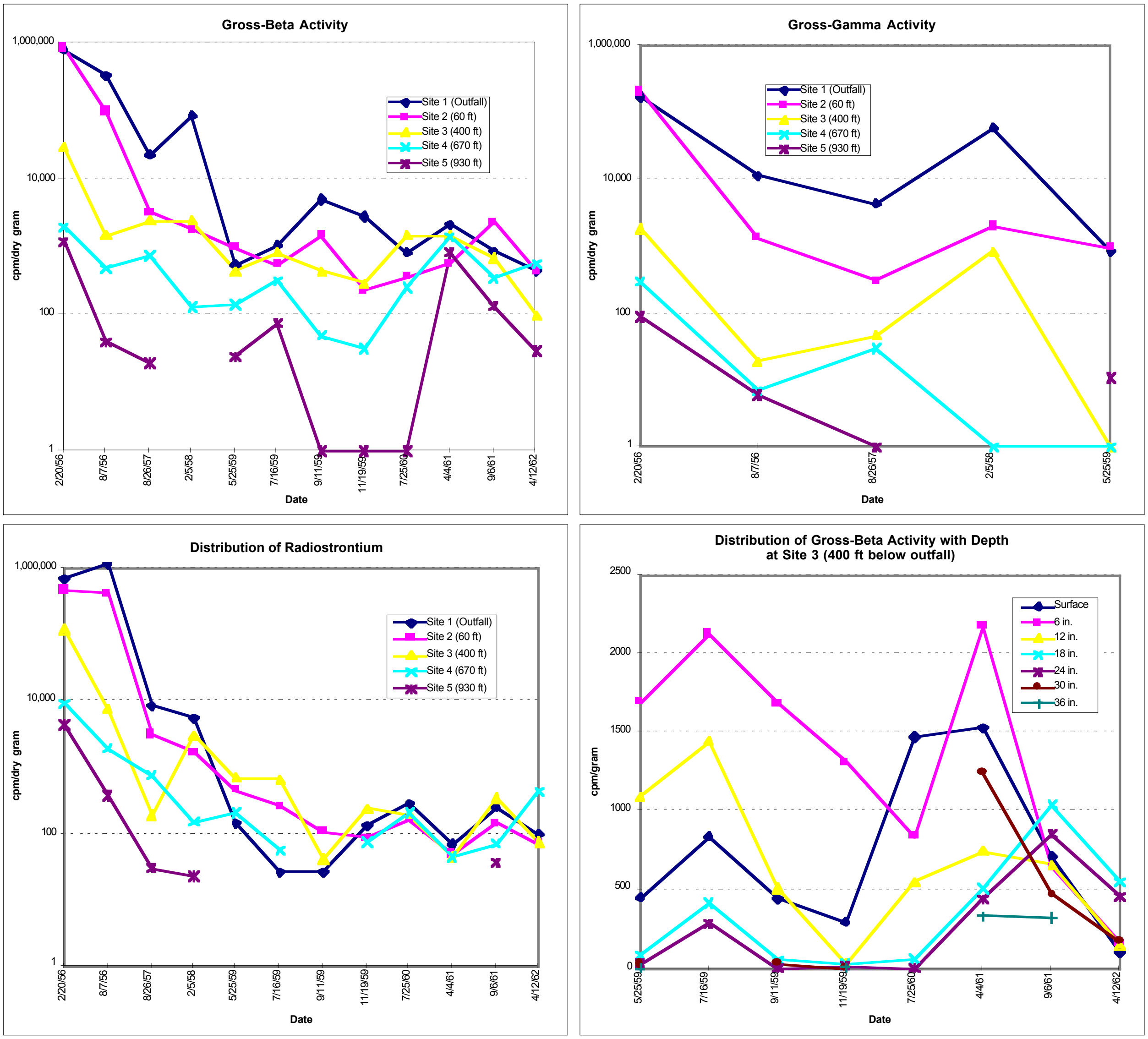


Figure 3.4.3-1. Early sediment sampling sites in Pratt Canyon.



Source: Dodd 1956, 4695; Purtymun 1975, 11787

Figure 3.4.3-2. Results of early surface sediment monitoring in Pratt Canyon.

3.4.4 Previous Field Screening and Sediment Analyses in Mortandad Canyon

Field screening and analyses of sediment samples within Mortandad Canyon have been conducted sporadically since the early 1950s, which provide considerable amounts of data on temporal and spatial variations in contaminant concentrations within the active channel downstream of Effluent Canyon, particularly after 1963. Additional data have also been obtained at some sites outside the active channel (inactive channels and/or floodplains), although investigation of these areas has been less intensive, and the distribution of contaminants away from the channel is not completely known. Downstream variations in contaminant inventory were investigated in the early 1970s (for example, Hakonson et al. 1976, 8920), but current inventories are not well defined, and the relative amounts of contaminants stored in active channels, inactive channels, and floodplains are also unknown.

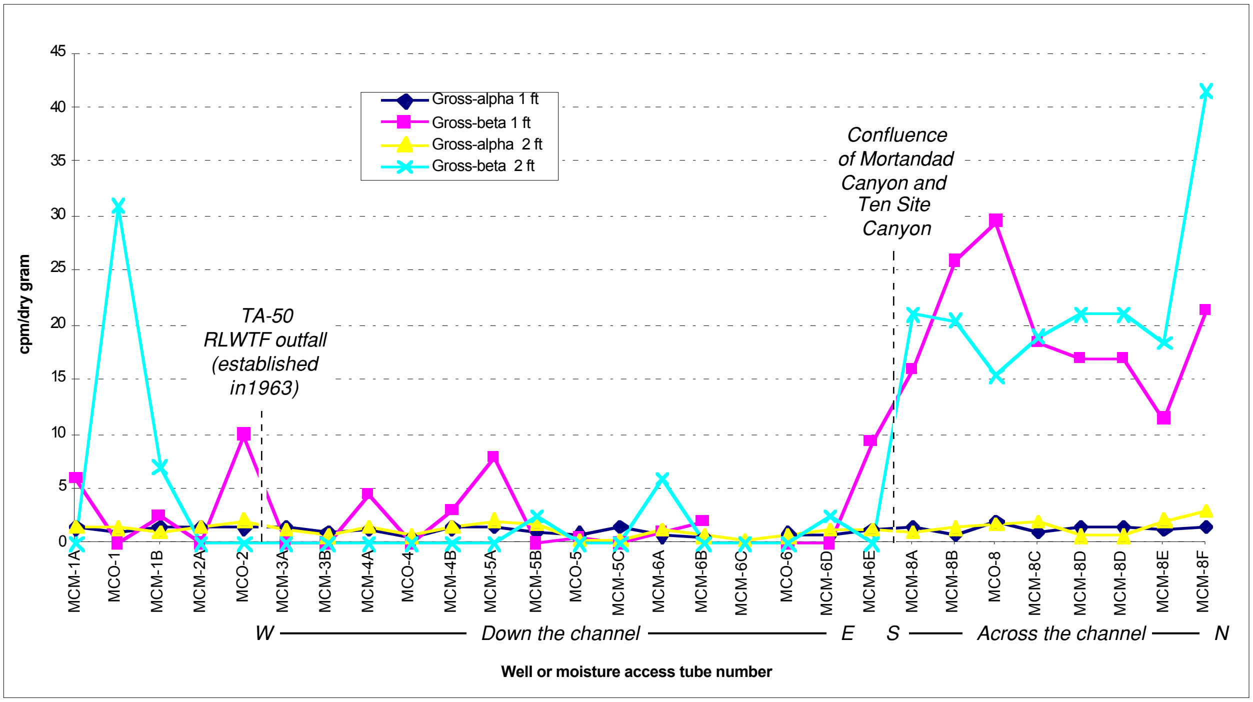
3.4.4.1 Contamination in Mortandad Canyon Sediments between 1950 and 1963

Several sources provide information on contamination in Mortandad Canyon sediments before initial discharges into Effluent Canyon from the TA-50 RLWTF in June 1963, although data from these early years are relatively sparse. No data from this period are available from Mortandad Canyon upstream of Effluent Canyon, also no data pertain to sediments in the watershed during the 1940s. Field measurements and analyses conducted before June 1963 included a combination of active channel and inactive channel or floodplain settings, although the geomorphic setting of some of the samples is not certain.

A drilling and sampling operation in 1960 found elevated gross-beta activity at depths of 0 to 1 ft (0 to 0.30 m) and 1 to 2 ft (0.30 to 0.60 m) in sediments at sites near wells MCO-1 and MCO-2 in Effluent Canyon, which may be due to discharges from the incinerator site at former TA-42 during 1950 and 1951 (Purtymun 1975, 11787). Slightly elevated gross-beta activity measured in sediments from the boreholes advanced in 1960 in Mortandad Canyon as far east as the borehole for moisture access tube MCM-6A (Figure 3.4.4-1) may have been due to downstream transport of radionuclides from the TA-42 source during the early 1950s. Because most of the boreholes were located outside the active channel, these measurements also indicate deposition of contaminated sediments in inactive channels or floodplains during the 1950s. Samples of sediment collected from the active channel of Mortandad Canyon (at depths of 0, 1, 2, and 3 ft [0, 0.30, 0.61, and 0.91 m]) in May 1963 also showed elevated gross-beta activity as far downstream as sediment sampling location MCS-7 (near well MCO-7), as shown in Figure 3.4.4-2 (Purtymun 1975, 11787). The specific radionuclides present were not identified in these studies but are presumed to include ^{90}Sr.

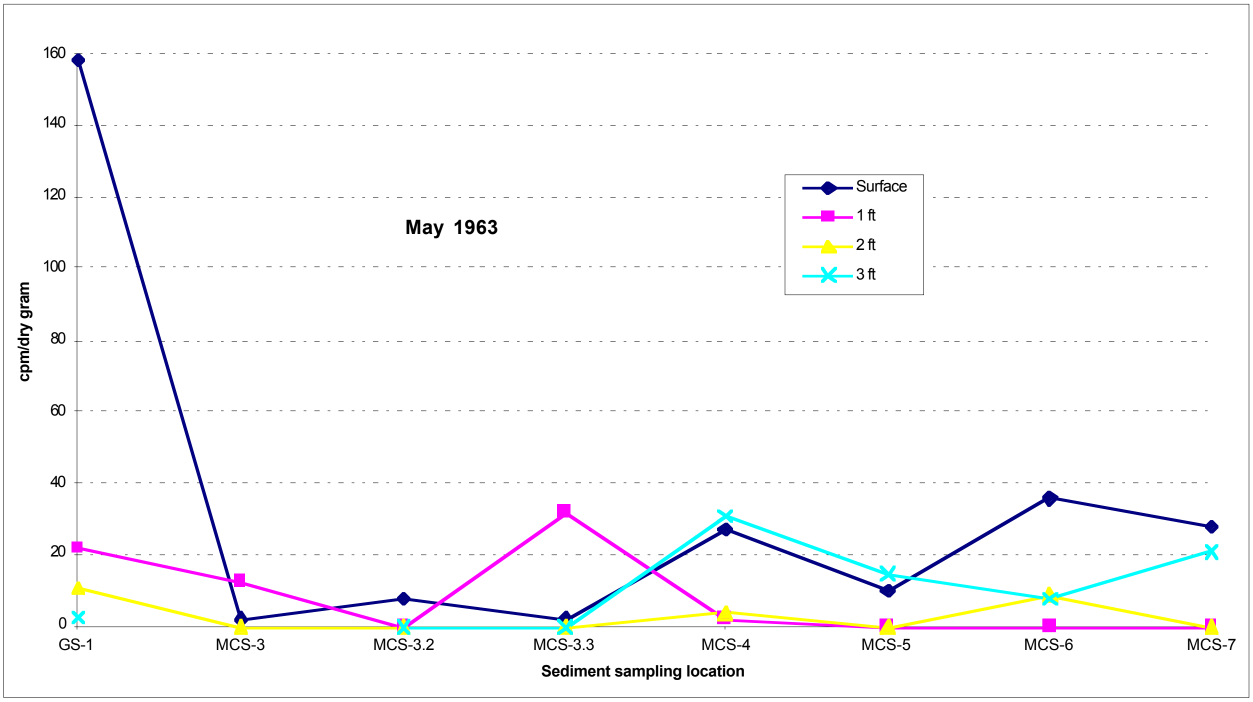
Analyses of samples collected from Effluent Canyon in 1972 and 1973 upstream of the TA-50 RLWTF outfall provide additional data on contamination that probably resulted from early releases from TA-42. The radionuclides ^{137}Cs, ^{238}Pu, and ^{239,240}Pu were all measured at above background levels (Hakonson and Bostick 1975, 29678; Nyhan et al. 1975, 11746), which suggests that a variety of contaminants are present in pre-1963 sediments in Effluent Canyon and downstream in Mortandad Canyon.

As mentioned in Section 3.4.3, elevated levels of radioactivity were tracked in 1952 from the former wastewater treatment plant at TA-35 downstream in Ten Site Canyon and into Mortandad Canyon (Aeby 1952, 741), and elevated levels in 1952 were also reported downstream as far as state road NM4 (Stoker and Koch 1996, 56027). An increase in gross-beta activity in boreholes advanced in 1960 at the MCO-8/MCM-8 transect line in Mortandad Canyon (downstream of Ten Site Canyon) relative to sites upstream in Mortandad Canyon (Purtymun 1975, 11787) is also probably attributable to discharges from TA-35 into Ten Site Canyon between 1951 and 1963 (Figure 3.4.4-1). The MCO-8/MCM-8 transect line spans a distance of more than 400 ft (122 m) across the canyon floor, which demonstrates wide dispersion of contaminants away from the main channel before 1960. The radionuclide ^{90}Sr is the primary contaminant documented in these discharges that could still be present; most other radionuclides discharged at that time have very short half-lives and would have decayed completely.



Source: Purtymun 1975, 11787

Figure 3.4.4-1. Activity in Mortandad Canyon sediments in 1960.



Source: Purtymun 1975, 11787

Figure 3.4.4-2. Gross-beta activity in Mortandad Canyon active channel sediments.

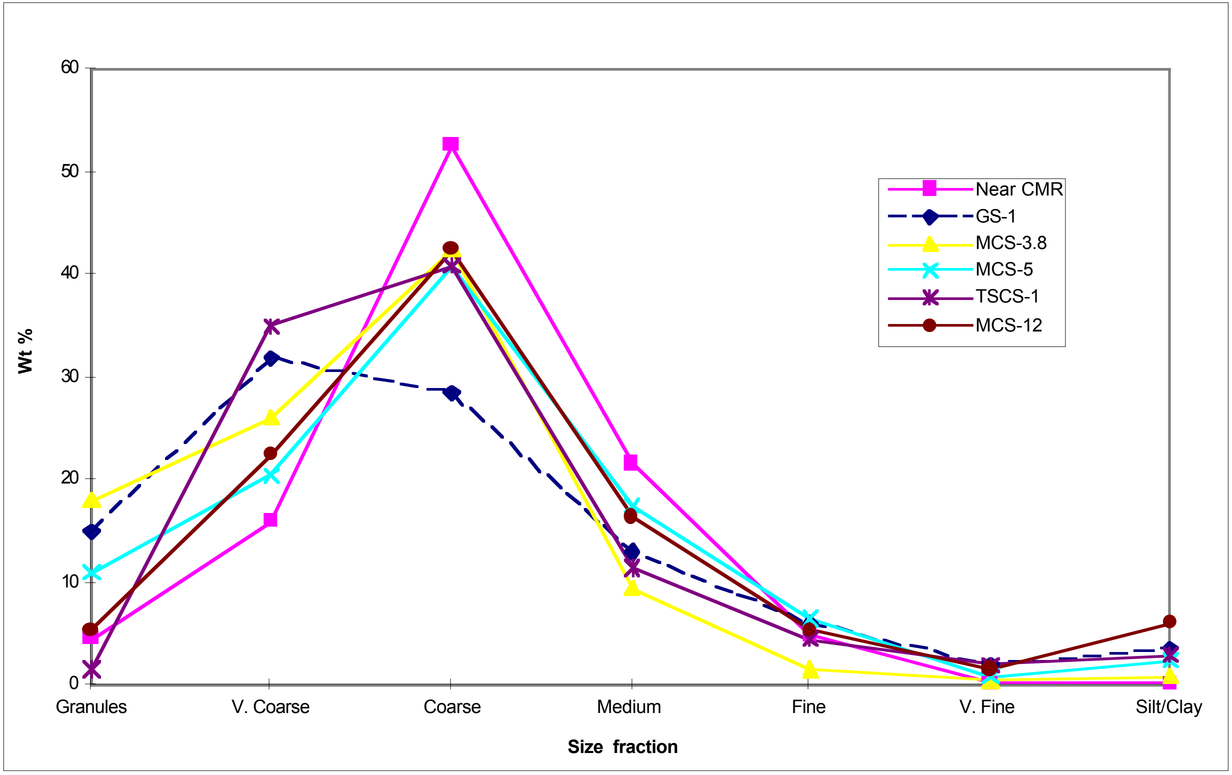
3.4.4.2 Contamination in Mortandad Canyon after 1963

3.4.4.2.1 Active Channels

Early Investigations of Channel Sediments

After the TA-50 RLWTF began discharging into Effluent Canyon in June 1963, the United States Geological Survey (USGS) and the Environmental Surveillance Group collected sediment samples from the active channel. Samples were analyzed for radioactivity and selected radionuclides in 1965, 1970, 1971, and 1972. The results showed that beta activity was highest at GS-1 a short distance downstream from the TA-50 RLWTF outfall in Mortandad Canyon and decreased downstream. Gross-beta and ^{238}Pu and ^{239}Pu activities measured at the farthest downstream site, MCS-12, were generally within natural fallout background levels (Purtymun 1975, 11787).

The distribution of particle sizes in Mortandad Canyon channel sediments is shown in Figure 3.4.4-3. Channel sediment samples were collected near the head of Mortandad Canyon, near the CMR Building, and from selected sites downstream, including one in Ten Site Canyon near well TSCO-1 (sediment sampling location TSCS-1) and one near well MCO-12 (sediment sampling location MCS-12) (Purtymun 1975, 11787). The channel sediments are derived from weathering of the Bandelier Tuff, and the distribution of the particle sizes appears to be similar throughout the canyon. The greatest percentage by weight of particles in the channel sediments was found in coarse and very coarse fractions, whereas the very fine sand, silt, and clay-size fractions are generally less than 5% by weight of the channel sediments.



Source: Purtymun 1975, 11787

Figure 3.4.4-3. Distribution of particle sizes in Mortandad Canyon channel sediments.

In 1979 the relationship between particle size and transport distance in individual floods was investigated in Mortandad Canyon by placing sediments containing radioactive tracers (^{141}Ce, ^{124}Sb, ^{46}Sc, and ^{182}Ta) in sediments in the stream channel and tracking their dispersion after three runoff events (ESG 1981, 6055, p. 60 by T. E. Hakonson). Results indicated that silt and clay-size particles (<53 µm) were depleted most rapidly at the source and were transported at least 10 times farther downstream than were the medium to coarse sands (106 to >495 µm) during a given runoff event. The silt and clay-size particles also tended to be concentrated in the stream channel where surface flow from a given event ceased. These results indicate that the lag time between changes in contaminant concentrations or contaminant ratios at the source and resultant changes downstream will be relatively short for silt and clay-size particles and longer for the coarser sand-size particles.

From 1972 through 1974 the Ecology section of the Environmental Science group (then Laboratory group H-8) conducted radioecology studies in Mortandad Canyon. Major objectives of the studies were to determine the distribution of radioactive and other contaminants in various segments of the ecosystem (for example, soil, sediments, vegetation, and fauna) and to attempt to understand the processes and rates for kinetics in the ecosystem. Major field sampling programs were completed in 1972, 1973, and 1974.

October through November 1972

Samples were collected 100 m (328 ft) upstream of the TA-50 RLWTF outfall and at distances of 0, 20, 40, 80, 160, 320, 640, 1280, 2560, 5120, and 10,240 m (0, 66, 131, 262, 525, 1050, 2100, 4200, 8400, 16,800, and 33,600 ft) downstream of the outfall. (The sample collected 1280 m [4200 ft] downstream of the outfall was located upstream of GS-2; the sample collected 2560 m [8400 ft] downstream of the outfall was located at the Ten Site Canyon confluence; the sample collected 5120 m [16,800 ft] downstream of the outfall was located just upstream of the Laboratory boundary; the sample collected 10,240 m [33,600 ft] downstream of the outfall was located downstream of state road NM4.) Three boreholes were drilled at each sampling location: one in the center and one on each side of the active channel. Samples were collected at the center of the channel from the following depth intervals: 0 to 2.5, 2.5 to 7.5, 7.5 to 12.5, and 12.5 to 30 cm (0 to 1, 1 to 3, 3 to 4.9, and 4.9 to 11.8 in.). Samples collected from the side of the channel were composited from the 0 to 30-cm (0 to 1-ft) depth interval. All samples were analyzed for ^{241}Am, ^{134}Cs, ^{137}Cs, ^{40}K, ^{238}Pu, and ^{239,240}Pu (Hakonson et al. 1973, 4974).

May through July 1973

Samples were collected 100 m (328 ft) upstream of the TA-50 RLWTF outfall and at distances of 0, 20, 40, 80, 160, 320, 640, 1280, 2560, and 5120 m (0, 66, 131, 262, 525, 1050, 2100, 4200, 8400, and 16,800 ft) downstream of the outfall. Ten cores were collected at 0 to 30-cm (0 to 11.8-in.) depth intervals at each sampling location. The cores were cut into four depth segments: 0 to 2.5, 2.5 to 7.5, 7.5 to 12.5, and 12.5 to 30 cm (0 to 1, 1 to 3, 3 to 4.9, and 4.9 to 11.8 in.).

- *All four segments of the cores collected at the distances of 0, 40, 640, and 2560 m (0, 131, 2100, and 8400 ft) downstream of the outfall were nondestructively analyzed for ^{137}Cs to determine the environmental variation of this radionuclide at those four sampling locations (Nyhan et al. 1978, 5726).*
- *Five of the cores from each sampling location were composited by depth interval and dry-sieved into six size fractions: <53 µ, 53 to 105 µ, 105 to 500 µ, 500 to 1000 µ, 1 to 2 mm, and 2 to 23*

mm. Then the samples were destructively analyzed for ^{238}Pu and ^{239,240}Pu (Nyhan et al. 1976, 11747).

- *The other five cores from each sampling location were composited and analyzed for soil properties including organic matter, pH, cation exchange capacity, and exchangeable and water-soluble calcium, magnesium, potassium, and sodium.*

All samples were analyzed for ^{134}Cs, ^{137}Cs, ^{40}K, ^{238}Pu, and ^{239,240}Pu (Nyhan et al. 1976, 11746).

May 1974

Samples were collected from three sites in Mortandad Canyon, designated as intensive study sites I, II, and III, which were located near the previous sampling locations at 320, 1280, and 2560 m (1050, 4200, and 8400 ft) downstream of the TA-50 RLWTF outfall, respectively. Each intensive study site consisted of a 100-m-long (328-ft-long) section of the active stream channel that extended to each side of the stream channel 100 m (328 ft) or to the adjacent mesa top, whichever was encountered first. Sediment, soil, and vegetation samples were collected at the following 10 randomly-determined locations within each intensive study site: 15 m (49.2 ft) right, 20 m (65.6 ft) right, 24 m (78.7 ft) left, 36 m (118 ft) left, 38 m (125 ft) right, 52 m (171 ft) left, 58 m (190 ft) right, 67 m (220 ft) left, 78 m (256 ft) left, and 85 m (279 ft) right. (The numbers correspond to the distance downstream from the beginning of the upstream portion of each intensive study site; the right and left designations are defined from the upstream perspective looking downstream.)

The data were collected by H-8 personnel and, for the most part, represent an unpublished data set (Nyhan 1997, 56178).

- *Ten cores were collected in each sampling location. The cores were cut into two depth segments: 0 to 7.5 and 7.5 to 30 cm (0 to 3 and 3 to 11.8 in.).*

- *Both segments of the cores collected at the distances of 0, 40, 640, and 2560 m (0, 131, 2100, and 8400 ft) downstream of the outfall were nondestructively analyzed for ^{137}Cs to determine the environmental variation of this radionuclide at those four sampling locations. Cores collected at the distances of 20, 80, 160, 320, 1280, and 5120 m (66, 262, 525, 1050, 4200, and 16,800 ft) downstream of the outfall were composited by depth for each sampling location.*

- *Two types of stream bank samples were collected in each sampling location.*
  - *Composite samples were collected in 0.5 m^2 (5.4 ft^2) microplots (25 cm [9.8 in.] wide) used to evaluate the concentration of radionuclides in the soils to correlate with the corresponding vegetation samples. Four 60-cm-deep (23.6-in.-deep) samples were collected in each microplot from the following depth intervals: 0 to 10, 10 to 20, 20 to 40, and 40 to 60 cm (0 to 3.9, 3.9 to 7.9, 7.9 to 15.8, and 15.8 to 23.6 in.) and composited by depth. Most of the microplots were located 0 to 25 cm (0 to 9.8 in.) from the active stream channel, but at the 52 m (171 ft) left and 58 m (190 ft) right locations microplot samples were also collected 25 to 50 and 1000 to 1025 cm (9.8, 19.7, 394, and 404 in.) from the stream channel.*
  - *Noncomposited samples were collected along a transect perpendicular to the stream channel at the 52 m (171 ft) left and 58 m (190 ft) right locations. Sampling locations were*

situated at the following distances from the stream channel: 2, 10, 20, 50, 1000, and 10,000 cm (0.8, 3.9, 7.9, 19.7, 394, and 3937 in.) (or on the mesa top). Samples were collected from the following depth intervals: 0 to 10, 10 to 20, 20 to 40, and 40 to 60 cm (0 to 3.9, 3.9 to 7.9, 7.9 to 15.8, and 15.8 to 23.6 in.).

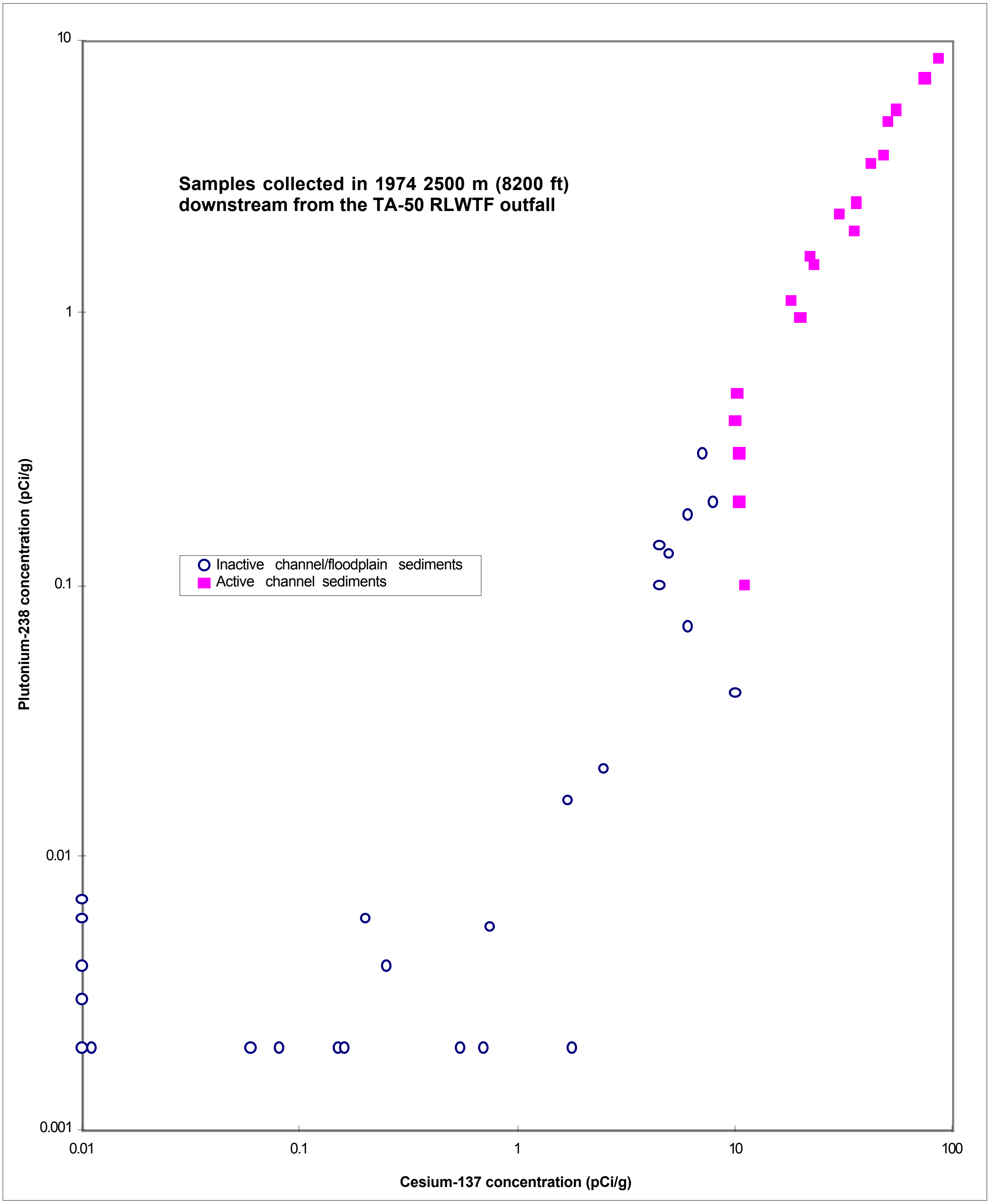
- *Vegetation samples were collected in each microplot. The dominant vegetation in each microplot was identified, and all the vegetation was collected for analysis. Each sample was sorted into green and nongreen portions for separate analysis for radionuclides. The results were correlated with the analytical results of the composite samples described above.*

All samples were analyzed for ^{134}*Cs,* ^{137}*Cs,* ^{40}*K,* ^{238}*Pu, and* ^{239,240}*Pu (Nyhan 1997, 56178).*

Data from the 1972 and 1973 sampling programs were published extensively; highlights of the results are summarized in this section. However, much of the data from the 1974 sampling program have never been published (Nyhan 1997, 56178). Recently these data have been located and retrieved from the Laboratory's archives. Because of the large volume, not all data have been reviewed at the time of preparation of this work plan. These data will be reviewed and used in conjunction with the data collection planned in Chapter 7 of this work plan to provide a detailed comparative evaluation of changes in contaminant concentrations during the past 25 years.

In 1972 and 1973 the sediment samples were collected to evaluate variations in cesium and plutonium concentration (Hakonson and Bostick 1975, 29678; Hakonson et al. 1976, 8920; Nyhan et al. 1975, 11746; Nyhan et al. 1976, 11747; Nyhan et al. 1978, 5726). Maximum concentrations (2200 pCi/g for ^{137}*Cs, 160 pCi/g for* ^{238}*Pu, and 70 pCi/g for* ^{239,240}*Pu) were measured within 160 m (525 ft) of the source, and concentrations generally decreased downstream. Concentrations remained well above background levels at a sampling location 2560 m (8400 ft) downstream from the outfall but were at background levels 5120 m (16,800 ft) from the outfall. Field gamma measurements indicated that the downstream extent of recognizable contamination was about 3.5 km (2.2 mi) from the outfall (Hakonson and Bostick 1975, 29678). The estimated plutonium inventory in the channel was highest at the 160-m (525-ft) sampling location (closest to the outfall), decreased downstream to the 1280-m (5000-ft) sampling location, and then increased at the 2560-m (8400-ft) sampling location where the channel widened and more sediment was deposited (Hakonson et al. 1976, 8920).*

Concentrations of ^{137}*Cs and* ^{238}*Pu were generally correlated in the 1972 and 1973 channel samples (Hakonson and Bostick 1975, 29678; Nyhan et al. 1975, 11746), which indicates collocation of radionuclide contaminants. This relationship was also seen in a data set from 1974 that included both active channel and inactive channel or floodplain samples (Figure 3.4.4-4) (Nyhan et al. 1982, 7164). Sampling and analyses at different depths at each location indicated that the channel sediments were generally well mixed within the upper 12 to 30 cm (4.7 to 12 in.); radionuclide concentrations varied little with depth. Cesium and plutonium concentrations in these samples were generally correlated with the percent of silt and clay-size sediment, the cation exchange capacity, the organic matter content, and calcium carbonate (*$CaCO_3$*) percentages in the samples (Nyhan et al. 1975, 11746), which indicates some of the potential controls on variations in contaminant concentration between samples. Analyses of separate sediment particle-size fractions from individual samples showed that plutonium concentrations were about 10 times higher in the silt and clay-size fraction than in the coarse sand-size fraction, although most of the inventory within the channel was associated with the larger size fractions because of their greater abundance (Nyhan et al. 1976, 11747).*



Source: Nyhan et al. 1982, 7164

Figure 3.4.4-4. Relationship between plutonium and cesium concentrations in active channel sediments and inactive channel or floodplain sediments.

In 1974 a series of suspended sediment samples transported by one 31-cm-deep (12.2-in.-deep) runoff event were collected at GS-2 located about 1.3 km (0.81 mi) downstream from the TA-50 RLWTF outfall. Analysis yielded data on variations in suspended sediment and contaminant concentrations within a flood (Hakonson et al. 1976, 8920). Concentrations ranged from 110 to 650 pCi/g for ^{137}Cs, 7 to 91 pCi/g for ^{238}Pu, and 1 to 13 pCi/g for ^{239,240}Pu; the highest concentrations were measured from the top of the flow where the sediments were finer-grained. The highest concentrations were up to 10 times higher than those measured in channel sediments at a nearby sampling location, which is consistent with the effect of particle size on contaminant concentration shown by Nyhan et al. (1976, 11747). About 1% of the total radionuclide inventory in each sample was in the dissolved load; 99% was associated with the suspended sediments (Hakonson et al. 1976, 8920). The concentrations of ^{137}Cs, ^{238}Pu, and ^{239,240}Pu in these samples were correlated, which is also consistent with the analysis of channel samples by Hakonson and Bostick (1975, 29678) and Nyhan et al. (1975, 11746).

Routine Environmental Surveillance of Channel Sediments

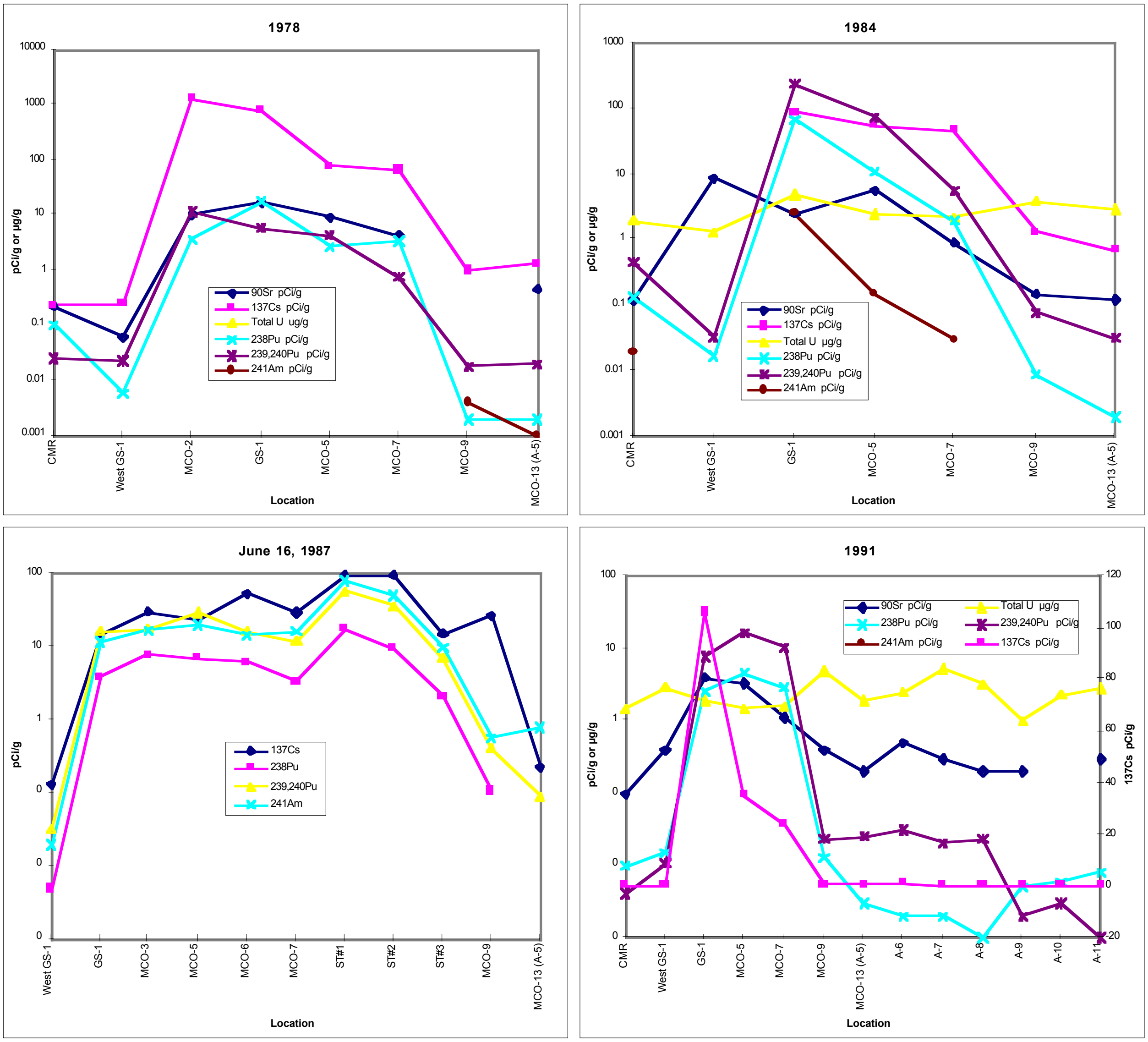
Since 1977 the Laboratory has collected surficial sediment samples annually from various locations along the active channel of Mortandad Canyon. At present, seven locations are sampled on Laboratory property, and six are sampled on San Ildefonso Pueblo land; the samples are analyzed for radioactive constituents and trace metals. Results are reported in the Laboratory's annual surveillance reports (for example, Environmental Protection Group 1995, 50285). The sediment sampling locations in Mortandad Canyon are listed in Table 3.4.4-1 and shown in Figure A-2 in Appendix A of this work plan. Some of the analytical results from samples collected at these locations are summarized in Figure 3.4.4-5(a), Figure 3.4.4-5(b), and Figure 3.4.4-5(c). When examining the figures, the reader should note differences in the scales of the ordinates; different scales were needed to capture the broad ranges of values.

TABLE 3.4.4-1

SEDIMENT SAMPLING LOCATIONS

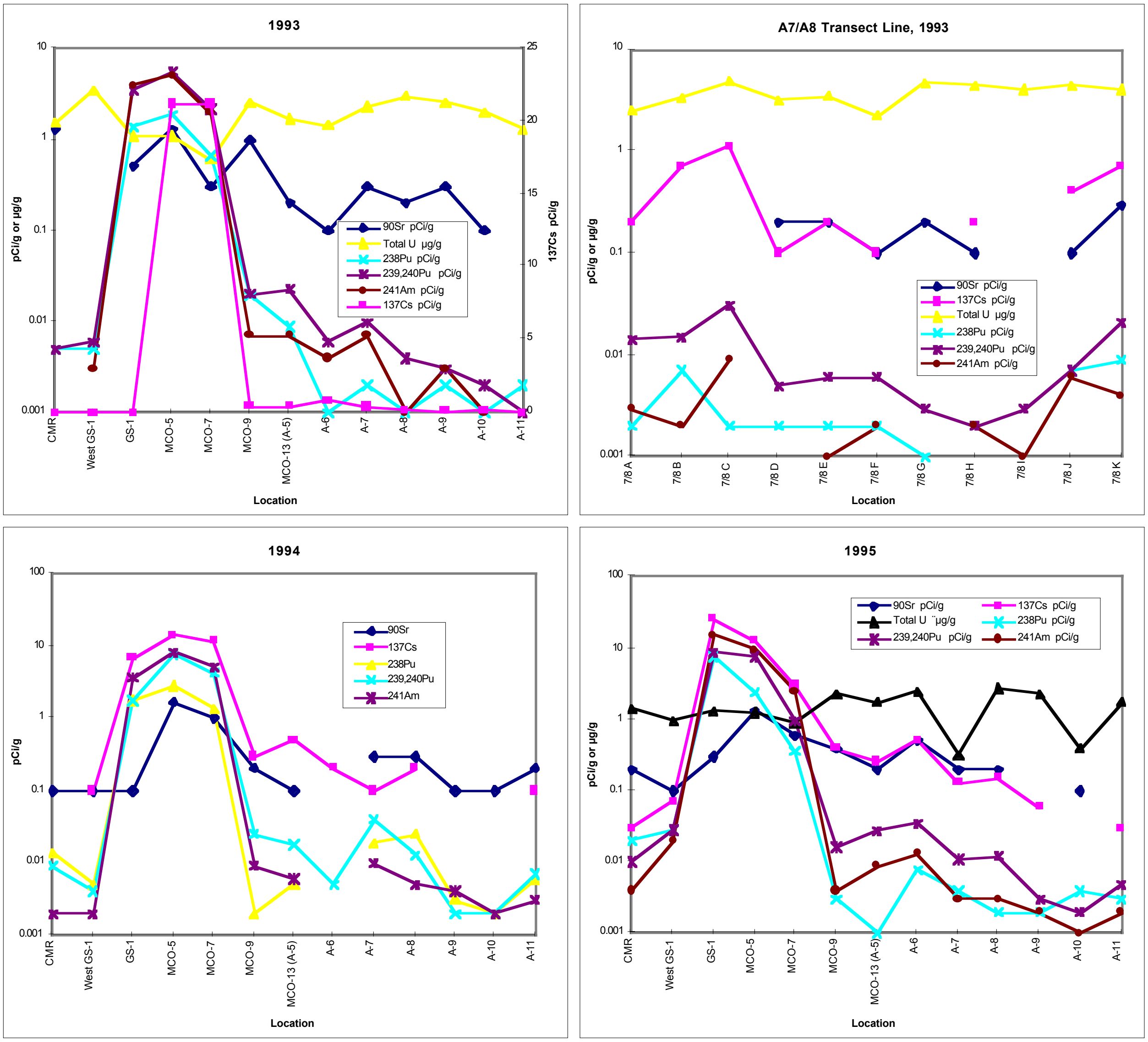
Location	Northing	Easting	Comment
Mortandad Canyon on Laboratory Property *			
Near CMR Building	*1772150*	*1619730*	*At head of canyon*
West of GS-1	*1770350*	*1626650*	*Upstream of Effluent Canyon*
At GS-1	*1770280*	*1626750*	*Downstream of Effluent Canyon*
At MCO-5	*1769530*	*1632460*	*Upstream of Ten Site Canyon*
At MCO-7	*1768600*	*1634480*	*Downstream of Ten Site Canyon, upstream of sediment traps*
At MCO-9	*1768450*	*1638050*	*Downstream of sediment traps*
At MCO-13 (A-5)	*1767550*	*1641250*	*Upstream of Laboratory boundary*
Mortandad Canyon on San Ildefonso Pueblo Land			
A-6	*1766750*	*1641900*	*Immediately downstream of Laboratory boundary*
A-7	*1766350*	*1643700*	
A-8	*1764750*	*1648900*	
A-9	*1762040*	*1651700*	*At state road NM4*
A-10	*1759200*	*1656150*	
A-11	*1757100*	*1664300*	*At Rio Grande*

**See Figure A-2 in Appendix A of this work plan for locations.*



Source: Environmental Surveillance Reports

Figure 3.4.4-5(a). Summary of routine sediment monitoring for radionuclides in Mortandad Canyon.



1993

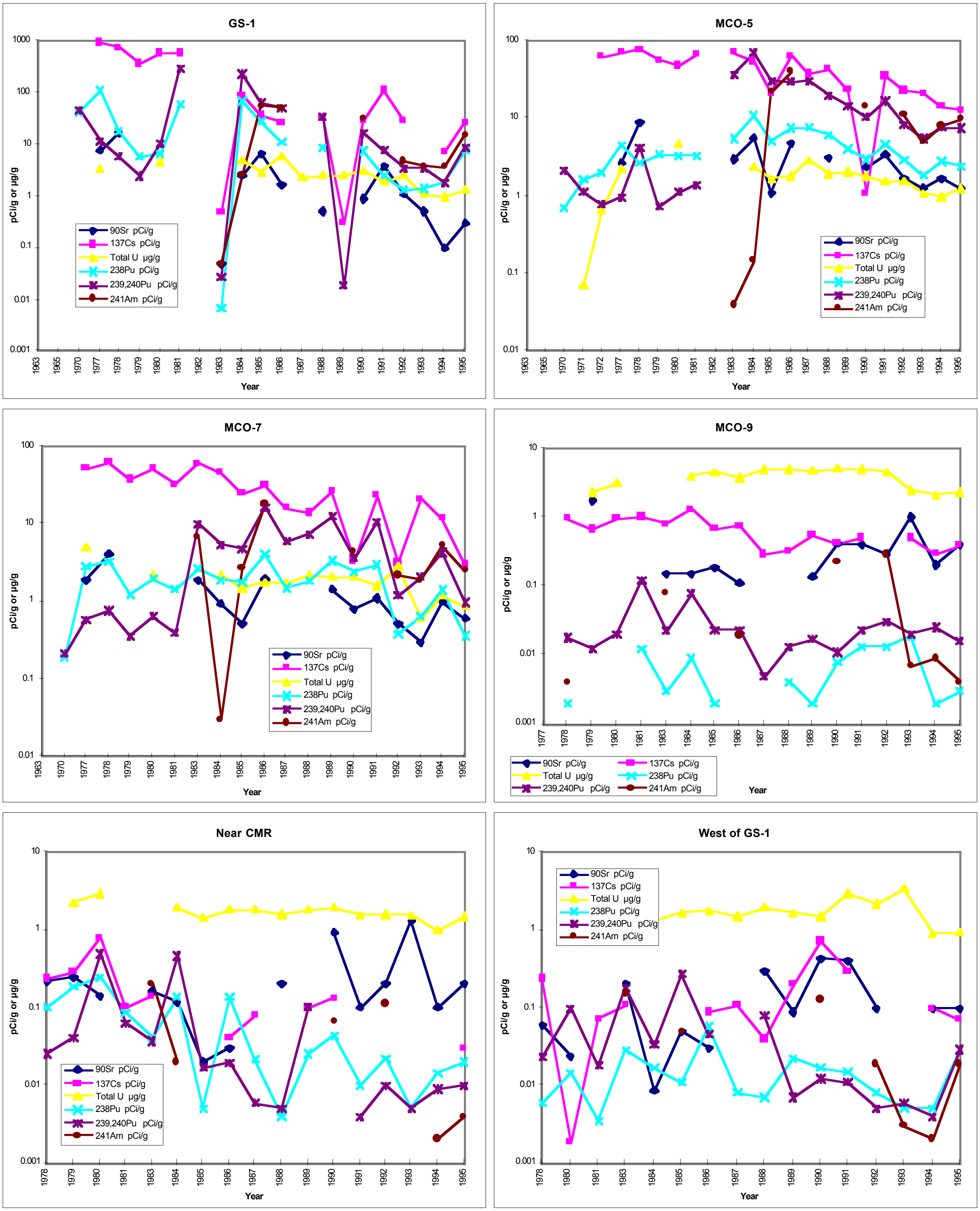
A7/A8 Transect Line, 1993

1994

1995

Source: Environmental Surveillance Reports

Figure 3.4.4-5(b). Summary of routine sediment monitoring for radionuclides in Mortandad Canyon.



Source: Environmental Surveillance Reports

Figure 3.4.4-5(c). Summary of routine sediment monitoring for radionuclides in Mortandad Canyon.

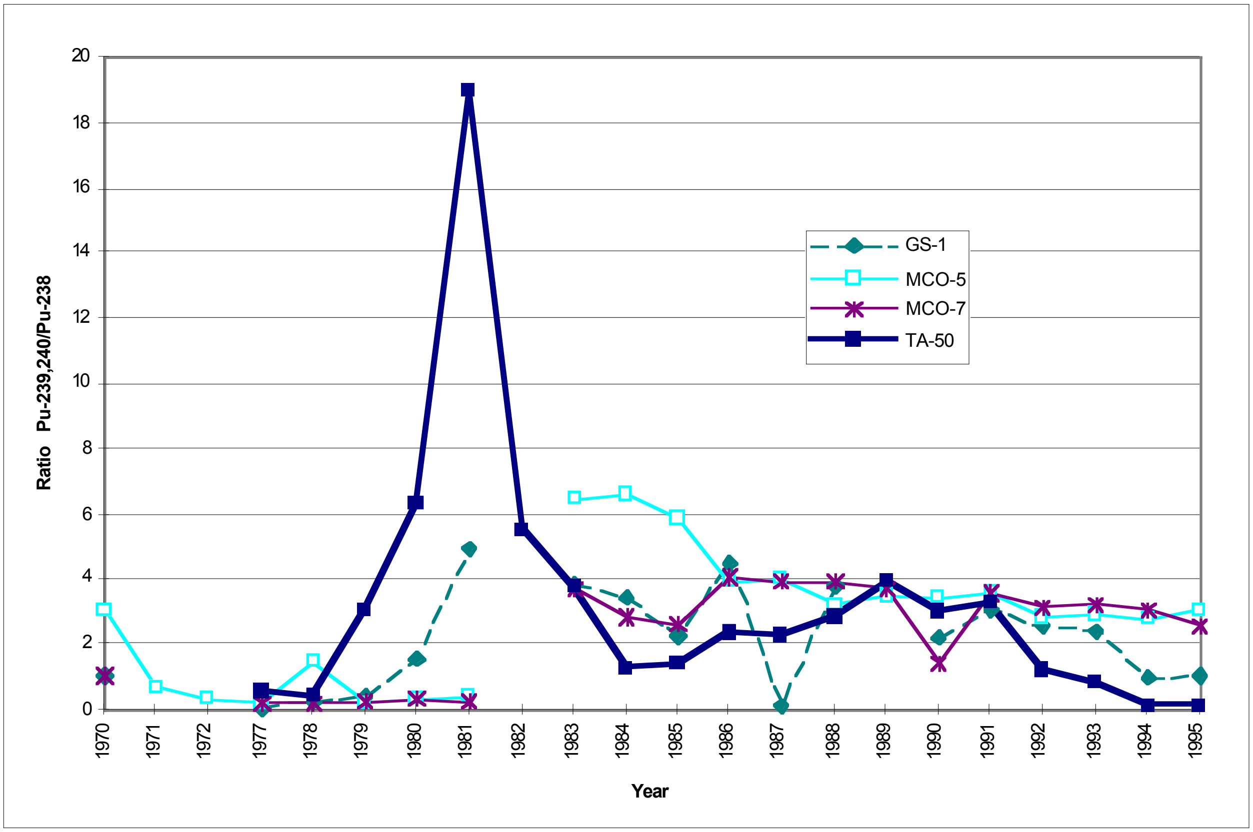
Two of the routine sampling locations in Mortandad Canyon are upstream of the main current contaminant source at the TA-50 RLWTF outfall: one is at the head of the canyon near the CMR Building and one is in Mortandad Canyon upstream of GS-1 and the confluence with Effluent Canyon. These locations may be affected by both fallout contaminants from Laboratory stacks and discharges into the upper canyon; however, most analytical results show concentrations close to background levels.

Sediments collected in the stream channel from GS-1 downstream to the sediment traps show elevated levels of radionuclides probably attributable to discharges from the TA-50 RLWTF outfall in Effluent Canyon. The highest concentrations of each analyte typically are found at GS-1 or at the next sampling location downstream, MCO-5. Concentrations at MCO-7, which is located between Ten Site Canyon and the sediment traps, are generally lower than at MCO-5. The highest concentrations reported in the active channel for these radionuclides are 920 pCi/g for ^{137}*Cs in 1977, 299 pCi/g for* ^{239,240}*Pu in 1981, 107 pCi/g for* ^{238}*Pu in 1977, 57 pCi/g for* ^{241}*Am in 1985, and 17 pCi/g for* ^{90}*Sr in 1978. Mercury has also been found in channel sediments near GS-1 (Hakonson et al. 1973, 4974).*

Reported concentrations of radionuclides in the Mortandad Canyon channel vary considerably from year to year at each sampling location, although concentrations in samples collected in the 1990s are generally less than from the mid-1970s to the mid-1980s (see Figure 3.4.4-5[a], Figure 3.4.4-5[b], and Figure 3.4.4-5[c]). Ratios of different contaminants can also vary greatly with the age of the sediments; these variations are probably associated with variations in the discharge from the TA-50 RLWTF. For example, the ^{239,240}*Pu/*^{238}*Pu ratio would have been highest before 1968 when significant amounts of* ^{238}*Pu were first discharged (Hakonson and Bostick 1975, 29678; Nyhan et al. 1975, 11746; Nyhan et al. 1976, 11747), and* ^{239,240}*Pu/*^{238}*Pu ratios at the outfall were least (<1.0) during the mid-1970s and again after 1994 (Figure 3.4.4-6). Therefore, strong correlations among the concentrations of different contaminants may not be present between sediment layers deposited in different years but may exist for sediments deposited in a single year or in a series of years in which contaminants were discharged in similar proportions, including the cesium/plutonium correlation reported from samples collected in the early 1970s, as shown in Figure 3.4.4-4 (Hakonson and Bostick 1975, 29678; Nyhan et al. 1975, 11746). Such changes in isotopic ratios over time may allow approximate dating of individual sediment layers deposited by flooding, including identification of sediments deposited before the first major discharge of* ^{238}*Pu in 1968.*

Concentrations at a specific sampling location can also vary among samples collected at different times in the same year; these variations possibly depend on recent flooding and/or on variations in particle size between samples. For example, Figure 3.4.4-7 shows results from routine sampling in 1987 and a series of samples collected on June 16, 1987, after an unusually large runoff event (ESG 1988, 6877). A sharp peak in concentrations is evident at MCO-5 from the routine sampling event, but overall higher values were obtained after the June 16 flood, with less of a peak at MCO-5.

Sediment transport past the sediment traps has occurred occasionally since their construction in 1976, including twice in 1991 following several large precipitation events when the traps completely filled with water and overflowed. Surface flow in 1991 extended for 650 ft (198 m) east of Sediment Trap No. 3. A series of samples were collected from the flooded area (Environmental Protection Group 1993, 23249). A channel sample 150 m (492 ft) east of the trap contained 225 pCi/g of ^{137}*Cs and 37 pCi/g of* ^{241}*Am, and a sample collected 12 m (39 ft) farther east (where a defined channel was no longer present) contained 11 pCi/g of* ^{137}*Cs and 10 pCi/g of* ^{241}*Am;* ^{57}*Co,* ^{60}*Co,* ^{83}*Rb, and* ^{75}*Se were also measured above background levels. In 1995 Field Unit 4 personnel collected additional samples from the fan immediately downstream*

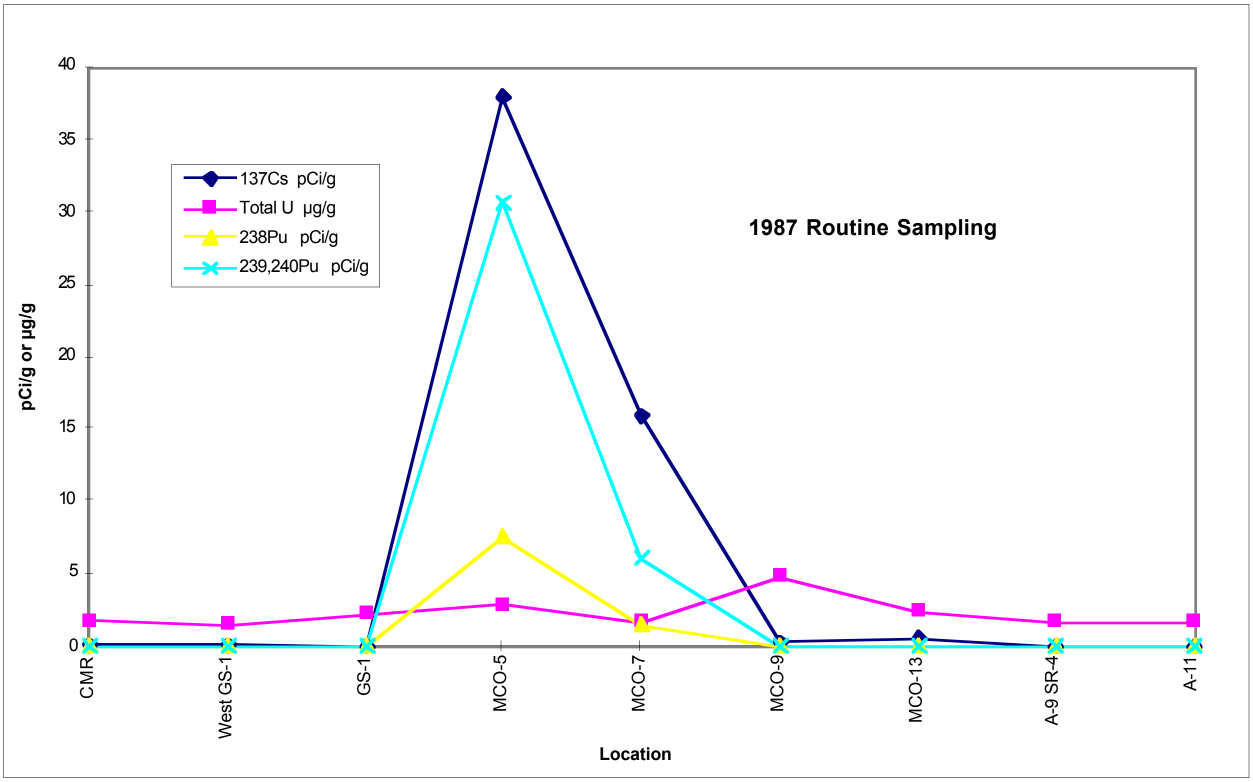


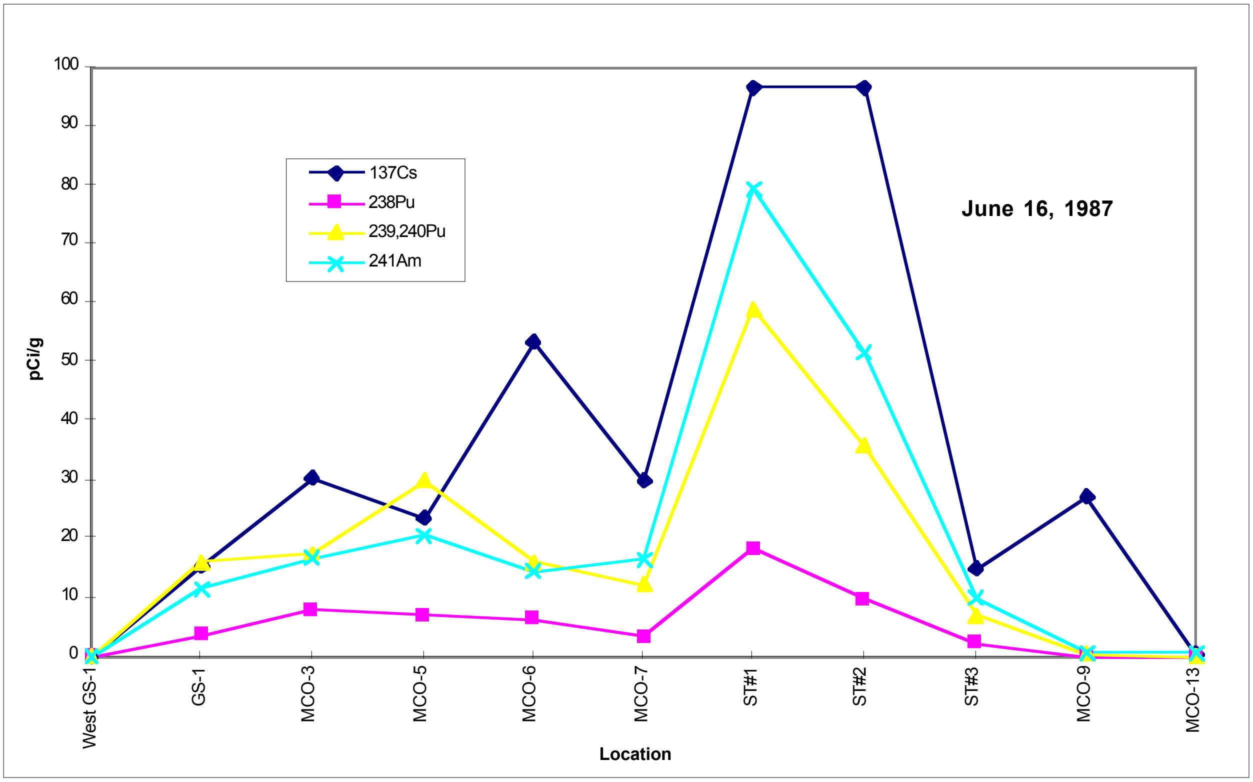
Source: Table 2.4.6-1 in Chapter 2 of this work plan

Figure 3.4.4-6. Plutonium isotopic ratios in TA-50 RLWTF discharge and Mortandad Canyon channel sediments.

of Sediment Trap No. 3, which was presumably deposited during the 1991 overflow event (see Section 3.4.4.2.3). One surface sample contained 8 pCi/g of ^{239,240}Pu and 2 pCi/g of ^{238}Pu, whereas one subsurface sample (2 to 3 ft) (0.30 to 0.61 m) contained low concentrations (0.2 pCi/g of ^{239,240}Pu and 0.1 pCi/g of ^{238}Pu), which suggests that the youngest deposits at this location are <2 ft (<0.61 m) thick. Other trap-overflow events were reported in the 1987 and 1988 environmental surveillance reports (ESG 1989, 6894; ESG 1990, 6995).

Sediments collected from the routine environmental surveillance locations in the channel downstream of the sediment traps, including near wells MCO-9 and MCO-13 on Laboratory property and sediment sampling locations A-6 to A-11 on San Ildefonso Pueblo land, typically have reported concentrations of radionuclides at or very close to background levels. These results suggest that little transport of contaminants occurred past the area of the sediment traps before they were constructed in 1976, although higher concentrations could be present in inactive channel and floodplain deposits in these areas. No runoff has been reported to have reached the Laboratory boundary in Mortandad Canyon since 1960 when routine monitoring of the canyon began, which suggests that if any contaminants have reached San Ildefonso Pueblo land, transport was probably before 1960 and thus before the initial discharges from the TA-50 RLWTF outfall.





Source: ESG 1988, 6877

Figure 3.4.4-7. Radionuclides in Mortandad Canyon channel sediments and sediment traps.

Other Channel Sediment Sampling

In 1981 sediment samples were collected from nonroutine sampling locations in lower Mortandad Canyon to assess the location of a proposed borrow pit (Purtymun 1994, 52951, p. 132–5). Samples were also collected in 1978. The results of the analyses for ^{137}Cs, ^{238}Pu, ^{239}Pu, and gross-gamma radiation are shown in Figure 3.4.4-8. The data show that in 1978 elevated ^{137}Cs activities (greater than 0.1 pCi/g) were present as far east as location 11; activities declined to around 0.01 pCi/g east of that location. However, the 1981 data show that elevated ^{137}Cs concentrations were present as far east as location 13a, near well MCO-9.5, which is downstream of where contaminants are usually detected in the annual surveillance sampling. These elevated concentrations suggest occasional transport of contaminated material to this area, possibly by the large flood event in 1978 or by localized sediment transport during several smaller precipitation events.

In 1993 Laboratory personnel collected additional sediment samples from 11 locations along a transect line between sediment sampling locations A-7 and A-8 on San Ildefonso Pueblo land. The results of the analyses of the samples for radioactivity and radionuclides are shown in Figure 3.4.4-5(b). One of these samples contained a ^{239,240}Pu concentration slightly higher than the statistically-derived levels from fallout in northern New Mexico, and the other 10 samples contained levels below the maximum fallout levels. Three of these samples contained ^{238}Pu at levels that slightly exceeded the fallout reference level, whereas 3 samples contained ^{137}Cs concentration levels slightly above the reference level. Total uranium concentrations slightly exceeded background levels at 2 of the transect locations (Environmental Protection Group 1995, 50285). These analyses suggest possible transport of very low levels of plutonium and ^{137}Cs onto San Ildefonso Pueblo land.

Published Dose Estimates for Exposure to Sediments

The pathways of exposure from sediments in Mortandad Canyon were evaluated and reported in Environmental Surveillance at Los Alamos during 1995 (Environmental Surveillance Program 1996, 55333). The exposure pathways considered in the evaluation were the external gamma radiation pathway from radioactive materials in the sediments, the inhalation pathway from materials resuspended by wind and animals, and the soil ingestion pathway. Because water in the canyon is not used for drinking, irrigation, cattle grazing, or gardens, the drinking water, meat ingestion, and fruit and vegetable ingestion pathways were not considered.

The computer model RESRAD was used to calculate the maximum total effective dose equivalent (TEDE), which is the total of the effective dose equivalents from all pathways plus twice the error value. The modeling considered three scenarios: (1) the entire canyon, (2) the sediment sampling location at GS-1, and (3) the sediment sampling location near well MCO-5. The maximum TEDE for the entire canyon was estimated to be 36.6 mrem, which is <37% of the DOE public dose limit (PDL) of 100 mrem/yr. The ^{137}Cs activity in the sediments at GS-1 and MCO-5 contributed more than 98% of the external gamma radiation pathway, which also contributed more than 84% to the maximum TEDE for the entire canyon area. The inhalation and soil ingestion pathway each contributed approximately 8% to the maximum TEDE. The maximum TEDEs derived for GS-1 and MCO-5 were 43.4 and 22.1 mrem, respectively (Environmental Surveillance Program 1996, 55333).

To consider the exposure rate from surface water in Mortandad Canyon, an exercise scenario was proposed because surface water derived from Mortandad Canyon is not used for drinking, industrial, or agricultural purposes. The exercise scenario assumed an individual exercising four times a week for 50 weeks and obtaining 10% of the necessary drinking water from the TA-50 RLWTF discharge or from the derived stream in Mortandad Canyon. This amount of drinking water was calculated to be 16.1 L/yr. The *total committed effective dose equivalent (CEDE) was calculated from activities measured in the TA-50 RLWTF discharge and the stream below the outfall, which were estimated to be 1.30 and 0.49 mrem/L, respectively (Environmental Surveillance Program 1996, 55333).*

Using the exercise scenario maximum consumption rate of 16.1 L/yr, the annual CEDE from ingestion of the TA-50 RLWTF discharge was calculated to be 20.9 mrem/yr or 21% of the DOE PDL; the CEDE from ingestion of surface water in Mortandad Canyon below the outfall was determined to be 7.8 mrem/yr or 7.8% of the DOE PDL. Using the average annual consumption rate of 5.7 L/yr, the annual CEDE decreased to 7.4 and 2.8 mrem/yr, respectively. The results of sediment sampling and analysis activities proposed in Chapter 7 of this work plan will be used to improve the dose estimates.

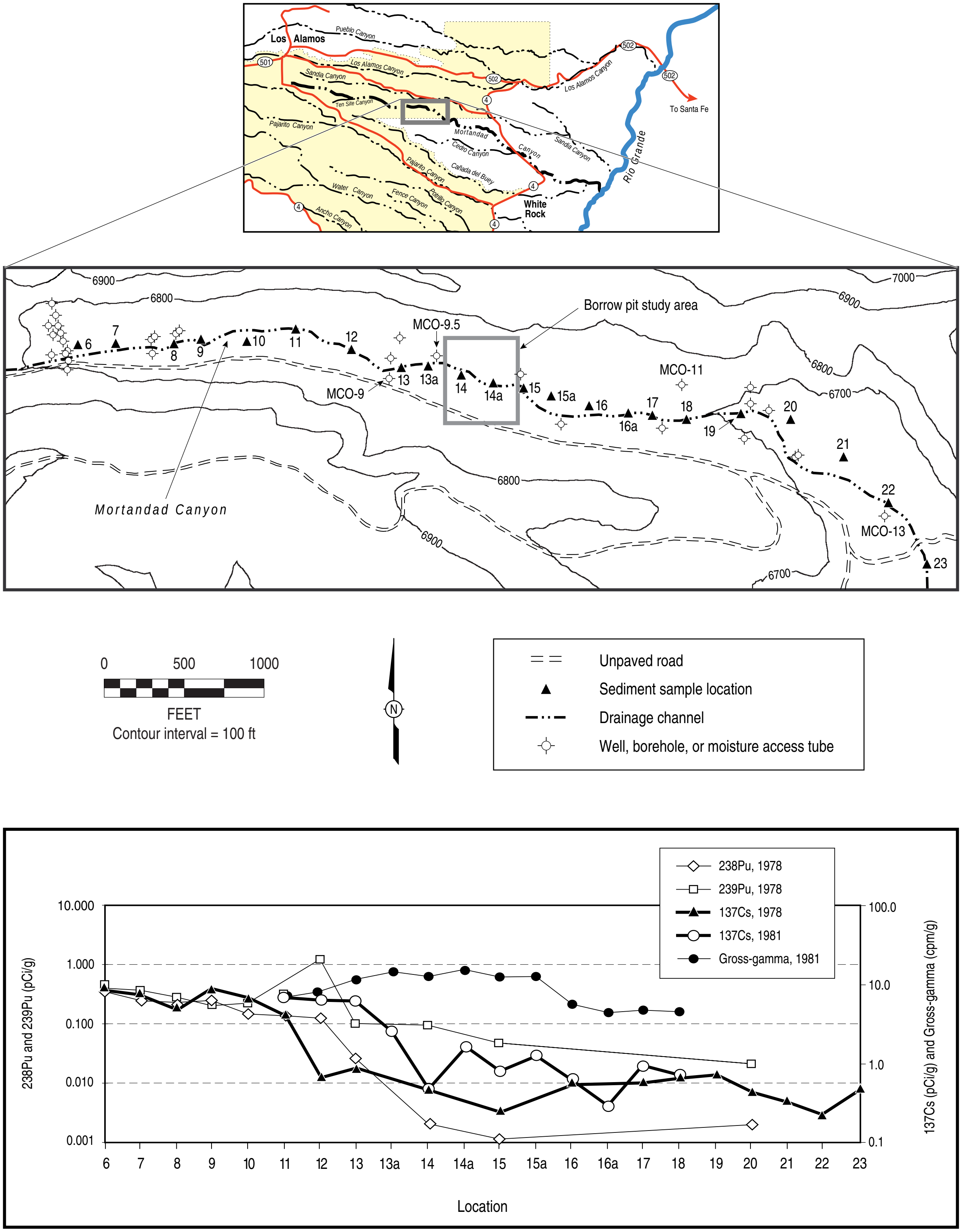
Recent High-Resolution Survey of Plutonium and Uranium Activity in Sediments

In 1994 additional sediment sampling and analysis in lower Mortandad Canyon was conducted to assess the potential for contaminant migration at very low concentrations. Seven channel sediment samples were collected at sediment sampling locations A-5, A-6 (at the Laboratory boundary), A-7, A-8, A-9, A-10, and A-11 (at the Rio Grande) (Gallaher et al. 1997, 04-0329). The samples were analyzed by thermal ionization mass spectrometry (TIMS) to accurately determine the plutonium and uranium activity levels and isotopic ratios. Measurement of the abundance of ^{235}U *and* ^{236}U *and the* ^{240}Pu/^{239}Pu *isotopic ratios in the sediments provides information about the Laboratory's contribution to plutonium and uranium concentrations relative to global fallout.*

Results of the analyses showed that combined ^{239}Pu + ^{240}Pu + ^{241}Pu *activity levels in sediments range from 0.06 pCi/g to approximately 0.0006 pCi/g. The* ^{239}Pu *and* ^{240}Pu *activity levels at all the sediment sampling locations were within the range of regional background levels (0.023 pCi/g) (Purtymun et al. 1987, 6687). Uranium activities ranged from 0.6 to 1.7 pCi/g, and* ^{236}U *was observed at two locations, A-6 and A-7, in concentrations slightly above detection limits (Gallaher et al. 1997, 04-0329). The* ^{240}Pu/^{239}Pu *ratios at locations A-5, A-9, and A-10 could not be estimated accurately because of* ^{240}Pu *activity levels near or below detection limits. The* ^{240}Pu/^{239}Pu *ratios at locations A-6, A-8, and A-11 indicated a possible Laboratory component of plutonium. The data also indicated possible off-site migration of plutonium from Laboratory sources as far as location A-8 near state road NM4. However, because only trace levels of plutonium, all attributable to global fallout, were observed from state road NM4 downstream to the Rio Grande (specifically at locations A-9 and A-10), the Laboratory component of the plutonium at the Rio Grande location (A-11) was attributed to a source upstream from Mortandad Canyon and is probably from Los Alamos Canyon (Gallaher et al. 1997, 04-0329).*

3.4.4.2.2 Preliminary RFI Sediment Sampling and Analysis at PRS No. 50-006(d) in Effluent Canyon

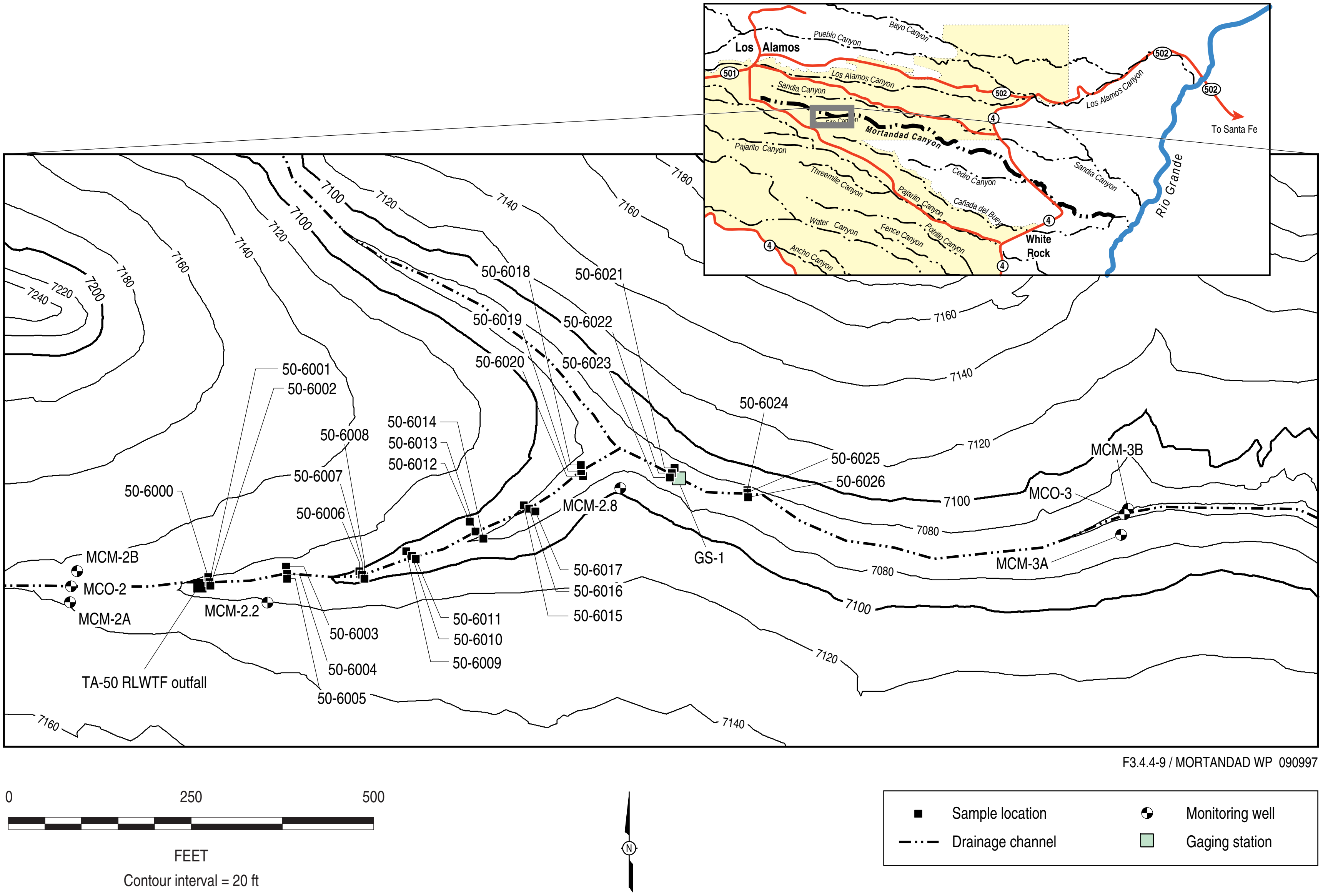
In 1993 an RFI was performed at PRS No. 50-006(d), the TA-50 RLWTF outfall that discharges to Effluent Canyon. The sampling was performed by Field Unit 5 personnel in accordance with the approved RFI work plan (LANL 1992, 7672). Soil samples were collected from 9 transect lines perpendicular to the drainage channel, beginning approximately 20 ft (6.1 m) downstream of the outfall, and at 100-ft (30.5-m) intervals approximately 900 ft (274 m) from the outfall. Each transect line consisted of three sampling locations approximately 5 ft (1.5 m) apart: one or two in the active channel and one or two on the adjacent inactive channels or floodplains. A total of 57 samples (including duplicates) were collected at 27 locations from the following depth intervals: 0 to 0.5 ft (0 to 0.15 m), 1.5 to 2.5 ft (0.46 to 0.76 m), and 3 to 4 ft (0.91 to 1.22 m) below ground surface. Table 2.4.6-2 (in Section 2.4.6 in Chapter 2 of this work plan) lists the sampling locations and depths and the radiation screening data measured for each sample. Figure 3.4.4-9 shows the sampling locations.



Source: Purtymun 1994, 52951

F3.4.4-8 / MORTANDAD WP 090597

Figure 3.4.4-8. Radionuclides in lower Mortandad Canyon sediments in 1978 and 1981.



F3.4.4-9 / MORTANDAD WP 090997

Figure 3.4.4-9. Locations of samples collected at PRS No. 50-006(d).

Preliminary analytical results for the samples are listed in Table C-1 (radionuclides), Table C-2 (metals), and Table C-3 (organic compounds) in Appendix C of this work plan. Background values available for each constituent (McDonald et al. 1987, 04-0328) are also shown on each table for comparison. Maximum activities observed for radionuclides ranged from approximately 20 times background levels for ^{90}Sr, ^{239,240}Pu, ^{235}U, and ^{238}U, approximately 300 times background levels for ^{137}Cs, 500 times background levels for ^{241}Am, to 2300 times background levels for ^{238}Pu and 1500 times background levels for tritium. Other radionuclides that were observed significantly above background levels include ^{57}Co, ^{60}Co, ^{152}Eu ^{226}Ra, ^{232}Th, and ^{234}U.

Concentrations of arsenic, barium, beryllium, chromium, lead, mercury, nickel, selenium, and silver were also observed above background levels in the sediments. Maximum concentrations of mercury were 0.2 mg/kg (about 7 times background levels), and maximum concentrations of nickel were 48 mg/kg (about 5 times background levels). Most maximum concentrations observed were about 1 to 5 times background levels except one sample that contained 8 mg/kg silver (28 times background level).

Organic compounds including acetone, aroclors, bis(2-ethylhexyl)phthalate, di-n-butylphthalate, and trichlorofluoromethane were observed at low concentrations, usually one or two orders of magnitude below mesa-top soil SALs. The data indicated that organic compounds do not occur in concentrations that pose significant risks. Because PRS No. 50-006(d) is located in Effluent Canyon and Mortandad Canyon, further investigation by Field Unit 5 was deferred to be part of the Mortandad Canyon investigation, and investigation of the sediments below the outfall are included as part of this work plan.

Potential ecological risk associated with soil contaminants at PRS No. 50-006(d) was assessed by performing an ecotoxicological risk screen using the data obtained from the surface sediment samples (Gonzales and Newell 1996, 56045). Ecotoxicological screening action levels (ESALs) were computed for nonradionuclide constituents in the soil; human risk SALs were used for radionuclide ESALs. The spatial change in radionuclide concentrations from the TA-50 RLWTF outfall to the downstream sampling locations was found to be statistically insignificant because periodic flow from the outfall extends beyond the sampling area for the PRS. The ecotoxicological risk screen concluded that PRS No. 50-006(d) could not be recommended for no further action based on the potential ecological impact. Additional risk assessment was recommended for at least 17 COPCs (Gonzales and Newell 1996, 56045), and ecological risk will be evaluated further, in accordance with the methodology being developed with NMED using the more extensive data collected during this investigation.

3.4.4.2.3 Inactive Channels and Floodplains

Several investigations in Mortandad Canyon have provided data on contaminant concentrations at selected locations in inactive channel or floodplain settings; these data allow comparisons of these deposits with adjacent active channel sediments. However, no systematic evaluation of the horizontal or vertical extent of contaminated sediments in these geomorphic settings has been attempted. In earlier work cited herein, no distinction was made between inactive channel and floodplain; any location outside the active channel was referred to as “bank.” In the following summary discussion, the term “bank” from the original reference is used when no more precise morphologic distinction can be made.

Hakonson et al. (1980, 8924) collected 40 core samples from 10 bank locations and core from 10 active channel locations along a 100-m (328-ft) segment of Mortandad Canyon about 500 m (1640 ft) downstream of the TA-50 RLWTF outfall. The samples were analyzed for mercury, ^{137}Cs, and plutonium isotopes. Results of the analyses showed contaminant concentrations in the banks that are generally equivalent to or *exceed those measured in the active channel sediments, which indicates storage of contaminants in these locations. Concentrations in the banks varied much more with depth than concentrations in the channels; concentrations also varied more with distance downstream from the outfall.*

The distribution of radionuclides in and near the Mortandad Canyon channel was investigated by Nyhan et al. (1982, 7164). In 1974 multiple sets of soil samples were collected through the banks from the active channel and at intervals of 0.02, 0.1, 0.2, 0.38, and 10 m (0.07, 0.33, 0.66, 1.25, and 33 ft) from the channel. Samples were collected at distances of 320 m (0.20 mi), 1250 m (0.78 mi), and 2500 m (1.55 mi) downstream from the TA-50 RLWTF outfall. Contaminants were present below the banks to a depth of at least 30 cm (11.8 in.) at the 320-m (1050-ft) location but only to a depth of 10 cm (3.9 in.) or less at the 2500-m (8200-ft) location, which suggests the thickness of sediment deposited at these locations between 1963 and 1974. The width of the deposition zone was not well defined, although it extended less than 10 m (33 ft) away from the active channel at the sampling locations. Contaminant concentrations were generally lower in the banks than in the channel and were lower where the banks were higher, which is consistent with less opportunity for floodwaters to overtop the higher banks. The calculated inventory of contaminants indicated that 1 to 47% of each analyte at each location was contained within the banks, although the volume of sediment deposited outside the active channel was probably underestimated because the contamination was assumed to extend only 0.38 m (1.25 ft) from the active channel. Notably, the bank samples generally displayed higher ^{239,240}Pu/^{238}Pu ratios than the active channel samples, which suggests that the overtopping of the banks and the deposition of contaminated sediments had occurred sometime earlier when discharges of ^{238}Pu were lower. Concentrations of cesium and plutonium were well correlated in these samples (see Figure 3.4.4-4).

In 1991 sampling and analyses downstream of Sediment Trap No. 3 after the traps overflowed documented dispersion of contaminated sediment away from the active channel; the dispersion extended locally to at least 20 m (66 ft) from the channel to both the north and the south. Measured contaminant concentrations in these out-of-channel areas ranged from 98 to 173 pCi/g for ^{137}Cs and 9 to 32 pCi/g for ^{241}Am (Environmental Protection Group 1993, 23249). The thickness of the sediment deposited in 1991 was not reported. It is likely that these samples contained sediment from both 1991 and earlier floods. Similar concentrations were also reported from this area after previous overflow events (ESG 1989, 6894; ESG 1990, 6995).

3.4.4.2.4 Sediment Traps

The Mortandad Canyon sediment traps constitute a unique setting where sediments transported as both bedload and suspended load in individual floods are deposited, which results in deposits that are, in some ways, unlike sediments typical of either the active channel or the floodplains elsewhere in the canyon. Contaminant concentrations in samples collected from the sediment traps vary with the particle size distribution as well as the sediment age, although few quantitative data on particle size distribution of the samples are available. The sediment traps have been cleaned out at irregular intervals after floods; the clean-out piles where the sediments are placed (see Figure 2.3.1-1 in Chapter 2 of this work plan) contain varying mixtures of contaminated and uncontaminated sediment.

Sampling and analysis of ponded water within the sediment traps has provided data on the concentrations of contaminants transported as suspended sediment in individual floods. These data can be compared with data from samples of stream bed sediment collected nearby to evaluate general particle size effects on contaminant concentrations. Suspended sediment was collected from water ponded in the sediment traps in 1987 and 1991 and analyzed for plutonium (ESG 1988, 6877; Environmental Protection Group 1993, 23249). Concentrations ranged up to 39 pCi/g for ^{238}Pu and 137 pCi/g for ^{239,240}Pu (see Table

3.6.5-1), which are up to an order of magnitude higher than those reported from the same years at the closest upstream sediment sampling location near well MCO-7. The suspended sediment samples collected in 1987 were also analyzed for pesticides, organic compounds, volatile organic compounds (VOCs), and metals, none of which were detected above background levels (ESG 1988, 6877).

Samples of sediment have been collected from the sediment traps in various years from both coarse- and fine-grained deposits. Samples of fine-grained sediment collected from a depression in Sediment Trap No. 3 after the 1991 floods showed 282 pCi/g of ^{137}*Cs, 38 pCi/g of* ^{241}*Am, and 3.6 pCi/g of* ^{60}*Co (Environmental Protection Group 1993, 23249). Maximum concentrations for various contaminants reported in sediment traps samples collected in 1987, 1988, and 1991 were 97 pCi/g of* ^{137}*Cs (1987, Sediment Trap No. 1 and Sediment Trap No. 2); 80 pCi/g of* ^{241}*Am (1987, Sediment Trap No. 1); 59 pCi/g of* ^{239,240}*Pu (1987, Sediment Trap No. 1); 18 pCi/g of* ^{238}*Pu (1987, Sediment Trap No. 1); 5.8 pCi/g of* ^{60}*Co (1988, Sediment Trap No. 2); 40 pCi/g of* ^{57}*Co (1988, Sediment Trap No. 2); and 7.6 pCi/g of* ^{75}*Se (1987, Sediment Trap No. 1) (ESG 1988, 6877; ESG 1989, 6894; Environmental Protection Group 1993, 23249, LANL 1994, 55811).*

In 1994 ESH-18 and the Department of Energy Oversight Bureau of the New Mexico Environment Department (NMED) obtained data on variations in contaminant concentrations with sediment particle size at Sediment Trap No. 1. Two samples were collected from each of two locations in the sediment trap. Samples of fine-grained surface material and the underlying sandy material were collected near the inlet to the sediment trap and in the center of the sediment trap. Results of the analyses showed that the finer-grained sediments contained higher concentrations of radionuclides. Concentrations ranged from 3 to 18 times higher in the fine-grained sediments compared with the sand-sized sediments, averaging about 6 times higher (Table 3.4.4-2). The maximum concentrations in the finer-grained sediments were 10 pCi/g for ^{238}*Pu, 26 pCi/g for* ^{239,240}*Pu, 34 pCi/g for* ^{241}*Am, and 57 pCi/g for* ^{137}*Cs. These values are generally lower than those in the suspended sediments collected in 1987 and 1991 (see Table 3.6.5-1 and Table 3.6.5-2) but higher than channel sediment samples collected near well MCO-7, which perhaps reflects variable particle size distributions among the samples.*

Preliminary RFI Sampling and Analysis at PRS No. 00-001

Field Unit 4 personnel prepared a sampling and analysis plan for preliminary sediment sampling of the sediment traps (PRS No. 00-001) and submitted it to the Environmental Protection Agency (EPA) for approval on April 14, 1995 (LANL 1995, 46084). The EPA approved the plan with modifications on September 19, 1995 (Davis 1995, 50094). The plan was revised based on EPA's modifications in a memorandum to the Field Unit 4 File dated October 24, 1995 (Pratt 1995, 51508).

Before conducting sampling activities (in February and March 1995), the field team conducted a radiation grid survey near the sediment traps. Field screening during site surveys and sample collection activities was performed using a Hazco 1256 organic vapor analyzer, a Ludlum Model 39 alpha meter, and an Eberline ESP-1 beta/gamma meter. Background radiation measurements in Mortandad Canyon ranged from 200 to 500 counts per minute (cpm) beta/gamma radiation depending on the location and substrate rock type. Field screening measurements greater than 500 cpm beta/gamma radiation are generally considered to be above background levels. Figure 3.4.4-10 shows the results of the radiation grid survey. A total of 377 radiation grid locations were established at 20-ft (6.1-m) intervals in the sediment traps and at 50-ft (15-m) and 100-ft (30-m) intervals along the periphery of the sediment traps. The beta/gamma radiation measurements ranged from 137 to 535 cpm, with a mean of 289 cpm. The highest *measurements were obtained from the floor of Sediment Trap No. 3 and, generally, higher measurements were obtained from active channel sediments than from inactive channel or floodplain deposits.*

TABLE 3.4.4-2

CONCENTRATIONS OF RADIONUCLIDES AND METALS IN SEDIMENT TRAP No. 1[a]

Radionuclides

Part 1

Sample ID	Gross-Alpha		Gross-Beta		Sr-90		Sr-89		U-234		U-235	
	pCi/g	Unc[b]	pCi/g	Unc	pCi/g	Unc	pCi/g	Unc	pCi/g	Unc	pCi/g	Unc
Limits of Detection	*N.A.[c]*	*0.4*	*3*	*2*	*0.1*	*1*	*0.02*	*0.02*	*0.02*	*3*	*3*	*N.A.*
BSV[d]	*58.8*	*N.A.*	*46.1*	*N.A.*	*1.0*	*N.A.*	*N.A.*	*N.A.*	*2.39*	*N.A.*	*0.16*	*N.A.*
FINES-1	*32.80*	*4.0*	*29.50*	*3.4*	*3.01*	*0.87*	*<2.6*	*BDL[e]*	*1.44*	*0.21*	*<0.03*	*BDL*
SAND-1	*4.44*	*0.56*	*4.16*	*0.51*	*<0.72*	*BDL*	*<0.83*	*BDL*	*0.31*	*0.07*	*<0.01*	*BDL*
FINES-2	*86*	*12*	*67.6*	*7.8*	*4.51*	*0.95*	*NA*	*N.A.*	*RP[f]*	*N.A.*	*RP*	*N.A.*
SAND-2	*N.A.*	*N.A.*	*N.A.*	*N.A.*	*N.A.*	*N.A.*	*N.A.*	*N.A.*	*N.A.*	*N.A.*	*N.A.*	*N.A.*

Part 2

Sample ID	U-238		Pu-238		Pu-239/240		Am-241		Cs-137	
	pCi/g	Unc	pCi/g	Unc	pCi/g	Unc	pCi/g	Unc	pCi/g	Unc
Limits of Detection	*N.A.*	*N.A.*	*N.A.*	*N.A.*	*N.A.*	*N.A.*	*N.A.*	*N.A.*	*N.A.*	*N.A.*
BSV	*2.29*	*N.A.*	*0.006*	*N.A.*	*0.197*	*N.A.*	*0.139*	*N.A.*	*1.28*	*N.A.*
FINES-1	*1.58*	*0.23*	*2.95*	*0.40*	*8.3*	*1.0*	*10.50*	*0.989*	*27*	*4.1*
SAND-1	*0.27*	*0.06*	*0.37*	*0.07*	*1.29*	*0.19*	*1.19*	*0.241*	*3.15*	*0.225*
FINES-2	*RP*	*N.A.*	*10.0*	*1.2*	*26.4*	*3.1*	*33.87*	*4.50*	*57.0*	*7.1*
SAND-2	*N.A.*	*N.A.*	*N.A.*	*N.A.*	*N.A.*	*N.A.*	*N.A.*	*N.A.*	*3.0*	*0.48*

Part 3

Sample ID	Na-22		Co-60		Tl-208		Pb-212		Pb-214	
	pCi/g	Unc	pCi/g	Unc	pCi/g	Unc	pCi/g	Unc	pCi/g	Unc
Limits of Detection	*N.A.*	*N.A.*	*N.A.*	*N.A.*	*N.A.*	*N.A.*	*N.A.*	*N.A.*	*N.A.*	*N.A.*
BSV	*<0.1*	*N.A.*	*<0.14*	*N.A.*	*0.906*	*N.A.*	*2.36*	*N.A.*	*1.97*	*N.A.*
FINES-1	*25*	*3.7*	*0.309*	*0.062*	*2.2*	*0.59*	*2.5*	*0.56*	*1.5*	*0.29*
SAND-1	*RP*	*N.A.*	*<0.043*	*BDL*	*RP*	*N.A.*	*RP*	*N.A.*	*RP*	*N.A.*
FINES-2	*RP*	*N.A.*	*<1.2*	*BDL*	*RP*	*N.A.*	*RP*	*N.A.*	*RP*	*N.A.*
SAND-2	*N.A.*	*N.A.*	*<0.03*	*BDL*	*N.A.*	*N.A.*	*N.A.*	*N.A.*	*N.A.*	*N.A.*

a. DOE Oversight Bureau sampling (October 28, 1994)
b. Unc = uncertainty in counting statistics
c. N.A. = not available
d. BSV = background screening value (McDonald et al. 1997, 04-0328); values may include 95% UTLs and maximum observed values
e. BDL = below detection limit
f. RP = report pending

TABLE 3.4.4-2 (continued)

CONCENTRATIONS OF RADIONUCLIDES AND METALS IN SEDIMENT TRAP No. 1[a]

Radionuclides

Part 4

Sample ID	Bi-214		Ra-226		Ac-228		Th-234		Th-208	
	pCi/g	Unc[b]	pCi/g	Unc	pCi/g	Unc	pCi/g	Unc	pCi/g	Unc
Limits of Detection	*N.A.[c]*	*N.A.*	*N.A.*	*N.A.*	*N.A.*	*N.A.*	*N.A.*	*N.A.*	*N.A.*	*N.A.*
BSV[d]	*N.A.*	*N.A.*	*N.A.*	*N.A.*	*3.3*	*N.A.*	*<4.48*	*N.A.*	*N.A.*	*N.A.*
FINES-1	*1.5*	*0.32*	*1.5*	*2.9*	*1.8*	*0.45*	*2.7*	*0.77*	*2.2*	*0.59*
SAND-1	*RP[e]*	*N.A.*	*RP*	*N.A.*	*RP*	*N.A.*	*RP*	*N.A.*	*RP*	*N.A.*
FINES-2	*RP*	*N.A.*	*RP*	*N.A.*	*RP*	*N.A.*	*RP*	*N.A.*	*RP*	*N.A.*
SAND-2	*N.A.*	*N.A.*	*N.A.*	*N.A.*	*N.A.*	*N.A.*	*N.A.*	*N.A.*	*N.A.*	*N.A.*

Metals

Part 1

Sample ID	Ag mg/kg	Al mg/kg	As mg/kg	B mg/kg	Ba mg/kg	Be mg/kg	Ca mg/kg	Cd mg/kg	Cr mg/kg	Co mg/Kg
BSV	*0.28*	*13260*	*3.98*	*4.1*	*127*	*1.31*	*3850*	*0.18*	*10.5*	*4.73*
FINES-1	*<1*	*5100*	*2.5*	*<1*	*80*	*0.8*	*2000*	*<0.5*	*6*	*3*
SAND-1	*<1*	*650*	*<0.5*	*<1*	*<10*	*0.1*	*220*	*<0.5*	*<1*	*<1*
FINES-2	*<2*	*4330*	*2.1*	*N.A.*	*92.9*	*1*	*2810*	*<0.2*	*12*	*3.2*
SAND-2	*<2*	*278*	*<0.5*	*N.A.*	*10.3*	*<0.2*	*184*	*<0.2*	*0.41*	*<2*

Part 2

Sample ID	Cu mg/kg	Fe mg/kg	Hg mg/kg	K mg/kg	Mg mg/kg	Mn mg/kg	Mo mg/kg	Na mg/kg	Ni mg/kg
BSV	*9.97*	*13800*	*0.03*	*2690*	*2130*	*543*		*1470*	*9.38*
FINES-1	*9*	*9400*	*<0.2*	*900*	*940*	*380*	*1*	*70*	*4*
SAND-1	*<1*	*1600*	*<0.2*	*100*	*100*	*62*	*<1*	*20*	*<2*
FINES-2	*12*	*7190*	*<0.025*	*N.A.*	*1090*	*439*	*<2*	*127*	*5*
SAND-2	*0.87*	*791*	*<0.025*	*N.A.*	*54.5*	*93*	*<2*	*<50*	*<5*

Part 3

Sample ID	Pb mg/kg	Sb mg/kg	Se mg/kg	Si mg/kg	Sn mg/kg	Sr mg/kg	Tl mg/kg	V mg/kg	Zn mg/kg
BSV	*19.7*	*5*	*<0.2*				*3.2*	*19.7*	*60.2*
FINES-1	*13*	*<6*	*0.6*	*580*	*6*	*12*	*<0.5*	*10*	*39*
SAND-1	*1.9*	*<6*	*<0.5*	*200*	*3*	*<1*	*<0.5*	*1*	*9*
FINES-2	*18*	*<10*	*<0.05*	*N.A.*	*<10*	*N.A.*	*N.A.*	*10.1*	*37.4*
SAND-2	*1.5*	*<10*	*<0.5*	*N.A.*	*<10*	*N.A.*	*<0.5*	*<2*	*<5*

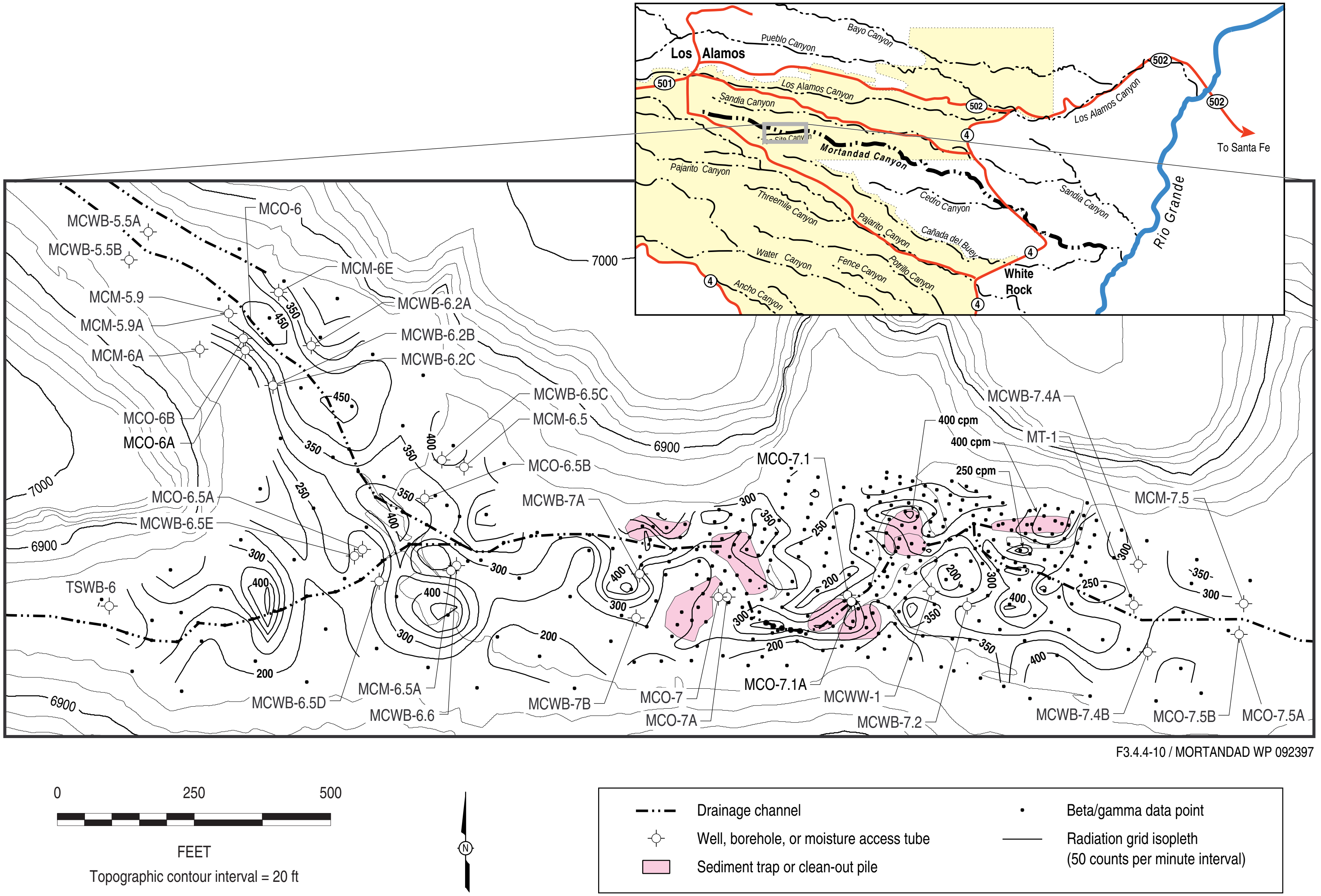
a. DOE Oversight Bureau sampling (October 28, 1994)

b. Unc = uncertainty in counting statistics

c. N.A. = not available

d. BSV = background screening value (McDonald et al. 1997, 04-0328); values may include 95% UTLs and maximum observed values

e. RP = report pending



F3.4.4-10 / MORTANDAD WP 092397

Figure 3.4.4-10. Results of beta/gamma radiation grid survey near the Mortandad Canyon sediment traps.

On November 15, 1995, sediment samples were collected at 10 locations in and around the sediment traps and were identified by beta/gamma field screening to have radiation levels elevated about two times above background. Elevated radiation levels were found in Sediment Trap No. 2, Sediment Trap No. 3, and the clean-out pile northwest of Sediment Trap No. 1. Two sediment samples were collected at each location (shown in Figure 3.4.4-11 and listed in Table 3.4.4-3) at depth intervals of 0 to 0.5 and 2 to 3 ft (0 to 0.15 and 0.61 to 0.91 m) using a shallow hand-auger. The samples were analyzed for gross-alpha, -beta, and -gamma radiation; alpha spectrometry; gamma spectroscopy; metals; VOCs; semivolatile organic compounds (SVOCs); moisture content; and tritium. The results of the analyses for radionuclides are listed in Table 3.4.4-4.

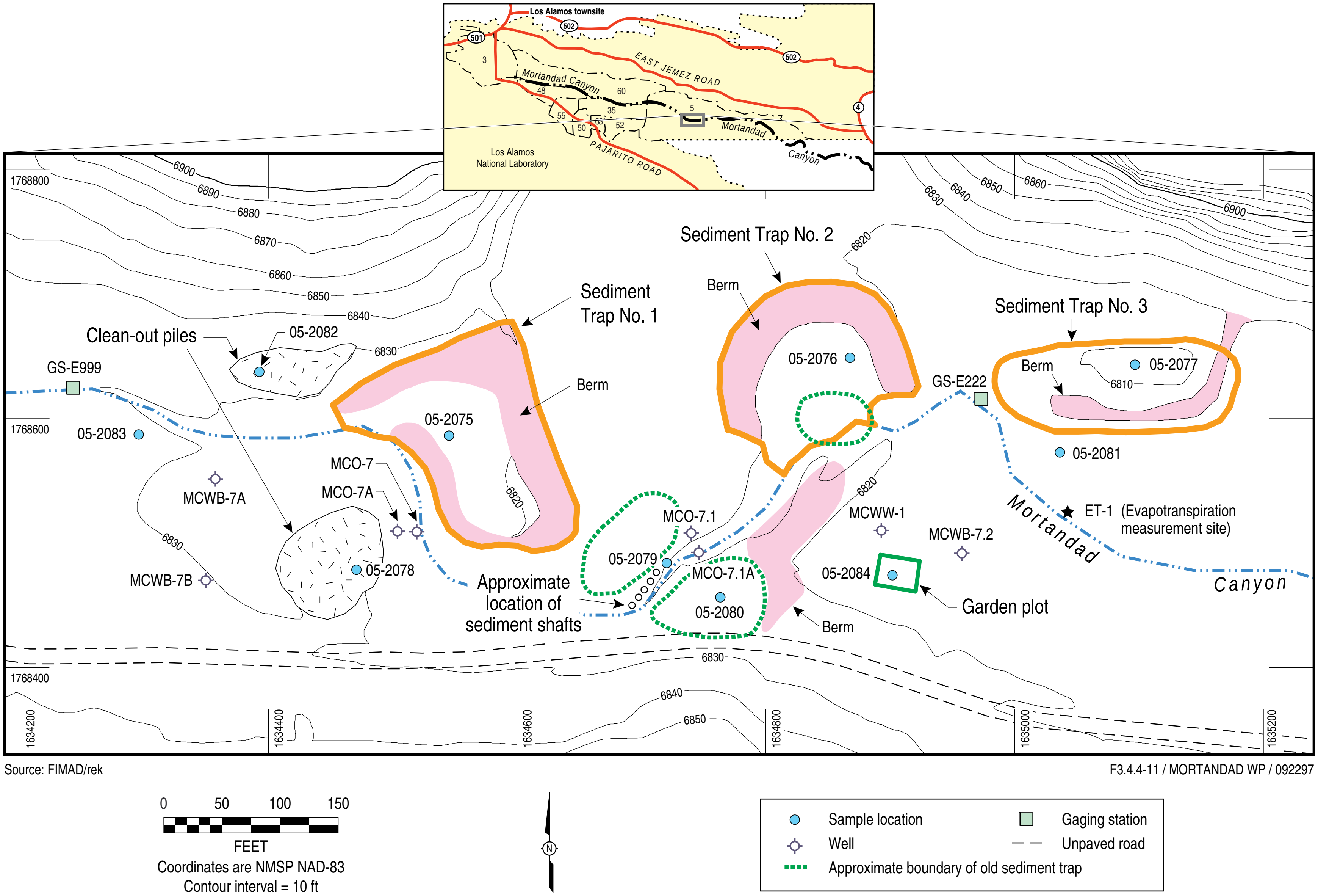
TABLE 3.4.4-3

SEDIMENT TRAP SAMPLE LOCATIONS FOR PRS Nos. 00-001 AND 00-005*

Location ID	Depth (ft)	No. of Samples	Location	Comment
05-2075	*3*	*2*	*Sediment Trap No. 1*	*Center of sediment trap at toe of prograding fan*
05-2076	*3*	*2*	*Sediment Trap No. 2*	*Edge of sediment trap*
05-2077	*3*	*2*	*Sediment Trap No. 3*	*Center of sediment trap*
05-2078	*3*	*2*	*Pile southwest of Sediment Trap No. 1*	*Clean-out pile from Sediment Trap No. 1*
05-2079	*3*	*2*	*Center of channel between Sediment Trap No. 1 and No. 2*	*Old sediment trap filled with sediment*
05-2080	*3*	*2*	*Center of old sediment trap*	*Old sediment trap filled with sediment*
05-2081	*3*	*2*	*Outflow fan*	*Downstream from Sediment Trap No. 3*
05-2082	*3*	*2*	*Pile northwest of Sediment Trap No. 1*	*Clean-out pile from Sediment Trap No. 1*
05-2083	*3*	*2*	*Alluvial bank deposit upstream of sediment traps*	*Mortandad Canyon alluvial reference sample*
05-2084	*3*	*2*	*Center of "Garden plot"*	*Sample collected at PRS No. 00-005, the "Garden plot"*

**Preliminary RFI sampling*

Results show that the surface samples (0 to 0.5-ft [0 to 0.15-m] depth) collected in each of the three sediment traps (Location ID Nos. 05-2075, 05-2076, and 05-2077) contain ^{239}Pu concentrations ranging from approximately 5 to approximately 23 pCi/g, but the samples collected at depth contain no more than 0.59 pCi/g of ^{239}Pu. The surface samples probably contained very fine-grained sediments left behind after evaporation and infiltration of the surface water. The deeper samples probably consist of coarser-grained alluvial material wetted by post-deposition infiltration of surface waters. Most of the contaminants are evidently adsorbed onto suspended sediment in the water or on sediments at the surface of the sediment traps.



Source: FIMAD/rek

F3.4.4-11 / MORTANDAD WP / 092297

Figure 3.4.4-11. Locations of sediment samples at PRS Nos. 00-001 and 00-005 in Mortandad Canyon.

ABLE 3.4.4-4

ACTIVITY OF RADIONUCLIDES IN SEDIMENTS AT PRS No. 00-001[a]

Part 1

Location ID	Depth (ft)	Sample ID	U-234		U-235		U-238	
				Uncertainty		Uncertainty		Uncertainty
Background Screening Value[b]			*2.39*		*0.16*		*2.29*	
05-2075	*0–0.5*	*0405-95-0303*	*0.76*	*0.600*	*0.06*	*0.015*	*0.76*	*0.6*
05-2075	*2–3*	*0405-95-0304*	*0.93*	*0.075*	*0.04*	*0.01*	*0.91*	*0.075*
05-2076	*0–0.5*	*0405-95-0305*	*1.36*	*0.1*	*0.06*	*0.01*	*1.43*	*0.105*
05-2076	*2–3*	*0405-95-0306*	*0.95*	*0.075*	*0.04*	*0.01*	*0.97*	*0.075*
05-2077	*0–0.5*	*0405-95-0308*	*1.34*	*0.095*	*0.09*	*0.015*	*1.25*	*0.9*
05-2077	*2–3*	*0405-95-0309*	*0.61*	*0.5*	*0.04*	*0.01*	*0.60*	*0.035*
05-2078	*0–0.5*	*0405-95-0311*	*0.68*	*0.055*	*0.02*	*0.005*	*0.69*	*0.1*
05-2078	*2–3*	*0405-95-0312*	*0.50*	*0.045*	*0.05*	*0.01*	*0.50*	*0.045*
05-2079	*0–0.5*	*0405-95-0315*	*0.74*	*0.6*	*0.08*	*0.015*	*0.65*	*0.055*
05-2079	*2–3*	*0405-95-0317*	*0.74*	*0.6*	*0.05*	*0.01*	*0.75*	*0.6*
05-2080	*0–0.5*	*0405-95-0318*	*1.04*	*0.08*	*0.04*	*0.01*	*1.06*	*0.8*
05-2080	*2–3*	*0405-95-0319*	*1.57*	*0.11*	*0.10*	*0.015*	*1.47*	*0.105*
05-2081	*0–0.5*	*0405-95-0320*	*0.92*	*0.075*	*0.08*	*0.015*	*0.85*	*0.7*

Part 2

Location ID	Depth (ft)	Sample ID	Pu-238		Pu-239/240	
				Uncertainty		Uncertainty
Background Screening Value			*0.006*		*0.197*	
05-2075	*0–0.5*	*0405-95-0303*	*1.95*	*0.125*	*5.48*	*0.331*
05-2075	*2–3*	*0405-95-0304*	*0.047*	*0.010*	*0.043*	*0.010*
05-2076	*0–0.5*	*0405-95-0305*	*5.7*	*0.345*	*14*	*0.850*
05-2076	*2–3*	*0405-95-0306*	*0.038*	*0.005*	*0.117*	*0.015*
05-2077	*0–0.5*	*0405-95-0308*	*8.41*	*0.502*	*22.6*	*1.35*
05-2077	*2–3*	*0405-95-0309*	*0.208*	*0.010*	*0.592*	*0.011*
05-2078	*0–0.5*	*0405-95-0311*	*0.018*	*0.005*	*0.018*	*0.005*
05-2078	*2–3*	*0405-95-0312*	*0.104*	*0.015*	*0.153*	*0.018*
05-2079	*0–0.5*	*0405-95-0315*	*3.870*	*0.235*	*12.1*	*0.713*
05-2079	*2–3*	*0405-95-0317*	*6.74*	*0.402*	*1.98*	*0.115*
05-2080	*0–0.5*	*0405-95-0318*	*7.48*	*0.450*	*28.3*	*1.65*
05-2080	*2–3*	*0405-95-0319*	*6.39*	*0.385*	*36.1*	*2.12*
05-2081	*0–0.5*	*0405-95-0320*	*2.08*	*0.135*	*7.85*	*0.471*

a. Preliminary RFI sampling in pCi/g

b. Background data from McDonald et al. 1997, 04-0328; values may include 95% UTLs and maximum observed values

TABLE 3.4.4-4 (continued)

ACTIVITY OF RADIONUCLIDES IN SEDIMENTS AT PRS No. 00-001[a]

Part 1

			U-234		U-235		U-238	
Location ID	**Depth (ft)**	**Sample ID**		**Uncertainty**		**Uncertainty**		**Uncertainty**
Background Screening Value[b]			*2.39*		*0.16*		*2.29*	
05-2081	*2–3*	*0405-95-0321*	*0.43*	*0.04*	*0.01*	*0.005*	*0.45*	*0.045*
05-2082	*0–0.5*	*0405-95-0322*	*0.92*	*0.7*	*0.02*	*0.005*	*0.91*	*0.7*
05-2082	*2–3*	*0405-95-0323*	*0.75*	*0.6*	*0.05*	*0.01*	*0.72*	*0.6*
05-2083	*0–0.5*	*0405-95-0324*	*0.89*	*0.7*	*0.04*	*0.01*	*1.04*	*0.8*
05-2083	*2–3*	*0405-95-0325*	*0.33*	*0.035*	*0.02*	*0.005*	*0.27*	*0.03*
05-2084	*0–0.5*	*0405-95-0326*	*0.75*	*0.065*	*0.05*	*0.01*	*0.73*	*0.6*
05-2084	*2–3*	*0405-95-0327*	*0.45*	*0.04*	*0.03*	*0.005*	*0.49*	*0.045*
		Minimum	*0.33*		*0.01*		*0.27*	
		Maximum	*1.57*		*0.10*		*1.47*	
		Mean	*0.78*		*0.04*		*1.74*	

Part 2

			Pu-238		Pu-239/240	
Location ID	**Depth (ft)**	**Sample ID**		**Uncertainty**		**Uncertainty**
Background Screening Value			*0.006*		*0.197*	
05-2081	*2–3*	*0405-95-0321*	*0.134*	*0.015*	*0.214*	*0.022*
05-2082	*0–0.5*	*0405-95-0322*	*4.33*	*0.265*	*12.7*	*0.754*
05-2082	*2–3*	*0405-95-0323*	*0.314*	*0.028*	*0.914*	*0.065*
05-2083	*0–0.5*	*0405-95-0324*	*0.221*	*0.022*	*1.15*	*0.078*
05-2083	*2–3*	*0405-95-0325*	*0.011*	*0.005*	*0.011*	*0.005*
05-2084	*0–0.5*	*0405-95-0326*	*7.35*	*0.435*	*2.45*	*0.151*
05-2084	*2–3*	*0405-95-0327*	*0.43*	*0.035*	*0.401*	*0.016*
		Minimum	*0.011*		*0.01*	
		Maximum	*8.410*		*36.10*	
		Mean	*0.617*		*1.121*	

a. *Preliminary RFI sampling in pCi/g*

b. *Background data from McDonald et al. 1997, 04-0328; values may include 95% UTLs and maximum observed values*

Samples collected from the clean-out piles adjacent to Sediment Trap No. 1 (Location ID Nos. 05-2078 and 05-2082) show inconsistent analytical results. The samples collected from the east side of the large clean-out pile located southwest of Sediment Trap No. 1 (Location ID No. 05-2078) contained 0.018 pCi/g of ^{239}*Pu at the surface and 0.15 pCi/g of* ^{239}*Pu at depth; both values were below the background screening values (BSVs). However, at Location ID No. 05-2082 the surface sample contained 12.7 pCi/g of* ^{239}*Pu, and the 2- to 3-ft (0.61- to 0.91-m) sample contained 0.91 pCi/g. This clean-out pile probably represents the contaminated sediment material that was cleaned from the bottom of the sediment trap, whereas the larger* *clean-out pile southwest of the sediment trap may contain alluvial material from clean out and enlargement of Sediment Trap No. 1 in 1992. The base of this large pile was not sampled, but it may contain contaminated sediment from the sediment trap that was removed before the sediment trap was deepened.*

Two of the samples (Location ID Nos. 05-2079 and 05-2080) were collected from locations of old sediment traps that had filled and have been abandoned. Location ID No. 05-2079 was in the old trench sediment trap that now serves as the channel between Sediment Trap No. 1 and Sediment Trap No. 2. Some of the sediments from this old sediment trap have probably been eroded by overflow from Sediment Trap No. 1 and have presumably been redeposited into Sediment Trap No. 2. The surface sample at this location contained 3.87 pCi/g of ^{238}*Pu and 12.1 pCi/g of* ^{239}*Pu, and the sample collected from the 2- to 3-ft (0.61- to 0.91-m) depth interval contained 6.74 pCi/g of* ^{238}*Pu and 1.98 pCi/g of* ^{239}*Pu. Location ID No. 05-2080 was in the old pond sediment trap south of Sediment Trap No. 2. The samples contained up to 36.1 pCi/g of* ^{239}*Pu at the 2- to 3-ft (0.61- to 0.91-m) depth interval, which was the highest activity of radionuclides observed at this PRS. These data show that sediment retained in the old sediment traps contains relatively higher activities of radionuclides, which is consistent with the TA-50 RLWTF discharge history; higher activities of radionuclides were discharged during the early 1980s (see Figure 2.4.6-1 in Chapter 2 of this work plan) when the old sediment traps were used.*

Location ID No. 05-2081 was in the outflow area downstream from Sediment Trap No. 3. Samples collected from the 0 to 0.5-ft (0 to 0.15-m) depth interval contained 2.08 pCi/g of ^{238}*Pu and 7.85 pCi/g of* ^{239}*Pu, whereas the samples collected from the 2- to 3-ft (0.61- to 0.91-m) depth interval contained only 0.13 pCi/g of* ^{238}*Pu and 0.21 pCi/g of* ^{239}*Pu. The surface samples probably contain sediment deposited from overflow of the sediment traps in 1987 and 1991, whereas the deeper samples have been exposed to little, if any, discharge.*

Location ID No. 05-2083 represents the floodplain/overbank alluvial material upstream from the sediment traps and south of the channel. The channel in this area is incised about 5 ft (1.5 m) into the alluvium; therefore, no recent streamflow appears to have occurred at this sampling location. The area appears to be normally vegetated and relatively undisturbed by recent flooding. The sample collected from the 0 to 0.5-ft (0 to 0.15-m) depth interval from this location contained 0.22 pCi/g of ^{238}*Pu and 1.15 pCi/g of* ^{239}*Pu, and the sample collected from the 2- to 3-ft (0.61- to 0.91-m) depth interval contained 0.011 pCi/g of* ^{238}*Pu and 0.011 pCi/g of* ^{239}*Pu. These results indicate that the floodplain surface of the alluvium has been exposed to contaminated overbank streamflow, but the sediment material at the 2- to 3-ft (0.61- to 0.91-m) depth interval has not.*

The results of the analyses for metals are shown in Table 3.4.4-5. One sample from the surface of Sediment Trap No. 3 contained concentrations of chromium, copper, mercury, selenium, and zinc greater than the BSVs. A total of nine samples from seven locations contained concentrations of mercury greater than BSVs, and all samples collected from the old sediment traps (Location ID Nos. 05-2079 and 05-2080) contained mercury concentrations greater than BSVs. All other samples containing elevated mercury concentrations were surface samples. A sample collected from one of the old sediment traps contained concentrations of silver about 11 times the BSV. Similarly elevated concentrations of mercury and silver were noted in the sediments downstream of the TA-50 RLWTF outfall (see Section 3.4.4.2.1) but have not been observed in the sediments downstream of the cooling water outfalls at the head of Effluent Canyon at TA-48.

Results of sediment sampling and analyses at PRS Nos. 48-007(a and d) and 48-010 did not show mercury concentrations greater than 0.07 mg/kg (LANL 1997, 55326), which suggests that mercury (and possibly other metals) in Mortandad Canyon may have resulted from historic discharges from the former incinerator at former TA-42 or from the TA-50 RLWTF.

TABLE 3.4.4-5

CONCENTRATIONS OF METALS IN SEDIMENTS AT PRS No. 00-001[a]

Part 1

Location ID	Depth (ft)	Ag	Al	As	Ba	Be	Ca	Co	Cr	Cu	Fe
Background Screening Value[b]		*0.28*	*13260*	*3.98*	*127*	*1.31*	*3850*	*4.73*	*10.5*	*9.97*	*13800*
Max x Background		*11.43*	*0.59*	*0.80*	*0.82*	*0.92*	*0.78*	*0.78*	*1.13*	*1.50*	*0.93*
05-2075	*0.5*	*BDL[c]*	*2520*	*1.5*	*31.7*	*0.42*	*795*	*1.31*	*2.1*	*2.65*	*7197*
05-2075	*3*	*BDL*	*3650*	*1.9*	*51*	*0.71*	*1250*	*2*	*2.8*	*2.2*	*7850*
05-2076	*0.5*	*BDL*	*5600*	*2.5*	*83.9*	*1*	*2880*	*3*	*6.8*	*10.3*	*10100*
05-2076	*3*	*BDL*	*4610*	*1.9*	*65.9*	*0.96*	*1770*	*2.2*	*3.6*	*3*	*8840*
05-2077	*0.5*	*0.15*	*7860*	*3.2*	*104*	*1.2*	*3000*	*3.7*	*11.9*	*15*	*12900*
05-2077	*3*	*BDL*	*1390*	*0.63*	*16.7*	*0.42*	*377*	*0.86*	*1.5*	*0.43*	*5330*
05-2078	*0.5*	*BDL*	*2860*	*1.5*	*43.1*	*0.62*	*901*	*1.6*	*2*	*2*	*6540*
05-2078	*3*	*BDL*	*2160*	*0.98*	*26.8*	*0.43*	*713*	*1.1*	*2.9*	*1.2*	*4980*
05-2079	*0.5*	*BDL*	*2810*	*1*	*39.5*	*0.51*	*1670*	*1.4*	*3.7*	*6.2*	*5510*
05-2079	*3*	*BDL*	*3550*	*1.4*	*44.7*	*0.53*	*1420*	*1.7*	*4.6*	*5.6*	*6000*

Part 2

Location ID	Depth (ft)	Hg	K	Mg	Mn	Na	Ni	Pb	Se	V	Zn
Background Screening Value		*0.03*	*2690*	*2130*	*543*	*1470*	*9.38*	*19.7*	*<0.2*	*19.7*	*60.2*
Max x Background		*5.00*	*0.51*	*0.70*	*0.87*	*0.08*	*0.70*	*0.95*	*4.05*	*0.66*	*1.00*
05-2075	*0.5*	*BDL*	*476*	*421*	*341*	*68.6*	*1.7*	*9.6*	*0.60*	*7.7*	*45.6*
05-2075	*3*	*BDL*	*566*	*657*	*315*	*68.1*	*2.9*	*8*	*0.81*	*6.8*	*38*
05-2076	*0.5*	*0.05*	*1150*	*1060*	*444*	*72.6*	*4.9*	*15*	*0.6*	*9.7*	*51.8*
05-2076	*3*	*BDL*	*732*	*808*	*374*	*88.4*	*3.7*	*10.1*	*BDL*	*7.9*	*39.7*
05-2077	*0.5*	*0.1*	*1360*	*1490*	*472*	*114*	*6.6*	*18.7*	*0.55*	*13.1*	*60.3*
05-2077	*3*	*BDL*	*264*	*237*	*172*	*41.2*	*1.3*	*4.4*	*BDL*	*3.4*	*28.5*
05-2078	*0.5*	*BDL*	*594*	*531*	*276*	*46.4*	*2.3*	*7.3*	*BDL*	*5.5*	*31.7*
05-2078	*3*	*BDL*	*400*	*395*	*192*	*49.8*	*2.3*	*5.3*	*BDL*	*3.9*	*25.1*
05-2079	*0.5*	*0.04*	*538*	*548*	*217*	*50.1*	*2.4*	*8*	*BDL*	*5.2*	*29.2*
05-2079	*3*	*0.09*	*611*	*602*	*240*	*68.5*	*3.2*	*9.5*	*BDL*	*5.5*	*29.5*

a. Preliminary unpublished results from Field Unit 4 in mg/kg

b. Background data from McDonald et al. 1997, 04-0328; values may include 95% UTLs and maximum observed values

c. BDL = below detection limit

TABLE 3.4.4-5 (continued)

CONCENTRATIONS OF METALS IN SEDIMENTS AT PRS No. 00-001[a]

Part 1

Location ID	Depth (ft)	Ag	Al	As	Ba	Be	Ca	Co	Cr	Cu	Fe
Background Screening Value[b]		*0.28*	*13260*	*3.98*	*127*	*1.31*	*3850*	*4.73*	*10.5*	*9.97*	*13800*
Max x Background		*11.43*	*0.59*	*0.80*	*0.82*	*0.92*	*0.78*	*0.78*	*1.13*	*1.50*	*0.93*
05-2080	*0.5*	*BDL*[c]	*4210*	*1.8*	*64.4*	*0.72*	*2710*	*2.2*	*5.5*	*12.1*	*7410*
05-2080	*3*	*3.2*	*5330*	*2*	*85.3*	*0.87*	*2470*	*3*	*7.8*	*14.8*	*9110*
05-2081	*0.5*	*BDL*	*2710*	*0.94*	*34.2*	*0.53*	*988*	*1*	*2.7*	*4.7*	*5780*
05-2081	*3*	*BDL*	*1040*	*0.42*	*11.9*	*0.28*	*288*	*0.56*	*2*	*0.26*	*3590*
05-2082	*0.5*	*BDL*	*3580*	*1.7*	*49.2*	*0.66*	*1690*	*1.8*	*5.1*	*7.7*	*6670*
05-2082	*3*	*BDL*	*2360*	*1.1*	*34.6*	*0.55*	*1000*	*1.1*	*3.3*	*1.9*	*5680*
05-2083	*0.5*	*BDL*	*5340*	*2.1*	*94.9*	*0.68*	*1790*	*3.4*	*4.6*	*4.7*	*8010*
05-2083	*3*	*BDL*	*1050*	*BDL*	*13.8*	*0.26*	*244*	*0.57*	*2.6*	*0.17*	*3050*
05-2084	*0.5*	*BDL*	*2640*	*0.62*	*33.8*	*0.49*	*1110*	*1.1*	*3.2*	*5.2*	*4770*
05-2084	*3*	*BDL*	*1790*	*0.6*	*22.6*	*0.36*	*619*	*1.1*	*2.8*	*1.1*	*5120*
Minimum		*0.15*	*1040*	*0.42*	*11.9*	*0.26*	*244*	*0.56*	*1.5*	*0.17*	*3050*
Maximum		*3.2*	*7860*	*3.2*	*104*	*1.2*	*3000*	*3.7*	*11.9*	*15*	*12900*
Geometric Mean		*0.6928*	*2936*	*1.2846*	*40.18*	*0.56*	*1112*	*1.51303*	*3.5584*	*2.9*	*6363*

Part 2

Location ID	Depth (ft)	Hg	K	Mg	Mn	Na	Ni	Pb	Se	V	Zn
Background Screening Value		*0.03*	*2690*	*2130*	*543*	*1470*	*9.38*	*19.7*	*<0.2*	*19.7*	*60.2*
Max x Background		*5.00*	*0.51*	*0.70*	*0.87*	*0.08*	*0.70*	*0.95*	*4.05*	*0.66*	*1.00*
05-2080	*0.5*	*0.07*	*1020*	*872*	*311*	*58.9*	*4*	*11.4*	*BDL*	*7.6*	*39*
05-2080	*3*	*0.15*	*959*	*1040*	*341*	*93.4*	*6.5*	*15.9*	*BDL*	*10.6*	*52.6*
05-2081	*0.5*	*BDL*	*533*	*551*	*249*	*52.4*	*2.2*	*7.2*	*BDL*	*4.4*	*32.7*
05-2081	*3*	*BDL*	*199*	*162*	*115*	*34.3*	*1.4*	*2.6*	*BDL*	*2.4*	*19*
05-2082	*0.5*	*0.06*	*758*	*672*	*262*	*56.4*	*3.3*	*9.4*	*BDL*	*6.5*	*33.9*
05-2082	*3*	*BDL*	*480*	*420*	*239*	*53.9*	*2.7*	*6.5*	*BDL*	*4.5*	*29.2*
05-2083	*0.5*	*0.08*	*1370*	*1170*	*299*	*45.8*	*4.4*	*12.3*	*0.73*	*11*	*28*
05-2083	*3*	*BDL*	*216*	*176*	*100*	*31*	*1.8*	*2.6*	*BDL*	*2.2*	*15.2*
05-2084	*0.5*	*0.07*	*561*	*499*	*174*	*40.7*	*2.2*	*6.9*	*BDL*	*4.2*	*23.9*
05-2084	*3*	*BDL*	*330*	*344*	*170*	*37.3*	*2*	*4.5*	*BDL*	*4.2*	*27.6*
Minimum		*0.04*	*199*	*162*	*100*	*31*	*1.3*	*2.6*	*0.55*	*2.2*	*15.2*
Maximum		*0.15*	*1370*	*1490*	*472*	*114*	*6.6*	*18.7*	*0.81*	*13.1*	*60.3*
Geometric Mean		*0.0736*	*570*	*541.36*	*246*	*55.3*	*2.8*	*7.7*	*0.65*	*5.7*	*32.3*

a. Preliminary unpublished results from Field Unit 4 in mg/kg

b. Background data from McDonald et al. 1997, 04-0328; values may include 95% UTLs and maximum observed values

c. BDL = below detection limit

The results of VOC and SVOC analyses in samples collected at PRS No. 00-001 are shown in Table 3.4.4-6. Analyses showed most constituents below method detection limits with estimated values reported; the table shows only those values that were not estimated by the laboratory. Toluene was detected at very low levels in many samples and is thought to be due to laboratory contamination. Four SVOCs and all PAHs were detected at low concentrations. The PAHs are probably due to runoff from asphalt roads and parking lots within the Mortandad Canyon watershed. VOCs and SVOCs were detected at several orders of magnitude below those found in mesa-top soils and are not considered to be COPCs in Mortandad Canyon.

3.4.5 Radiometric Surveys in Mortandad Canyon and Pratt Canyon

In April 1994 EG&G Las Vegas performed a Laboratory-wide aerial radiometric survey on behalf of the Laboratory. The survey was conducted by a helicopter flying at 200 ft (61 m) above ground level using much more sensitive detectors than those used for the ground radiation survey shown in Figure 3.4.4-10. The final report of the survey has not been prepared, but preliminary results show a gamma radiation anomaly in Mortandad Canyon. The indicated anomaly was identified as "man-made gross-gamma radiation" that extends from the area of the TA-50 RLWTF outfall about 10,000 ft (3048 m) down the canyon. Figure 3.4.5-1 shows the preliminary results of the aerial radiometric survey. The magnitude of the anomaly is greatest at the approximate location of the sediment traps, and the eastern end of the anomaly is approximately 2000 ft (610 m) downstream of the sediment traps. The apparent width of the anomaly is approximately the width of the alluvium in the canyon floor, although the survey may overestimate the lateral extent of contamination away from the channel.

In August 1996 the Washington Aerial Measurements Department of Bechtel Nevada took a number of in situ gamma radiation measurements along the stream bed of Mortandad Canyon and Ten Site Canyon. The measurements each consisted of a 15-min radiation measurement at 1 m (3.3 ft) above ground surface using an 80% high-purity germanium detector. Lower Mortandad Canyon near the Laboratory boundary was found to be at background radiation levels. Radiation increased upstream near well MCO-8 and near the sediment traps where ^{241}*Am,* ^{137}*Cs, and possibly* ^{60}*Co were identified by the high-resolution detector. The highest measurement obtained was near well MCO-4, which was also the most upstream location measured in Mortandad Canyon. Ten Site Canyon was found to be at or near background levels for gamma radiation except for one measurement obtained in Pratt Canyon, which contained a slightly elevated gamma radiation measurement. Bechtel is expected to deliver the final report of the gamma radiation in situ measurements by mid 1997.*

An in situ beta/gamma radiation grid survey was conducted in Pratt Canyon as part of the RFI for PRS No. 35-003(r). The radiation grid consisted of 230 locations spaced at approximately 20-ft (6.1-m) intervals. Beta/gamma radiation measurements ranged from 128 to 10,130 cpm, with an average of 617 cpm. The grid locations with elevated measurements were selected for subsequent sample collection (LANL 1996, 54422). They were located in an area approximately 200 ft (61 m) long by 100 ft (30 m) wide along the upper part of Pratt Canyon and on the western and southwestern headwall slopes of the canyon. The highest beta/gamma measurement (10,130 cpm) was obtained in an area covered with vegetation on the southwest headwall of the canyon near the outfall from the former diversion channel (PRS No. 35-003[d]). Other measurements obtained near the outfall of the diversion channel ranged from 2000 to 6500 cpm. The results of the radiation grid survey are shown in Figure 3.4.5-2.

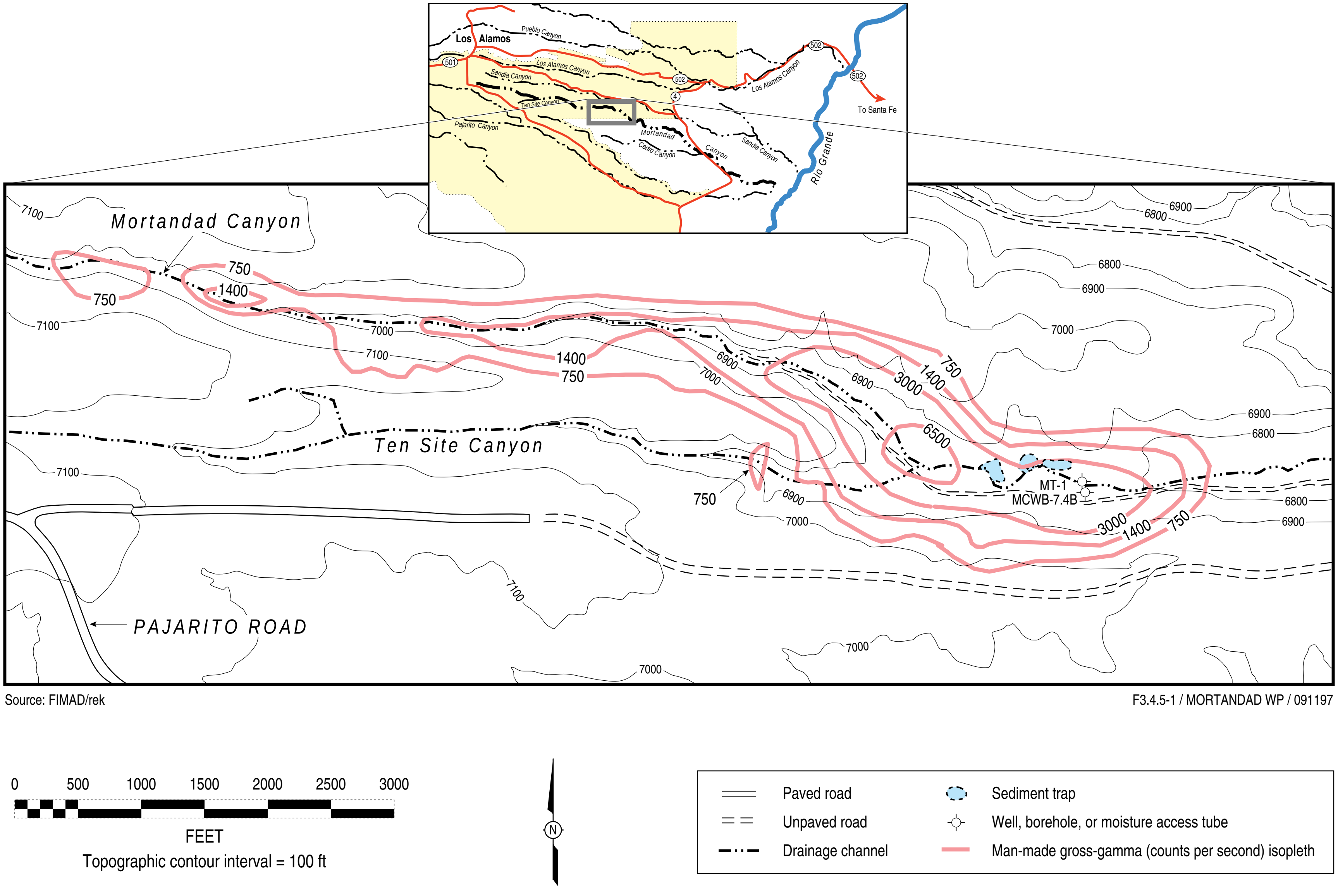
3.4.6 Sediment Transport Modeling

Limited attempts have been made to model sediment transport in the Mortandad Canyon watershed. Lane and Hakonson (1982, 11677) developed hydrologic and sediment transport models to route water *and sediment through alluvial channels and applied these models to Mortandad Canyon. Key components of their modeling included differential transport of different particle size classes of sediment and an enrichment ratio that describes changes in contaminant concentrations that result from sedimentary segregation.*

TABLE 3.4.4-6

CONCENTRATIONS OF VOLATILE AND SEMIVOLATILE ORGANIC COMPOUNDS AT PRS No. 00-001

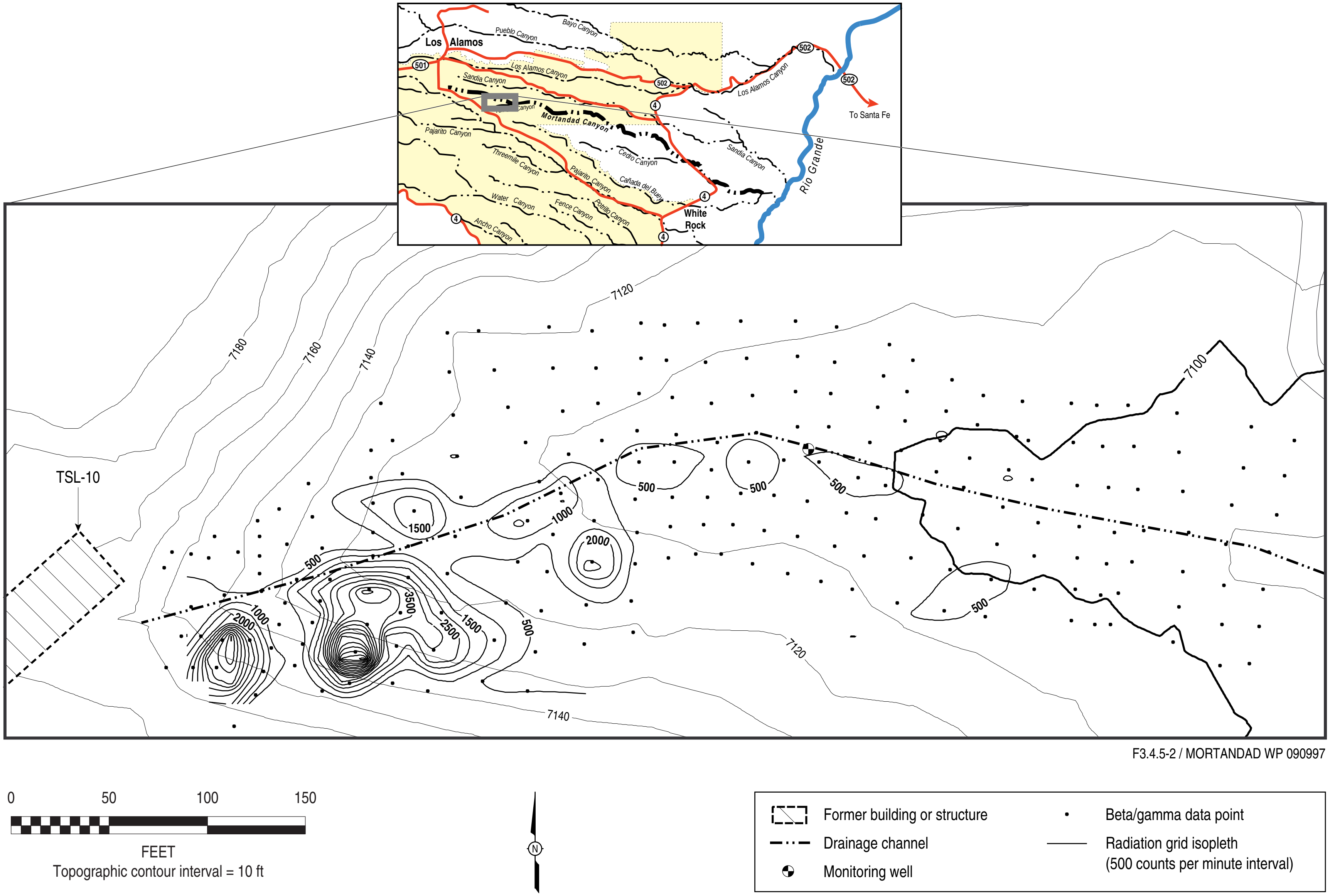
VOCs					
Location ID	Depth (ft)	Sample ID	Sample Type	Analyte	Result (mg/kg)
05-2075	3	0405-95-0304	Sample	Toluene	0.01
05-2076	0.5	0405-95-0305	Dup	Toluene	0.012
05-2076	0.5	0405-95-0305	Sample	Toluene	0.016
05-2076	0.5	0405-95-0305	Dup	Tetrachloroethene	0.006
05-2076	3	0405-95-0306	Sample	Toluene	0.012
05-2077	0.5	0405-95-0308	Dup	Toluene	0.013
05-2077	0.5	0405-95-0308	Sample	Toluene	0.013
05-2078	0.5	0405-95-0311	Sample	Toluene	0.013
05-2078	3	0405-95-0312	Sample	Toluene	0.014
05-2079	3	0405-95-0317	Sample	Toluene	0.01
05-2079	3	0405-95-0317	Sample	Acetone	0.038
05-2080	0.5	0405-95-0318	Sample	Toluene	0.006
05-2080	0.5	0405-95-0318	Dup	Toluene	0.006
05-2080	3	0405-95-0319	Sample	Toluene	0.008
05-2081	0.5	0405-95-0320	Sample	Toluene	0.007
05-2082	0.5	0405-95-0322	Dup	Toluene	0.008
05-2082	0.5	0405-95-0322	Sample	Toluene	0.012
05-2082	3	0405-95-0323	Sample	Toluene	0.027
05-2082	3	0405-95-0323	Sample	Tetrachloroethene	0.008
05-2083	0.5	0405-95-0324	Sample	Toluene	12
05-2083	0.5	0405-95-0324	Dup	Toluene	13
SVOCs					
Location ID	Depth (ft)	Sample ID	Sample Type	Analyte	Result (mg/kg)
05-2075	3	0405-95-0304	Sample	Pyrene	0.42
05-2079	3	0405-95-0317	Sample	Pyrene	1.4
05-2079	3	0405-95-0317	Sample	Benzo[g,h,i]perylene	0.73
05-2079	3	0405-95-0317	Sample	Fluoranthene	1.5
05-2079	3	0405-95-0317	Sample	Phenanthrene	1.5



Source: FIMAD/rek

F3.4.5-1 / MORTANDAD WP / 091197

Figure 3.4.5-1. Preliminary results of aerial radiometric survey showing man-made gross-gamma radiation.



F3.4.5-2 / MORTANDAD WP 090997

Figure 3.4.5-2. Results of beta/gamma radiation grid survey at PRS No. 35-003(r).

Gallegos and Wenzel (1990, 6993) presented additional modeling that includes sediment transport in Mortandad Canyon. They used the environmental risk simulation model BIOTRAN with a series of subroutines (RUNOFF, GEOFLX, EROSON, and AQUIFER) to predict the movement of radionuclides and pertinent chemical compounds in association with sediments through lateral and channel flow of runoff. In addition, they modeled the movement of water into and out of portions of channels to simulate the dynamics of moisture flow through specific groundwater-bearing zones within the watershed. The BIOTRAN soil water flux subroutine, WATFLX, was modified to interface the relationships found in the SPUR model for runoff and sediment transport into channels with the particle sorting relationships used by Lane et al. (1985, 6604) to predict radionuclide enrichment and movement in watersheds. They applied the model to four reaches within upper Mortandad Canyon (between the headwaters and a point upstream of Ten Site Canyon) using ^{238}*U for demonstration of the model. The model predicted net accumulation of* ^{238}*U downstream of Effluent Canyon and net depletion in upstream reaches, a pattern that is observed generally in results of field investigations.*

3.4.7 Data Requirements for Understanding Surface Sediments and Associated Contaminants

Data required for the evaluation of contaminants within the sediments of the Mortandad Canyon system include the following.

- *The horizontal and vertical extent of contaminated sediments deposited by floods, including the nature and effects of historic channel changes (for example, channel bed aggradation and/or degradation, lateral migration and diversion of the active channel, and abandonment of inactive channels)*
- *The full suite of contaminants that are present within the sediments at or above background levels and their respective sources and approximate dates of discharge*
- *The inventory of contaminants present in the alluvium, partitioned into different reaches, into different geomorphic units within each reach and possibly into different stratigraphic layers within geomorphic units*

3.5 Previous Subsurface Sediment and Bedrock Core Sampling and Analysis

3.5.1 Borehole Sampling Near Well MCO-6

In 1978 five unnamed boreholes were drilled in Mortandad Canyon to assess the potential movement of plutonium in the bedrock tuff beneath the alluvium. Three boreholes were drilled in a line perpendicular to the stream channel near MCO-6, and two other boreholes were drilled to determine background levels or control conditions. Core samples were collected from the alluvium and the underlying tuff to determine the moisture, tritium, and plutonium content of the alluvium and the underlying tuff and the tritium and plutonium concentrations in the alluvial groundwater (ESG 1984, 6523; Devaurs and Purtymun 1985, 7415). The exact locations of the boreholes were not documented.

The results of the investigation indicated that some infiltration of tritium and water into the underlying tuff had occurred to a depth of at least 30 ft (9.1 m) below the alluvium. No significantly elevated concentrations of ^{238}*Pu were found in the silts and clay of the alluvium or the underlying tuff. The concentration of* ^{239,240}*Pu in the three boreholes was slightly elevated when compared with the control core samples (maximum value was 0.011 ± 0.025 pCi/g), but the concentrations were much lower than those* *found in solution (filtered water samples) in the alluvial groundwater or in the stream sediments (ESG 1984, 6523). The investigation concluded that most of the plutonium in the alluvial groundwater is in solution as an ionic complex that does not readily exchange by adsorption with clay minerals in the alluvium (sorption/desorption processes and geochemical speciation in groundwater are discussed in more detail in Section 3.5.4 and Section 3.8). However, this conclusion may be biased by the field sample processing procedure. The water samples may have been acidified in the field and later filtered at the laboratory. If so, dissolution of plutonium into the water from fine-grained suspended solids or organic complexes in the sample before filtration would have occurred.*

3.5.2 MT Boreholes

In November 1988 four test boreholes (MT-1 through MT-4) were drilled into the alluvium in lower Mortandad Canyon in an effort to determine the shape, extent, and lithologic setting of the alluvial groundwater. The boreholes were completed as wells. The locations of these wells are shown on Figure A-2 in Appendix A of this work plan; borehole and well construction and water level information are discussed in Section 3.6. Geologic logs of the boreholes were presented by Stoker et al. (1991, 7530) and Purtymun (1995, 45344).

The borehole for well MT-1 was drilled to a depth of 69 ft (21 m) in the middle of the canyon floor about 500 ft (152 m) east of Sediment Trap No. 3 where the alluvium was reported to be 30 ft (9.1 m) thick. Reinterpretation of the geologic logs during preparation of this work plan suggests that this borehole probably bottomed in the alluvium at 69 ft (21 m). Boreholes for wells MT-2 and MT-3 were drilled about 700 ft (213 m) east of MT-1 near MCO-8 along a line transverse to the canyon. MT-2 was drilled to a depth of 64 ft (19.5 m), and MT-3 was drilled to a depth of 74 ft (22.7 m). Although reports identified the base of the alluvium at 35 and 31 ft (10.7 and 9.5 m), respectively, based on the lithologic descriptions and correlation with logs from nearby wells, these boreholes probably did not penetrate through the alluvium. The borehole for well MT-4 was drilled in the center of the canyon approximately 500 ft (152 m) east of the boreholes for wells MT-2 and MT-3. This borehole was drilled to depth of 74 ft (22.7 m) and probably penetrated the Cerro Toledo interval at approximately 65 ft (19.8 m), although the depth of the alluvium was reported to be 44 ft (13.4 m).

The core samples obtained from the MT boreholes showed that the alluvium is composed of two distinct stratigraphic units. The upper part of the alluvium is composed of coarse sand with lenses of silt and clay, and the lower alluvium is composed of silt and clay with thin lenses of sand. The core samples also indicated that alluvial groundwater occurs in the transition between the silt, clay, and sand lenses and that in places the silt and clay are aquitards that serve to perch the water within the alluvium. These boreholes were drilled in 1987 after a high runoff event that filled the sediment traps. This event may have provided a relatively rare episode of infiltration from the stream channel to these interalluvial perched zones. Core samples were collected from the four boreholes and analyzed for ^{137}*Cs,* ^{238}*Pu,* ^{239}*Pu, tritium, and uranium. The results showed that the alluvium contained relatively low concentrations of contaminants. Maximum concentrations were* ^{137}*Cs (0.243 pCi/g), tritium in core water (370 nCi/L), uranium (7.92 µg/g),* ^{238}*Pu (0.012 pCi/g), and* ^{239}*Pu (0.038 pCi/g) (Stoker et al. 1991, 7530).*

3.5.3 RCRA Compliance Boreholes

In 1989 and 1990 four boreholes (MCM-5.1, MCM-5.9A, MCC-8.2, and SIMO) were drilled to partially fulfill a special condition of the Hazardous and Solid Waste Amendments (HSWA) Module (EPA 1990, 1585). Three of the four boreholes (MCM-5.1, MCM-5.9A, and MCC-8.2) penetrated the saturated portion of the *alluvium; SIMO did not. The total depths were 111.5, 194, 184, and 104 ft (33.99, 59.13, 56.1, and 31.7 m) below ground surface, respectively. The boreholes were drilled using a large-diameter hollow-stem auger as a temporary casing while collecting cores from the underlying unsaturated Bandelier Tuff. Details of drilling operations and core retrieval are provided by Stoker et al. (1991, 7530).*

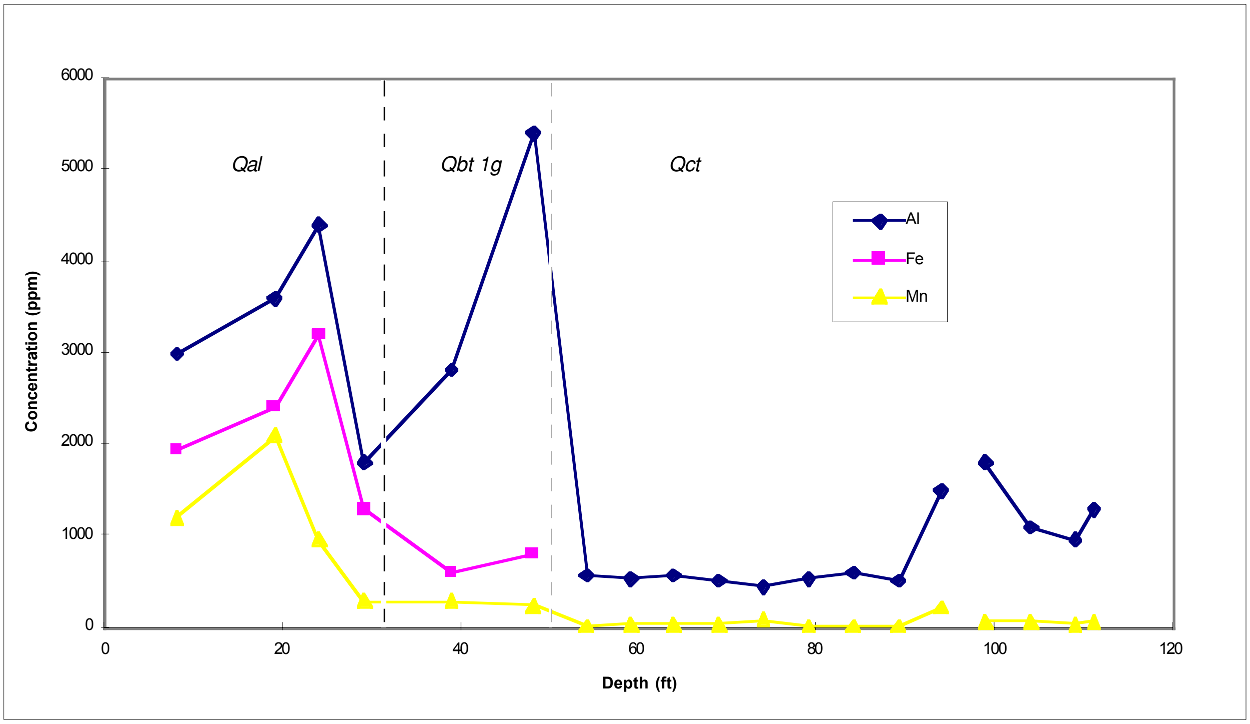
The lithologic descriptions of the stratigraphy encountered were presented by Stoker et al. (1991, 7530) and Purtymun (1995, 45344). At the time, stratigraphic correlation between the existing and newly drilled boreholes was not performed. During preparation of this work plan, inconsistencies in stratigraphic thickness of the Tshirege Qbt 1g unit, the Tsankawi Pumice Bed, and Cerro Toledo interval sediments were noted. This section presents revised stratigraphic intervals for the boreholes based on re-evaluation of lithologic descriptions, chemistry, and photographs of the core samples. Because the Tsankawi Pumice Bed has not been positively identified in samples from Mortandad Canyon, this unit has been combined with the Cerro Toledo interval until more accurate stratigraphic information is available. Additional information about the re-evaluation of the stratigraphy is discussed in Section 3.7.

Core samples were collected for analysis. One-gram split samples from each core sample were partially digested using hot nitric acid (pH 1) for 24 hours; the acidic extracts were then analyzed for different trace metals and uranium. Concentrations are reported as ppm (µg/g) of extractable metals in the original core sample. Total uranium and rare earth element concentrations in the core samples were determined using delayed neutron activation analysis. Activities of several radionuclides, including ^{241}Am, ^{137}Cs, ^{238}Pu, ^{239,240}Pu, ^{90}Sr, tritium, and other isotopes, were determined using scintillation counting, alpha spectrometry, and gamma spectroscopy. Chloride, fluoride, and nitrate concentrations in deionized water extracts were determined using ion chromatography. Metal and trace element concentrations in the acidic extracts were determined using atomic absorption and inductively coupled plasma spectroscopy methods (Stoker et al. 1991, 7530). Results of the analyses are discussed in the following sections.

3.5.3.1 Borehole for Moisture Access Tube MCM-5.1

The contact between the alluvium and the Tshirege Qbt 1g unit of the Bandelier Tuff occurs at 31 ft (9.5 m) in MCM-5.1. The contact between Qbt 1g and the Tsankawi Pumice Bed/Cerro Toledo interval occurs at approximately 50 ft (15 m) based on the revised stratigraphy. The bottom of MCM-5.1 is within the lower part of the Cerro Toledo interval at 112 ft (34.1 m), probably within approximately 20 ft (6.1 m) of the top of the Otowi Member. Alluvial groundwater was encountered from 24 to 31 ft (7.3 to 9.5 m) at the time of drilling (Stoker et al. 1991, 7530).

Figure 3.5.3-1 shows the distribution of aluminum, iron, and manganese with depth in the upper section. Analytical data for iron are not available below 48 ft (14.6 m). Aluminum and iron are concentrated in the samples at 24 ft (7.3 m) within the alluvium. Aluminum shows another concentration increase between 39 ft (11.9 m) and 47.5 ft (14.5 m) within the lower Tshirege Qbt 1g unit. Increases in aluminum concentrations at these two depths may reflect an increase in abundance of clay minerals within the samples of alluvium and Qbt 1g. Iron may occur as amorphous Fe(OH)$_3$, hematite, or goethite, although mineralogical analyses have not be performed on the core samples. These solid phases are important because of their high surface areas, which enhance the sorption of contaminants from solution (Longmire et al. 1995, 48818). Manganese shows a maximum concentration at 18.5 ft (5.64 m) in the alluvium and continues to decrease in concentration to a depth of 58.5 ft (17.8 m) at the top of the Cerro Toledo interval. A slight increase in aluminum and manganese concentrations at 94 and 99 ft (28.7 and 30.2 m) may indicate a change in lithology within the Cerro Toledo interval at these depths.

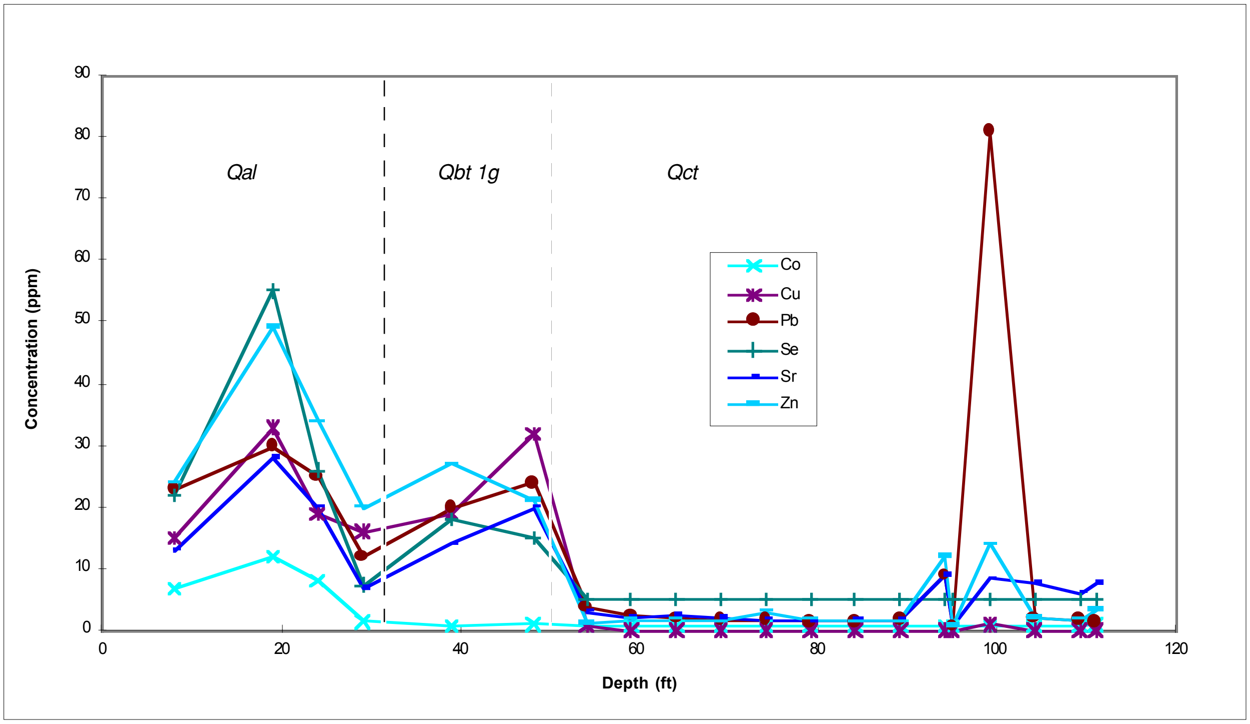


Source: Stoker et al. 1991, 7530

Figure 3.5.3-1. Distribution of aluminum, iron, and manganese in borehole MCM-5.1.

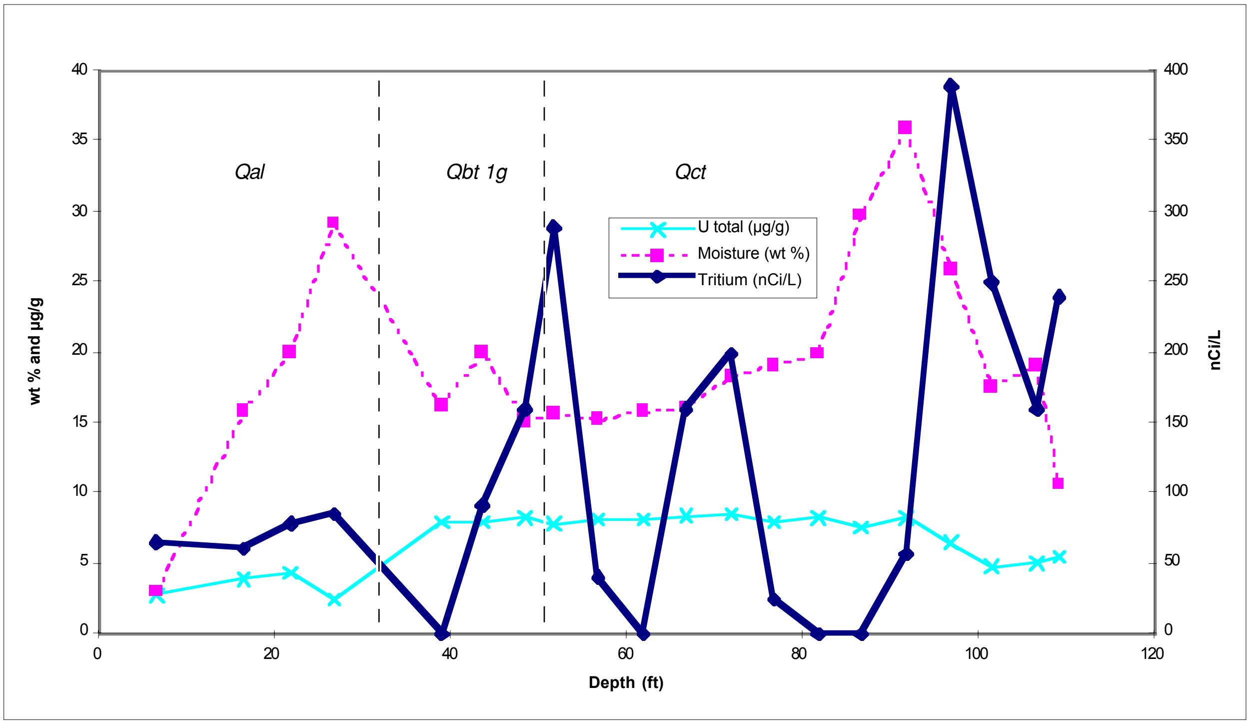
Distribution of several trace metals (cobalt, copper, lead, selenium, strontium, and zinc) with depth is shown in Figure 3.5.3-2. These trace metals show concentration increases at 18.5 ft (5.64 m), 47.5 ft (14.5 m), and 93 to 110 ft (28.4 to 33.5 m). The concentration increases at 18.5 ft (5.64 m) correlate with increasing manganese concentrations in the alluvium, whereas the increases at 47.5 ft (14.5 m) correlate with an increase in aluminum concentrations within the Tshirege Qbt 1g unit. These two depths may represent zones of enhanced chemical weathering within the alluvium and the underlying Bandelier Tuff. The contact between Qbt 1g and the Tsankawi Pumice Bed/Cerro Toledo interval occurs at approximately 50 ft (15 m), below which the concentrations of the trace metals decrease notably. Increases in trace metal concentrations at 94 and 99 ft (28.7 and 30.2 m) correlate with increases of aluminum and manganese concentrations and may be due to chemical weathering within the Cerro Toledo interval, possibly forming clay minerals. Buried soils within the Cerro Toledo interval that contain clay minerals may also explain the increases.

Figure 3.5.3-3 shows the distribution of gravimetric moisture content, tritium activity, and total uranium concentrations with depth. Gravimetric moisture content varies from 2.3 to 36.8 wt % (Stoker et al. 1991, 7530). Saturated conditions occur at the 24- to 31-ft (7.3- to 9.5-m) depth interval at the base of the alluvium. Another zone at or near saturation occurs near the base of the Cerro Toledo interval at 94 ft (28.7 m). Activities of measurable tritium range from 25 to 390 nCi/L; the highest values occur within the Cerro Toledo interval at 99 ft (30.2 m). Tritium occurs as tritiated water (HTO) and is nonsorbing, migrating at the same rate as groundwater either as saturated flow or as a wetted front moving through the sediments and Bandelier Tuff. Zones of high moisture content and relatively low tritium activity within the Cerro Toledo interval at 80 to 90 ft (24.4 to 27.4 m) may represent samples from clay zones where HTO has not been able to fully displace older, uncontaminated water.



Source: Stoker et al. 1991, 7530

Figure 3.5.3-2. Distribution of extractable metals in borehole MCM-5.1.



Source: Stoker et al. 1991, 7530

Figure 3.5.3-3. Distribution of moisture, tritium, and total uranium with depth in borehole MCM-5.1.

Concentrations of total uranium range from 2.5 to 8.6 ppm. Concentrations of nitric acid-digestible uranium range from 0.5 to 0.7 µg/g (Stoker et al. 1991, 7530), which are slightly higher than those measured in background tuff samples (0.25 to 0.5 µg/g in the Tshirege Qbt 1g unit) collected at TA-21 by Broxton et al. (1995, 50121). In addition, concentrations of uranium elevated above background levels occur in alluvial groundwater within Mortandad Canyon, which is discussed in detail in Section 3.8.

Activities of ^{137}*Cs,* ^{238}*Pu, and* ^{239,240}*Pu with depth are shown in Figure 3.5.3-4. Activities of* ^{238}*Pu and* ^{239,240}*Pu range from 0.001 to 0.117 pCi/g and from 0.001 to 0.095 pCi/g, respectively (Stoker et al. 1991, 7530). Activities of* ^{137}*Cs range up to 2.56 pCi/g and generally correlate with activities of the plutonium isotopes. The highest activities of cesium and plutonium isotopes occur within the upper part of the alluvium, which indicates that these contaminants probably infiltrated into the alluvium from surface water flow rather than from underflow of groundwater within the alluvium. These observations corroborate calculated distribution coefficients for these species that show that plutonium migrates at a much slower rate in the subsurface than uranium and tritium (see Section 3.8).*

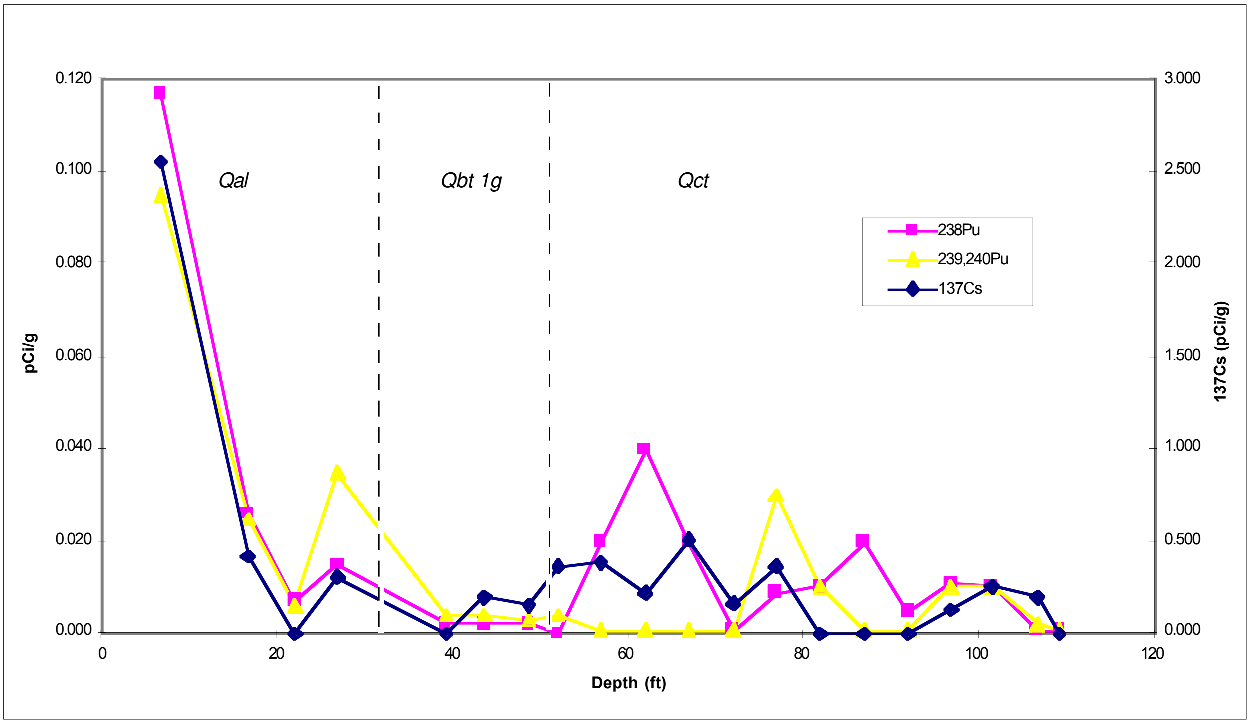
Figure 3.5.3-5 is a bivariate concentration plot of aluminum versus iron for the alluvium and the Tshirege Qbt 1g unit. The correlation between these two elements in the alluvium is excellent, which suggests that clay minerals (aluminum-rich) are associated with iron phases. Correlations in Qbt 1g cannot be determined because only two points are available. Concentrations of iron are higher in the alluvium than in Qbt 1g, which suggests that more chemical weathering has occurred in the alluvium, possibly because of persistent saturated conditions. Concentrations of aluminum are similar both in the alluvium and in Qbt 1g.

Figure 3.5.3-6 and Figure 3.5.3-7 are bivariate concentration plots of aluminum versus total uranium and iron versus total uranium, respectively. The correlation among these three elements is excellent in the alluvium, which suggests that total uranium is associated with both clay minerals and iron-rich phases. No correlations can be found in the Tshirege Qbt 1 unit or the Cerro Toledo interval. Concentrations of total uranium are higher in Qbt 1g and the Cerro Toledo interval than in the alluvium, which may reflect both natural and anthropogenic uranium within the bedrock units. Two distinct cluster patterns are noted on the aluminum/uranium bivariate plot for the Cerro Toledo interval, which suggests a difference in lithology within the interval.

3.5.3.2 Borehole for Moisture Access Tube MCM-5.9A

The contact between the alluvium and the Tshirege Qbt 1g unit of the Bandelier Tuff occurs at 38 ft (11.6 m). Alluvial groundwater was encountered at 36 ft (11.0 m). The contact between Qbt 1g and the Tsankawi Pumice Bed/Cerro Toledo interval occurs at approximately 48 ft (14.6 m) based on the revised stratigraphy of this borehole. Deeper in the borehole, the contact between the Cerro Toledo interval and the Otowi Member (Qbo) occurs at 118 ft (36.0 m) (Stoker et al. 1991, 7530).

Figure 3.5.3-8 shows the distribution of nitric acid-extractable barium, cerium, lead, manganese, and zinc with depth. These metals generally correlate with each other, showing enrichment at 4, 29, 49, and 71.5 ft (1.2, 8.8, 14.9, and 21.8 m). Concentrations of barium and manganese generally increase with depth in the Otowi Member, whereas concentrations of cerium, lead, and zinc are lowest in the Otowi Member. Clay minerals and/or ferric hydroxides, which have a chemical affinity for metals through adsorption processes, could be present at these depths. Data on aluminum and iron concentrations are not available for this borehole; therefore, this discussion focuses on other metals, radionuclides, and nonmetals that are either naturally occurring or anthropogenic.

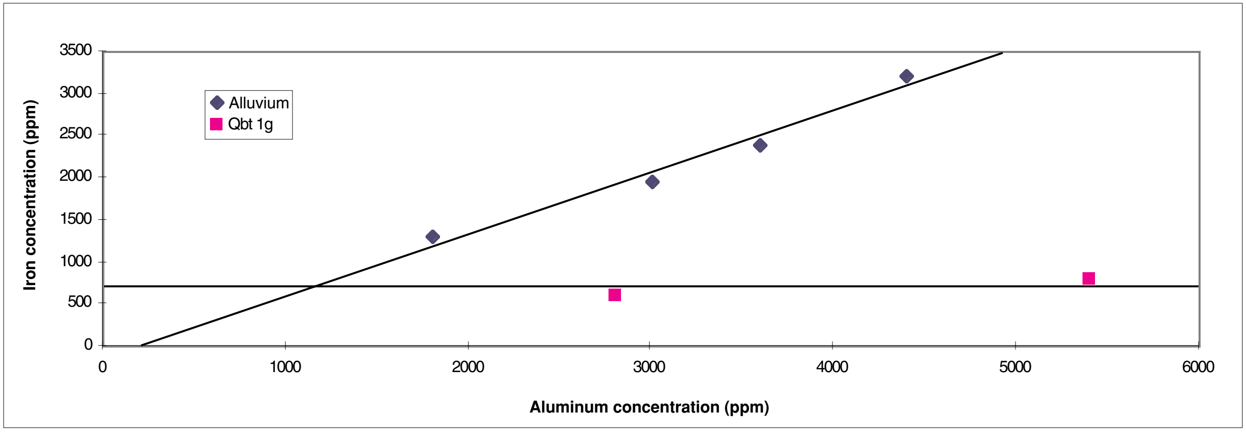


Source: Stoker et al. 1991, 7530

Figure 3.5.3-4. Distribution of ^{137}Cs, ^{238}Pu, and ^{239,240}Pu activities with depth in borehole MCM-5.1.

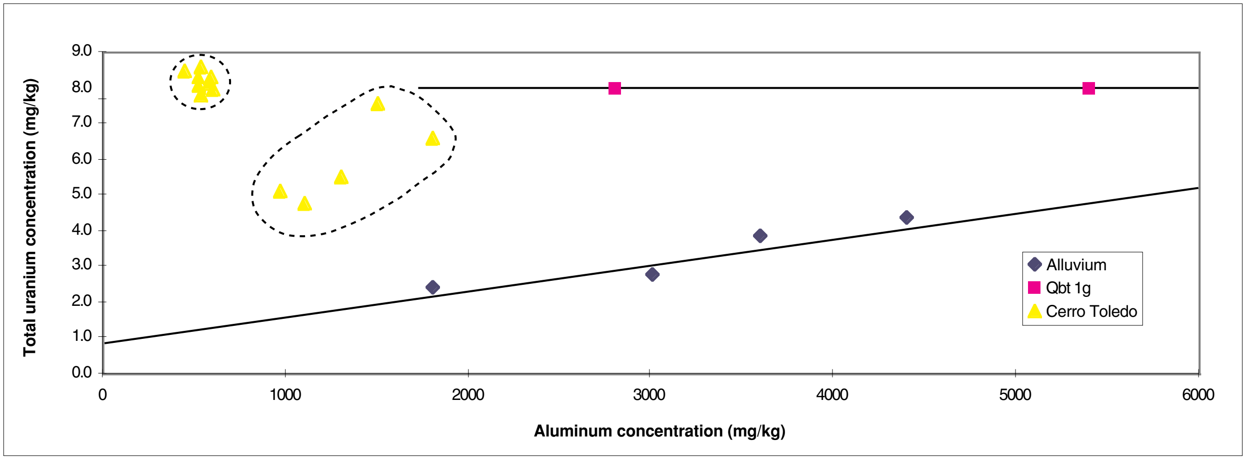
Figure 3.5.3-9 shows the distribution of chloride, fluoride, and nitrate (as nitrogen) with depth. The concentrations of these anions generally correlate with each other, showing enrichment at 29, 39, and 49 ft (8.8, 11.9, and 14.9 m). They are soluble in groundwater, forming no significant solid phases by precipitation, and are constituents present in the TA-50 RLWTF discharge. However, these solutes can become concentrated in the vadose zone through drying processes and may represent wetted fronts migrating through the alluvium and Bandelier Tuff (Longmire et al. 1996, 56030). Concentrations of chloride and nitrate are highest in the Cerro Toledo interval: chloride at 72 ft (22.0 m) and nitrate at 109 ft (33.2 m), which suggests slightly different mobility and/or affinity of these species in the bedrock units.

Figure 3.5.3-10 shows distributions of tritium, gross-alpha and -beta activity, total uranium, and gravimetric moisture content with depth. Activities of tritium vary throughout the borehole (3.7 to 280 nCi/L) (Stoker et al. 1991, 7530), which illustrates movement of water and/or water vapor through the alluvium, the Tshirege Qbt 1g unit, the Tsankawi Pumice Bed/Cerro Toledo interval, and into the upper portion of the Otowi Member. Activities of tritium increase with depth through the alluvium and through the alluvial saturation zone and are highest in the Qbt 1g interval and the top of the Tsankawi Pumice Bed/Cerro Toledo interval. Activities of tritium and concentrations of chloride decrease within the 65- to 94-ft (19.8- to 28.7-m) depth interval, and moisture content increases, which suggests that inflow of fresher groundwater in this portion of the Cerro Toledo interval may account for the apparent dilution of these two solutes. However, inspection of core sample photographs and lithologic descriptions indicate that this interval is a fine-grained, clayey zone within the Cerro Toledo interval that might contain a percentage of older, uncontaminated water that has not been entirely displaced by tritium-contaminated water.



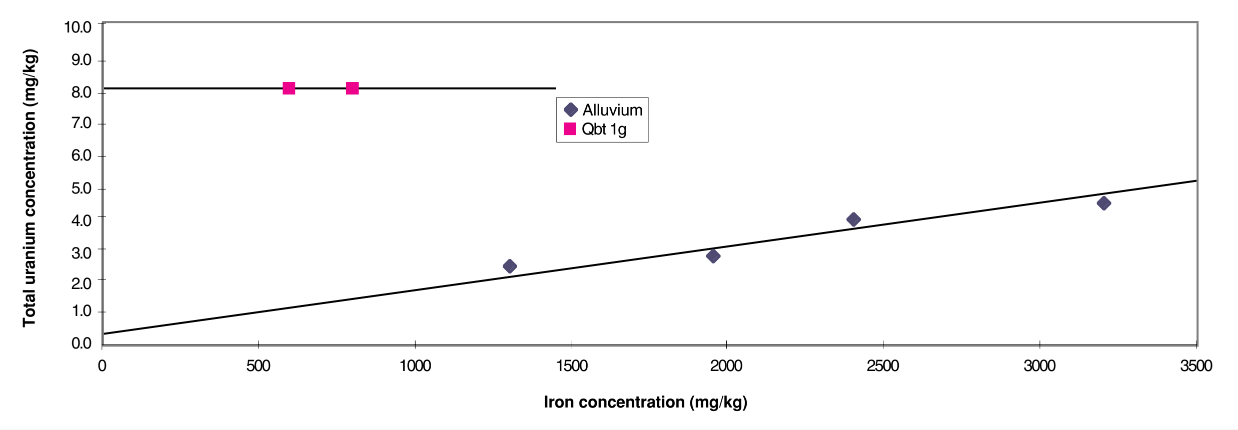
Source: Stoker et al. 1991, 7530

Figure 3.5.3-5. Bivariate plot of aluminum versus iron in borehole MCM-5.1.



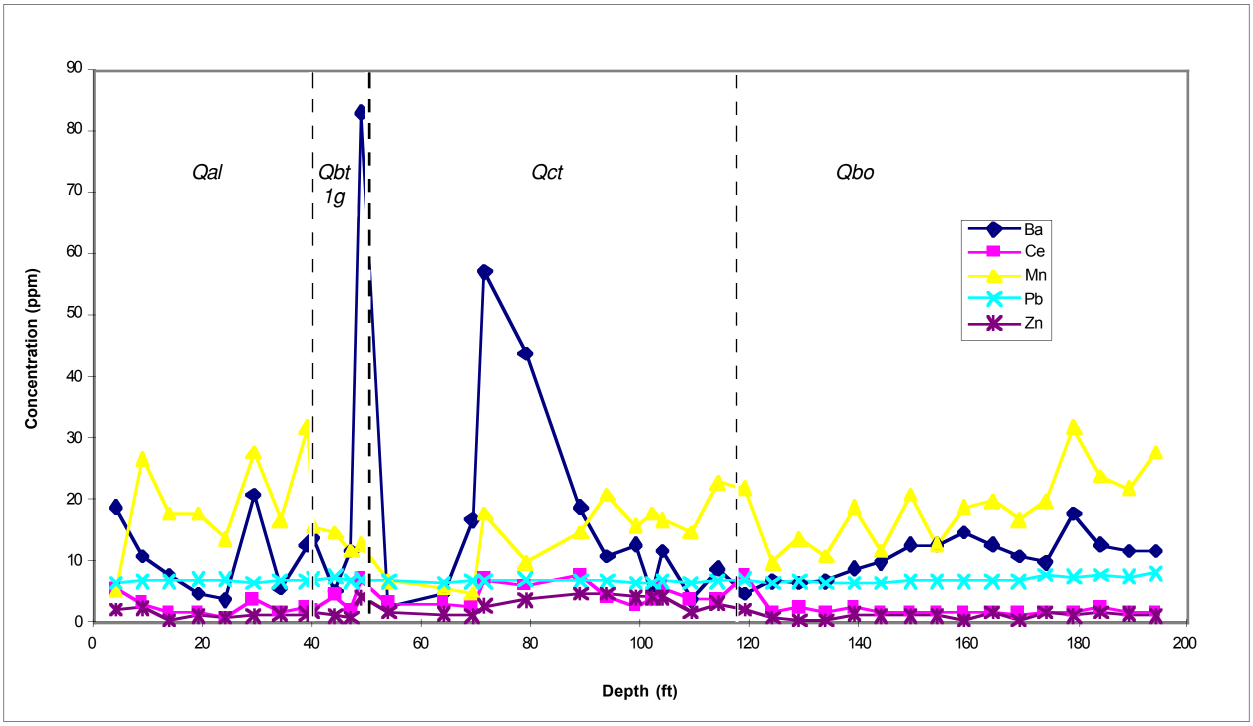
Source: Stoker et al. 1991, 7530

Figure 3.5.3-6. Bivariate plot of aluminum versus total uranium in borehole MCM-5.1.



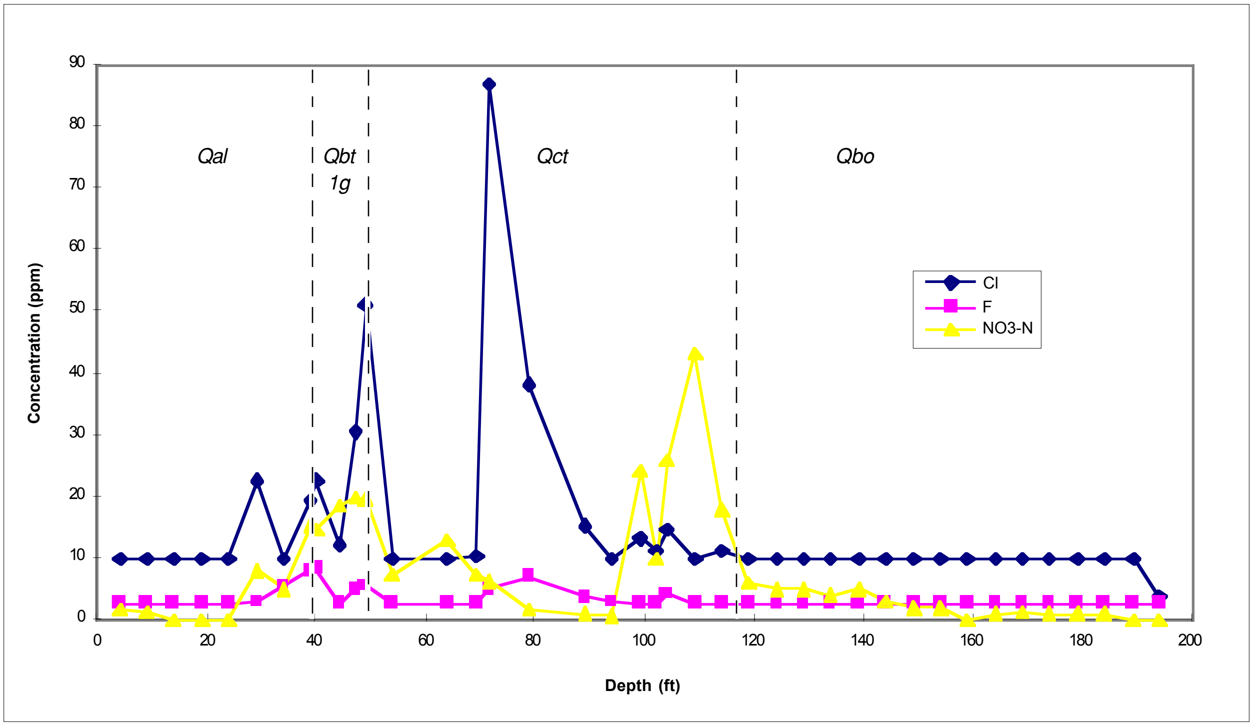
Source: Stoker et al. 1991, 7530

Figure 3.5.3-7. Bivariate plot of iron versus total uranium in borehole MCM-5.1.



Source: Stoker et al. 1991, 7530

Figure 3.5.3-8. Distribution of nitric acid-extractable metals in borehole MCM-5.9A.



Source: Stoker et al. 1991, 7530

Figure 3.5.3-9. Distribution of chloride, fluoride, and nitrate in borehole MCM-5.9A.

The tritium activity and nitrate concentration increase below this clay zone at approximately 100 ft (30.5 m), but the chloride content does not significantly increase. The activity of tritium remains elevated at approximately 70 nCi/L through the upper portion of the Otowi Member to a depth of approximately 160 ft (48.8 m), below which the activity decreases to approximately 5 nCi/L at 194 ft (59.1 m), which is the total depth of the borehole. Nitrate concentrations remain slightly elevated at approximately 5 ppm in the top of the Otowi Member to a depth of approximately 140 ft (42.7 m), below which concentrations decrease to approximately 1 ppm at a depth of 184 ft (56.1 m). The deepest of the samples (10 ft [3.0 m]) did not contain nitrate (Stoker et al. 1991, 7530).

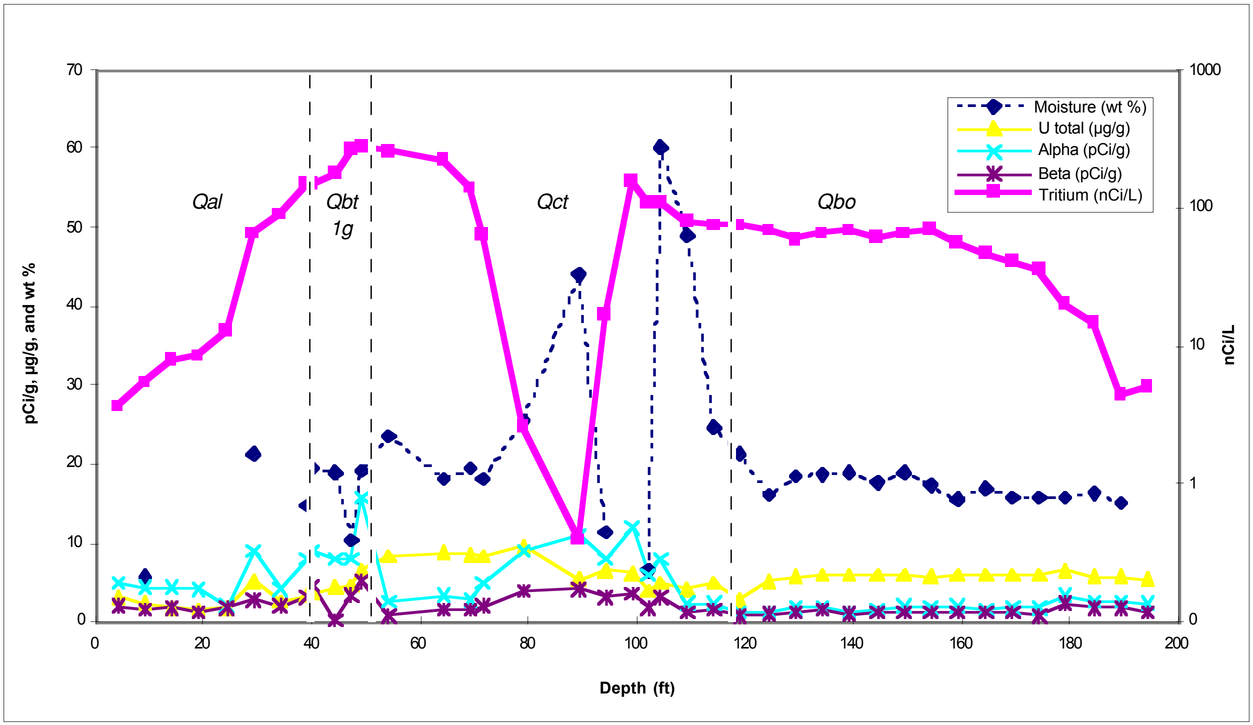
Concentrations of total uranium range from 1.6 to 9.7 ppm (Figure 3.5.3-10). Measurable concentrations (≥0.5 ppm) of nitric acid-extractable uranium range from 0.5 to 2.4 ppm (Stoker et al. 1991, 7530), which are higher than uranium concentrations in background tuff samples (from the Tshirege Qbt 1g unit) collected at TA-21 (0.25 to 0.5 ppm) by Broxton et al. (1995, 50121). This suggests that some of the uranium extracted from borehole MCM-5.9A core samples is anthropogenic. Total uranium and chloride concentrations generally correlate with each other in the alluvium, which suggests that uranium is present as an anion, as indicated by Longmire et al. (1996, 56030), and that both were transported under similar hydrologic conditions. Drying processes may increase concentrations of chloride, uranium, and other solutes in specific zones (47 ft [14.3 m]) where moisture content decreases. However, in other depth intervals (34 to 40 ft [10.4 to 12.2 m], 72 to 94 ft [22.0 to 28.7 m], 102 to 106 ft [31.1 to 32.3 m]) the gravimetric moisture content increases.

Activities of measurable ^{90}Sr (≥0.2 pCi/g) and ^{241}Am (≥2.7 pCi/g) range from 0.20 to 1.18 pCi/g and from 0.001 to 2.7 pCi/g, respectively, as shown in Figure 3.5.3-11 (Stoker et al. 1991, 7530). Activities of ^{90}Sr are the highest in the Tshirege Qbt 1g unit near the Tsankawi Pumice Bed/Cerro Toledo interval contact. The radionuclide ^{90}Sr undergoes cation exchange with solid organic matter and clay minerals, which results in partial removal of this isotope from surface water and groundwater in Los Alamos Canyon (Longmire et al. 1996, 54168). The same processes influencing ^{90}Sr mobility are expected to occur in Mortandad Canyon. However, ^{90}Sr is more mobile in groundwater relative to plutonium isotopes and ^{241}Am (Longmire et al. 1996, 54168; Longmire et al. 1996, 56030). Activities of ^{241}Am are highest in the alluvium and fluctuate with depth (Stoker et al. 1991, 7530). This radionuclide adsorbs strongly onto the Bandelier Tuff based on experimental results reported by Longmire et al. (1996, 56030). Movement of ^{241}Am in alluvial groundwater in Mortandad Canyon is possibly controlled by adsorption onto colloids (Penrose et al. 1990, 11770). Activities of ^{137}Cs are less than the detection limit (1.8 pCi/g) in borehole MCM-5.9A core samples (Stoker et al. 1991, 7530).

3.5.3.3 Borehole MCC-8.2

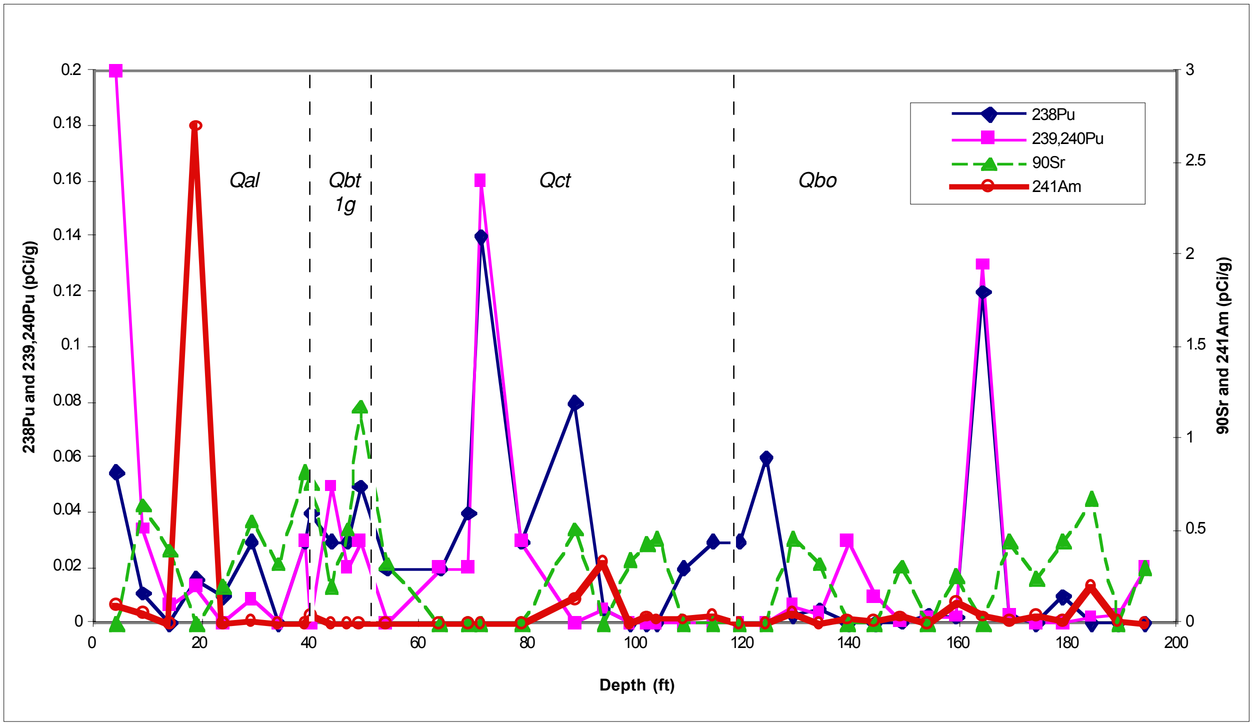
The contact between the alluvium and the Cerro Toledo interval occurs at approximately 59 ft (18.0 m) based on the revised stratigraphy. Alluvial groundwater was encountered at the 73- to 76-ft (22.3- to 23.3-m) depth interval in the borehole, probably in the Cerro Toledo interval. Based on the revised stratigraphy, the Otowi Member was encountered at approximately 124 ft (37.8 m). The total depth of the borehole was 184 ft (56.1 m).

Activities of tritium and gravimetric moisture content with depth are shown in Figure 3.5.3-12. Activities of measurable tritium range from 0.70 to 310 nCi/L; the highest values are found within the Cerro Toledo interval and the Otowi Member. Tritium was observed at elevated concentrations of more than 100 nCi/L in the saturated zone to the bottom of the borehole (Stoker et al. 1991, 7530). The upper 52 ft (15.9 m) contained the lowest activity of tritium; activities decreased with depth through this upper interval. The



Source: Stoker et al. 1991, 7530

Figure 3.5.3-10. Distribution of tritium, gross-alpha and -beta, total uranium, and moisture content in borehole MCM-5.9 A.



Source: Stoker et al. 1991, 7530

Figure 3.5.3-11. Distribution of americium, plutonium, and strontium in borehole MCM-5.9 A.

minimal contamination in the upper alluvium indicates that infiltration amounts have been minimal at this location, which is consistent with observations that contaminated surface flow does not regularly extend this far downstream (see Section 3.7). Activities of tritium increase sharply with depth at 54 ft (16.5 m), probably due to underflow of contaminated alluvial groundwater discharging to the subcropping Cerro Toledo interval at this location. The vertical extent of tritium migration into bedrock units at this location is unknown because background conditions had not been reached at the bottom of the borehole. Gravimetric moisture content fluctuates with depth and correlates approximately with the tritium activities. The highest moisture contents occur within the Cerro Toledo interval at 104 ft (31.7 m). This zone of high moisture content may correlate to similar zones observed near the base of the Cerro Toledo interval in boreholes for moisture access tubes MCM-5.1 and MCM-5.9A.

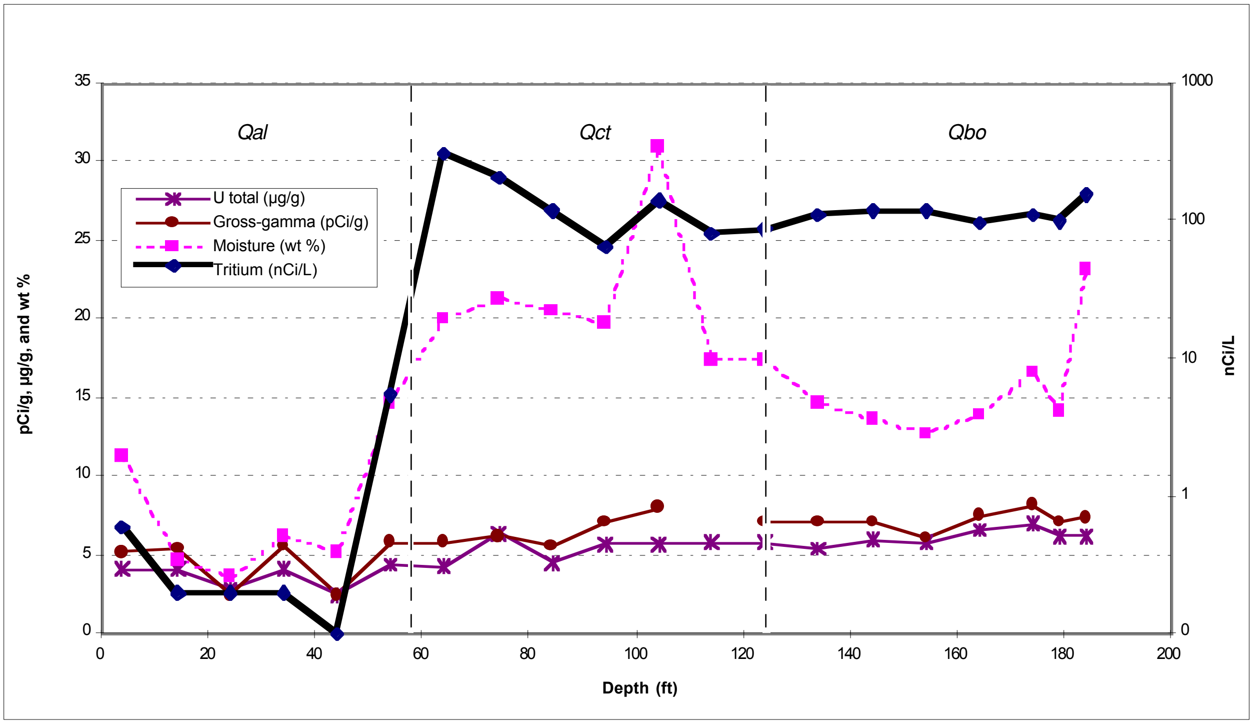
Stoker et al. (1991, 7530) did not report concentrations of nitric acid-extractable uranium; therefore, a comparison with background uranium concentrations is not possible. Concentrations of total uranium range from 2.5 to 7.0 ppm (Stoker et al. 1991, 7530) and appear to correlate with lithology; the highest values are observed in the Cerro Toledo interval and the Otowi Member, which is consistent with observations in boreholes for moisture access tubes MCM-5.1 and MCM-5.9A.

Figure 3.5.3-13 shows the distributions of ^{241}Am, ^{137}Cs, ^{238}Pu, and ^{239,240}Pu activities with depth. Activities of plutonium isotopes are generally within background levels, which indicates that plutonium has been sorbed onto sediments upstream. Activities of measurable ^{241}Am ($\geq$ 0.001 pCi/L) range from 0.004 to 0.057 pCi/g (Stoker et al. 1991, 7530). Activities of ^{241}Am greater than 0.001 pCi/g are observed from the surface to a depth of about 165 ft (50.3 m) within the Otowi Member, but activities are very low and are within background fallout values.

Activities of measurable ^{137}Cs (variable detection limits) range from 0.063 to 0.226 pCi/g. The radionuclide ^{137}Cs strongly adsorbs onto soils and sediments in the Los Alamos area (Kung et al. 1995, 56044); the highest activities of this isotope are found in stream channel and floodplain deposits within Mortandad Canyon (Environmental Protection Group 1995, 50285). Activities of ^{90}Sr are generally less than detection limits in core samples from this borehole (Stoker et al. 1991, 7530), which suggests that subsurface contamination by this isotope is minimal at this location.

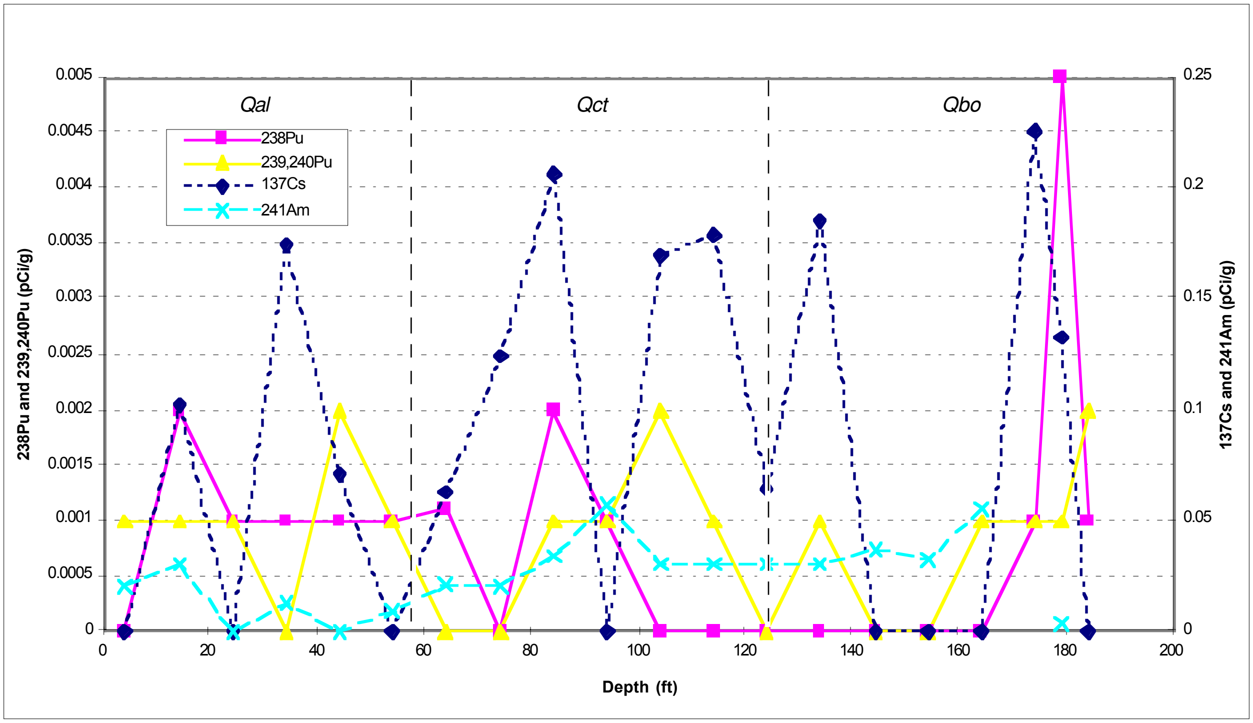
3.5.3.4 Boreholes for Wells SIMO and SIMO-1

Wells SIMO and SIMO-1 are located in Mortandad Canyon on San Ildefonso Pueblo land about 100 ft (30.5 m) from the Laboratory boundary. The contact between the alluvium and the Cerro Toledo interval has been reinterpreted to occur at about 51 ft (15.5 m) in borehole SIMO (Stoker et al. [1991, 7530] reported that the contact was at 11 ft [3.4 m]). Alluvial groundwater was not encountered in borehole SIMO (Stoker et al. 1991, 7530). The Tshirege Qbt 1g unit was reported by Stoker et al. to be present from 11 to 47 ft (3.4 to 14.3 m) but, after reinterpretation, the presence of this unit at this location is questionable. Borehole SIMO was drilled to a total depth of 104 ft (31.7 m), which has been reinterpreted to be within the Cerro Toledo interval. Well SIMO-1 was installed adjacent to SIMO by the Bureau of Indian Affairs for San Ildefonso Pueblo in 1992; the borehole for this well is reinterpreted to have encountered the Otowi Member at a depth of 118 ft (36.0 m). Core samples from borehole SIMO-1 were not analyzed. Additional information about wells SIMO and SIMO-1 is presented in Appendix D of this work plan.



Source: Stoker et al. 1991, 7530

Figure 3.5.3-12. Distribution of tritium, gross-gamma, total uranium, and moisture content in borehole MCC-8.2.



Source: Stoker et al. 1991, 7530

Figure 3.5.3-13. Distribution of americium, cesium, and plutonium in borehole MCC-8.2.

Total uranium concentrations in borehole SIMO (Figure 3.5.3-14) range from 1.5 to 6.7 ppm. Data for other metals and nonmetals are not available for SIMO. Activities of measurable tritium ranged from 700 to 1600 pCi/L; the highest values occur at depths less than 19 ft (5.8 m), which suggests that contaminated surface water has reached the Laboratory boundary and has infiltrated to a depth of about 20 ft (6.1 m) at this location. Gravimetric moisture content ranged from 3.9 to 19.2 wt %, and all core samples were unsaturated (Stoker et al. 1991, 7530). The highest observed moisture content was at 94 ft (28.7 m), within the lower Cerro Toledo interval; this moisture content is similar to that observed in the boreholes for moisture access tubes MCM-5.1 and MCM-5.9A and borehole MCC-8.2. Activities of measurable ^{137}*Cs,* ^{238}*Pu, and* ^{239,240}*Pu (Figure 3.5.3-15) range from 0.004 to 0.347 pCi/g, 0.001 to 0.008 pCi/g, and 0.001 to 0.006 pCi/g, respectively, all within background levels, which suggests that plutonium contamination has been sorbed onto sediments upstream.*

3.5.3.5 Borehole 35-2028

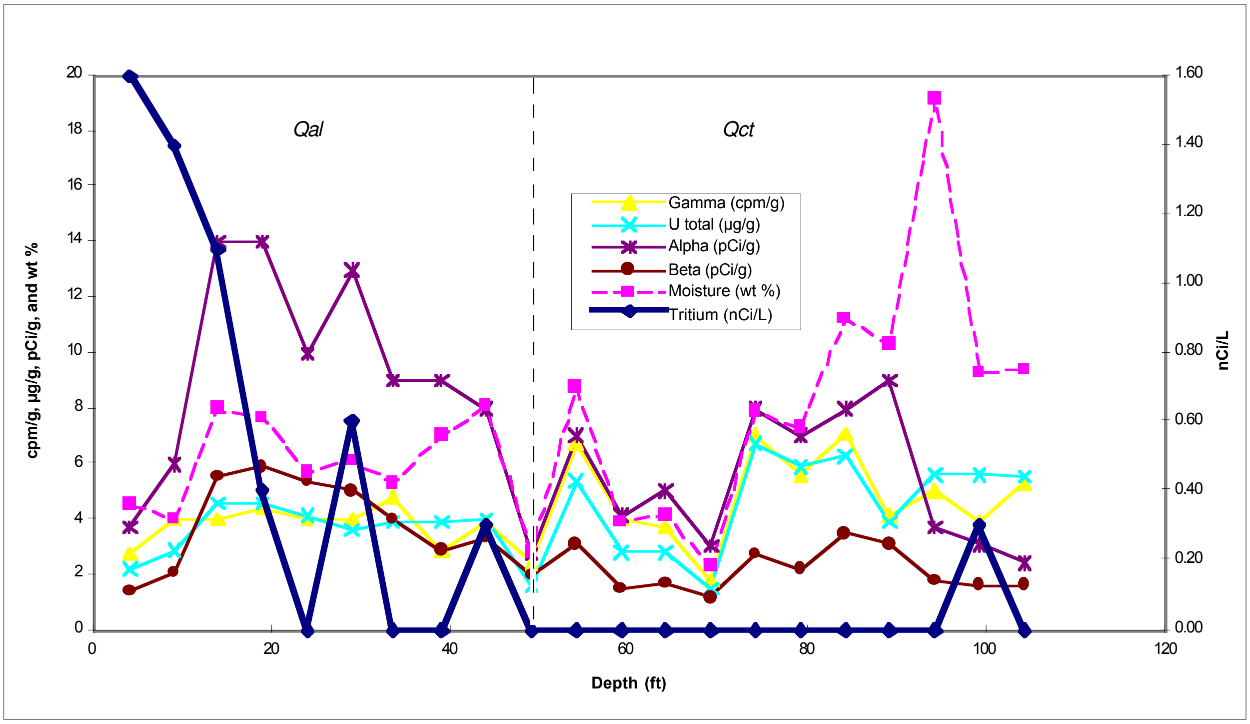
Field Unit 4 personnel drilled borehole 35-2028 in Pratt Canyon to support the RFI for PRS No. 35-003(r), the canyon that received discharge from the former TA-35 wastewater treatment plant (LANL 1992, 7666; LANL 1996, 54422). Figure A-2 in Appendix A of this work plan shows the location of the borehole, and Figure A-3 in Appendix A of this work plan shows the stratigraphy encountered. This borehole was drilled to a total depth of 299 ft (91.1 m) at the top of the Otowi Member, and core samples were collected at 10-ft (3.0-m) intervals for field screening and laboratory analyses. Units encountered included the following: alluvium from 0 to 4.5 ft (0 to 1.4 m); Tshirege Member Unit 3 from 4.5 to 25 ft (1.4 to 7.6 m); Tshirege Member Unit 2 from 25 to 90 ft (7.6 to 27.4 m); Tshirege Member Unit Qbt 1v from 90 to 149 ft (27.4 to 45.4 m); Tshirege Member Unit Qbt 1g from 149 to 217.5 ft (45.4 to 66.3 m); the Tsankawi Pumice Bed from 217.5 to 219.5 ft (66.3 to 66.9 m); the Cerro Toledo interval from 219.5 to 297 ft (66.9 to 90.5 m); and the Otowi Member from 297 to 299 ft (90.5 to 91.1 m).

Figure 3.5.3-16 and Figure 3.5.3-17 show the results of field screening of the core samples. Samples from the alluvium and from the weathered tuff beneath the alluvium to a depth of about 10 ft (3.0 m) contained elevated beta activity. The moisture content was highest in Cerro Toledo interval sediments at depths of 220 and 270 ft (67.1 and 82.3 m). A coarse-grained cobble/gravel zone composed of intermediate volcanic rocks was encountered from 256 to 260 ft (78.0 to 79.3 m) in the Cerro Toledo interval. Poor core recovery through this zone limited sampling and analyses, but damp samples in the core barrel indicated the possibility of intermediate zone moisture. Additional details were reported in the RFI report for PRS No. 35-003(r) (LANL 1996, 54422), and supplemental sampling at this PRS was conducted in April 1997 (LANL 1997, 56175).

3.5.4 Plutonium Distribution Coefficients

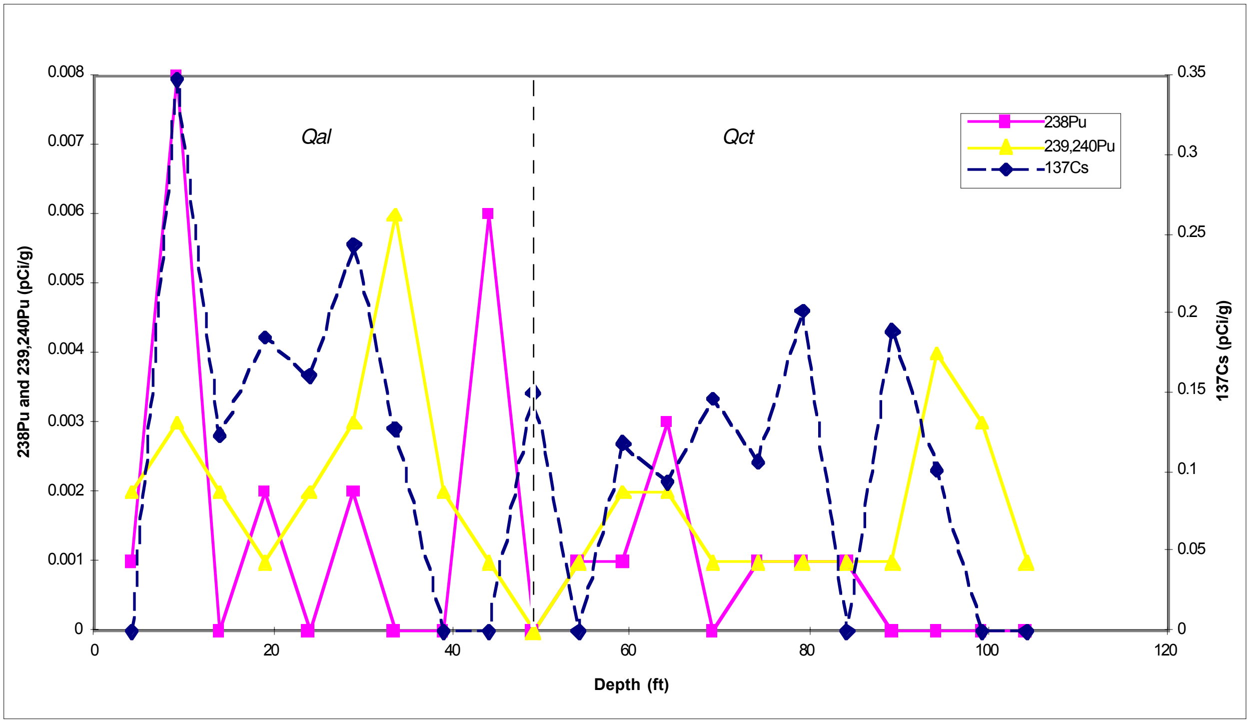
The distribution coefficient (K_d) *quantifies the partitioning of a constituent between solid and liquid phases when the two phases are in contact and at equilibrium.* K_d *is defined as the ratio of the concentration of the constituent in the solid phase (moles/g) to that in the liquid phase (moles/mL). Thus* K_d *is in units of mL/g (Longmire et al. 1996, 56030). The* K_d *for a given constituent, regardless of the isotope, tends to be constant for a given solid phase but varies with ionic strength of the liquid phase and with temperature.*

Figure 3.5.4-1 shows calculated K_d*s (in units of mL/g) for* ^{238}*Pu and* ^{239,240}*Pu using radiochemical data presented in Stoker et al. (1991, 7530, Table 6.2.1-V, p. 62). Plutonium isotopic data obtained for the solid phase from core samples and for the liquid phase from groundwater pumped from alluvial wells MCO-4, MCO-4B, MCO-6, MCO-6B, MCO-7, and MCO-7A were used in the calculations. Similar* K_d*s were calculated for* ^{238}*Pu and* ^{239,240}*Pu for each well. The similarity verifies the isotopic analyses by confirming a well-specific sorption capacity of the alluvium for plutonium regardless of the element's isotopic composition.*



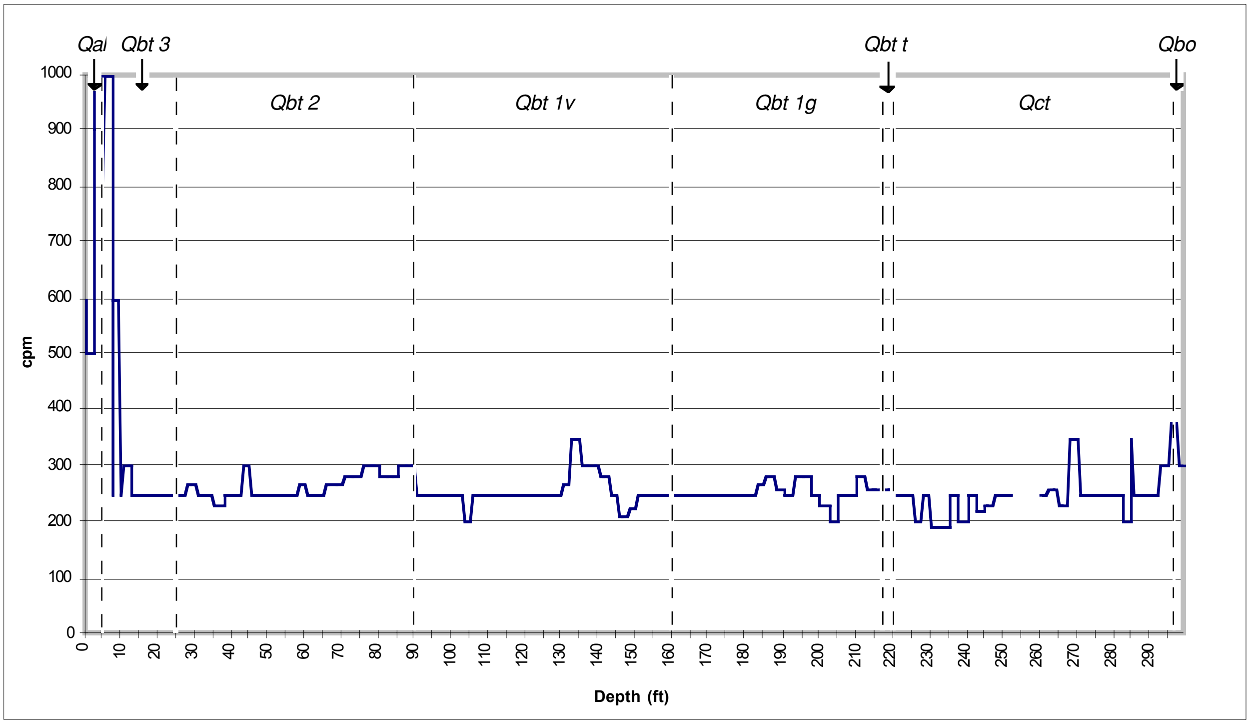
Source: Stoker et al. 1991, 7530

Figure 3.5.3-14. Distribution of tritium; gross-alpha, -beta, and -gamma; total uranium; and moisture content in borehole SIMO.



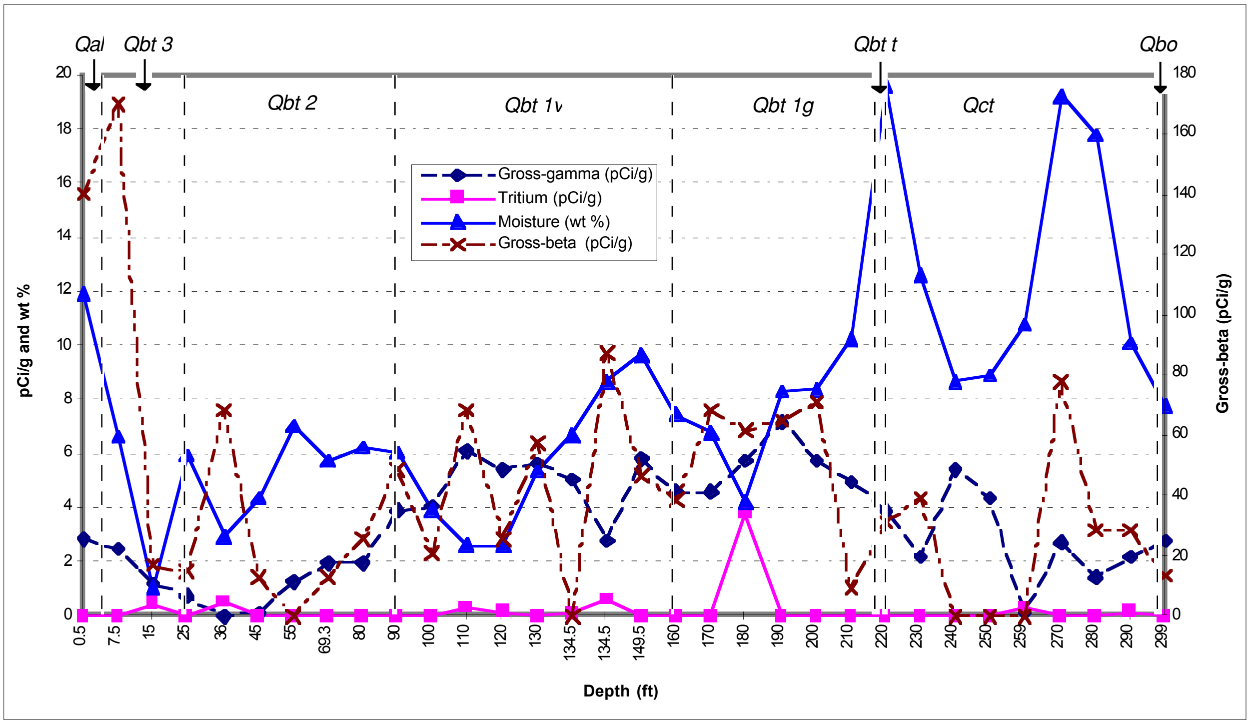
Source: Stoker et al. 1991, 7530

Figure 3.5.3-15. Distribution of cesium and plutonium in borehole SIMO.



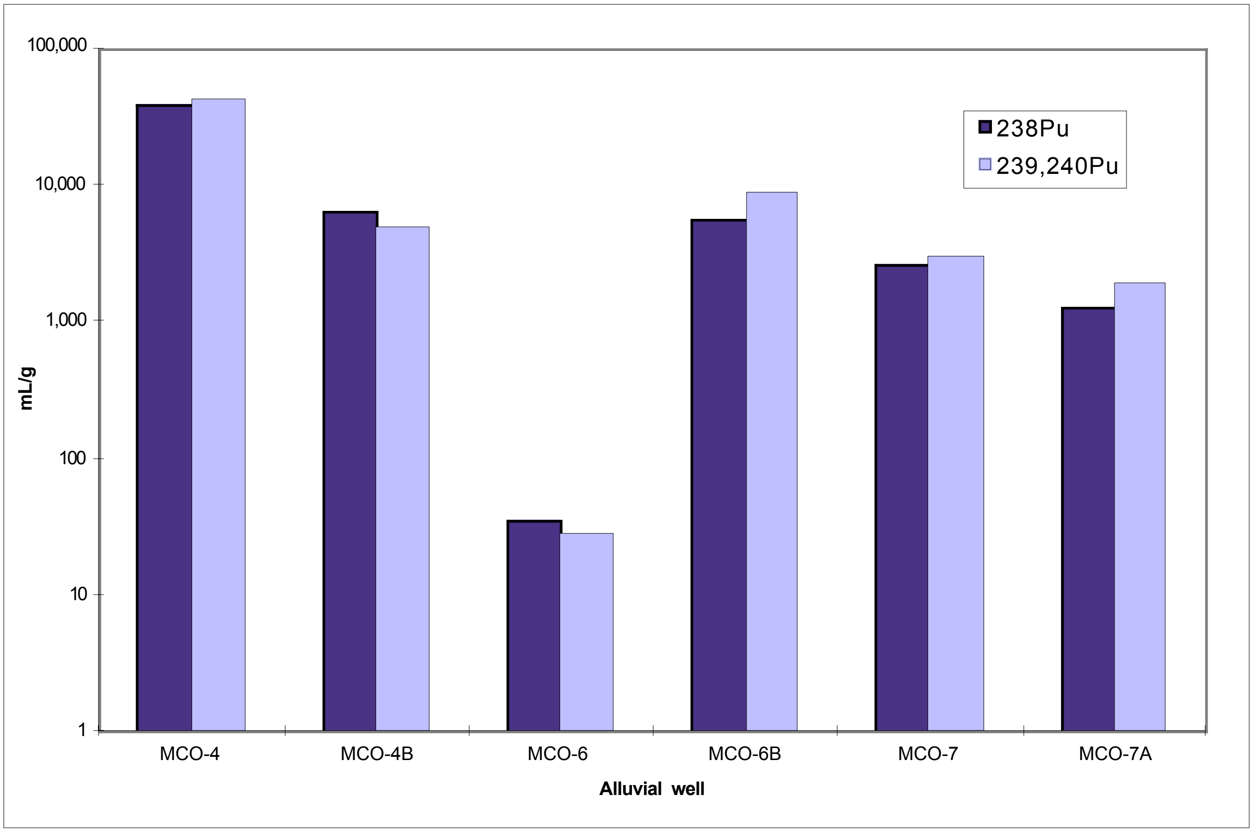
Source: LANL 1996, 54422

Figure 3.5.3-16. Beta/gamma activity in borehole 35-2028.



Source: LANL 1996, 54422

Figure 3.5.3-17. Results of field screening in borehole 35-2028.



Source: Stoker et al. 1991, 7530 (data only)

Figure 3.5.4-1. Calculated distribution coefficients for plutonium isotopes in alluvial well water and suspended sediments.

The calculated K_ds for plutonium are generally greater than 1000 mL/g, excluding those calculated for well MCO-6. It is possible that MCO-6 is completed in coarse-grained alluvium and/or Bandelier Tuff, which are characterized by a small surface area to mass ratio. The result is a limited sorption capacity for plutonium and a lower K_d. Large K_ds suggest that plutonium is strongly adsorbed onto solid surfaces; therefore, activities of plutonium in alluvial groundwater should significantly decrease downgradient of the TA-50 RLWTF outfall (see Section 3.8).

The K_ds for plutonium generally decrease along the groundwater flow path in the alluvium. The reason for the decrease is not completely understood; it could be due to a number of factors including a proportion of plutonium irreversibly bound to fine and/or colloidal-size particulates in the TA-50 RLWTF discharge, which tend to remain suspended in the liquid phase and be measured as "dissolved" constituents in analysis. Transport of fine and/or colloidal-size particles with adsorbed plutonium in both surface water and groundwater may account for the widespread distribution of this actinide in the alluvium (Penrose et al. 1990, 11770).

3.5.5 Summary of Borehole Geochemical Data

Boreholes drilled in Mortandad Canyon were analyzed for inorganic species, metals, radionuclides, and gravimetric moisture content. Tritium was detected throughout the entire lengths of the boreholes for *moisture access tubes MCM-5.1 and MCM-5.9A and borehole MCC-8.2, which suggests that alluvial groundwater has infiltrated to depths of 194 ft (59.1 m) or greater beneath Mortandad Canyon. The maximum activity of tritium measured is 390 nCi/L in borehole MCM-5.1 at a depth of 97 ft (29.6 m) (Stoker et al. 1991, 7530). Tritium is stable as HTO and can migrate in both liquid and gaseous phases.*

Concentrations of nitric acid-extractable uranium, at 0.5 to 2.4 ppm, are slightly elevated above background levels within the alluvium and Bandelier Tuff in Mortandad Canyon. Background concentrations of nitric acid-extractable uranium observed within the Tshirege Qbt 1g unit range from 0.1 to 0.5 ppm (Broxton et al. 1995, 50121). Distributions of nitric acid-extractable uranium generally correlate with gravimetric moisture content in borehole MCC-8.2 samples, which suggests that anthropogenic uranium has migrated with the wetted fronts beneath Mortandad Canyon. Additional isotopic analyses of borehole samples collected in the future will help determine the source(s) of this anomalous uranium.

The K_d*s for plutonium, calculated from plutonium activities measured in alluvial sediment and groundwater in Mortandad Canyon (Stoker et al. 1991, 7530), range from 30 to 40,000 mL/g. Based on the* K_d*s, plutonium strongly adsorbs onto sediments, and activities of this element in solution should be minimal (<0.1 pCi/L). Surface water and groundwater transport of colloidally-bound plutonium may contribute to the widespread distribution of total (unfiltered) plutonium observed in alluvial groundwater within Mortandad Canyon. Little is known about the oxidation state(s) of plutonium and its form(s) (particulate oxide and/or adsorbed species onto sediments) within Mortandad Canyon.*

3.5.6 Data Requirements for Understanding the Geochemistry of Subsurface Sediments and Associated Contaminants

Analyses of samples from previously cored boreholes in Mortandad Canyon have shown that contamination has migrated to variable depths. The existing data show that contamination (particularly by tritium) at some locations has migrated to a depth of at least 194 ft (59.1 m), the total depth of the borehole for moisture access tube MCM-5.9A. However, the extent of contaminant migration to depth has not been determined. Similar results were observed at borehole MCC-8.2 where elevated tritium activity extends to the total depth of 184 ft (56.1 m) within the Otowi Member.

Additional data on the subsurface sediments are needed to determine the extent of contaminant migration beneath Mortandad Canyon. Boreholes through the Bandelier Tuff beneath alluvial groundwater in Mortandad Canyon are needed to determine moisture content, the activity of tritium and other radionuclides, the concentrations of other dissolved constituents, the extent of contaminant migration to depth and to potentially identify the source(s) of moisture in underlying bedrock units.

3.6 Surface Water Hydrology

The water that flows through Mortandad 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 the primary mechanism for redistributing and transporting contaminants that are present in the Mortandad Canyon system. The contaminants are due to past and present Laboratory operations and discharges, which are primarily from the TA-50 RLWTF outfall and from the historic TA-35 liquid waste treatment plant outfall. The primary mechanisms that affect mobilization of contaminants within the canyon system include sediment transport, contaminant dissolution and desorption, infiltration, and vapor-phase transport. Effluent-supported flow from the TA-50 RLWTF may also affect the mobilization of contaminants (Penrose et al. 1990, 11770).

Relevant aspects of surface water hydrology include the following:

- *areas and pathways of surface water runoff, wastewater discharges, and sediment deposition;*
- *rates of contaminant dissolution and desorption, transport, and sedimentation;*
- *relationships between infiltration, runoff, and wastewater discharges;*
- *presence and effectiveness of adsorptive media in the sediments in retarding infiltration of water-borne contaminants; and*
- *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 (Revision 6) (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 contaminant transport pathway in the Mortandad Canyon system. Figure A-2 in Appendix A of this work plan shows the locations of ephemeral streamflow in the Mortandad Canyon watershed.

3.6.1 Mortandad Canyon Stream Channel System and Streamflow

The stream channel characteristics of Mortandad Canyon and its tributaries were described in Section 3.1. Sources of streamflow include stormwater and snowmelt runoff, and discharges of cooling water and treated wastewater.

Table 3.6.1-1 summarizes the NPDES-permitted outfalls into Mortandad Canyon and its tributaries, the current status, and the source and discharge point. Some of the outfalls have created small wetland areas: one is located on the canyon wall north of TA-48 and another is located on the edge of the mesa east of TA-48. The discharges to Effluent Canyon support a small intermittent stream that occasionally flows as far as Mortandad Canyon and supports a small body of alluvial groundwater in Effluent Canyon. Figure A-1 in Appendix A of this work plan shows the locations of NPDES-permitted outfalls and associated wetlands. Historically, each outfall discharged about 10 gal. per minute (gpm) (Purtymun 1964, 11822), but discharges are variable (depending on operations) and seasonal; summer water usage for cooling buildings is the highest.

The TA-50 RLWTF discharges to Effluent Canyon approximately 600 ft (183 m) upstream of the confluence with Mortandad Canyon. Discharge volumes are summarized in Section 2.4.6 in Chapter 2 of this work plan; recently discharges have averaged approximately 15,000 gal. per day (gpd).

TABLE 3.6.1-1

SUMMARY OF NPDES OUTFALLS* INTO MORTANDAD CANYON WATERSHED

Outfall No.	PRS No.	Water Source	Outfall Location	Discharge	Comment
03A-021		*TA-3-29 CMR Building*	*South of TA-3-1698*	*Seasonal, intermittent discharge*	*Treated water from air washers near head of Mortandad Canyon*
03A-022		*TA-3-66 Sigma Building*	*South of TA-3-66*	*Currently continuous (15 to 25 gpm), being evaluated for rerouting to SWSC*	*Treated cooling water to head of Mortandad Canyon*
03A-181		*TA-55-6*	*North of TA-55*	*Intermittent discharge*	*Treated cooling water to Effluent Canyon*
04A-127	*35-016(g)*	*TA-35-213*	*North of TA-35-213*	*No discharge, rerouted to SWSC in 1997*	*Noncontact cooling water to Effluent Canyon. Abandoned 1997*
06A-132	*35-016(b)*	*TA-35-87*	*South of TA-35-87*	*No discharge, rerouted to SWSC 1997*	*Photo wastewater to Ten Site Canyon*
Former 10S	*35-010(e)*	*TA-35 sanitary sewage lagoon and sand filter beds*	*Ten Site Canyon*	*40,000 gpd from about 1975 until December 1992*	*Sewage lagoons abandoned 1992, outfall abandoned and NPDES No. delisted*
03A-046	*48-007(a)*	*TA-48-1*	*East of TA-48-1*	*No discharge, rerouted to SWSC 1997*	*Treated cooling water to Effluent Canyon*
04A-016	*48-007(b)*	*TA-48-1*	*Northeast of TA-48-1*	*Discharge eliminated 1997 (recirculated)*	*Noncontact cooling water to Mortandad Canyon*
04A-131	*48-007(c)*	*TA-48-1*	*North of TA-48-1*	*No discharge for several years*	*Noncontact cooling water to Mortandad Canyon*
04A-152		*TA-48-28*	*North of TA-48-28*	*Discharge eliminated in 1995*	*Noncontact cooling water to Mortandad Canyon*
04A-153	*48-007(d)*	*TA-48-1*	*East of TA-48-1*	*No discharge, rerouted to SWSC, but some flow has been observed*	*Noncontact cooling water to Effluent Canyon*
04A-126	*48-007(e)*	*TA-48-8*	*North of TA-48-8, previously east of TA-48-8*	*Discharge eliminated, deleted from permit 12/95*	*Noncontact cooling water to Mortandad Canyon*
04A-137	*48-007(f)*	*TA-48-46*	*North of TA-48-46*	*Discharge eliminated, deleted from permit 12/95*	*Noncontact cooling water to Mortandad Canyon*
051	*50-006(d)*	*TA-50 RLWTF*	*North of TA-50 and north of TA-35-213*	*15,000 gpd average since 1990*	*Radioactive waste treatment effluent to Effluent Canyon*

**NPDES Permit No. NM0028355*

Downstream of the Effluent Canyon confluence, Mortandad Canyon becomes a steep, narrow, relatively straight canyon for approximately 1.1 mi (1.8 km) to well MCO-4. This part of the canyon forms the north side of TA-35 where the canyon is approximately 800 ft (244 m) wide at the mesa rim and approximately 200 ft (61 m) deep. Streamflow through this part of the canyon is supported by intermittent discharges from TA-48 and Effluent Canyon.

Gaging station GS-1 is located in Mortandad Canyon approximately 100 ft (30.5 m) downstream of the confluence with Effluent Canyon. GS-1 was installed in 1962 to monitor natural stream conditions in Mortandad Canyon before the TA-50 RLWTF began discharging in June 1963; it operated continuously from 1962 to 1972 and occasionally for specific studies during the 1970s. GS-1 was reactivated by the Laboratory in May 1995 (renamed GS-E200) (Shaull et al. 1996, 56019). A summary of the monthly streamflows and precipitation from March 1962 through June 1963 was provided by Purtymun (1964, 11822) and is shown in Figure 3.6.1-1.

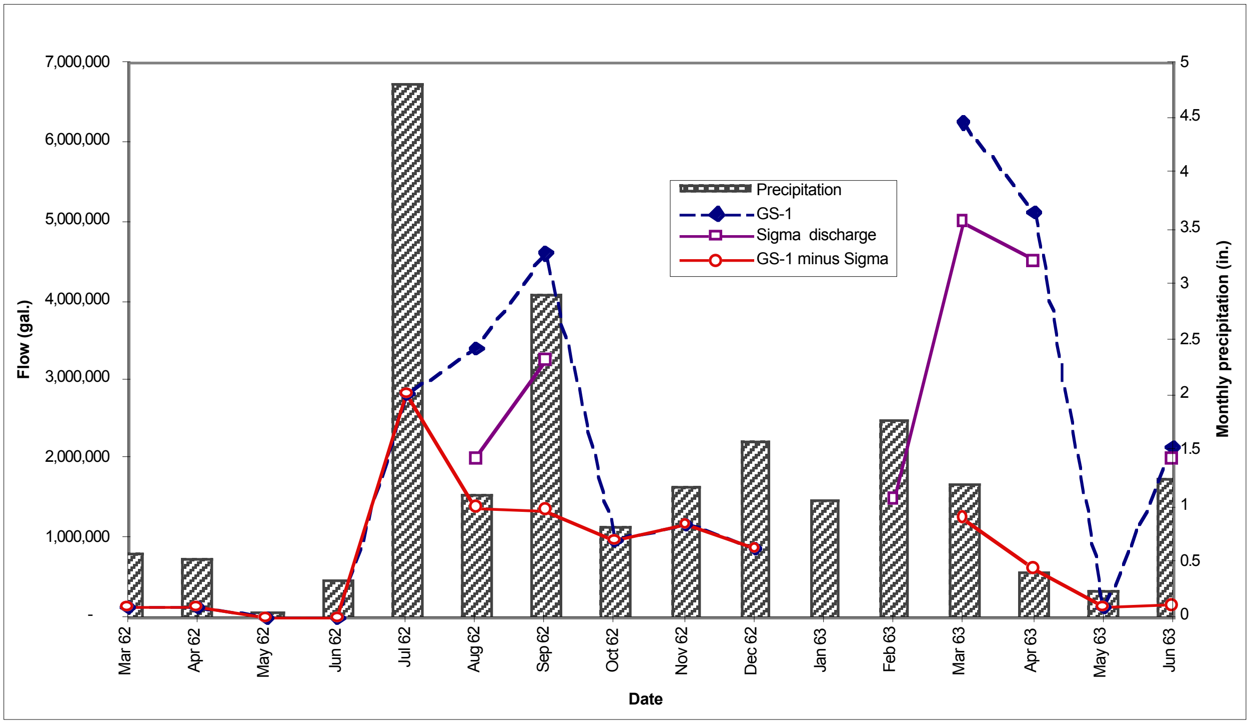
Not all measured flow for the period (shown in Figure 3.6.1-1) is natural because cooling water discharges from the New Sigma building at TA-3 and from TA-48 were also recorded at GS-1 (Purtymun 1964, 11822). When the New Sigma discharges are subtracted from the streamflow measurements (as shown on the figure), the resulting monthly volume of streamflow generally parallels the monthly precipitation. No flow was recorded during the winter months because the gauge was frozen. For this period of record, discharge from the New Sigma building was the major contributor to streamflow in Mortandad Canyon.

GS-2 was installed in 1962 in middle Mortandad Canyon approximately 4500 ft (1372 m) east of GS-1 and approximately 200 ft (61 m) west of well MCO-4. Figure 3.6.1-2 shows the monthly records of flow at GS-2 from March 1962 through June 1963. A relatively high surface flow at GS-1 is necessary for surface flow to persist as far east as GS-2. Purtymun (1964, 11822) concluded from the data that an estimated 1.8 million gal. (6810 m^3) of water must pass GS-1 at 250 to 300 gpm to saturate the alluvium between GS-1 and GS-2; after the alluvium is saturated, surface flow will pass GS-2. The monthly stream loss between GS-1 and GS-2 is calculated from the gaging records and is shown on Figure 3.6.1-2. The amount of stream loss was found to vary with seasonal ET; it was approximately 40,000 gpd during the spring and approximately 60,000 gpd during the hotter summer months (Purtymun 1964, 11822). Purtymun further stated:

> *Surface water will flow on fully saturated alluvium and then will infiltrate into the first unsaturated alluvium downstream; therefore, the section of fully saturated alluvium will be extended downgradient only when the amount of surface flow exceeds the amount needed to keep the alluvium saturated.*

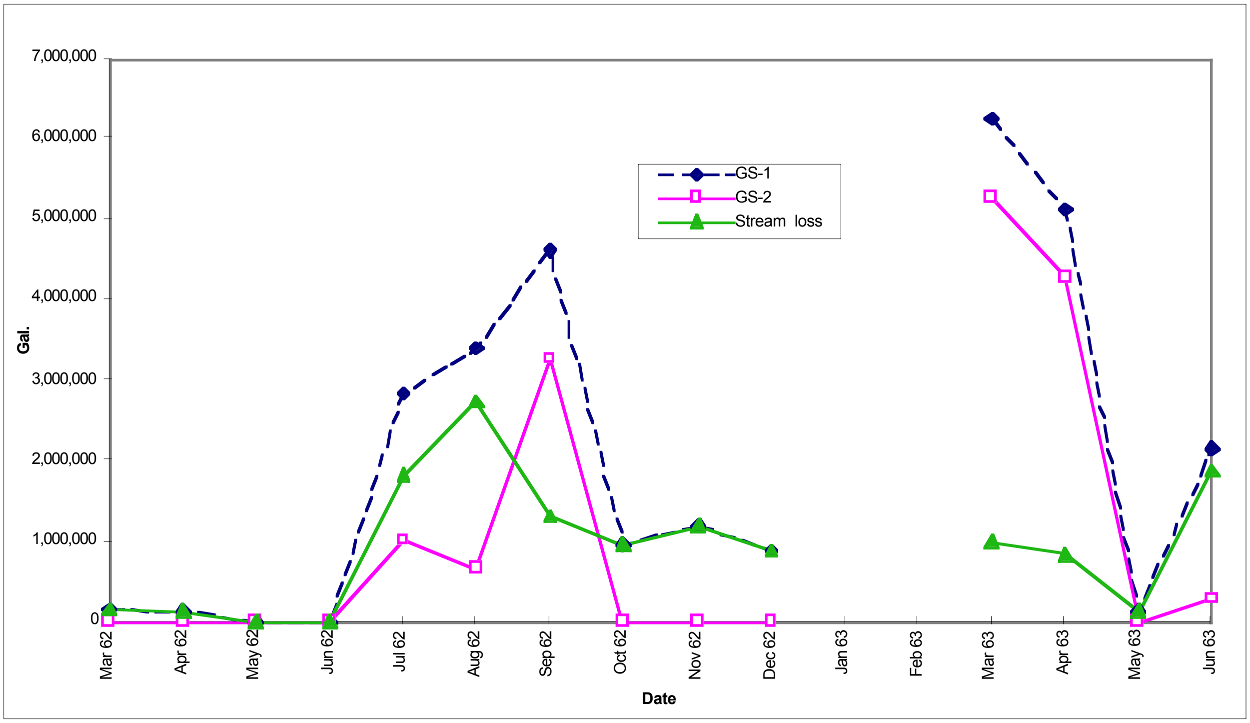
GS-2 was subsequently removed, and a new gaging station was installed at GS-2 circa 1974. Operating a gaging station in Mortandad Canyon is problematic because of sediment deposition in the gauges by periodic floods. A large precipitation event was recorded on September 15, 1974, at the new GS-2; at that time the flow volume and suspended sediment load in the water were measured. The results of the water sampling were reported by Hakonson et al. (1976, 8920). GS-2 is still present in Mortandad Canyon west of well MCO-4; however, a flood in 1987 eroded a new channel around the gaging station, and the stream channel is now approximately 3 ft (0.91 m) below the level of the gauge.

Another gaging station, GS-3, was constructed (date unknown) between MCO-5 and MCO-6 approximately 2000 ft (610 m) east of GS-2. No flow records are available from this gaging station, probably because of the extreme difficulty in controlling sediment deposition in the gauge.



Source Purtymun 1964, 11822

Figure 3.6.1-1. Monthly surface water flows at GS-1 compared with cooling water discharges and precipitation.



Source Purtymun 1964, 11822

Figure 3.6.1-2. Monthly surface water flow at GS-1 and GS-2.

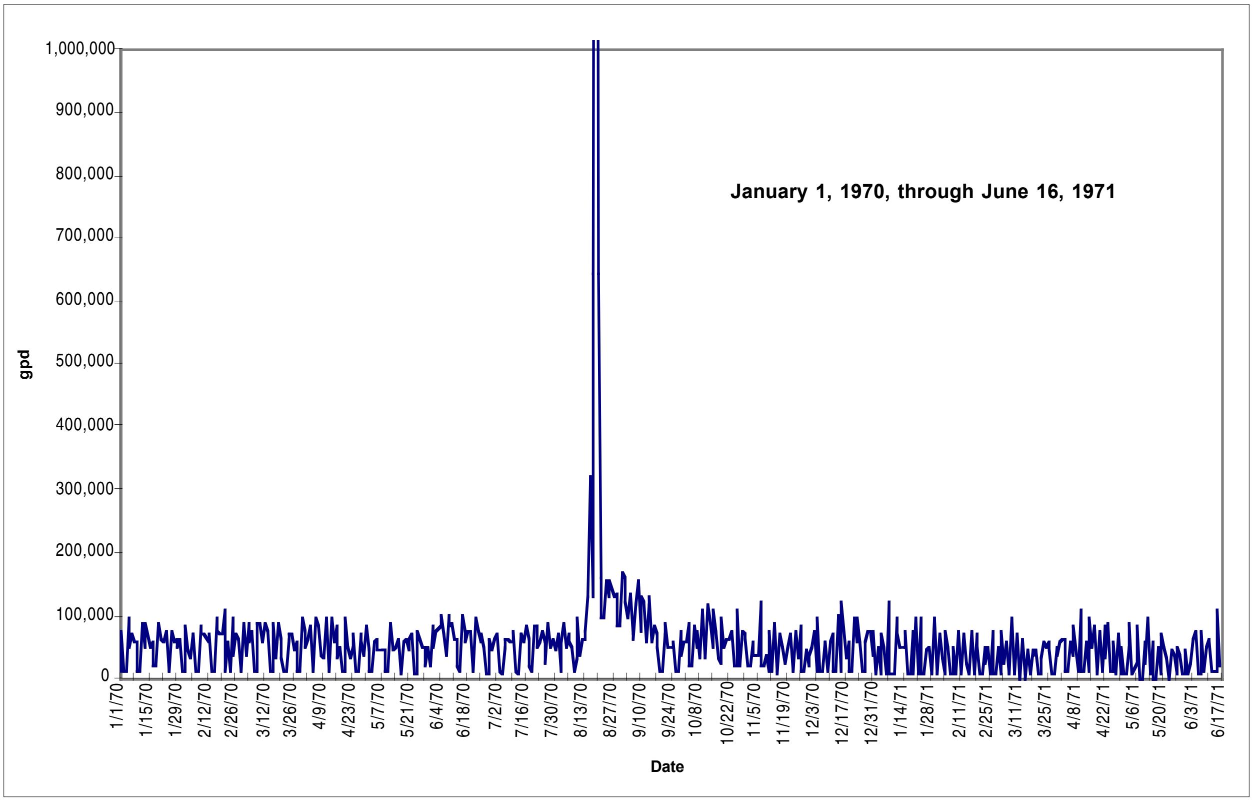
Daily records of streamflow at GS-1 are available for January 1970 through June 1971 and May 1995 through September 1996. The daily flow volumes are shown on Figure 3.6.1-3. The daily flow records show the regular contribution to streamflow from the TA-50 RLWTF and TA-48 discharges as well as the seasonal flow contribution from precipitation. The streamflow records document one large precipitation event in 1970, whereas several precipitation events are recorded in 1995 and 1996. The routine, daily flow volumes from Laboratory discharges are apparent on the figures. In 1970 and 1972 daily flow volumes from Laboratory discharges averaged more than 50,000 gpd, whereas in the winter of 1995 to 1996 the daily flow volumes averaged less than 7000 gpd. The difference in flow volumes is likely due to changes in Laboratory operations, primarily decreases in cooling tower discharges and decreased discharges from the TA-50 RLWTF (see Section 2.4.6 in Chapter 2 of this work plan). During the 1970s and 1980s surface water in Mortandad Canyon normally flowed about as far as well MCO-4. However, during the 1990s streamflow normally has not extended much beyond well MCO-3.

Between MCO-3 and MCO-4 the Mortandad Canyon stream channel flows through a deep, narrow canyon. Downstream of MCO-4 the canyon widens and the alluvium thickens. At MCO-5 and TW-8 the canyon floor is more than 100 ft (30.5 m) wide, and the alluvium is approximately 30 ft (9.1 m) thick in the center of the canyon. Near of MCO-6, the canyon floor is approximately 300 ft (91.4 m) wide and the alluvium is approximately 40 ft (12.2 m) thick. This large volume of alluvium in the lower canyon is largely unsaturated except for a relatively thin zone of saturation at the base of the alluvium and/or within the Cerro Toledo interval. Most normal streamflow volumes are absorbed by the alluvium before they reach the MCO-5 area. Occasional heavy rains during the summer cause abnormally high streamflow volumes and velocities that rapidly saturate the alluvium in the middle canyon and, occasionally, override unsaturated alluvium and continue downstream. These events transport and redistribute sediments downstream and redeposit sediment in the lower canyon. Downstream of the MCO-5 area, the occasional high streamflows tend to overflow the stream channel and spread out, depositing the sediment load in a broad fan along the floor of the canyon.

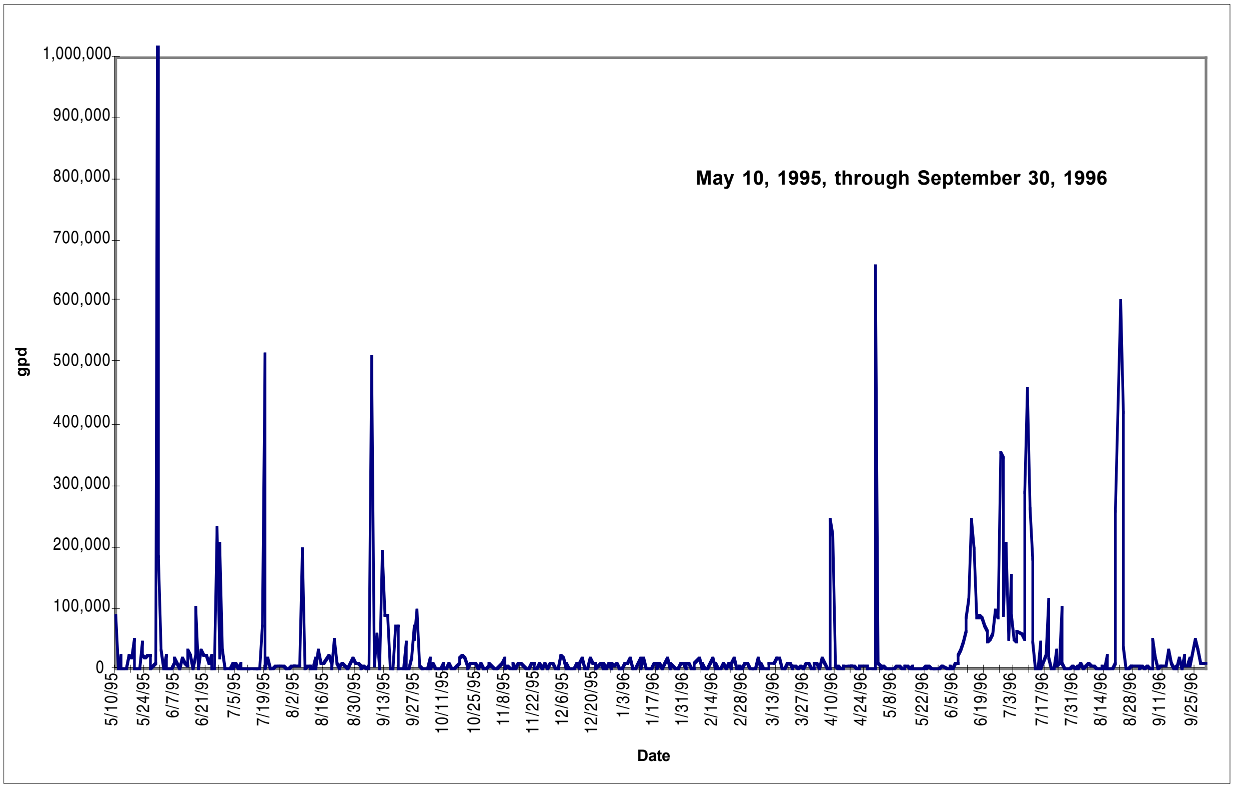
Past storm events occasionally washed out the access road to the wells in the middle canyon. This occurred in 1987 when high streamflows continued as far east as the sediment traps. A storm event on June 7, 1987, produced a record 50-yr, 2-h rainfall totaling 2.16 in. (54.9 mm) of precipitation. The rainfall resulted in the largest runoff event in Mortandad Canyon since hydrologic studies of the canyon began in 1960. The peak discharge in the upper canyon at GS-1 was estimated to be 160 cubic feet per second (cfs). The peak discharge into the sediment traps was estimated to be about 100 cfs. The runoff filled two of the sediment traps, and water flowed into the third sediment trap. The estimated volume of runoff was 930,000 gal. (3520 m^3) (ESG 1988, 6877). This storm event caused wells MCO-3 and MCO-4, GS-2, and the access road to the wells in the middle canyon to wash out.

Before the current sediment traps were installed in 1986, one of the largest documented runoff events occurred in the canyon in November 1978. A large precipitation event was preceded by several days of snow and rain that saturated the channel, which together caused flow in the channel as far east as well MCO-9. Flow at GS-1 was approximately 102 cfs (Purtymun 1994, 52951, p. 132–5).

After the 1987 flood, the Laboratory channelized and diverted part of the stream to prevent wash-out of the roads and wells. The stream channel was deepened and straightened, and an embankment was constructed along the north side of the channel from near well MCO-5 to near moisture access tube MCM-5.1. Downstream of MCM-5.1, a diversion channel was constructed along the north edge of the canyon floor to near MCM-6E. Figure 3.6.1-4 shows the location of the stream diversion channel. The previous, natural stream channel was approximately in the center of the canyon floor and was a relatively shallow, narrow, semibraided stream channel system that sheet-flooded regularly. Well MCO-6 was installed near the center of the old stream channel.

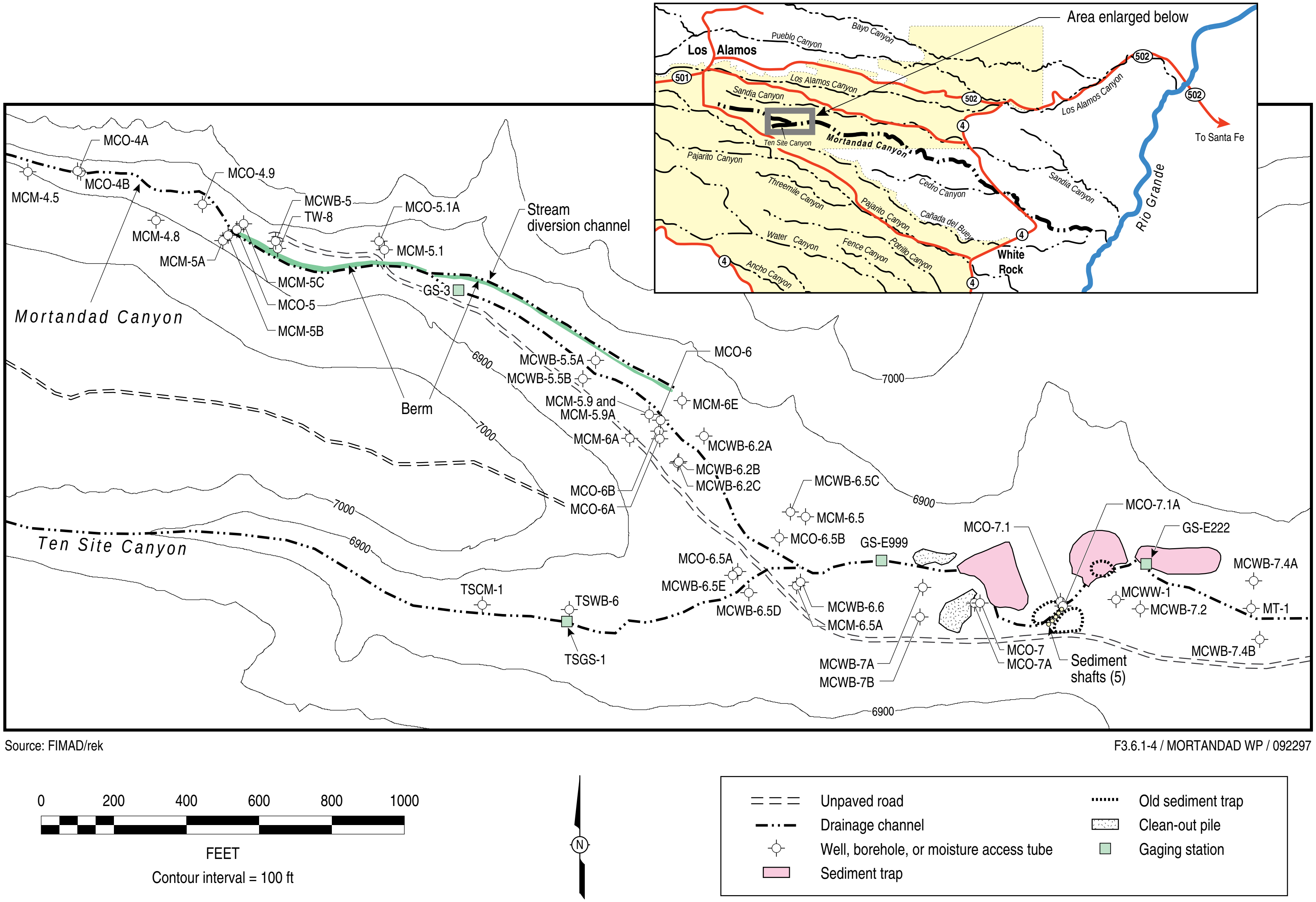


Source: USGS data sheets (courtesy of the Hydrology section of Laboratory group ESH-18)



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

Figure 3.6.1-3. Daily discharge at GS-1.



Source: FIMAD/rek

F3.6.1-4 / MORTANDAD WP / 092297

Figure 3.6.1-4. Wells, boreholes, moisture access tubes, gaging stations, and stream diversion channel in middle Mortandad Canyon.

Since construction of the diversion channel in 1987, the stream flows into the diversion channel and discharges to a nonchannelized, relatively flat canyon floor area approximately 600 ft (183 m) upstream from the confluence with Ten Site Canyon. At the confluence with Ten Site Canyon, the natural stream channel is approximately 1 to 2 ft (0.30 to 0.61 m) deep and approximately 3 ft (0.91 m) wide; it deepens and widens downstream toward the sediment traps. Immediately upstream of the sediment traps, the stream channel is approximately 5 ft (1.5 m) deep and 8 ft (2.4 m) wide with near vertical banks incised into the alluvium. Upstream from the sediment traps the alluvium is approximately 300 ft (91 m) wide and approximately 50 ft (15 m) deep at the center of the canyon.

In 1996 two new gaging stations were installed in lower Mortandad Canyon by the Laboratory and the USGS. GS-E999 was installed in the main channel downstream of the confluence with Ten Site Canyon and approximately 250 ft (76 m) upstream from the first sediment trap (some streamflow may divert around this gaging station before entering the sediment traps). GS-E222 was installed at the overflow from Sediment Trap No. 3. Figure A-2 in Appendix A of this work plan shows the location of the gaging stations. During 1996 no flow was measured at either GS-E999 or GS-E222 (Shaull et al. 1996, 56020).

Between the sediment traps and the Laboratory boundary no well developed stream channel is present. Since monitoring of the canyon began in 1960, and before the sediment traps were installed, surface flow from the upper canyon had extended as far downstream as approximately MCO-11 on July 31, 1968 (Purtymun 1994, 52951, p. 40-1). After the sediment traps were installed, surface flow has rarely extended beyond the sediment traps. In 1991 all three sediment traps were filled to capacity, and flow extended beyond the sediment traps on two occasions (July 24, 1991, and August 6, 1991) when evidence of surface flow was noted as far downstream as approximately 650 ft (198 m) east of Sediment Trap No. 3 (Environmental Protection Group 1993, 23249). In 1995 surface flow from the upper canyon extended as far as Sediment Trap No. 1 on one occasion, causing this sediment trap to partially fill with water. Flow did not reach GS-E999 or the sediment traps during 1996 (Shaull et al. 1996, 56020).

Gaging station GS-8313024 was installed in Mortandad Canyon on Laboratory property immediately upstream from the Laboratory boundary in October 1993 (Shaull et al. 1996, 56019). No flow has been recorded at this station since October 1, 1993. Since monitoring in Mortandad Canyon began in 1960 and since the TA-50 RLWTF outfall began discharging in 1963, no continuous streamflow from the discharges has been documented as far east as the Laboratory boundary (Stoker et al. 1991, 7530). During periods of heavy rainfall, locally-derived sheet runoff collects in small rills and channels, and localized flow crosses the Laboratory boundary.

3.6.2 Normal Seasonal Runoff and Contributions from TA-48 and TA-50

Surface water runoff into the canyon system varies with the amount of seasonal precipitation on the watershed. Runoff and wastewater discharges from TA-48 and TA-50 are monitored by streamflow past GS-1. Between 1967 and 1978 the volume of runoff was highly variable, whereas the volume of wastewater from TA-48 and the TA-50 RLWTF (see Table 2.4.6-1 in Chapter 2 of this work plan) remained relatively constant at about 1.5 and 13 million gal. (5680 and 49,200 m^3*) per year, respectively. During this period, the total flow at GS-1 averaged 22.7 million gal. (85,920 m*^{3}*) per year (Purtymun et al. 1983, 6407). For the period, the annual percentage of the total flow through GS-1 from the TA-50 RLWTF discharges ranged from 36 to 80% and averaged 62%.*

For the 1996 water year (October 1, 1995, through September 30, 1996) a total of 9.27 million gal. (35,100 m^3*) were recorded at GS-1, although many of the daily measurements are estimated values (Shaull et al. 1996, 56020). During this period approximately 4.6 million gal. (17,400 m*^{3}*) may be attributable to TA-50*

RLWTF discharges (using the 1995 flow volume) assuming little or no infiltration into the bedrock in the 700 ft (213 m) of channel between the TA-50 RLWTF outfall and the gaging station. Therefore, approximately 4.67 million gal. (17,700 m^3) may be attributable to natural precipitation runoff and other Laboratory discharges. Of the total volume of water passing GS-1 during this period, about 50% may be from the TA-50 discharges. This is slightly less than the average contribution (62%) reported by Purtymun et al. (1983, 6407) for the TA-50 discharges during the 1960s and 1970s; however, it is within the range observed during the earlier period and is not inconsistent when considering the natural variability of precipitation and runoff.

3.6.3 Flooding Potential

The Laboratory is conducting ongoing studies of expected flood size in the Los Alamos region (McLin 1992, 12014). These studies involve the use of computer-based models developed by the United States Army Corps of Engineers Hydrologic Engineering Center to project the effects of severe thunderstorms on all the watersheds in the Los Alamos area. The modeling effort predicts the effects of storm runoff on flood elevations within the canyons and on different Laboratory areas and structures. Precipitation totals and floodplain elevations have been projected for 2-, 5-, 10-, 25-, 50-, and 100-yr storms (LANL 1995, 50124).

The theoretically estimated 24-h runoff for a 2-yr recurrence 6-h storm for Mortandad Canyon at the Laboratory boundary with San Ildefonso Pueblo land is less than 1 acre-foot (1230 m^3) (McLin, 1992, 12014). This amount of flow would not be expected to extend to the confluence with the Rio Grande (Stoker 1993, 56021). The conservative nature of the calculated estimates can be judged from the fact that there has not been any continuous flow from upper and middle Mortandad Canyon to or across the eastern Laboratory boundary since formal monitoring began in 1960. However, it was reported that after an especially heavy rainfall season in 1952, flow from Mortandad Canyon may have reached as far east as state road NM4 near White Rock (Aeby 1952, 741; Stoker and Koch 1996, 56027). The highest precipitation recorded in any month at Los Alamos was 11.18 in. during August 1952 (Bowen 1990, 6899, Table 1.1).

Runoff from Cañada del Buey is more likely to reach the Rio Grande than is runoff from upper and middle Mortandad Canyon. The theoretically estimated 24-h runoff at the eastern Laboratory boundary for a 2-yr recurrence 6-h storm in the subdrainage of Cañada del Buey within the Laboratory boundary is less than 1 acre-foot (1230 m^3). The theoretically estimated 24-h runoff for a 2-yr recurrence 6-h storm in all of Cañada del Buey at the Rio Grande is about 6 acre-feet (7400 m^3) (McLin 1992, 12014).

3.6.4 Infiltration

Surface water entering the canyon is runoff, discharges from cooling processes at TA-48, and discharges from the TA-50 RLWTF. The runoff and discharges infiltrate into the alluvium to recharge a relatively small body of groundwater overlying the tuff in the middle and lower canyon. As the water moves through the alluvium, some is lost to ET, and the remainder infiltrates into the underlying tuff and/or the Cerro Toledo interval.

Investigations of streamflow and infiltration into the alluvium in Mortandad Canyon were performed beginning in 1960 (Abrahams et al. 1962, 8140; Baltz et al. 1963, 8402; Purtymun 1967, 8987; Purtymun and Kunkler 1969, 11783; Purtymun 1974, 5476). Two weirs were constructed in upper Mortandad Canyon circa 1962 to monitor the surface flow volume and to determine the amount of water infiltrating into the alluvium. Early estimates of natural infiltration from the stream channel into the underlying tuff obtained from moisture measurements of the tuff indicated that little water moved into the tuff from the saturated alluvium (Baltz et al. 1963, 8402).

An inventory of surface water and water in the alluvium obtained between July 1963 and June 1964 indicated that more water was lost into the tuff in the upper canyon than in the middle or lower canyon. This was thought to be the case because the alluvium overlying the tuff in the upper canyon is more permeable (silty sand) than that in the middle and lower canyon (sandy silt and clay). The movement of water in the tuff was determined to be downward into the unsaturated volcanic rocks (Purtymun 1967, 8987). The average loss of surface water and alluvial groundwater caused by ET and infiltration into the tuff between July 1966 and June 1967 was estimated to be approximately 2 million gal. (7570 m^3) per month (Purtymun and Kunkler 1969, 11783). Water-balance study results are discussed further in Section 3.7.2.5.

An investigation into the disposition of wastewater discharges was performed after 10 Ci of tritium was released into the canyon in 1969 (Purtymun 1974, 5476). At that time, it was estimated that 43% of the tritium was either lost from the canyon by infiltration of the alluvial groundwater into the underlying strata or was suspended with soil moisture above the alluvial groundwater.

Monitoring results for the surface water flow between GS-1 and GS-2 and the groundwater in storage in the alluvium from 1967 through 1978 were presented by Purtymun et al. (1983, 6407). A water balance was made using surface water (wastewater discharge and runoff) inflow, storage, and the annual change in storage. The annual surface water inflow for the period studied was about equal to surface water and groundwater losses in the canyon. An increase in surface water inflow into the canyon resulted in increased storage in the alluvium and increased water losses. The reverse occurred with a decrease in surface water inflow. Therefore, with annual changes in the volume of surface water inflow, storage in the alluvium varies as does the annual water loss from the alluvium. The surface water and groundwater losses from Mortandad Canyon between 1967 and 1978 ranged from 13 to 40 million gal. (49,200 to 151,400 m^3) annually. The distribution of the total water in storage in the alluvium was determined to average 18% upstream of well MCO-4, 23% between MCO-4 and MCO-6, and 59% downstream of well MCO-6 (Purtymun et al. 1983, 6407).

Moisture data on the tuff that underlies the alluvium (Stoker et al. 1991, 7530) showed a variable moisture content dependent on the underlying stratigraphy. Tritium analysis in the underlying units at the borehole for moisture access tube MCM-5.9A shows variability not correlated to the moisture content (see Section 3.6.3). Beneath the alluvium, the Tshirege Qbt 1g unit and the Cerro Toledo interval contain relatively low moisture, averaging approximately 20% moisture by weight, which contains more than 100 nCi/L of tritium. However, a relatively moist zone in the Cerro Toledo interval (described as the lower Tshirege 1g Member by Stoker et al. 1991, 7530) contains greater than 40% moisture by weight but only 1 to 10 nCi/L of tritium (see Figure 3.5.3-10). Below this interval, but still in the Cerro Toledo, the moisture content increases to 50 to 60%, by weight, and the tritium concentration increases to approximately 100 nCi/L. The zone of relatively high moisture content and low tritium content is interpreted to be a clay zone within the Cerro Toledo interval that, because of relatively low hydraulic conductivity, contains older water with a lower tritium concentration than that of the surrounding sediments, which have been invaded by tritium-contaminated waters.

The moisture content of the Otowi Member in the borehole for moisture access tube MCM-5.9A is less than 20%; it contains tritium concentrations greater than 30 nCi/L to a depth of approximately 180 ft (55 m), below which the tritium concentration decreases to less than 10 nCi/L to the depth of the borehole, 195 ft (59 m).

The moisture and tritium data from borehole MCM-5.9A suggest that infiltration into the underlying tuff may be restricted and/or affected locally by natural stratigraphic and lithologic variations in the bedrock tuff and the Cerro Toledo interval and, possibly, by preferential horizontal flow of water in certain stratigraphic units. The moisture and tritium data also indicate that contaminated water, infiltrating as vapor, may have moved as deep as approximately 150 ft (46 m) below the alluvial groundwater (Stoker et al. 1991, 7530).

In 1993 tritium concentrations measured at the top level of the regional aquifer in TW-8 were elevated (89 pCi/L), which suggests the possibility of local migration of alluvial water down the well bore at TW-8 (Gallaher 1995, 54716) and/or saturated or unsaturated flow to the regional aquifer beneath Mortandad Canyon. Possible flow pathways for recharge to the regional aquifer are discussed in Chapter 4 of this work plan.

3.6.5 Surface Water Quality and Contaminant Data

ESH-18 personnel routinely collect surface water samples at GS-1 for water quality analyses. Because this is the only location where surface water samples are collected and because of the close association between the surface water and the alluvial groundwater downstream from GS-1, the occurrence of contaminants in the surface water are presented and discussed in Section 3.7. Generally, the reported quality of surface water at GS-1 does not reflect the quality of the TA-50 RLWTF discharge because the surface water samples are collected at times of high runoff in the canyon. The mixing effect of the natural runoff and the discharges can be seen in the data on alluvial groundwater quality at well MCO-3.

Prior investigations of the surface water quality in Mortandad Canyon are summarized and briefly discussed below.

Between 1966 and 1969 the Laboratory Environmental Group (H-8) conducted a regional survey of tritium in surface water (and some groundwater) in the Los Alamos area in cooperation with the USGS and the Atomic Energy Commission (AEC). A total of 36 surface water samples were collected below the TA-50 RLWTF outfall (at GS-1, MCS-3.8, MCS-3.9, and GS-2). Tritium activities ranged from nondetect to 100 nCi/L; the maximum concentration was observed at GS-1. Surface water at GS-2 had lower tritium activities than would have been expected based on those actually measured in the TA-50 RLWTF discharge (Purtymun 1973, 4971). Because discharges do not normally reach downstream as far as GS-2, only periods of high precipitation and natural runoff create enough flow to extend that far.

Several large thunderstorm runoff events during late July and early August 1991 filled all three sediment traps to capacity. Sediment Trap No. 3 overflowed on two separate occasions. An estimated 20,000 to 30,000 gal. (76 to 114 m^3) of runoff flowed a short distance downstream of the sediment traps during this time. These flows terminated approximately 650 ft (198 m) east of Sediment Trap No. 3 (Environmental Protection Group 1993, 23249). Samples of water standing in each of the sediment traps after the two overflows were collected and filtered. The filtered samples and the filters containing suspended sediments were analyzed separately. The results of radiochemical analyses are shown in Table 3.6.5-1. The results are similar to those obtained in previous years after major runoff events and similar to those obtained in water samples collected from the sediment traps in 1991 (Table 3.6.5-2).

The concentrations of radionuclides in the suspended sediments are comparable with the maximum concentrations found previously on dry stream bed sediments in Mortandad Canyon (see Section 3.4.4). The suspended sediments are predominantly finer particles and therefore exhibit somewhat higher concentrations than those found in the stream bed sediments. The concentrations of ^{238}*Pu and* ^{239}*Pu in* *the suspended sediment range from 10,000 to 100,000 times higher than the concentrations in the water (pCi/g divided by pCi/mL), with an average of 40,000 times higher, which is on the high side of the range of K_ds for plutonium found by Stoker et al. (1991, 7530) as discussed in Section 3.5.4. The high values of the apparent K_ds illustrate the affinity of the contaminants for the sediments, particularly the finer-grained sediments.*

TABLE 3.6.5-1

RADIONUCLIDES IN SURFACE WATER AND SUSPENDED SEDIMENT IN THE SEDIMENT TRAPS (1987)

Location	Gross-Alpha		Gross-Beta		Tritium		Total U		Pu-238		Pu-239/240		Cs-137	
Suspended Sediment														
	pCi/g	Unc[a]	pCi/g	Unc	nCi/L	Unc	µg/g	Unc	pCi/g	Unc	pCi/g	Unc	pCi/g	Unc
Sediment Trap No. 1	*NR[b]*	*NR*	*NR*	*NR*	*NR*	*NR*	*NR*	*NR*	*39.2*	*1.72*	*137*	*5.17*	*NR*	*NR*
Sediment Trap No. 2	*NR*	*NR*	*NR*	*NR*	*NR*	*NR*	*NR*	*NR*	*31.1*	*1.43*	*107*	*4.13*	*NR*	*NR*
Sediment Trap No. 3	*NR*	*NR*	*NR*	*NR*	*NR*	*NR*	*NR*	*NR*	*21.5*	*1.04*	*75.3*	*2.97*	*NR*	*NR*
Surface Water in Sediment Traps														
	pCi/L	Unc	pCi/L	Unc	nCi/L	Unc	µg/g	Unc	pCi/L	Unc	pCi/L	Unc	pCi/L	Unc
Sediment Trap No. 1	*5.0*	*1.0*	*35*	*4.0*	*9*	*1*	*2.0*	*1.0*	*0.23*	*0.225*	*1.24*	*0.331*	*-18*	*59*
Sediment Trap No. 2	*1.5*	*0.7*	*26*	*3.0*	*4.7*	*0.6*	*1.0*	*1.0*	*0.767*	*0.334*	*1.34*	*0.363*	*26*	*40*
Sediment Trap No. 3	*2.4*	*0.9*	*17*	*2.0*	*5.9*	*0.7*	*1.0*	*1.0*	*-0.212*	*0.150*	*0.265*	*0.206*	*3*	*59*

a. Unc = uncertainty in counting statistics

b. NR = not reported

Source: Environmental Protection Group 1993, 23249

Concentrations of ^{137}Cs in suspended sediments were not measured in this study. Data collected in Sediment Trap No. 1 by the NMED DOE Oversight Bureau in 1994 showed ^{137}Cs concentrations of 27 and 57 pCi/g in the fine fraction of sediments (see Table 3.4.4-2). The ^{238}Pu/^{137}Cs correlation (Figure 3.4.4-4) would suggest ^{137}Cs concentrations ranging from approximately 90 to 130 pCi/g. Therefore, ^{137}Cs concentrations would appear to be 500 to 1000 times higher in suspended sediments than in water, which is in agreement with the K_ds for ^{137}Cs reported by Kung et al. (1995, 56044).

3.6.6 Data Requirements for Understanding the Surface Water Hydrology

Accurate and frequent measurements of discharge along the reach from GS-1 to near well MCO-3 are needed to accurately measure stream loss.

TABLE 3.6.5-2

RADIONUCLIDES IN SURFACE WATER AND SUSPENDED SEDIMENT IN THE SEDIMENT TRAPS (1991)

Location	Gross-Beta		Tritium		Pu-238		Pu-239/240		Am-241		Cs-137	
Suspended Sediment												
July 24, 1991												
	pCi/L	Unc[a]	nCi/L	Unc	pCi/g	Unc	pCi/g	Unc	pCi/g	Unc	pCi/g	Unc
Sediment Trap No. 1	*NR*[b]	*NR*	*NR*	*NR*	*20*	*2*	*61*	*6*	*NR*	*NR*	*NR*	*NR*
Sediment Trap No. 2	*NR*	*NR*	*NR*	*NR*	*7*	*3*	*21*	*10*	*NR*	*NR*	*NR*	*NR*
Sediment Trap No. 3	*NR*	*NR*	*NR*	*NR*	*12*	*7*	*36*	*18*	*NR*	*NR*	*NR*	*NR*
August 6, 1991												
Sediment Trap No. 1	*NR*	*NR*	*NR*	*NR*	*37*	*5*	*120*	*15*	*NR*	*NR*	*NR*	*NR*
Sediment Trap No. 2	*NR*	*NR*	*NR*	*NR*	*35*	*5*	*110*	*15*	*NR*	*NR*	*NR*	*NR*
Sediment Trap No. 3	*NR*	*NR*	*NR*	*NR*	*33*	*5*	*102*	*15*	*NR*	*NR*	*NR*	*NR*
Surface Water in Sediment Traps												
July 24, 1991												
	pCi/L	Unc	nCi/L	Unc	pCi/L	Unc	pCi/L	Unc	pCi/L	Unc	pCi/L	Unc
Sediment Trap No. 1	*110*	*10*	*7.2*	*0.8*	*0.50*	*0.05*	*1.7*	*0.1*	*2.33*	*0.12*	*91*	*61*
Sediment Trap No. 2	*88*	*9*	*7.6*	*0.8*	*0.76*	*0.06*	*2.08*	*0.12*	*3.87*	*0.17*	*155*	*64*
Sediment Trap No. 3	*33*	*3*	*3.1*	*0.04*	*0.64*	*0.06*	*1.81*	*0.11*	*1.72*	*0.10*	*76*	*56*
August 6, 1991												
Sediment Trap No. 1	*55*	*5*	*5.7*	*0.7*	*0.46*	*0.07*	*2.03*	*0.28*	*1.50*	*0.10*	*98*	*66*
Sediment Trap No. 2	*51*	*6*	*2.0*	*0.4*	*0.35*	*0.05*	*1.19*	*0.09*	*1.21*	*0.10*	*80*	*65*
Sediment Trap No. 3	*40*	*4*	*1.2*	*0.3*	*0.37*	*0.08*	*0.96*	*0.25*	*1.02*	*0.09*	*36*	*60*

a. Unc = uncertainty in counting statistics

b. NR = not reported

Source: Environmental Protection Group 1993, 23249

A determination of the relative contribution of surface water flowing into middle Mortandad Canyon from upper Mortandad Canyon versus surface water from Effluent Canyon is also needed. The possibility of installing an additional gaging station in Mortandad Canyon upstream of the confluence with Effluent

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 stormwater runoff.

3.7 Hydrogeology

This section presents a summary of prior investigations of the hydrogeology of the Mortandad Canyon system and discusses the hydrogeology of the known saturated zones located in the alluvium and in the regional aquifer. No intermediate perched zones have been found in the Mortandad Canyon area to date.

Groundwater pathways in the Mortandad 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 (0.1 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; Rogers et al. 1996, 54714). In addition to tritium, other contaminants, particularly chloride, nitrates, ^{241}Am, ^{137}Cs, ^{238}Pu, ^{239,240}Pu, and ^{90}Sr, have been documented in the alluvial groundwater as a result of discharge from the TA-50 RLWTF. The fate and transport of these contaminants in Mortandad Canyon has been the subject of investigations since the early 1960s.

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. Mortandad Canyon receives inflow from precipitation and several NPDES-permitted discharges; the largest is the TA-50 RLWTF. In the upper canyon, from about well MCO-2 to near well MCO-3, discharges flow nearly continuously in the channel, and the thin alluvium is almost always saturated. Alluvium in floodplains 3 to 4 ft (0.91 to 1.2 m) above the stream channel through this reach are not saturated but probably contribute to storage. Downstream from MCO-3 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 well MCO-5 are usually approximately 20 ft (6.1 m), at well MCO-7 approximately 30 ft (9.1 m), and in the MCO-8 to MT-4 area approximately 60 to 70 ft (18.3 to 21.3 m) below ground surface. Borehole MCC-8.2 encountered groundwater at 74 ft (22.6 m), and groundwater may have been encountered in the borehole for well MCO-13 at 105 ft (32.0 m) below ground surface.

During periods of precipitation and increased streamflow, the surface water infiltrates into the sediments as the stream front moves downstream and the alluvium becomes saturated. Baltz et al. (1963, 8402) investigated the streamflow and infiltration characteristics of Mortandad Canyon during 1961 and 1962 and made the following observations.

> *Streamflow began in March, because the thin alluvium above line 4 [MCO-4] was unable to absorb and transmit all the snowmelt water. The front of the stream advanced eastward in March as the stream saturated, or partly saturated, the alluvium immediately subjacent to the streambed, causing a temporary perching effect where the surface flow was large enough to exceed the rate of infiltration. Infiltration occurred at the front of the stream and in the channel throughout the reach upstream from the front. However, the front of the stream advanced eastward more rapidly than did the front of the zone of complete saturation in the alluvium. This was observed at TW-8A where the*

front of the stream passed the well on or about April 1, but the water level in the well indicated that the alluvium was not saturated to the level of the stream channel until April 13 or 14.

The rate of lateral movement through the alluvium in the reach upstream from the front was sufficiently slow to cause a small mound of groundwater to form in the alluvium directly beneath and parallel to the channel. The mound existed from the point upstream where the alluvium was saturated to the level of the stream channel to some point west of the front of the surface stream. The sides of the mound sloped away from the channel . . . The eastern front of the mound also sloped steeply near the front of the stream.

A streamflow of about 250 gpm was measured near line 3 [MCO-3] on March 27, 1961 when the flow in the channel was near maximum for the season and the front of the stream was progressing downstream between lines 4 and 5 [MCO-4 and MCO-5]. The flow on March 27 diminished eastward to a point a short distance upstream from line 5, where, because of infiltration into the alluvium, it decreased from about 75 gpm to no flow within a reach of about 15 yards. The front of the stream progressed downstream until April 17 or 18, when it reached a point about 100 yards east of TW-8. Here the volume of alluvium was great enough to absorb all of the surface water until the snowpack in the upper part of the canyon was depleted.

. . . No streamflow was observed in the lower part of Mortandad Canyon below line 6 at any time during the study. The volume of porous and permeable alluvium in the lower part of the canyon was sufficient to accommodate the infiltrating streamflow during the spring of 1961. Presumably there is intermittent streamflow in stretches of the lower part of the canyon during heavy summer rains, but the discontinuous nature of the stream channels indicates that this water infiltrates rapidly and does not flow far at the surface.

. . . The winter melt water in the upper part of the canyon may have infiltrated directly downward through the thin soil at the top of the alluvium, or it may have trickled into the stream channel and then infiltrated the alluvium. At the time of the April 11-14 moisture measurements at lines 3, 4, and 5, the moisture content within the capillary fringe above the zone of saturation was 20 to 30 percent by volume. The moisture content above the capillary fringe was 10 to 20 percent by volume, and the moisture content of the upper 1 foot of soil was as much as 30 percent at some places, particularly on the shaded south side of the canyon floor, which remained frozen during the colder months.

. . . No surface flow was observed in the broad lower part of Mortandad Canyon below line 6. Much of the snow in this part of the canyon evaporated or sublimated during the period of study. Thin clayey soil at the surface may have inhibited infiltration of the melt water to some extent, because the clay absorbs water and swells slightly to form a less pervious soil. The increase in moisture content of the soil and upper part of the alluvium at lines 6 and 8 and MCM-10 indicates that some water infiltrated during the melting of winter snows and heavy spring snows. The maximum depth of infiltration of this water was 6 or 7 feet. Most of the water infiltrated during the relatively cool months of March and early April, when there was alternate freezing and thawing in the canyon and when the evaporation was low.

Measurements in May and June show that some of the water in the top several feet of soil and alluvium drained downward toward the 8-foot depth. Below the 8-foot level there are practically no changes in the moisture curves that can be attributed to downward movement of water that infiltrated near the access tubes, and the June decline in moisture content above the 8-foot level probably is due mainly to evapotranspiration.

> *The moisture content below a depth of about 6 to 8 feet, and above the water table, is 8 to 10 percent at access tube MCM-6B and 6.5 percent at MCM-6C. The lack of increase in the moisture content between depths of about 6 and 20 feet suggests that the low content is the result of a long-term redistribution of moisture rather than annual wetting and draining in the upper sand unit of the alluvium. Similarly, the low moisture content of 6.5 percent in the upper part of the alluvium around MCM-8C and -8D suggests a long-term period of redistribution.*
>
> *. . . During heavy precipitation, small amounts of water undoubtedly enter the alluvium in the lower part of the canyon through the coarse alluvial fans at the mouths of side canyons. However, data from access tubes MCM-6A, -6E, -8A, and -8E, near the walls of the canyon, bottom in the Bandelier Tuff at relatively shallow depths beneath the floor of the canyon indicated that the moisture content of the tuff generally is less than 10 percent and commonly less than 5 percent. This low range of moisture content is common also in tuff beneath the soil on the mesas and probably indicates that little, if any, moisture percolates down through the soil into the tuff.*

Samples from the unsaturated part of the alluvium in boreholes drilled in Mortandad Canyon in 1990 and 1991 were analyzed for moisture content. Unsaturated alluvium in boreholes for moisture access tubes MCM-5.1 and MCM-5.9A, borehole MCC-8.2, and the borehole for well SIMO generally contained less than 10% moisture by weight. The moisture content increased in the capillary fringe above the saturated alluvium and ranged from approximately 15 to 20% moisture by weight. The moisture content of the saturated alluvium was measured to be approximately 20 to 30% by weight of the core material (Stoker et al. 1991, 7530).

3.7.2 Alluvial Groundwater

This section describes the wells that have been installed in Mortandad 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 Mortandad Canyon.

Laboratory discharge, combined with runoff, infiltrates through the stream channel and maintains a saturated zone in the alluvium that extends for approximately 2.2 mi (3.5 km) downstream of the TA-50 RLWTF outfall. The easternmost known extent of saturation in the alluvium is near wells MCO-8 and MCO-8.2 1 mi (1.6 km) west of the Laboratory boundary.

Water level measurements obtained in November 1996 at well MCO-13, located near the Laboratory boundary, showed that approximately 1 ft (0.30 m) of water was present in the bottom of the well. The source of this water was not immediately known; however, analyses of samples collected from this well by the NMED Oversight Bureau suggested that the alluvial groundwater in Mortandad Canyon may extend as far east as the Laboratory boundary. Reinterpretation of the bedrock stratigraphy may place the water encountered at MCO-13 in the Cerro Toledo interval rather than in the alluvium (see Section 3.7.2.4).

Figure A-2 in Appendix A of this work plan shows the locations of existing wells in and near Mortandad Canyon. Five tables in Appendix D of this work plan (Table D-1 through Table D-5) list the wells, boreholes, and moisture tubes; location and current status; location coordinates; construction information; stratigraphic information; and recent water level measurements. Much of the stratigraphic information provided when each of the boreholes was originally drilled was found to be inconsistent with that from adjacent boreholes and with current understanding of the stratigraphy of the area. Therefore, Table D-4 contains both the original stratigraphic information, obtained mostly from Purtymun (1995, 45344), and a revised set of *stratigraphic picks based on review of lithologic descriptions and on local and regional stratigraphy information. Discussion of some of the revised stratigraphy is presented in the following sections.*

3.7.2.1 Early Alluvial Groundwater Investigations

Historically, investigations have been performed in Mortandad Canyon to document the location and extent of alluvial groundwater and to understand the behavior of the groundwater system. Investigations began in 1960 when the USGS, in cooperation with the Laboratory and the AEC, drilled 33 boreholes in Mortandad Canyon. This investigation was implemented to determine the background sediment, surface water, and alluvial groundwater conditions before June 1963 when the TA-50 RLWTF began discharging to the canyon (for example, Baltz et al. 1963, 8402; Purtymun 1964, 11822). The 33 original boreholes were drilled in 1960 and 1961 at 10 locations along Mortandad Canyon from Effluent Canyon to near the Laboratory boundary.

Of the original 33 boreholes, 10 were cased with perforated pipe that was open to the alluvial groundwater zone and were completed as Mortandad Canyon observation (MCO) wells, and 23 were cased with capped plastic or polyvinyl chloride pipe to seal alluvial groundwater out of the tubes. These 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 Effluent Canyon, with numbers increasing downstream. Several of the boreholes were drilled in transect lines across the floor of the middle and lower canyon to monitor the alluvial groundwater conditions. These installations were assigned letters with the numerical system (for example, MCO-6B) to indicate multiple wells at a location. Boreholes subsequently drilled between the locations of earlier wells were designated with a decimal system. For example, MCO-5.1 and MCO-5.9 are between MCO-5 and MCO-6, and the decimal number indicates that MCO-5.1 is relatively close to MCO-5.

An abundance of information about the alluvial groundwater was obtained from the drilling, sampling, and analysis of these initial boreholes and wells (Abrahams et al. 1962, 8140; Baltz et al. 1963, 8402; Purtymun 1964, 11822). During drilling of the boreholes, it was recognized that the alluvium was composed of an upper unit of coarse, loose sand and an underlying unit of sandy clay. In the reach between MCO-4 and MCO-6, the canyon widens and the alluvium thickens, and the alluvium is recharged from underflow in the alluvium from upstream as well as from ephemeral flow in the channel. During heavy snowmelt and summer rain storms, the stream front extends down the canyon to the vicinity of MCO-5 and MCO-6. At the time of the early investigations in 1962 and 1963, the streamflow did not extend beyond MCO-6. Abrahams et al. (1962, 8140) made the following observations about recharge from the stream channel.

> *In this reach of the canyon the groundwater body in the coarse sand beneath the channel was built into a mound with a steep eastward-sloping front. This happened because the coarse sand absorbed water from the stream and transmitted it downward at a faster rate than the sandy clay absorbed the water and transmitted it laterally. Water filtering downward in the coarse sand beneath the eastern part of the stream was accreted to the front of the ground-water mound, causing the front of the ground-water mound in the coarse sand to advance eastward faster than the movement of the ground-water body as a whole.*
>
> *Late in April the front of the stream receded upstream as the snow pack in the upper part of the canyon was depleted. The front of the ground-water mound began to decay and flatten because it no longer received recharge directly from the stream. Subsequent changes of the water levels resulted from continued lateral subsurface drainage of groundwater from the upper part of the canyon to the lower part.*

After the wells were installed, water level measurements were obtained by the USGS from the MCO-series wells weekly or bimonthly between 1961 and 1965. Between 1966 and 1969 water level measurements were obtained at each of the wells approximately monthly. Beginning in 1970, no regular water level measurements were made, and water level information was usually obtained during routine surveillance sampling. The historic water level measurements obtained between March 1961 and June 1963 (before discharge from the TA-50 RLWTF) are shown in Figure 3.7.2-1. These water levels may be considered to represent background conditions, although cooling water discharges from TA-48 and TA-3 undoubtedly contributed to alluvial groundwater levels.

Purtymun (1964, 11822) made the following observations about the water level characteristics in the alluvial groundwater.

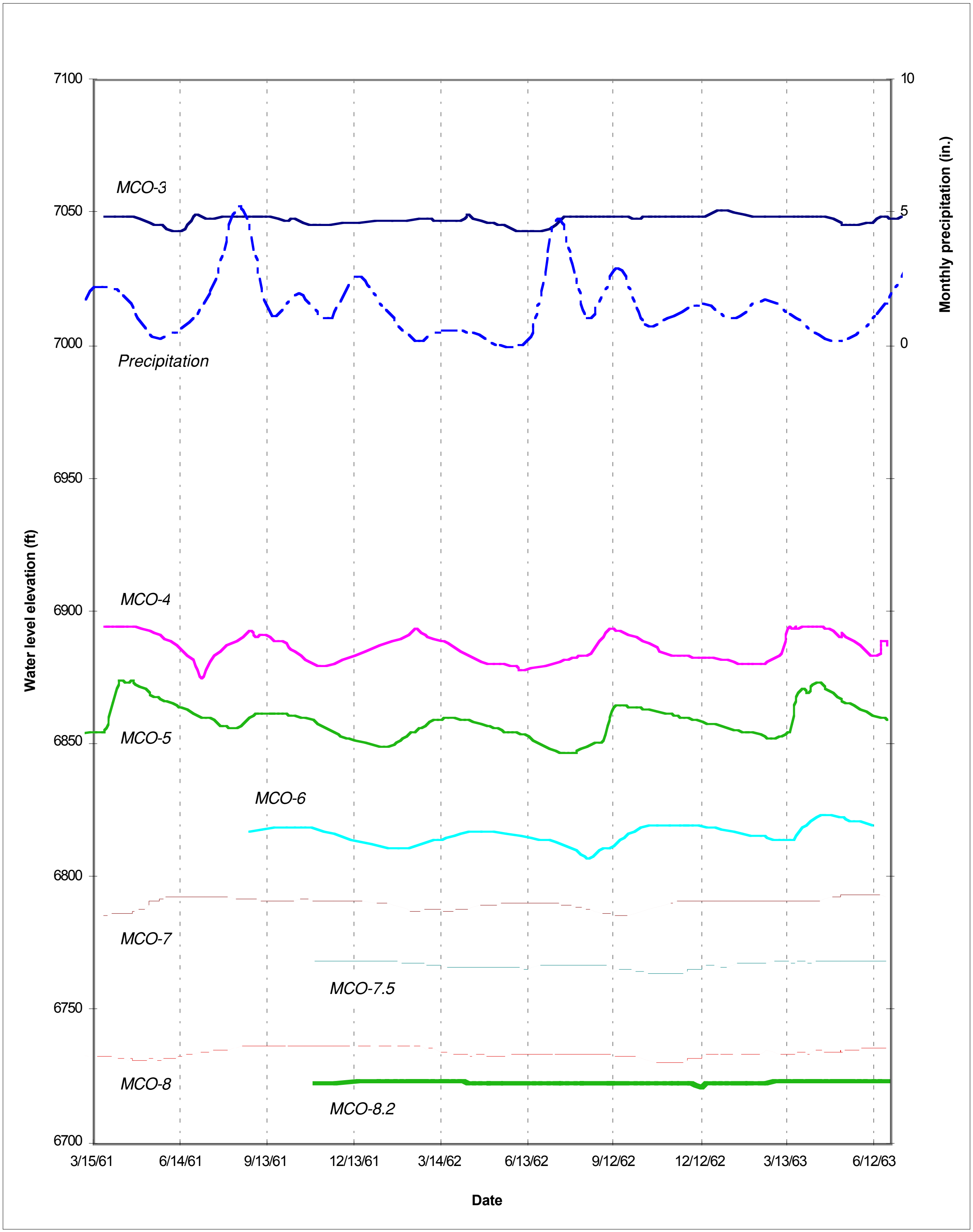
> *Recharge from storm runoff in the summer of 1961 and spring of 1962 raised the water levels only slightly in observation wells east of MCO-7. Storm runoff and cooling water in the summer of 1962 and spring of 1963 caused a larger water-level rise in these wells. The volume of alluvium becomes greater (the canyon widens and the alluvium thickens) eastward from MCO-6 so that available storage for water is larger. The water levels in wells east of MCO-6 rise progressively less due to the increasing area for storage and the greater loss of water from the alluvium into the tuff in this area.*
>
> *The rate of movement of water in the alluvium increased from August-September 1962 to March-April 1963. The August-September recharge caused a water-level rise in MCO-8 in about 85 days and the March-April recharge caused a similar rise in MCO-8 in about 70 days.*

Several boreholes encountered a confining layer that exhibited artesian conditions. Baltz et al. (1963, 8402) described the occurrence as follows.

> *The holes for access tubes MCM-8C and -8D were drilled through a semipervious layer, probably clay, at a depth of about 60 feet. Water confined in the alluvium beneath this layer moved upward under artesian pressure in these holes when they were drilled and then slowly drained away after the access tubes were installed.*

When well MT-3 was installed in 1988 near the MCO-8 line, water was encountered in the alluvium at a depth of 45 ft (13.7 m), compared with water level depths of approximately 60 ft (18.3 m) in the surrounding wells. Apparently, a perching horizon is present within the alluvium in the lower canyon that is capable of retaining infiltrated water from the stream channel for a time. The floods in 1987 (see Section 3.6) may have caused an unusually large amount of infiltration in the lower canyon that could have been retained on finer-grained layers within the alluvium.

The alluvium is less than 5 ft (1.5 m) thick in the upper canyon and near well MCO-3 and thickens to more than 60 ft (18.3 m) near the Laboratory boundary. The saturated portion of the alluvium is generally less than 10 ft (3.0 m) thick and is perched on weathered and unweathered bedrock units. There is considerable seasonal variation in saturated thickness depending on the amount of precipitation and runoff in any particular year (Stoker et al. 1991, 7530). The lateral velocity of water movement in the alluvium was found to vary from about 60 ft/day (18.3 m/day) in the upper canyon to about 7 ft/day (2.1 m/day) in the lower canyon (Purtymun 1974, 5476; Purtymun et al. 1983, 6407).



Source: USGS data sheets (courtesy of the Hydrology section of Laboratory group ESH-18)

Figure 3.7.2-1. Water levels in Mortandad Canyon alluvial wells before discharge from the TA-50 RLWTF.

As shown in Figure 3.7.2-1, the groundwater drains from the alluvium seasonally; the greatest lowering of water levels occurs in wells MCO-4 and MCO-5 where the canyon is relatively narrow and the alluvium thickens. After periods of increased precipitation, water levels rise in response to the recharge from the runoff. The alluvium below the channel at MCO-3 is approximately 5 ft (1.5 m) thick and is observed to drain almost entirely during seasonal periods of low precipitation. After seasonal periods of low precipitation, a spatial and temporal lag is noted in the low water levels in the wells downstream, probably because of water draining from the alluvium in the upper canyon and moving downgradient through the alluvium. Alternately, many of the increases in the water levels do not show a similar temporal and spatial lag, probably because of flow in the channel causing relatively faster recharge to the wells in the middle canyon.

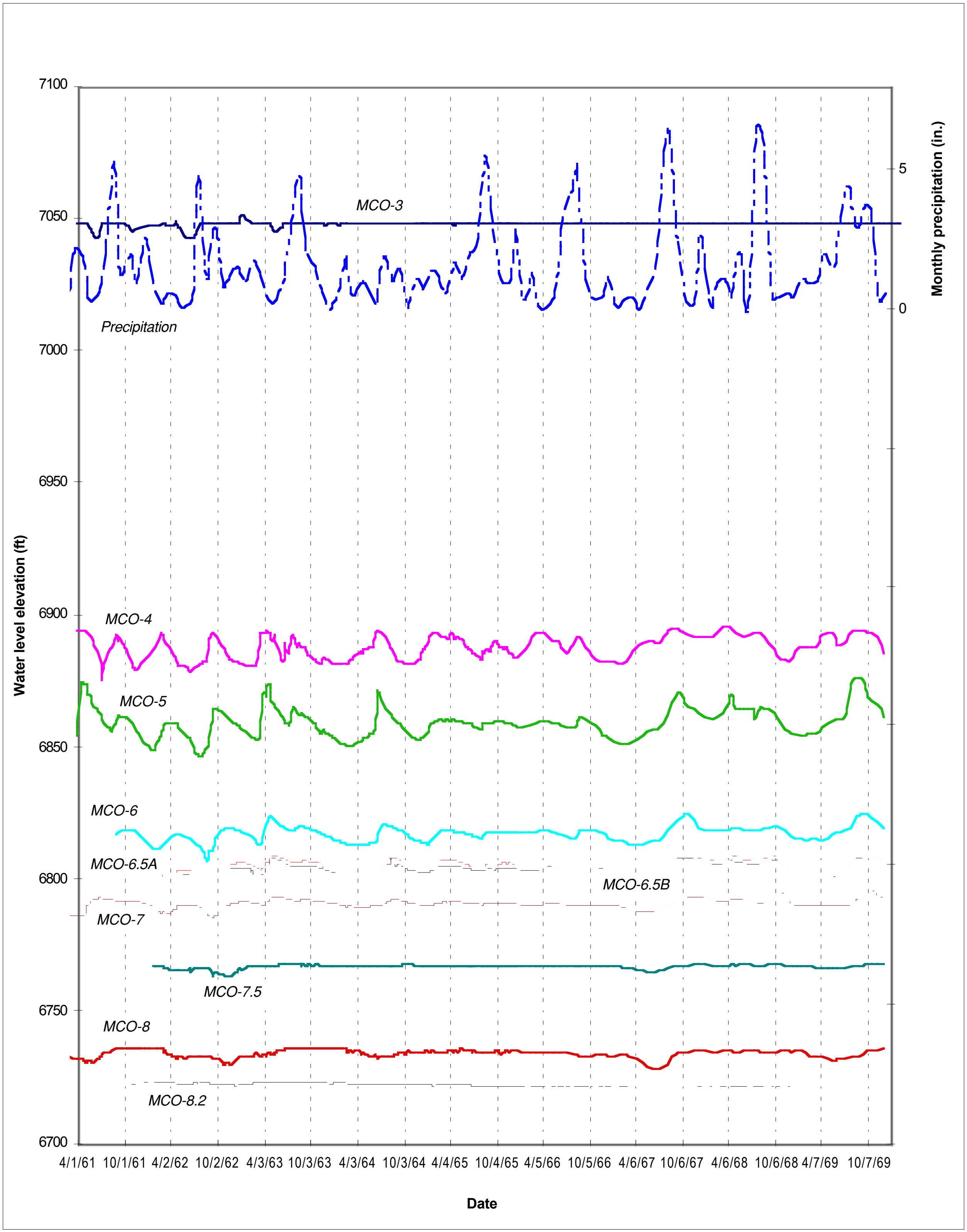
The variation in the water levels of the wells farthest downstream is considerably less. The water level variations at MCO-7 and MCO-7.5 are significantly less than those observed at MCO-6. The variations seen at MCO-8 still reflect the seasonal fluctuations, but water levels vary by only approximately 5 ft (1.5 m). The water levels observed at MCO-8.2 vary by only approximately 1 ft (0.30 m) during the time period shown on Figure 3.7.2-1 and do not appear to reflect the seasonal water level fluctuations observed in the wells farther upstream.

Figure 3.7.2-2 shows the water levels in the alluvial groundwater from 1961 through 1969, when water levels were obtained regularly by the USGS. The differences in the water levels before and after discharges from the TA-50 RLWTF can be observed in this figure. The water levels in MCO-3 show a seasonal decline of up to 5 ft (1.5 m) (the thickness of the alluvium beneath the stream channel at this location) before July 1963, but after discharge began, water level declines through 1969 were not greater than 1 or 2 ft (0.30 or 0.61 m) in this well. This reduction in the degree of seasonal variation in water levels suggests that the TA-50 RLWTF discharge maintains the water level in the alluvium near MCO-3 during the seasonal dry periods.

Water levels in the alluvium at MCO-4 and MCO-5 show a similar but more subdued response to the effects of the TA-50 RLWTF discharge. Before July 1963 groundwater levels varied 10 to 20 ft (3.0 to 6.1 m) with seasonal wet and dry periods. After July 1963 the seasonal water level variations are still present, but the effect of the seasons is less pronounced, and the seasonal low water levels are generally less than previously observed. During seasonal low water levels, there is a spatial and temporal shift in the water levels at successive downstream wells as the alluvium downstream dries. The drying of the alluvium continues for several months, even during periods of precipitation and recharge that may produce enough surface water flow to affect water levels in the upper canyon wells. However, these flows are normally not sufficient to reach the lower canyon; therefore, water levels in the lower canyon wells are not affected until underflow through the alluvium reaches the lower wells.

Water levels in the alluvium at MCO-6 (shown in Figure 3.7.2-2) show similar trends to those discussed above but with less seasonal variability. Seasonal water level fluctuations before July 1963 were about 10 ft (3.0 m) and occasionally as much as 15 ft (4.6 m); after the TA-50 RLWTF discharge began, the water level fluctuations are rarely greater than 10 ft (3.0 m). The seasonal trends seen in MCO-4 and MCO-5 are present but, because of a greater volume of alluvium to store the water near MCO-6, the magnitude of seasonal variations is about half of that observed at MCO-5.

Seasonal water level changes in the alluvium in lower Mortandad Canyon below the confluence with Ten Site Canyon are significantly less than those observed upstream. Before the TA-50 RLWTF discharge, water levels at MCO-7 varied seasonally by approximately 5 ft (1.5 m), and after discharges began, seasonal variations were generally approximately 2 to 3 ft (0.61 to 0.91 m). The fluctuations observed in water levels at MCO-7.5 during the 1960s were very small and generally within 1 to 2 ft (0.30 to 0.61 m). At this location, the seasonal high and low water levels were nearly indistinguishable.



Source: USGS data sheets (courtesy of the Hydrology section of Laboratory group ESH-18)

Figure 3.7.2-2. Water levels in Mortandad Canyon alluvial wells before and after discharge from the TA-50 RLWTF.

The low water levels in the alluvium during 1966 and 1967 were recorded on December 1, 1966, at MCO-4; March 1, 1967, at MCO-5 and MCO-6; May 1, 1967, at MCO-7; June 2, 1967, at MCO-7.5; and July 2, 1967, at MCO-8. During this time the water levels dropped below the level of the open screened interval at well MCO-8.2. The drop in water levels observed during this period decreases in each well downstream except at well MCO-8 where the drop in the water level was greater than the drop at wells MCO-7 and MCO-7.5. These data suggest that water moved downgradient through the alluvium during this period, draining the alluvium to some extent in the middle canyon and maintaining water levels in the lower canyon for a time, until recharge was not sufficient and water levels declined there also. The time lag observed in the low water levels from MCO-5 to MCO-8, a distance of approximately 3780 ft (1152 m), is approximately 95 days, from which a lateral velocity of groundwater in the alluvium of approximately 40 ft/day (12.2 m/day) is calculated.

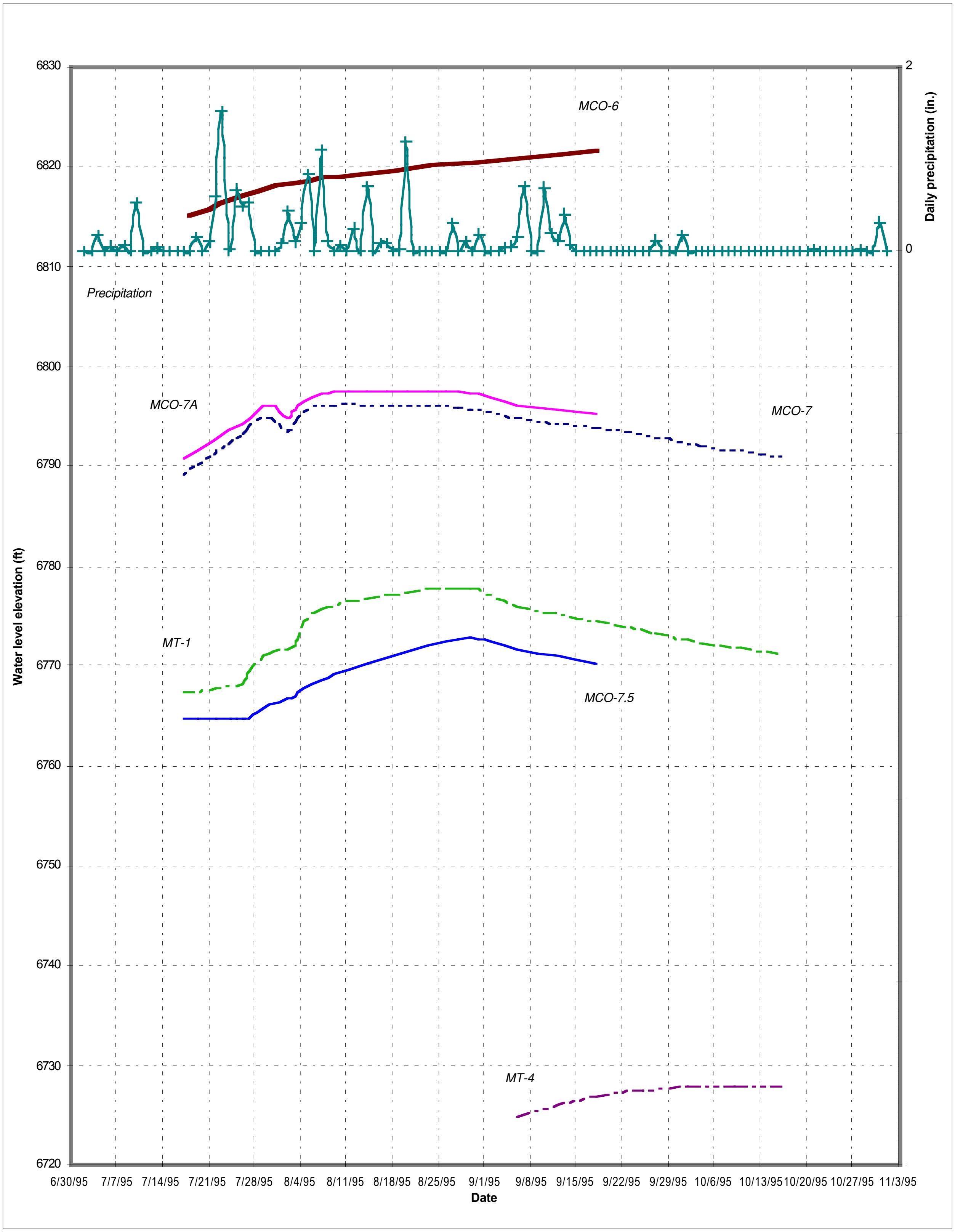
During the 1960s the water level changes observed at well MCO-8 are slightly greater than those observed at wells MCO-7 and MCO-7.5, which suggests a slightly higher infiltration rate in the area of MCO-8. Water level fluctuations observed at MCO-8.2 do not reflect the seasonal changes in water levels seen in the other wells, which suggests a different source of water or a different recharge mechanism. Well MCO-8.2 filled with silt in 1968, and water levels have not been observed in this well since then. An obstruction was found in well MCO-8 in the late 1970s, and that well has not been capable of recording water levels since then.

3.7.2.2 Alluvial Groundwater Response to Filling of the Sediment Traps

In July 1991 several large thunderstorms during a period of six days caused high runoff into Mortandad Canyon. The runoff saturated the stream bed and caused streamflow to extend to the sediment traps, filling all three sediment traps to capacity. An estimated 20,000 to 30,000 gal. (75.7 to 114 m^3) of water overflowed from the Sediment Trap No. 3 and flowed for approximately 650 ft (198 m) downstream to near well MT-1 (Environmental Protection Group 1993, 23249). The water from the channel and the sediment traps infiltrated into the alluvium during several days, causing a response in the alluvial groundwater level, which was observed in the wells near the sediment traps (Koenig and McLin circa 1993, 56029).

Water levels in wells adjacent to Sediment Trap No. 1 (MCO-7 and MCO-7A) showed a rise of nearly 5 ft (1.5 m) within approximately five days after the sediment traps filled with water (Figure 3.7.2-3). MCO-7A is approximately 20 ft (6.1 m) west of MCO-7 and slightly upgradient, which is reflected in the water levels that were consistently observed approximately 1 ft (0.30 m) higher than at MCO-7. After approximately three days without precipitation, the water levels at MCO-7 and MCO-7A began declining, probably in response to leveling of the groundwater mound near the sediment traps and the alluvial groundwater moving downgradient.

After five days with little or no precipitation, several days of nearly 1 in. of rain per day in early August caused the stream channel to saturate, and the sediment traps again filled with water. The water levels in wells MCO-7 and MCO-7A again rose by 2 to 3 ft (0.61 to 0.91 m) and remained relatively constant, probably because of recharge from the water in the sediment traps and possibly also because of infiltration from the channel during periodic heavy rains during the first three weeks of August. The water levels in these wells began to decline slowly after the third week in August and returned to near pre-July levels by about the end of October 1991.



Source: Koenig and McLin circa 1993, 56029

Figure 3.7.2-3. Alluvial groundwater levels after the sediment traps filled with water.

Well MT-1, 125 ft (38.1 m) east of the three sediment traps, showed an increase of approximately 4 ft (1.2 m) in the water level after the initial filling of the sediment traps. During the subsequent five days without precipitation, the water level remained constant when the water levels at MCO-7 and MCO-7A were declining. When the sediment traps filled the second time in early August, the water level increased another 3 to 4 ft (0.91 to 1.2 m), with perhaps a one- or two-day time lag behind MCO-7. The water level continued to rise an additional 2 ft (0.61 m) at MT-1 during most of August (when MCO-7 and MCO-7A levels were relatively constant) and did not begin to decline until the end of August.

The water level responses at well MCO-7.5, located approximately 325 ft (99 m) east of the sediment traps, were similar to those observed at MT-1, although the initial water level rise was much slower and delayed approximately one or two days. However, the water level continued to rise at MCO-7.5 through August, probably due to recharge of water from the sediment traps. The peak water levels at wells MT-1 and MCO-7.5 were observed near the end of August, after which the water levels began to decline about the same time in both wells.

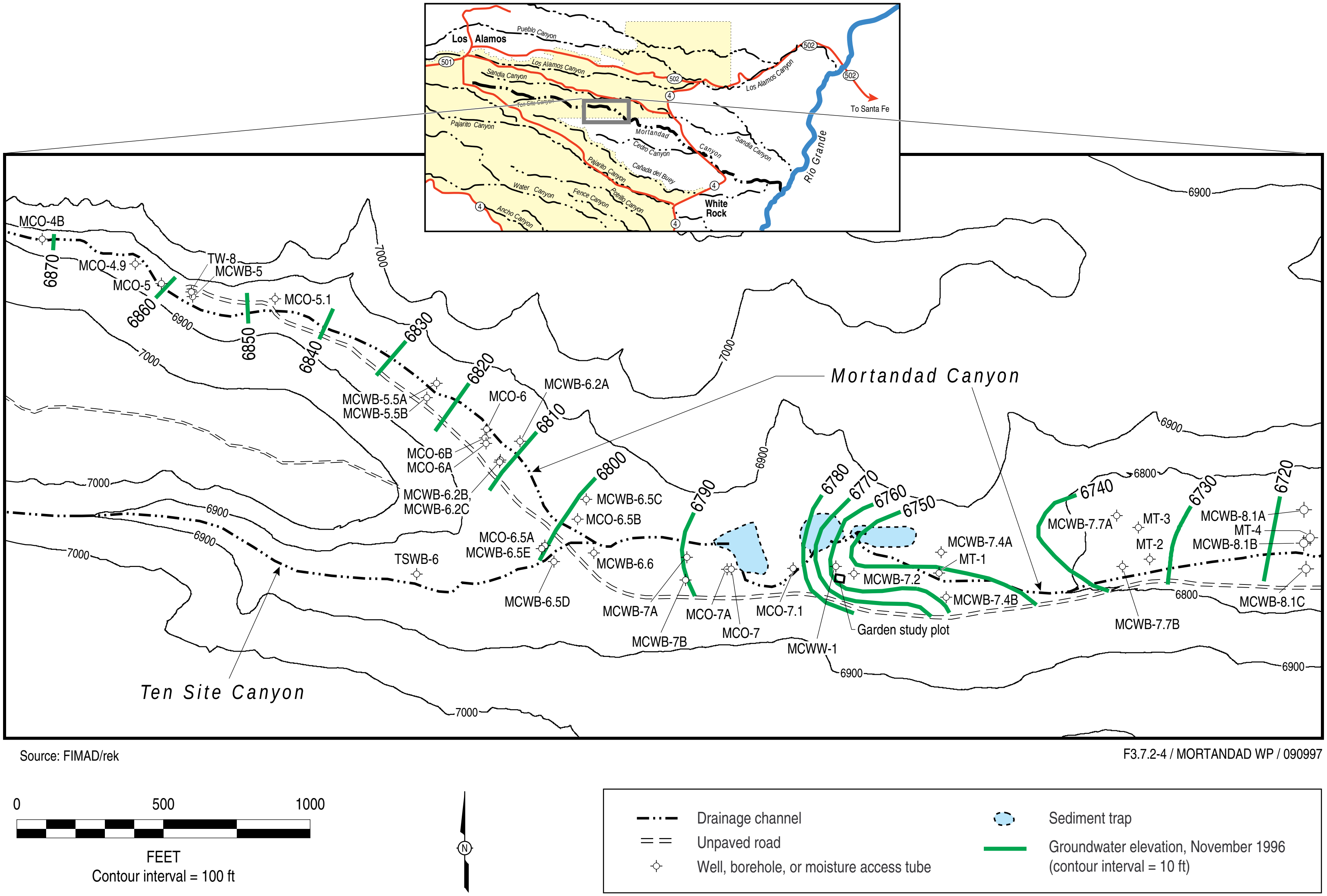
The rise in groundwater levels resulting from the infiltration at the sediment traps was also observed in well MT-4, located approximately 1300 ft (396 m) east of well MT-1. The record of the water levels during this period is not complete for this well, but the peak water level was observed approximately 35 days after the peak levels were observed at MT-1 and MCO-7.5. The water level rose approximately 8 ft (2.4 m) at MT-4 and did not decline for several weeks. These water level data indicate that the groundwater mound traveled downgradient through the alluvium east of the sediment traps at a rate of approximately 31 to 37 ft/day (9.4 to 11.3 m/day).

3.7.2.3 Recent Alluvial Groundwater Level Observations

Table D-5 in Appendix D of this work plan lists water level data that have been obtained since 1995. Most water level data are acquired during routine ESH-18 environmental surveillance sampling of the wells; however, many water level measurements have recently been obtained by the NMED Oversight Bureau. Figure A-3 in Appendix A of this work plan shows the extremes in recent water levels of the alluvial groundwater. Figure 3.7.2-4 shows recent alluvial groundwater levels.

Figure A-3 in Appendix A of this work plan 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 confined in the lower portion of the alluvium within the V-shaped channel in the upper and middle canyon and in the U-shaped channel in the lower canyon. The width of the saturated zone in the V-shaped channel at the MCO-5 and MCO-6 lines is approximately 100 ft (30.5 m), whereas the probable width of the saturated zone in the lower canyon at the MCO-8 line is approximately 200 ft (61.0 m). The gradient of the surface of the alluvial groundwater in the middle canyon from MCO-4 to near MCO-5 is less than 3%, in the MCO-6 and MCO-7 area approximately 4%, and in the MCO-8 area approximately 3%. Historically, groundwater has not been found in the alluvium east of the MCO-8.2 area.

Near the sediments traps, the gradient of the alluvial groundwater increases markedly. The water level elevation drops 30 ft between wells MCO-7.1 and MCWB-7.2, a distance of 220 ft (67 m), for a 13% gradient (see Figure 3.7.2-4). The cause of the lower water levels below the sediment traps is unknown, but two possible causes could explain this occurrence. One is that, at the time of erosion of the canyon and before deposition of sediments in the canyon, a plunge pool or nick point may have formed at this location. A plunge pool or nick point could have resulted from the erosion of softer Cerro Toledo interval sediments from beneath the Tshirege Qbt 1g unit. Subsequent deposition of alluvial sediments along this part of the canyon could have buried the plunge pool. However, nick points and plunge pools have not been observed at the contact of these units in other locations on the Pajarito Plateau.



Source: FIMAD/rek

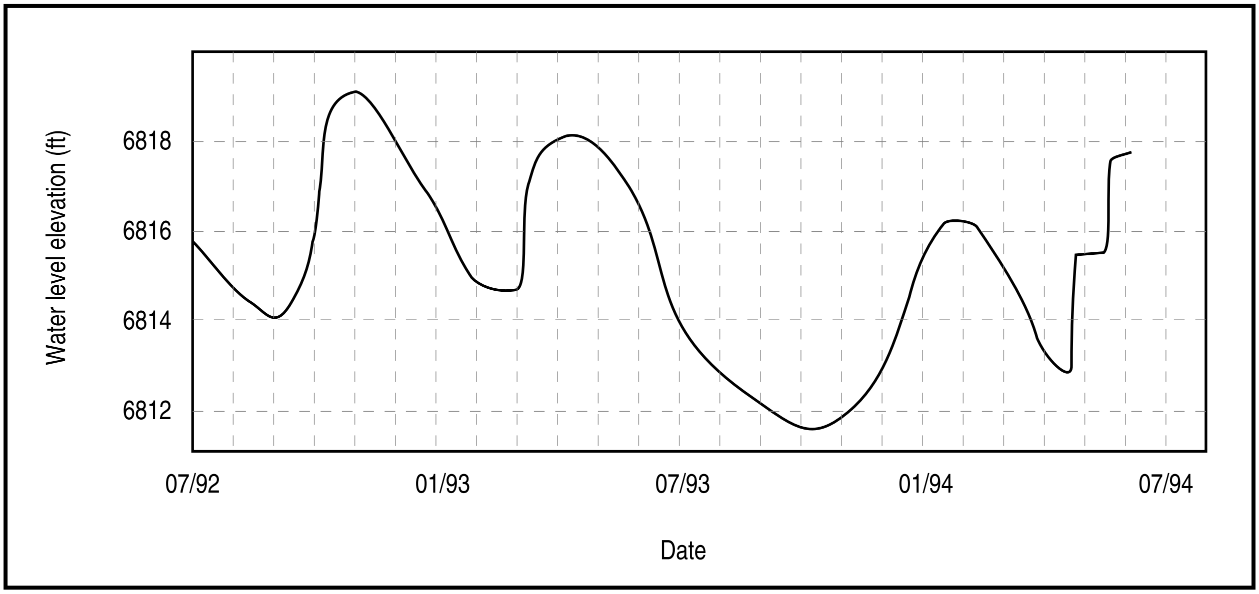
F3.7.2-4 / MORTANDAD WP / 090997

Figure 3.7.2.4. Recent elevations of alluvial groundwater in lower Mortandad Canyon.

Another possible explanation for the drop in water levels between wells MCO-7.1 and MCWB-7.2 may be related to the intersection of the alluvial hydrogeologic unit with the Cerro Toledo hydrogeologic unit, which is discussed in Section 3.7.2.4. The Tshirege Qbt 1g unit may be absent below the alluvium at this location because of erosion. The weathered Qbt 1g provides the perching layer beneath the alluvium in the middle part of the canyon. As a result of removal of the Qbt 1g by erosion, the alluvial groundwater may no longer be perched and may discharge into the Cerro Toledo interval. The groundwater may find a lower perching zone within the Cerro Toledo interval approximately 30 ft below the alluvium/Cerro Toledo interval contact.

Currently at least 16 groundwater wells are sampled as part of the Laboratory's routine monitoring program. These include MCO-3, -4, -5, -6, -7, and -7.5, which range in depth from approximately 12 to 71 ft (3.7 to 21.6 m); depths to water range from approximately 3 to 61 ft (0.91 to 18.6 m). In recent years, well MCO-4B has replaced well MCO-4, which was partially washed out in 1991. In addition, MCO-8A, -8.2, -12, and -13 and the four MT wells are available for sampling and water level measurements. In any year, some wells may be dry and water samples cannot be collected. Wells installed in the lower canyon downstream of MCO-8 generally have not contained alluvial groundwater (Environmental Protection Group 1996, 54769).

In October 1992 the Laboratory began measuring and recording water level fluctuations in wells completed into the alluvial groundwater in Mortandad Canyon. These data are automatically recorded at hourly intervals using pressure transducers (Environmental Protection Group 1995, 50285). Measurements at MCO-5 and MCO-6B commenced during October 1992, and the data were summarized by McLin (1996, 56025). The water levels obtained at MCO-6 are shown in Figure 3.7.2-5. The water levels indicate a seasonal variation based on precipitation and are comparable to those observed during the 1960s (see Figure 3.7.2-2).



Source: McLin 1996, 56025

F3.7.2-5 / MORTANDAD WP / 081197

Figure 3.7.2-5. Hydrograph of transducer water level measurements in well MCO-6.

3.7.2.4 Relationship between Alluvium and Bedrock Stratigraphic Units

In 1960 when most of the wells were installed in Mortandad Canyon, it was recognized that a change in the bedrock geology occurred beneath the alluvium between boreholes for wells MCO-6 and MCO-7 near the confluence of Mortandad Canyon and Ten Site Canyon. West of this area the Tshirege Qbt 1g unit (then called Tshirege Unit 1a by Baltz et al. [1963, 8402]) subcrops beneath the alluvium, whereas east of the confluence area the Otowi Member was reportedly encountered beneath the alluvium (Baltz et al. 1963, 8402; Purtymun 1964, 11822). Descriptions of the lithology encountered beneath the alluvium in boreholes drilled in the 1980s east of the confluence usually refer to "tuff" beneath the alluvium. These early investigations did not recognize the presence of the Cerro Toledo interval and probably assigned strata of this unit to the Tsankawi Pumice Bed, the Otowi Member, or to alluvium. Because of the potential thickness of the Cerro Toledo interval (76 ft [23.2 m] in borehole 35-2028), the misassignment of this unit has led to inconsistent stratigraphic information for boreholes in Mortandad Canyon. Borehole lithologic logs were reinterpreted to the extent possible during preparation of this work plan to resolve some of the stratigraphic inconsistencies, but the reinterpretations must be considered provisional until new cores can be obtained from boreholes proposed as part of this work plan.

Figure A-3 in Appendix A of this work plan shows the bedrock stratigraphic units identified during borehole drilling for the alluvial monitoring wells (Purtymun 1995, 45344) and the recently revised stratigraphic picks. 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) based on the revised stratigraphy discussed in Section 3.3. Regionally, the Tsankawi Pumice Bed is present at the base of the Tshirege Member; however, none of the boreholes drilled in Mortandad Canyon have identified the presence of the Tsankawi Pumice Bed. Boreholes drilled since about 1990 recognized undivided Tsankawi Pumice Bed/Cerro Toledo interval deposits beneath the Tshirege Member.

Baltz et al. (1963, 8402) mapped the contact between the Tshirege Qbt 1g and Qbt 1v units (which they called units 1a and 1b, respectively). This contact is present on the near vertically outcropping north wall of Mortandad Canyon downstream of well MCO-4. This contact is present on the north wall of the canyon approximately 6 ft (1.8 m) above the floor of the canyon at wells MCO-5 and TW-8 and is present on the canyon wall as far east as the Laboratory boundary. This contact is depicted as a heavy dashed line on the cross section of Figure A-3.

Based on the thickness of the Tshirege Qbt 1g unit encountered in borehole 35-2028 in Pratt Canyon (67 ft [20.4 m]), 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. Based on this projection, the base of the alluvium intersects the Tsankawi Pumice Bed/Cerro Toledo interval approximately at the location of wells MCO-7 and MCO-7A. It is likely that boreholes for the wells east of the confluence with Ten Site Canyon intersected a thin, weathered section of the Tshirege Qbt 1g unit, which may have been too thin to recognize in auger cuttings, and then penetrated into the Cerro Toledo interval. The upper part of the Cerro Toledo interval consists of well-stratified tuffaceous sandstones and siltstones and primary ash-fall and pumice-fall deposits as described in Section 3.3.1.4. These deposits are difficult to distinguish from the alluvial sediments in auger cuttings. Boreholes drilled in the lower canyon east of the sediment traps probably encountered the Cerro Toledo interval beneath the alluvium as well. The cross section shows the approximate stratigraphic position of the Cerro Toledo interval in the Mortandad Canyon area. Table D-4 in Appendix D of this work plan lists the revised stratigraphic picks that are interpreted to have been encountered in the boreholes.

The intersection of the alluvium and the Cerro Toledo interval demarks differing hydrogeology to the west and to the east. West of the confluence of Mortandad Canyon and Ten Site Canyon, the Cerro Toledo interval is likely present as a separate hydrogeologic unit and may form an intermediate perched zone. However, east of the confluence the alluvium may merge with the Cerro Toledo interval to form a single hydrogeologic unit. If the alluvium merges with the Cerro Toledo interval, 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 contaminants in the alluvium will consider the possibility that paleochannels within the Cerro Toledo interval may not coincide with the orientation of Mortandad Canyon, thus creating pathways for groundwater flow laterally away from the canyon.

3.7.2.5 Water-Balance Studies of the Alluvial Groundwater

3.7.2.5.1 Water Balance Obtained during the 1960s

During the early 1960s the USGS and the Laboratory monitored streamflow and infiltration using gaging stations and measured water levels in the alluvial groundwater. A water balance was calculated using a summation process (Purtymun 1967, 8987). It was concluded that more water was lost into the tuff in the upper canyon than in the middle and lower canyon. Purtymun (1967, 8987) summarized the results of the water-balance studies as follows.

> *Water losses from the alluvium into the tuff were estimated for the upper, middle, and lower canyons of the disposal area. The losses were determined by a comparison of the amount of surface water entering the upper and middle canyons . . .*
>
> *Surface water recharge to the zone of saturation in the alluvium in the upper canyon is rapid because the alluvium is highly permeable and is relatively thin. The upper canyon was able to absorb almost all of the streamflow that occurred in the canyon over a two year period except during discharge of waste water from New Sigma. The water discharged from New Sigma July 1963 and June 1964 caused near saturation of the alluvium in the upper canyon as did the waste water from TA-48 and storm runoff from November 1964 to June 1965. These periods of recharge are reflected by the increase of water in transit storage in the middle and upper canyons. The increase of water in transit storage in each section of the canyon is accompanied by increased losses into the tuff.*

The water-balance investigations continued through 1969; measurements of the concentration and distribution of contaminants in the groundwater and sediments in the canyon also were conducted (for example, John et al. 1966, 8796; Purtymun and Kunkler 1969, 11783).

The streamflow and water level data collected and presented by Purtymun (1967, 8987) were later reinterpreted by Koenig and McLin (circa 1993, 56029) using a lumped parameter model. This reevaluation of the data suggested that approximately 75 to 80% of the alluvial groundwater eventually infiltrates into underlying strata. The lumped-parameter model also indicated that more water may be lost from the alluvial groundwater in the lower canyon than in the middle canyon, which contrasts with the results of the earlier calculation. In the lower canyon, the relatively high infiltration rate and the relatively high response rate of the alluvial groundwater to surface water flow events indicates that the alluvial groundwater may be regularly passed through the alluvium and replaced by new infiltration from surface water flow.

3.7.2.5.2 Mortandad Canyon Water-Balance Wells

In 1995 24 wells were installed in Mortandad Canyon to monitor water levels in the alluvial groundwater (McLin et al. 1997, 04-0327). These wells are designated the Mortandad Canyon water-balance (MCWB) wells, as shown on Figure A-2 in Appendix A of this work plan. The data obtained from these wells are to be used for calculating a water balance for the alluvial groundwater; the primary objective is to obtain reliable estimates of infiltration from the alluvial groundwater into the underlying unsaturated bedrock units of the Bandelier Tuff and the Cerro Toledo interval. It is anticipated that the current investigation will require a minimum of three years of data collection before reliable water-balance calculations and infiltration rate estimates will be possible.

3.7.2.6 Other Alluvial Groundwater Investigations

3.7.2.6.1 Boreholes Near MCO-6

In 1978 three boreholes were drilled in a line perpendicular to the stream channel near MCO-6, and two other boreholes were drilled to determine "background" or control conditions. The purpose of collecting the core samples from the alluvium and the underlying tuff was to determine the moisture, plutonium, and tritium contents of the alluvium and the underlying tuff and the plutonium and tritium concentrations in the alluvial groundwater (ESG 1984, 6523; Devaurs and Purtymun 1985, 7415). The results of the investigation indicated that the moisture content approaches 30% by volume from 3 to 10 ft (0.91 to 3.0 m) above the top of the alluvial groundwater. Moisture content of the alluvial material ranged from 20 to 25% by volume. The results also indicated that some infiltration of water and tritium into the underlying tuff had occurred to a depth of at least 30 ft (9.1 m) below the alluvium, but tritium activities decreased dramatically with greater distance from the channel.

Results of the analyses of samples from the three boreholes are discussed in Section 3.5.1.

3.7.2.6.2 MT Boreholes

In November 1988 four boreholes (for wells MT-1 through MT-4) were drilled into the alluvial groundwater zone in the lower canyon in an effort to determine the lithology, shape, and extent of the zone (ESG 1989, 6894). Their locations are shown in Figure A-2 in Appendix A of this work plan; the construction information and recent water level information are listed in Table D-4 and Table D-5 in Appendix D of this work plan. Geologic logs of the boreholes were presented by Stoker et al. (1991, 7530) and Purtymun (1995, 45344). The boreholes were completed with 2-in.-diameter plastic pipe with screened openings in the saturated zone for subsequent determination of water levels. Figure A-3 in Appendix A of this work plan shows the cross section of the canyon, including the locations of wells MT-2 and MT-3, the projected stratigraphy, and the recent range of water levels observed in these wells.

The borehole for well MT-1 was drilled in the center of the canyon floor approximately 200 ft (61.0 m) southeast of Sediment Trap No. 3 to a depth of 69 ft (21.0 m). The water level was measured at 43 ft (13.1 m) in 1988 and 42.9 ft (13.1 m) in 1991. Boreholes for wells MT-2 and MT-3 were drilled approximately 700 ft (213 m) east of MT-1 near MCO-8 along a line transverse to the canyon. MT-2 was drilled to a depth of 64 ft (19.5 m), and the water level was 62 ft (18.9 m) when it was drilled; it was found to be dry in 1991. MT-3 was drilled to a depth of 74 ft (22.6 m), and the water level was 45 ft (13.7 m) in 1988 and 54.7 ft (16.7 m) in 1991. MT-4 was drilled approximately 500 ft (152 m) east of MT-2 and MT-3 in the center of the canyon to a depth of 74 ft (22.6 m). The water level was 58 ft (17.7 m) in 1988 and 59.8 ft (18.2 m) in 1991. The water level data show that in 1991 (three years after drilling these boreholes) the water level at MT-1 was almost *the same as in 1988; however, the water levels downstream had declined nearly 10 ft (3.0 m) at MT-3 and approximately 2 ft (0.61 m) at MT-4.*

The core samples obtained from the MT boreholes showed that the alluvium is composed of two distinct stratigraphic units. The upper part of the alluvium is composed of coarse sand with lenses of silt and clay, and the lower alluvium is composed of silt and clay with thin lenses of sand. The core samples also indicated that there is a distinct transition between the silt, clay, and sand lenses that make up the saturated alluvial zone and the silt and clay below the saturated zone that serves to perch the water (Stoker et al. 1991, 7530). Figure A-3 in Appendix A of this work plan shows that the thickest section of saturated alluvium is located near the sediment traps between MCO-7 and MT-1. The transverse cross section at MT-2, MT-3, MCO-8, MCO-8A, MCM-8A, and MCM-8F shows that the alluvium is thickest in the central part of the canyon and thins laterally to the edges. At least two perching layers are present at this location: one presumably within the alluvium at approximately 45 ft (13.7 m) and another presumably at the base of the alluvium at approximately 60 ft (18.3 m). However, reinterpretation of the stratigraphy in this part of the canyon suggests that the lower perching layer may be within the Cerro Toledo interval.

3.7.2.6.3 Alluvial Groundwater Modeling

The NMED Oversight Bureau (Stone 1995, 56043) performed a one-dimensional steady-state simulation of the alluvial groundwater for pre-1963 conditions. The model focused on the alluvium between wells MCO-1 and MCO-8 and was modeled as one layer, one column (scaled for valley cross sectional dimensions), and 30 rows. The USGS groundwater modeling package MODFLOW (McDonald and Harbaugh 1988, 56041) was used, including the recharge, ET, and streamflow-routing packages. When the model was run with ET maximized and no underflow or leakage to the underlying tuff, it predicted streamflow for the entire length of the canyon. Because streamflow does not occur for the entire length of the canyon, losses attributable to leakage or underflow from the system must occur, thus supporting the findings of the water-balance studies.

Variables used in the modeling were for a stream bed 1 ft (0.30 m) thick composed of silty sand and for alluvium composed of a silty sand, both with a hydraulic conductivity of 0.0015 ft/s (0.046 cm/s; 130 ft/day). Precipitation was estimated to be 19 in./yr (483 mm/yr), with 50% coming from the north slopes of the canyon. The ET rate was estimated to be 17 in./yr (432 mm/yr), with an extinction depth of 10 ft (3.0 m). The model predicted that approximately 0.177 cfs (114,000 gpd, 431 m^3/d) must be lost from the alluvium either by infiltration or underflow, a figure remarkably close to the 2 million gal. (7570 m^3) per month estimated in 1966 to 1967 by Purtymun and Kunkler (1969, 11783) (see Section 3.6.4).

3.7.2.7 HSWA Module Monitoring Well Installation

In 1989 and 1990 four boreholes (for moisture access tubes MCM-5.1, MCM-5.9A, and MCC-8.2 and well SIMO) were drilled in Mortandad Canyon to characterize the alluvium and the bedrock units. Additionally, four wells were installed (MCO-4A, MCO-4B, MCO-6A, and MCO-6B) to provide RCRA-compliant monitoring wells for the alluvial groundwater (Purtymun and Stoker 1990, 7508; Stoker et al. 1991, 7530; Purtymun 1995, 45344). These installations satisfied monitoring requirements of the HSWA Module (EPA 1990, 1585). Construction information is listed in Table D-1 and Table D-3 in Appendix D of this work plan.

Based on the data collected from previous investigations, which includes the data from the boreholes near MCO-6, the MT boreholes, and borehole MCC-8.2, significant variations in hydrologic properties, water contents, and distributions of contaminants with depth beneath the alluvial groundwater were noted (Stoker et al. 1991, 7530). The results of the investigation provided the basis for determining that the lower portion *of the alluvium is normally saturated for about 3.5 mi (5.6 km) downstream from the TA-50 RLWTF outfall. The eastern extent of known saturation in the alluvium is approximately 1 mi (1.6 km) west of the Laboratory boundary.*

The results of the investigations conducted in 1990, together with the results of previous investigations, were summarized by Stoker et al. (1991, 7530) and include the following.

- *Recharge by wastewater discharges and runoff into the shallow alluvial groundwater occurs in the middle canyon. Runoff recharges the upper and middle canyon and, depending on the volume, may extend as streamflow into the middle and lower canyon. High volumes of snowmelt runoff or wastewater discharge will overflow the saturated alluvium in the upper canyon and create surface flow on the canyon floor. Infiltration into the alluvium then also occurs along the length of the stream. When discharge ends, the streamflow will retreat upstream, and the saturated front will separate and move as a groundwater mound downgradient in the alluvium.*

- *The volume of recharge since 1960 has not been sufficient to significantly change the volume of water in the shallow alluvial groundwater. This groundwater has not been found to extend beyond the lower canyon or to the Laboratory boundary.*

- *The alluvium in the canyon becomes thicker and wider downstream from the TA-50 RLWTF outfall. In the lower canyon, the alluvium consists of two distinguishable stratigraphic units that affect the hydrologic characteristics of the water-bearing zone. Water in the alluvium west of MCO-5 is in a sand unit that grades laterally downstream into a silty clay unit near MCO-6. East of MCO-6 the groundwater is in alluvium composed primarily of silty clay.*

- *Little or no recharge to the alluvial groundwater occurs from precipitation on the canyon floor in the lower canyon. Recharge occurs primarily from runoff in the channel and by movement of water downgradient in the shallow alluvium.*

- *Tracer tests indicate that the velocity of the water in the alluvium in the sand unit is approximately 50 ft/day (15.2 m/day); in the transition zone the velocity from sand to silty clay (between MCO-5 and MCO-6) is approximately 20 ft/day (6.1 m/day); in the silty clay zone the velocity is 6 to 7 ft/day (1.8 to 2.1 m/day). Based on velocity, the transit time from the TA-50 RLWTF outfall to the eastern end of the alluvial saturation is approximately one year. Data from water level measurements indicate that flow in the alluvium in the lower canyon from MCO-5 to MCO-8.2 is approximately 30 to 40 ft/day (9.1 to 12.2 m/day).*

- *The saturated thickness of the alluvium varies depending on the amount of recharge. The greatest variation in saturated thickness is observed at MCO-4 and MCO-5 where the canyon is relatively narrow. Variations in the saturated thickness are primarily related to runoff from natural precipitation rather than to discharges from the TA-50 RLWTF.*

- *The water quality data indicate that groundwater in the alluvium is completely replaced each year.*

- *Data from boreholes and moisture access tubes indicate that the saturated section of the alluvium does not extend beneath the mesas to the north or south. The saturated section of alluvium exists as a narrow ribbon down the center of the canyon. In cross section, the saturated section is saucer-shaped (thicker near the middle and thinning outward to the edges of the canyon).*

- *During the 11-yr period from 1967 to 1978, the largest volume of water in storage in the alluvium was 7.9 million gal. (29,900 m^3) in 1967, and the smallest volume of water was 4 million gal. (15,100 m^3) in 1977. Surface water recharge in 1967 was 36.7 million gal. (138,900 m^3), whereas losses from storage were 34 million gal. (128,700 m^3). Surface water recharge in 1977 was 14.3 million gal. (54,100 m^3) with losses from storage during the year of 14.8 million gal. (56,000 m^3). The distribution of the total water in storage during this period was 18% in the upper canyon, 23% in the middle canyon, and 59% in the lower canyon.*

- *Water balance from 1965 to 1967 indicated that the largest loss from storage occurred in the upper canyon, probably because of the shallow groundwater and the large amount of vegetation in the canyon (high ET).*

- *Data obtained from moisture access tubes in the canyon indicate that the soil moisture zone and the capillary zone above the alluvial groundwater merge west of MCO-6. East of this area the alluvial groundwater becomes deeper, and a distinct soil moisture zone and capillary zone are present. Soil moisture extends down to approximately 10 ft (3.0 m), whereas the capillary rise above the groundwater is up to approximately 8 ft (2.4 m).*

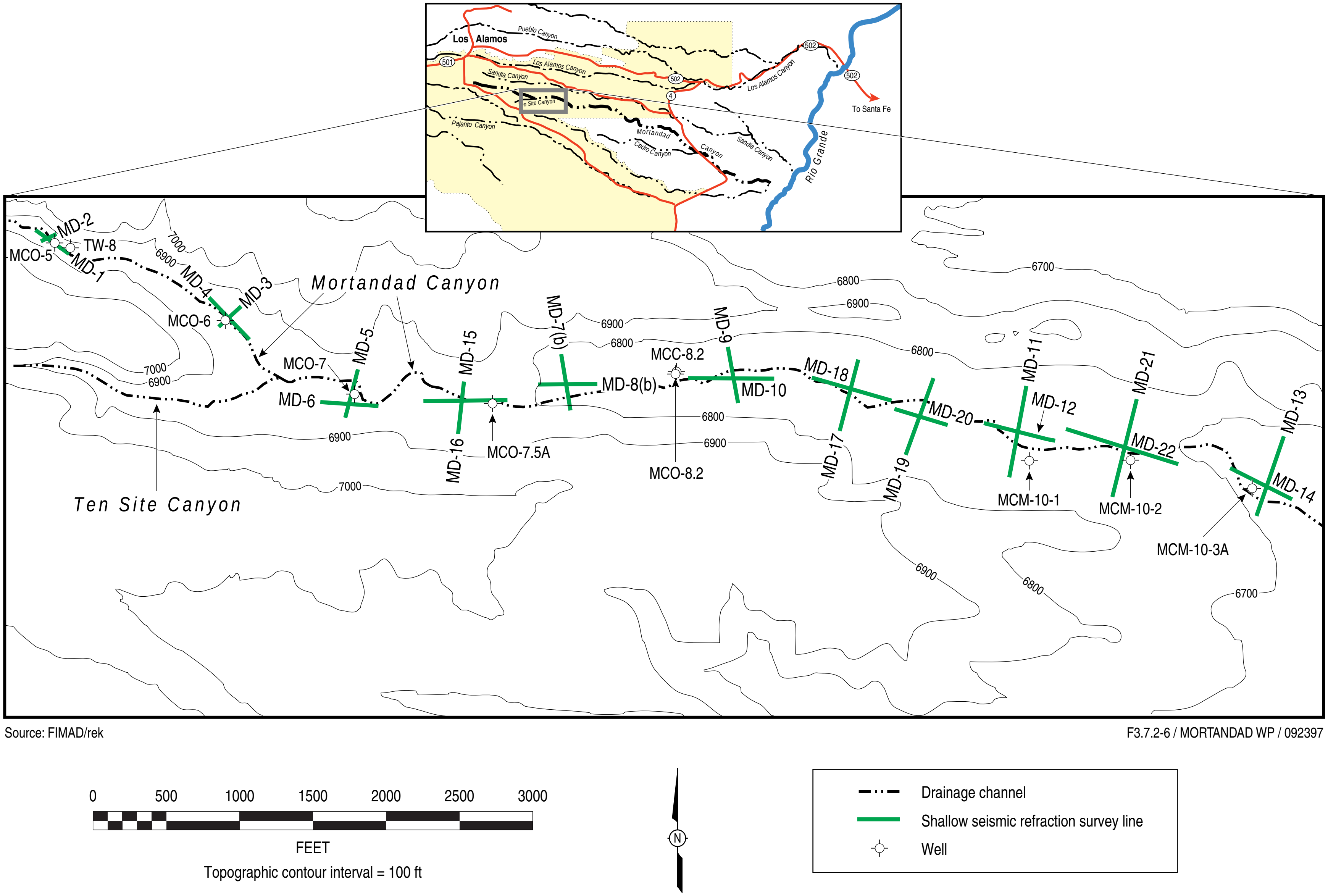
3.7.2.8 Investigations of Shallow Seismic Reflection

In September 1990 a shallow seismic reflection survey was performed in lower Mortandad Canyon to investigate the form and depth of the base of the alluvium (or the top of the buried bedrock) in the canyon and to detect areas of alluvial groundwater. A total of 14 seismic lines were arranged in seven sets of 2 lines along the middle and lower canyon, which contain the significant volumes of material and alluvial groundwater (Reynolds 1990, 54715). Figure 3.7.2-6 shows the locations of the seismic lines.

In August and September 1991 a second shallow seismic reflection survey was performed at several of the same locations surveyed in 1990 and at several additional locations. The second seismic survey was performed to (1) continue the investigation begun in 1990, (2) compare the data obtained in 1990 with new data obtained with a 50-Hz high-pass or low-cutoff filter, and (3) survey additional sections of the canyon that had not been surveyed in 1990. Also, greater precipitation in 1991 had caused alluvial groundwater levels to rise significantly and expand into a larger portion of the alluvium; therefore, the seismic survey was performed in an effort to determine if alluvial groundwater could be detected. In 1991 10 seismic lines were recorded, 2 of which (MD-7B and MD-8B) were at the location of previous lines MD-7 and MD-8 for comparison (Reynolds 1991, 56040).

In 1990 the mean velocity of the alluvium in Mortandad Canyon was measured to be approximately 1000 ft/s (304.8 m/s), which is consistent with the characteristics of soft, loose, dry clastic materials. The mean velocity of the dry bedrock Bandelier Tuff was found to be 2750 ft/s (838.2 m/s), which is within the range of observed velocities for this rock unit. The 1991 survey found that the velocity of the alluvium was faster, about 1300 to 1500 ft/s (396 to 457 m/s). The difference was attributed to the increased moisture content of the alluvium in 1991 and the increased sensitivity of the new seismograph equipment used in 1991.

The seismic surveys showed that the maximum depth of the alluvium in the canyon ranges from approximately 25 ft (7.6 m) at line MD-1, approximately 65 ft (19.8 m) at MD-7 and MD-9, to approximately 85 ft (25.9 m) at MD-19. The alluvial deposits were found to be approximately symmetrical except at MD-1 where the deeper part appeared to be closer to the north wall of the canyon.



Source: FIMAD/rek

F3.7.2-6 / MORTANDAD WP / 092397

Figure 3.7.2-6. Locations of shallow seismic refraction survey lines in Mortandad Canyon.

In 1990 seismic velocity anomalies greater than 4000 ft/s (1220 m/s) (which suggest wet alluvium) were noted in the zone immediately overlying the alluvium/bedrock interface locally on seismic lines MD-2, -3, -5, -7, -10, -11, and -13. For the most part, these anomalies were present under or near the present stream bed in the upper canyon on lines MD-2 through MD-7. In the upper canyon (on lines MD-1 through MD-6) indications of possible saturated alluvium were limited in size and suggested very narrow saturated zones along the length of the canyon. In the lower canyon, indications of possible saturated zones were more widespread, and the possibility of a saturated zone was noted under lines MD-7 through MD-10. Apparent groundwater "mounding" was indicated under the stream channel on line MD-13. A possible thin wet unit was noted on lines MD-11 and MD-13 that sloped to the southwest from the vicinity of the stream bed, which suggests possible infiltration from the stream channel.

The results of the 1990 seismic survey indicated the possible presence of alluvial groundwater much farther east in the canyon than had ever been recorded. Previously, the farthest east that alluvial groundwater had been noted was in borehole MCC-8.2, drilled in April 1989, which contained 3 ft (0.91 m) of perched groundwater at a depth of 73 ft (22.3 m) at the base of the alluvium. Water may have been used during drilling to equalize down-hole pressure (Stoker et al. 1991, 7530). The borehole was plugged and abandoned after drilling; therefore, no further information about water levels at MCC-8.2 is available.

Based in the results of the 1990 seismic survey, four shallow boreholes were drilled near lines MD-11 and MD-13 in August 1991. The borehole for moisture access tube MCM-10-1 was drilled to a depth of 119 ft (36.3 m) into bedrock tuff near the south end of line MD-11. The borehole for moisture access tube MCM-10-2 was drilled to a depth of 43 ft (13.1 m) southeast of the intersection of lines MD-11 and MD-12. Both boreholes were dry, and 2-in.-diameter capped plastic pipe was installed in each.

Two boreholes were also drilled near the southern end of line MD-13. The borehole for moisture access tube MCM-10-3A was drilled to a depth of 33 ft (10.1 m), and 2-in.-diameter capped plastic pipe was installed by filling the annulus between the pipe and the wall of the borehole with drill cuttings. The borehole for moisture access tube MCM-10-3B was drilled 12 ft (3.7 m) west of MCM-10-3A to a depth of 43 ft (13.1 m). A 2-in.-diameter capped plastic pipe was installed, but at this location the annulus was filled with 0.010- to 0.020-in.-diameter sand. Both boreholes were dry.

The results of drilling the four boreholes did not confirm the results of the 1990 seismic survey, which indicated that shallow groundwater was present in the alluvium in the lower canyon. The report of the 1991 seismic survey (Reynolds 1991, 56040) noted that the high velocities seen in the 1990 seismic data were evidently related to local development of denser, harder beds within the alluvium (or Cerro Toledo interval) rather than to the presence of moisture.

The results of the 1991 seismic survey showed that the thickness of the alluvium in the lower canyon may be up to about 85 ft (25.9 m), which was consistent with the results of the 1991 drilling. The 1991 seismic survey also detected possible reflectors but at depths generally shallower than the actual location of the water table. The reflectors were found to be at calculated depths of 25 to 35 ft (7.6 to 10.7 m) on lines MD-8B and MD-16, which is much shallower than the alluvial groundwater has ever been measured in these areas and probably represents higher velocity sediments within the alluvium. Variations in the depth of the alluvium-base reflector on the north and south sides of the canyon noted on several lines may be the result of the braided nature of the stream channel deposits.

3.7.3 Deep Unsaturated Zone

Understanding the hydrogeologic properties of the unsaturated zone of the Bandelier Tuff and other units present beneath Mortandad Canyon is important because the unsaturated zone possibly may serve as either a barrier or a conduit to the vertical movement of contaminated alluvial groundwater.

At TW-8 there is approximately 930 ft (283 m) of unsaturated volcanic tuff, sediments, and basaltic rocks between the base of the alluvium and the top of the regional aquifer. Numerous investigations focusing on hydrologic characterization of the upper 100 ft (30.5 m) of Bandelier Tuff have been conducted in the Laboratory area since the 1950s (for example, Abrahams et al. 1961, 8134; Weir and Purtymun 1962, 11890; Abrahams 1963, 8149; Purtymun and Koopman 1965, 11839; Purtymun and Kennedy 1971, 4798; Purtymun et al. 1978, 5728; Abeele et al. 1981, 6273; Kearl et al. 1986, 8414; Purtymun et al. 1989, 6889; Stoker et al. 1991, 7530). The vadose zone below 100 ft (30.5 m) is less well characterized.

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

- *physical properties (density, porosity, and specific gravity);*
- *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.*

The movement of alluvial groundwater containing tritium through the unsaturated zone beneath Mortandad Canyon was investigated by Stoker et al. (1991, 7530). This investigation involved drilling several boreholes through the alluvium into the unsaturated zone below. The investigations concluded the following.

- *Stratified hydrogeologic conditions are present in the unsaturated zone beneath the alluvial groundwater. The unsaturated zone generally contains moisture at about 30 to 50% of saturation; however, stratified zones contained moisture up to 80 to 90% of saturation.*
- *Nonsoluble and particulate radioactive constituents have moved less than approximately 10 ft (3.0 m) into the unsaturated zone beneath the alluvial groundwater.*
- *Tritium, as HTO, has moved at least 150 ft (45.7 m) below the alluvial groundwater to a depth of at least 195 ft (59.4 m).*
- *Tritium concentrations decrease by a factor of approximately 100 between 150 and 195 ft (45.7 and 59.4 m) in the borehole for moisture access tube MCM-5.9, which suggests that tritium may not have moved much deeper in the almost 30 years since discharges from the TA-50 RLWTF began. However, this conclusion must be considered tentative until additional, deeper boreholes can provide confirmation (Environmental Protection Group 1995, 50285).*

Rogers and Gallaher (1995, 49824) summarized the physical and unsaturated hydraulic properties of the Bandelier Tuff using data obtained from the boreholes for moisture access tubes MCM-5.1 and MCM-5.9A.

Rogers et al. (1996, 55543) subsequently reevaluated the hydraulic property data and estimated water fluxes at various depths (Table 3.7.3-1) in the unsaturated zone beneath Mortandad Canyon.

TABLE 3.7.3-1

ESTIMATES OF VERTICAL HEAD GRADIENTS, EFFECTIVE IN SITU UNSATURATED HYDRAULIC CONDUCTIVITY, AND VERTICAL WATER FLUX BENEATH MORTANDAD CANYON

Part 1						
				Harmonic Mean		
Borehole ID	**Depth Interval (ft)**	**Formation(s) (Revised)**	**Average Head Gradient**[a]	**K_{eff}**[b] **(cm/s)**	**Flux**[c] **(cm/s)**	**Flux**[c] **(cm/yr)**
MCM-5.1	*10–110*	*Al, Qbt 1v, Qct*	*0.9*	*5.41E-09*	*-4.87E-09*	*-0.154*
MCM-5.9A	*85–185 (psy)*[d]	*Lower Qct, Qbo*	*0.8*	*5.36E-10*	*-4.29E-10*	*-0.014*
	85–185 (ret)[e]	*Lower Qct, Qbo*	*1.5*	*5.36E-10*	*-8.04E-10*	*-0.025*
	120–165 (psy)[d]	*Qbo*	*0.8*	*4.58E-08*	*-3.66E-08*	*-1.155*
	120–165 (ret)[e]	*Qbo*	*1.5*	*4.58E-08*	*-6.87E-08*	*-2.167*
Part 2						
				Geometric Mean		
Borehole ID	**Depth Interval (ft)**	**Formation(s) (Revised)**	**Average Head Gradient**[a]	**K_{eff}**[b] **(cm/s)**	**Flux**[c] **(cm/s)**	**Flux**[c] **(cm/yr)**
MCM-5.1	*10–110*	*Al, Qbt 1v, Qct*	*0.9*	*5.78E-08*	*-5.20E-08*	*-1.64*
MCM-5.9A	*85–185 (psy)*[d]	*Lower Qct, Qbo*	*0.8*	*8.01E-08*	*-6.41E-08*	*-2.02*
	85–185 (ret)[e]	*Lower Qct, Qbo*	*1.5*	*8.01E-08*	*-1.20E-07*	*-3.79*
	120–165 (psy)[d]	*Qbo*	*0.8*	*1.99E-07*	*-1.59E-07*	*-5.02*
	120–165 (ret)[e]	*Qbo*	*1.5*	*1.99E-07*	*-2.99E-07*	*-9.41*

a. Gradients are positive downward

b. K_{eff} = effective in situ unsaturated hydraulic conductivity

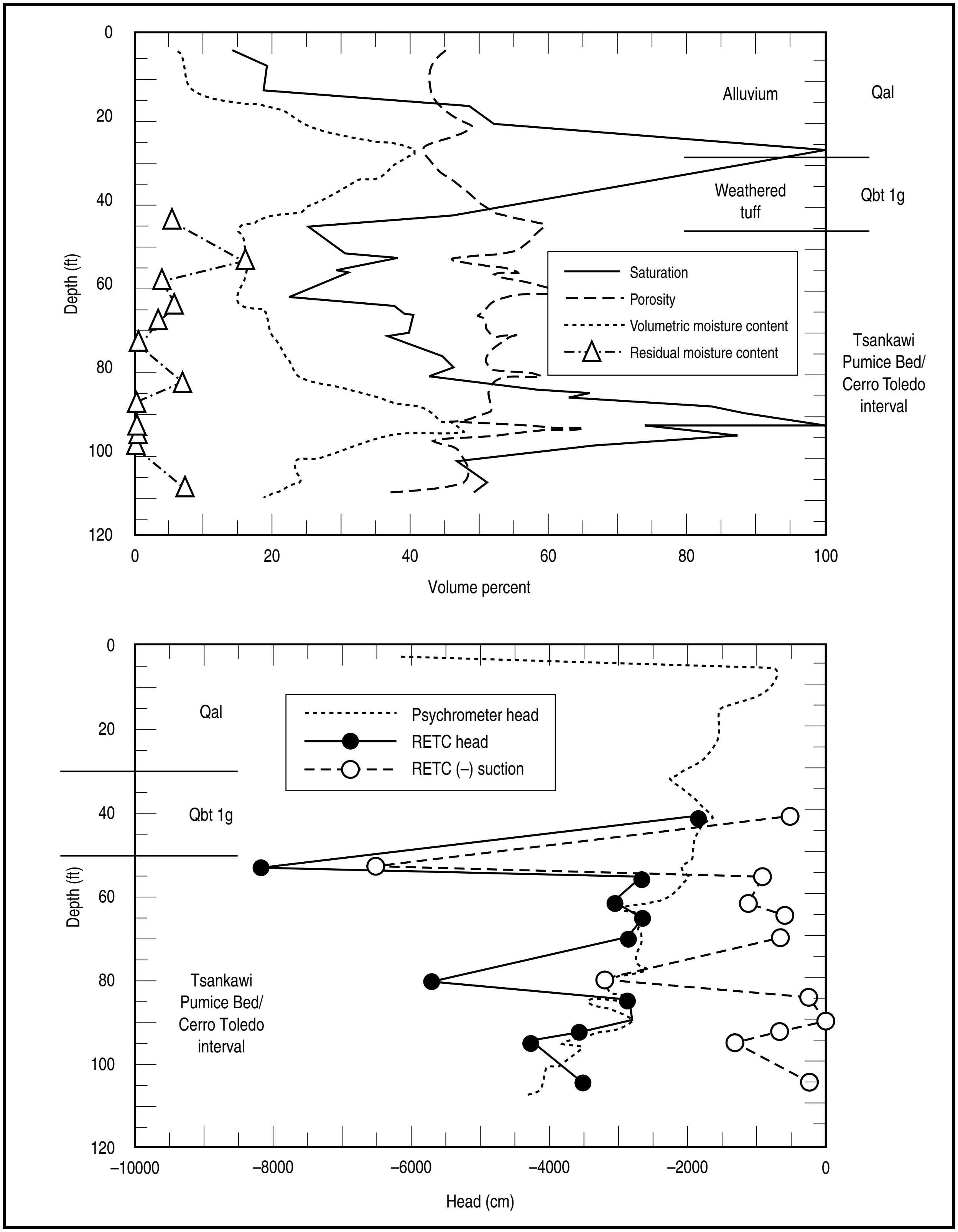
c. Fluxes are specific discharge, not groundwater velocities; negative flux is downward

d. psy = psychrometer measurements on core samples at in situ matric suction

e. ret = matric suction values from retention curves

Source: Rogers et al. 1996, 55543, Table 1

Subsurface moisture profiles of the borehole for well SIMO indicate no moisture buildup at the Tsankawi Pumice Bed/Cerro Toledo interval sequence but show a buildup within the Otowi Member at the base of the borehole. The reinterpreted stratigraphy of this borehole indicates that the increase in moisture content probably occurs within the Cerro Toledo interval. A similar increase in moisture content in the Cerro Toledo interval was noted in boreholes MCM-5.9A and MCC-8.2 (Stoker et al. 1991, 7530). Rogers and Gallaher (1995, 49824) found that two zones of saturation occur in the borehole for moisture access tube MCM-5.1: at the base of the alluvium and within the Tsankawi Pumice Bed/Cerro Toledo sequence (as reinterpreted) (see Figure 3.7.3-1). Using a combination of head values calculated from thermocouple psychrometer potential measurements at the in situ moisture content and head values calculated from moisture retention curves, they found that below approximately 10 ft (3.0 m) into the bedrock, the hydraulic head decreases uniformly with depth, which indicates downward flow of water into bedrock units beneath the canyon floor.



Source: Rogers and Gallaher 1995, 49824

F3.7.3-1 / MORTANDAD WP / 090597

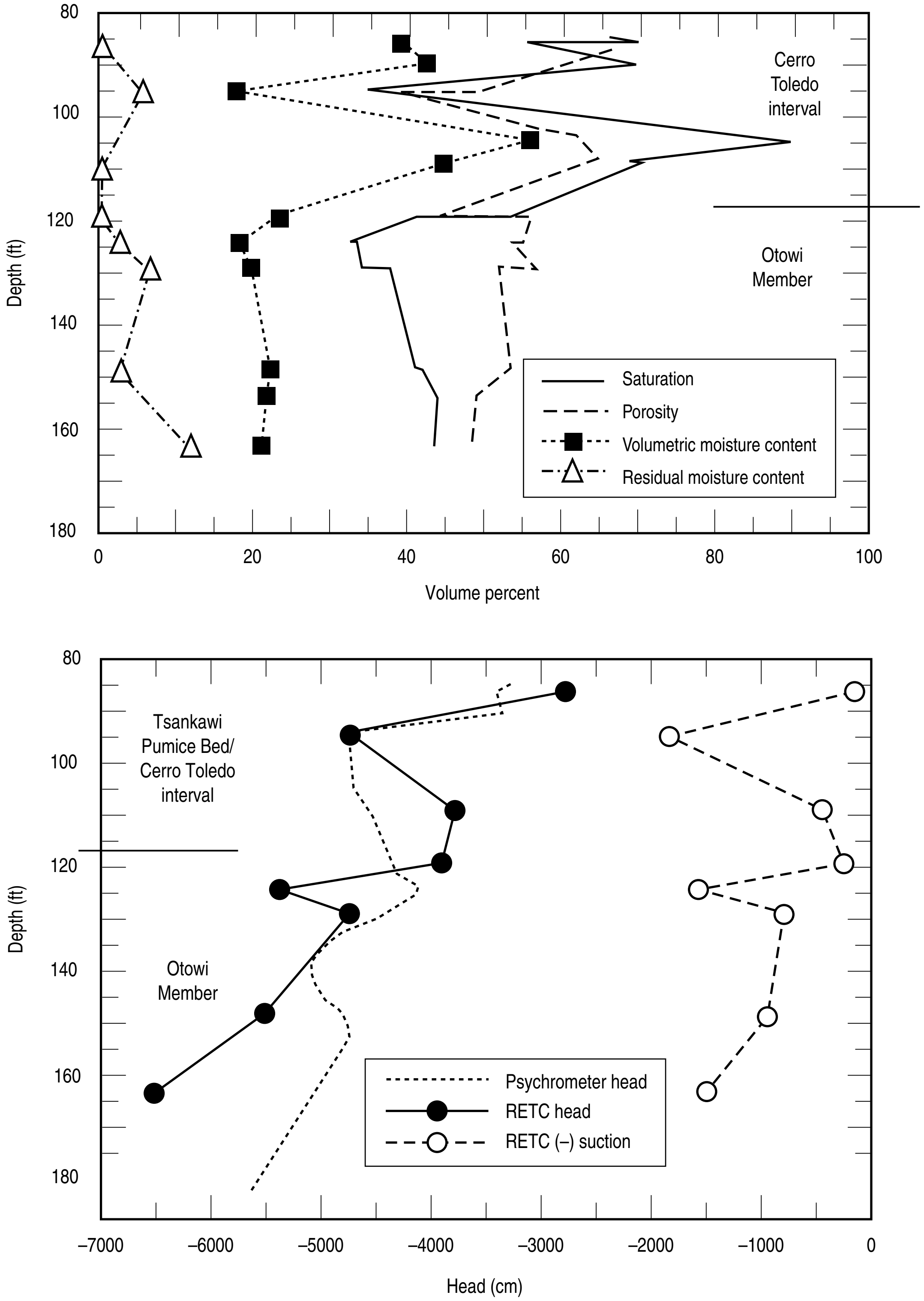
Figure 3.7.3-1. Revised core sample depth profiles for borehole MCM-5.1.

Core samples from the borehole for moisture access tube MCM-5.9A (Figure 3.7.3-2) also show an increase in degree of saturation to nearly 90% by volume in the Cerro Toledo interval (Rogers and Gallaher 1995, 49824). These data show that moisture content and degree of saturation increase with depth in the Otowi Member, which suggests that there is a downward flow of water into the bedrock beneath the canyon floor. A slight reversal in head occurred within the Cerro Toledo interval, which suggests the possibility of some upward or lateral flow within this unit.

Rogers and Gallaher (1995, 49824) noted that concentrations of tracer contaminants (nitrate and tritium) at depths up to 200 ft (61.0 m) beneath Mortandad Canyon are higher than the concentrations calculated using travel times obtained from core data. Rogers and Gallaher concluded that infiltration beneath Mortandad Canyon may occur by vertical unsaturated flow through the rock matrix, infiltration by matrix saturated flow, infiltration farther upstream followed by lateral flow within the Cerro Toledo interval, or vapor-phase flow. The vertical water fluxes calculated from NO_3^- *tracer measurements in Mortandad Canyon are larger than predicted using hydraulic property data. The derived hydraulic properties of alluvium and the Bandelier Tuff, as reported by Rogers and Gallaher (1995, 49824), are discussed in the core document (LANL 1997, 55622).*

Canyon-floor and mesa-top vertical hydraulic head profiles suggest that generally downward flow of water occurs beneath the surface of the Pajarito Plateau, except that possibly upward or lateral flow occurs within the Tsankawi Pumice Bed/Cerro Toledo interval beneath Cañada del Buey and Mortandad Canyon. Core data provide the basis for constructing vertical profiles of in situ matric suction and hydraulic head, which indicate the likely direction of subsurface water flux (Rogers and Gallaher 1995, 49824). Vertical profiles for the boreholes for moisture access tubes MCM-5.1 and MCM-5.9A, and well SIMO are shown in Figure 3.7.3-1, Figure 3.7.3-2, and Figure 3.7.3-3, respectively. The data shown in the figures are from Rogers and Gallaher (1995, 49824), but the stratigraphy shown in the figures is based on the reinterpretation of the subsurface stratigraphy discussed in Section 3.3.1. The saturated zone within the Cerro Toledo interval at 90 to 100 ft (27.4 to 30.5 m) in MCM-5.1 may correlate to the high saturation zones in MCM-5.9A at 100 to 110 ft (30.5 to 33.5) and in SIMO at 90 ft (27.4 m). Each of these zones is located at the base of the Cerro Toledo interval just above the contact (or the expected contact) with the Otowi Member.

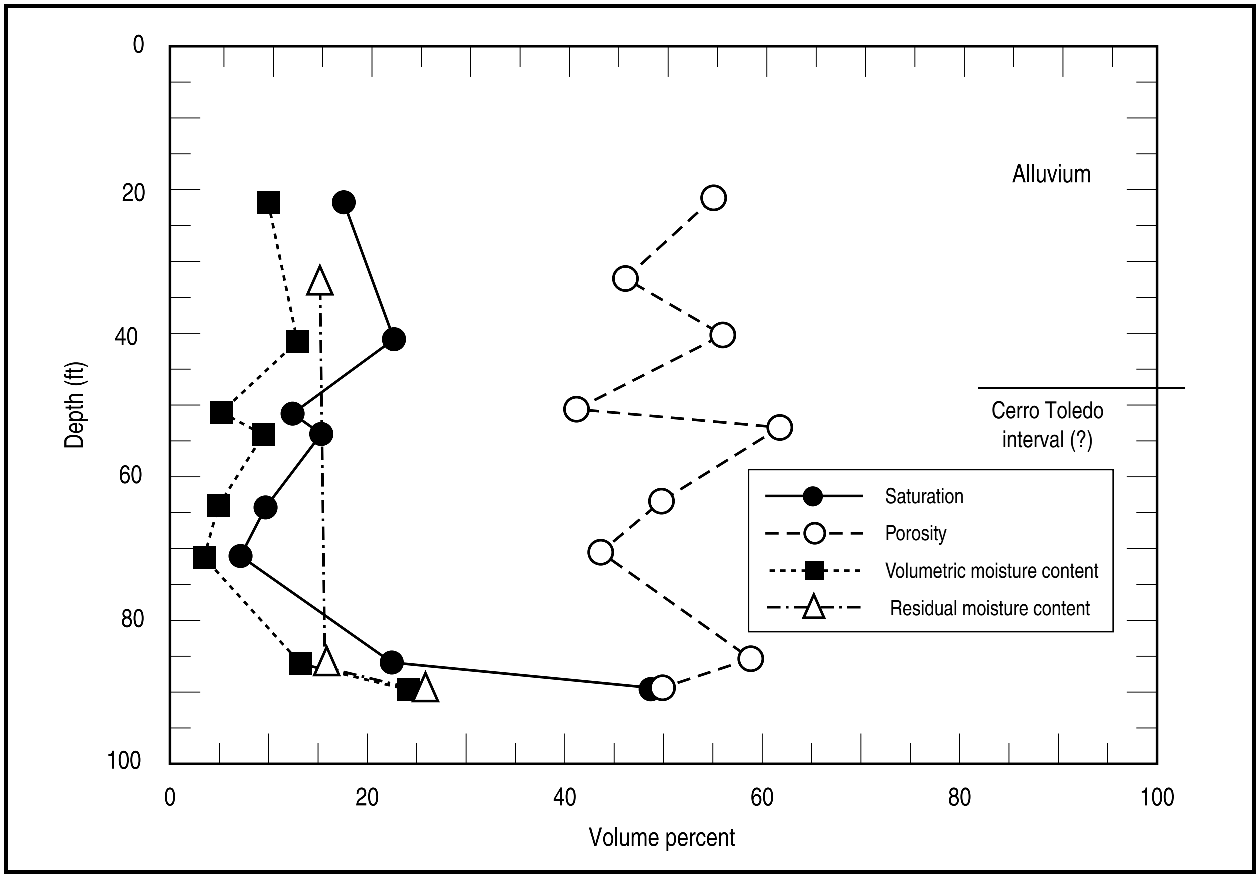
Geddis (1992, 31592) modeled moisture redistribution in the bedrock units beneath the alluvium near the boreholes for moisture access tubes MCM-5.1 and MCM-5.9A based on hydraulic properties reported by Stoker et al. (1991, 7530). The computer code UNSAT2 was used for the modeling. Two scenarios were considered for simulating the alluvial groundwater source term: a ponded upper boundary condition and a constant flux scenario. Infiltration flux of alluvial groundwater was calculated to be 0.0056 ft/day (0.171 cm/day), whereas the constant flux scenario used infiltration flux that was an order of magnitude greater or 0.056 ft/day (1.71 cm/day). The simulations were not able to recreate moisture conditions observed in the bedrock units, probably because the simplified nature of the model did not adequately represent the complexity and heterogeneity of the natural system. One of the uncertainties noted in the modeling was the value of the infiltration flux from the alluvial groundwater. The highly-weathered tuff immediately below the alluvium/tuff interface may restrict infiltration flux more than expected. The hydraulic characteristics of this weathered zone have not been evaluated, and it was recommended that this zone be sampled and evaluated. In addition, Geddis (1992, 31592) found that there was little or no propensity for lateral movement of moisture toward the mesa from the canyon floor.



Source: Rogers and Gallaher 1995, 49824

F3.7.3-2 / MORTANDAD WP / 090597

Figure 3.7.3-2. Revised core sample depth profiles for borehole MCM-5.9A.



Source: Rogers and Gallaher 1995, 49824

F3.7.3-3 / MORTANDAD WP / 090597

Figure 3.7.3-3. Revised core sample depth profiles for borehole SIMO.

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 Mortandad Canyon ranging from approximately 1200 ft (366 m) at the head of the canyon to approximately 600 ft (183 m) near the Laboratory boundary. The regional aquifer is separated from the water in the alluvium by more than 960 ft (293 m) of tuff and volcanic sediments (Environmental Protection Group 1993, 23249). 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 1960 when the borehole for TW-8 was drilled by cable tool in Mortandad Canyon, the water in the regional aquifer was partially confined. Water was encountered beneath a confining layer at a depth of 985 to 990 ft (300 to 302 m); the water rose approximately 25 ft (7.6 m) in the borehole to 962.6 ft (293.4 m) (Baltz et al. 1963, 8402). The borehole was drilled to a depth of 1065 ft (324.6 m) intercepting the Puye Formation and interbedded basaltic rocks.

Figure 3.7.4-1 shows the construction information for TW-8 and the revised stratigraphy encountered in this well. A surface casing was installed with 43.5 ft (13.4 m) of 20-in.-diameter (50.8-cm-diameter) steel pipe to a depth of 42 ft (12.8 m). From 0 to 64 ft (0 to 19.5 m) a 14-in.-diameter (35.6-cm-diameter) steel casing was installed inside the surface casing through the alluvium and the Tshirege Qbt 1g Member and 4 ft (1.2 m) into the top of the Cerro Toledo interval, based on the revised stratigraphy. Cement was circulated from the base of the 14-in.-diameter (35.6-cm-diameter) casing to the surface. The cement filled the annular space between the 14-in.-diameter (35.6-cm-diameter) casing and the 20-in.-diameter (50.8-cm-diameter) borehole from 42 to 64 ft (12.8 to 19.5 m) and was circulated to the surface inside the 20-in.-diameter (50.8-cm-diameter) surface casing. No cement or other grout was placed outside the 20-in.-diameter (50.8 cm-diameter) surface casing from surface to 42 ft (12.8 m), which is the interval that contains the alluvial groundwater. The production well string consists of 1067 ft (324.7 m) of 8-in.-diameter (20.3-cm-diameter) steel pipe with the lower 112 ft (34.1 m) torch slotted. The well was equipped with a pump jack to sample regional aquifer water. Baltz et al. (1963, 8402) and Purtymun (1995, 45344) describe the stratigraphy and well installation for TW-8.

After TW-8 was completed, the possibility of leakage of surface water or alluvial groundwater down the well bore was considered. Baltz et al. (1963, 8402, p. 51) suggested additional work to provide protection of the regional aquifer.

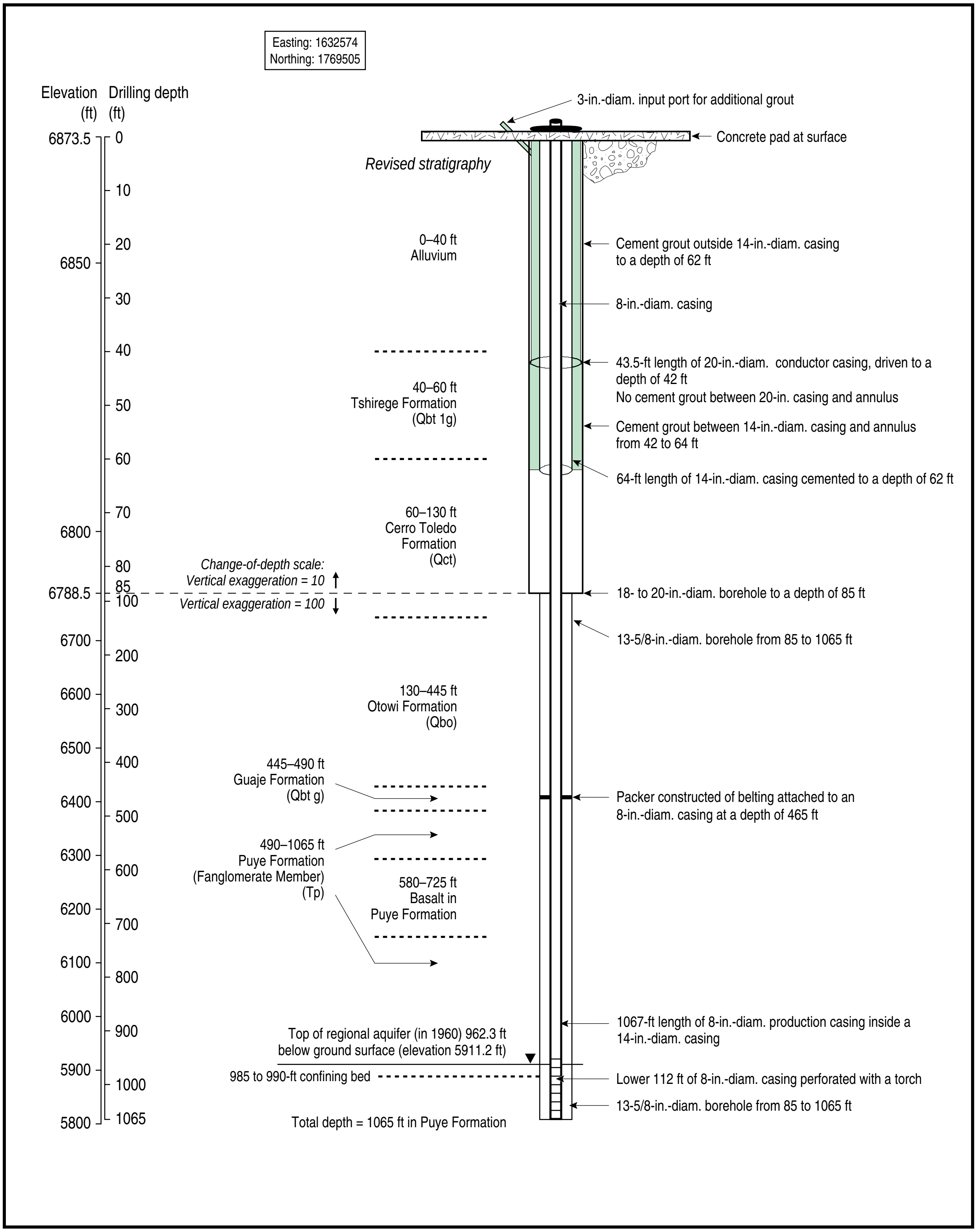
> *If surface water or shallow ground water should begin to leak down around the 20-inch and 14-inch surface casings, it may be possible to seal the upper 465 feet of the well by pouring grout into the annular space between the 8-inch casing and the borehole. A packer made of machinery belting is attached to the outside of the 8-inch casing at a depth of 465 feet to provide a bridge for the grout. Access to the annular space above this bridge is provided by a 3-inch diameter pipe at the well head.*

When the borehole for TW-8 was drilled, bedrock units were unsaturated between the alluvium and the regional aquifer, although possible perching zones were encountered during borehole advancement (Baltz et al 1963, 8402). After TW-8 was completed, a bailing test was performed to test the well and to determine the aquifer properties of the part of the regional aquifer tapped by the well. The well was bailed at a rate of 16 gpm for two hours, which induced 8 ft of drawdown for a specific capacity of 2 gpm/ft. The transmissivity of the formation was calculated to be 2400 gpd/ft with a field coefficient of permeability of 25 gpd/ft^2 (Baltz et al. 1963, 4802; Purtymun 1995, 45344).

In February 1961 a recording pressure transducer was installed in TW-8 to measure water level fluctuations of the regional aquifer. A comparison of barometric pressure changes at Los Alamos with the water level fluctuations in 1961 indicated that the water level in TW-8 fluctuates in response to barometric changes.

From 1960 until 1965 the water level at TW-8 changed only slightly, from 968 to 968.7 ft (295.1 to 295.3 m). By 1992 the water level was 992.45 ft (302.5 m), a decline of 23.75 ft (7.239 m) during 27 years. In 1993 the water level was 992.9 ft (302.6 m), a decline of approximately 30 ft (9.1 m) since the well was installed in 1960, for an average annual decline of approximately 1.1 ft/yr (0.34 m/yr) (Vozella 1994, 56048).

Groundwater level measurements 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 through the Santa Fe Group and the lower part of the volcanic and sedimentary rock units beneath the central and western part of the Pajarito Plateau (Purtymun and Johansen 1974, 11835; Rogers et al. 1996, 54714; LANL 1997, 55622; LANL 1996, 55430). Near TW-8 the hydraulic gradient of the regional aquifer was



Source: Baltz et al. 1963, 8402

F3.7.4-1 / MORTANDAD WP / 092597

Figure 3.7.4-1. Construction diagram for test well TW-8.

approximately 70 ft (21.3 m) per mile when the well was installed; a similar gradient was noted using 1993 water level data (Rogers et al. 1996, 54714). The hydraulic gradient of the regional aquifer averages approximately 60 to 80 ft (18.3 to 24.4 m) per mile within the Puye Formation. Along the eastern edge of the Pajarito Plateau, as the water in the aquifer enters the less permeable sediments of the Santa Fe Group, the 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 tests indicate that movement ranges from 20 ft/yr (6.1 m/yr) in the Tesuque Formation 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 ^{14}C and tritium dating methods. The ^{14}C data suggest that older water is found near the Rio Grande and that younger water is present under the central Pajarito Plateau. Recent investigations suggest that the regional aquifer water near the Rio Grande is 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).

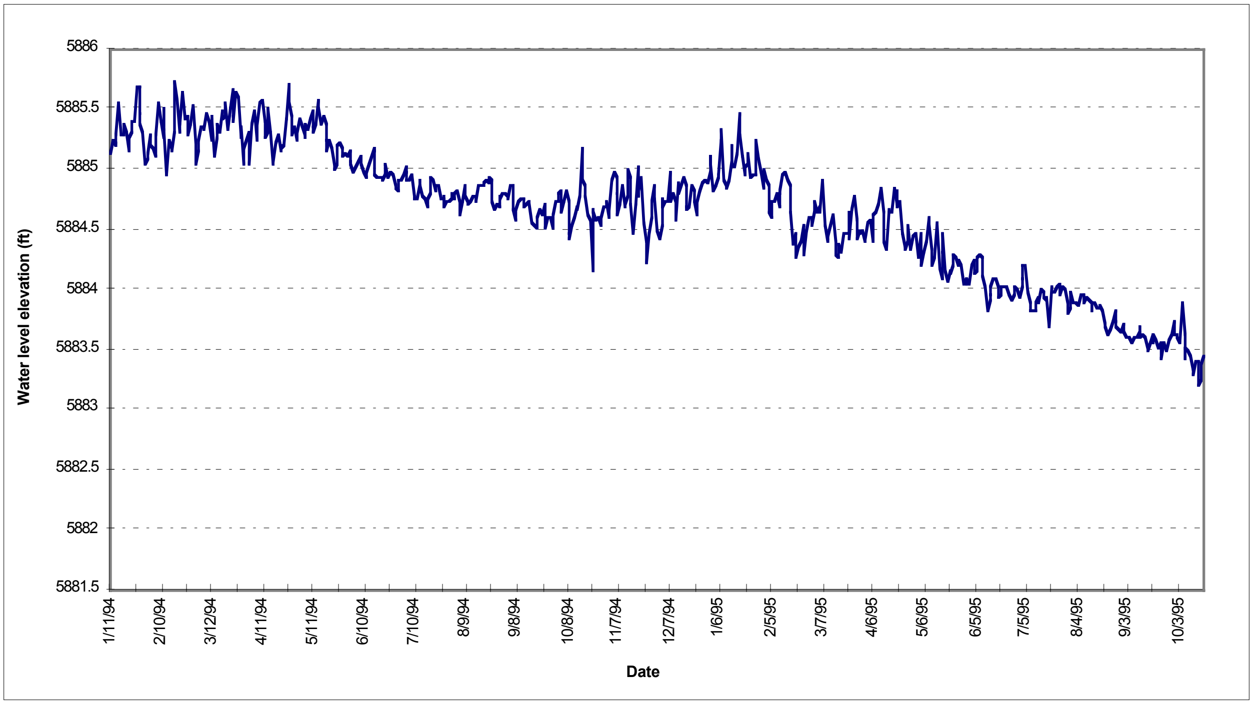
In October 1992 the Laboratory once again began measuring and recording water level fluctuations in test wells completed into the regional aquifer. These data are automatically recorded at hourly intervals using calibrated pressure transducers (Environmental Protection Group 1995, 50285). Measurements at TW-8 commenced in June 1993, and the data for November 1, 1994, through October 17, 1995, are shown in Figure 3.7.4-2. Data from hourly measurements show a fluctuation of approximately 0.2 to 0.5 ft (61 to 152 cm) during a given seven-day period; the hourly amplitudes and frequencies of fluctuations vary from month to month. The water level fluctuations may be related to pumping of nearby municipal and industrial supply wells, such as well PM-5 located approximately 2000 ft (610 m) south of TW-8.

Samples have been routinely collected and analyzed, and water levels have been measured from TW-8 for environmental monitoring purposes. The results of analyses for major ions and radionuclides are summarized in Figure 3.7.4-3, Figure 3.7.4-4, and Figure 3.7.4-5.

On December 6, 1993, TW-8 was sampled as part of the routine environmental monitoring program. The well had been out of service since 1991 because of pump failure. In October 1992 a submersible pump was installed to sample regional aquifer water. The previous sample collected in 1991 did not show measurable tritium (Environmental Protection Group 1995, 50285); however, the earlier measurements of tritium from TW-8 used a less sensitive technique that could not detect tritium at activities less than approximately 700 pCi/L (0.7 nCi/L). The activity of tritium measured in samples collected in December 1993 using low-detection-limit tritium analysis techniques was 89.4 ± 0.29 pCi/L. This result, although not significant for health purposes (the EPA maximum contaminant level for tritium is 20,000 pCi/L) shows the presence of recent recharge to the regional aquifer, possibly from the alluvial groundwater in Mortandad Canyon (Gallaher 1995, 54716).

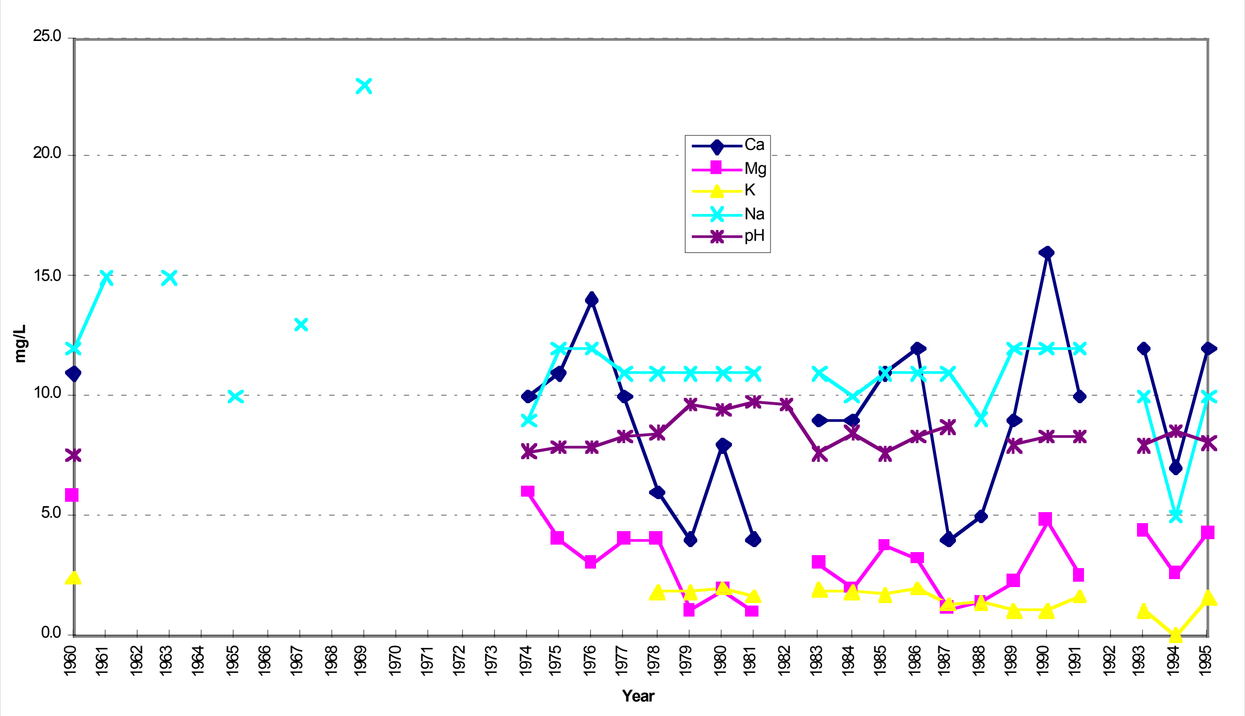
In recent years tritium activities in the alluvial groundwater 930 ft (283 m) above the regional aquifer near TW-8 have been 100,000 to 500,000 pCi/L (100 to 500 nCi/L); in the mid-1970s activities ranged as high as 4,000,000 pCi/L (4,000 nCi/L) (see Section 3.8.3). The results of low-detection-limit tritium analysis obtained in 1993 are not necessarily inconsistent with the tritium activities previously obtained; therefore, it cannot be determined where or when tritiated surface water has reached the regional aquifer. Gallaher (1995, 54716) proposed three possible pathways for tritium to reach to the regional aquifer.

- *Alluvial groundwater could migrate down the well bore of TW-8, especially considering that the borehole was drilled by cable tool. The casing was cemented in place to a depth of 62 ft (18.9 m) when the well was completed in 1960; however, the integrity of the seal may be questionable after more than 35 years.*



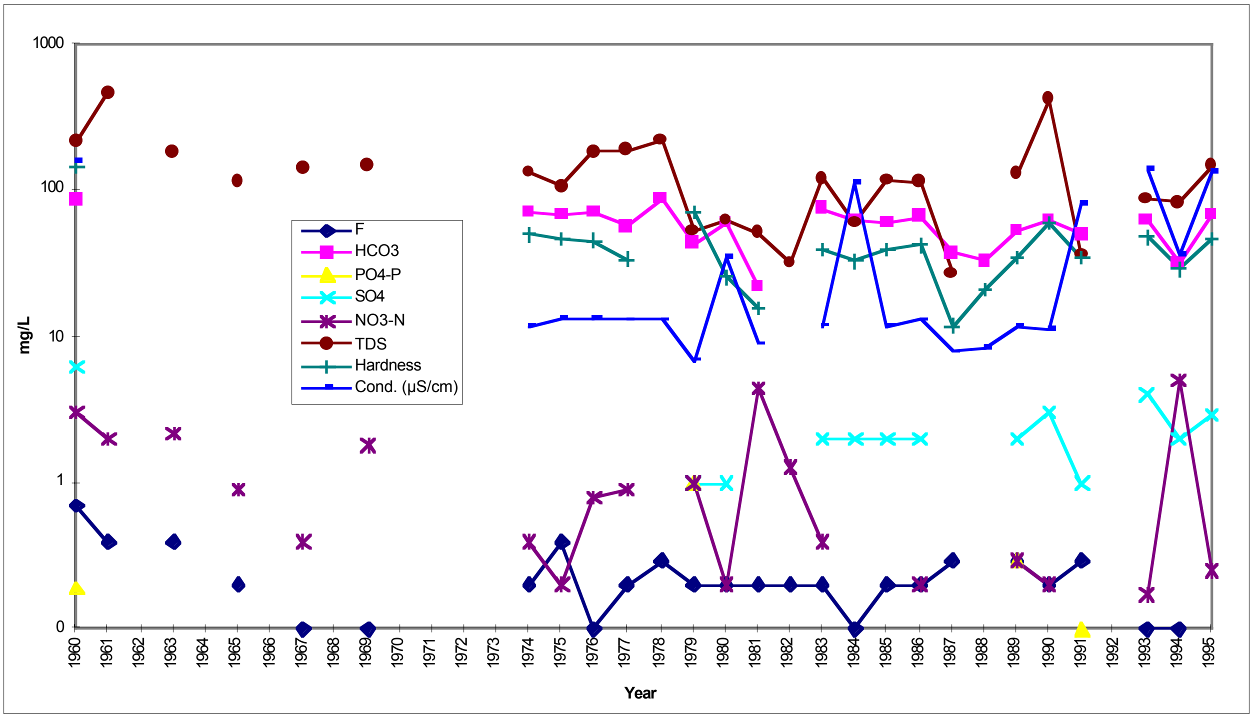
Source: McLin 1996, 56025

Figure 3.7.4-2. Recent water level measurements of the regional aquifer at TW-8.



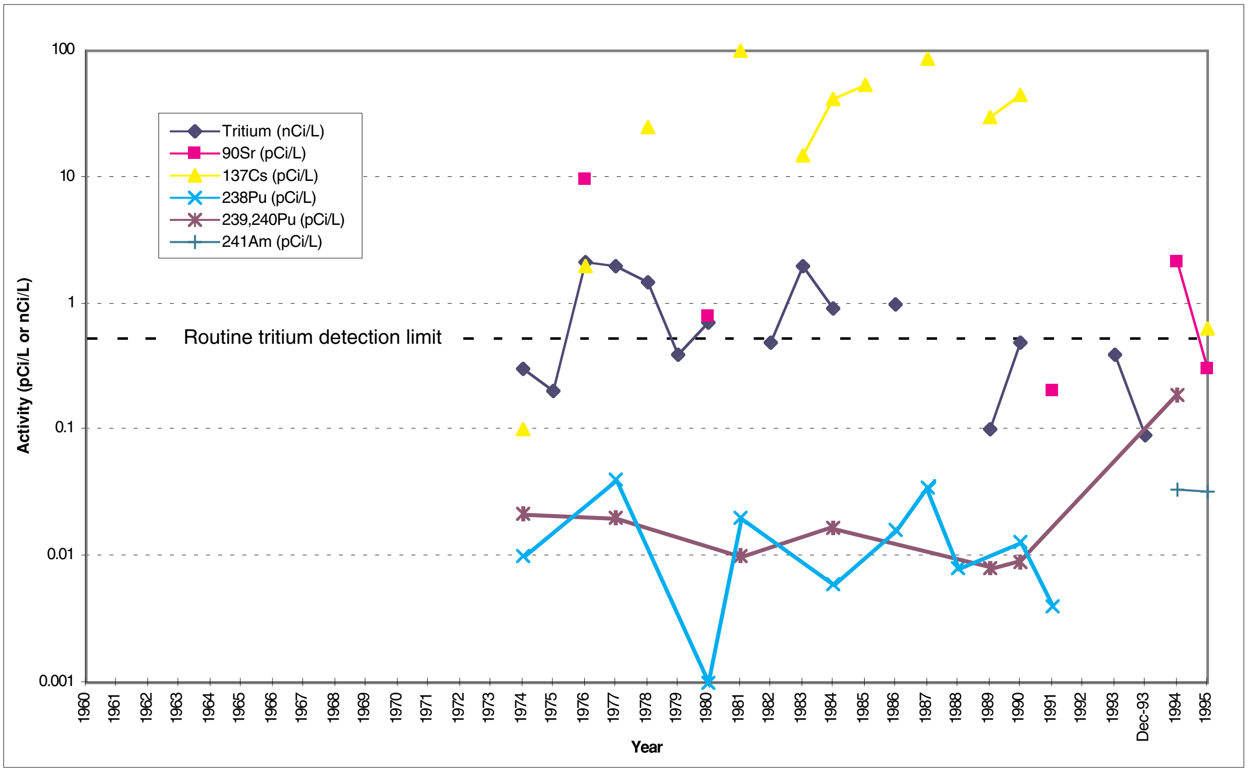
Source: Environmental Surveillance Reports

Figure 3.7.4-3. Cation concentrations and pH in the regional aquifer at TW-8.



Source: Enviromental Survellance Reports

Figure 3.7.4-4. Total dissolved solids and anion concentrations and specific conductance in the regional aquifer at TW-8.



Source: Environmental Surveillance Reports

Figure 3.7.4-5. Radionuclide activity in the regional aquifer at TW-8.

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

- *Water could migrate as unsaturated flow through the unsaturated zone. The information available from the boreholes for moisture access tubes MCM-5.9A and MCC-8.2, as discussed in Section 3.5.3, shows that tritium has migrated downward in the unsaturated zone to a depth of at least 150 ft (45.7 m) beneath the alluvial groundwater.*

In 1994 the tritium activity in the regional aquifer at TW-8 was measured using the less-sensitive technique to be -100 ± 300 pCi/L (detection limit 400 pCi/L); in 1995 the activity was measured at -100 ± 300 pCi/L (detection limit 300 pCi/L) (Environmental Protection Group 1996, 54769; Environmental Surveillance Program 1996, 55333). Based on these analyses, the results of the 1993 low-detection-limit analysis could not be confirmed.

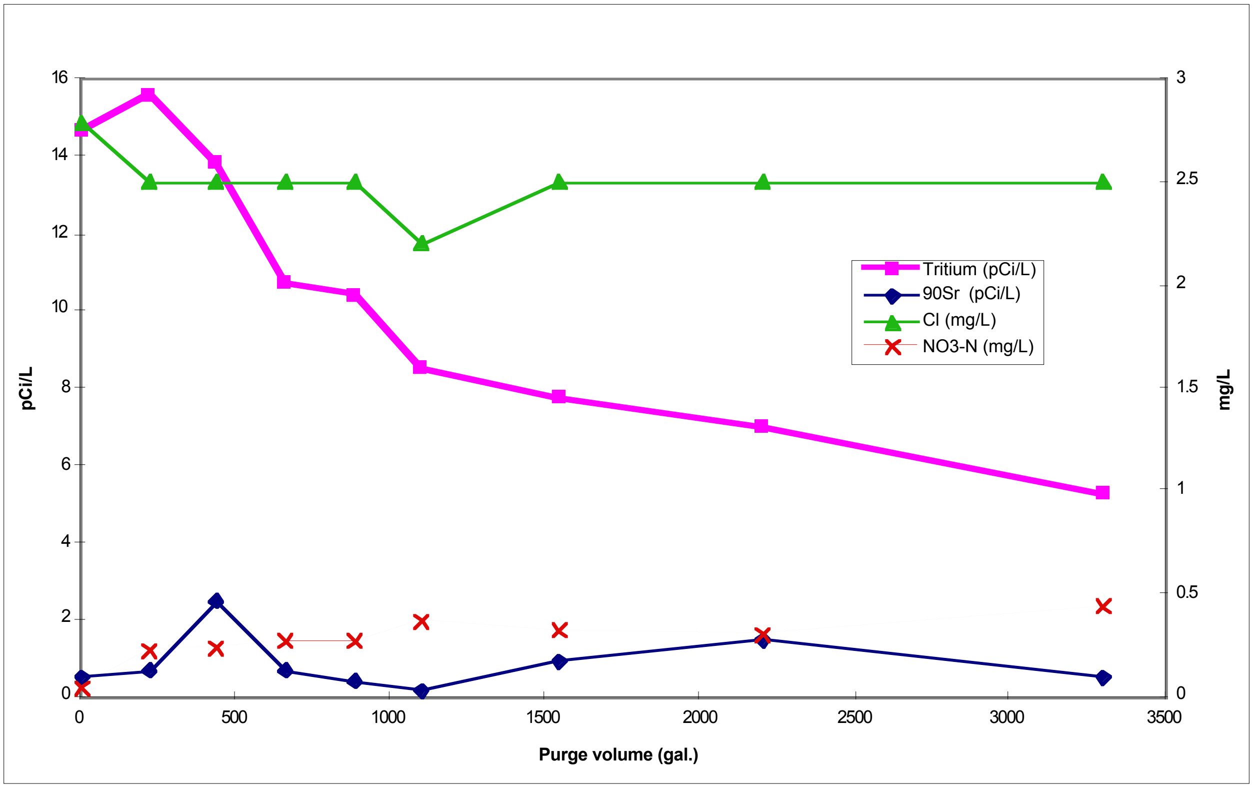
In 1994 TW-8 showed an increase in nitrate (as N) concentration from values of approximately 0.2 mg/L in previous years to 5.1 mg/L (Environmental Protection Group 1996, 54769). The source of the elevated nitrate in samples of the regional aquifer collected from TW-8 is not known, but the alluvial groundwater in Mortandad Canyon is a likely source. However, the possibility of sampling and/or analytical error exists. During the early 1990s nitrate was typically observed in the alluvial groundwater in concentrations of approximately 40 to 50 mg/L; during the 1980s the nitrate concentrations in the alluvial groundwater were typically more than 100 mg/L (see Section 3.8.1). In 1995 the concentration of nitrate from TW-8 was 0.25 mg/L, which indicates that either the source of contaminated water to the regional aquifer may not be continuous or the previous year's measurement was erroneous.

The routine sampling and analyses of TW-8 in 1994 also showed an anomalous activity of ^{239,240}*Pu of 0.188 ± 0.032 pCi/L (Environmental Protection Group 1996, 54769). Previous years' results for* ^{239,240}*Pu were typically less than 0.01 pCi/L (detection limit 0.02 pCi/L) (Figure 3.7.4-5). The results obtained in 1995 for* ^{239,240}*Pu were -0.007 ± 0.016 pCi/L (detection limit 0.04 pCi/L) (Environmental Surveillance Program 1996, 55333), which suggests that the results obtained in 1994 for both nitrate and* ^{239,240}*Pu may not have represented the regional aquifer water.*

In response to the 1994 findings, ESH-18 personnel conducted time series sampling of TW-8 in July 1995. The normal sampling procedure for wells is to collect a water sample after purging at least three well volumes of water to ensure that stagnant water in the well casing and the surrounding formation has been removed and to insure that the sample represents in situ formation water. In July 1995 regional aquifer water samples were collected during purging of 0, 1, 2, 3, 4, 5, 7, 10, and 15 well volumes (220 gal. [833 L] per well volume). The samples were analyzed for chloride, nitrate (as N), ^{90}*Sr, and low-detection-limit tritium (Environmental Surveillance Program 1996, 55333).*

The results of the time series sampling and analyses are shown in Figure 3.7.4-6. The initial tritium activity was approximately 15 pCi/L, which suggests influence of contaminated surface water or alluvial groundwater at the depth of the regional aquifer (Environmental Surveillance Program 1996, 55333). The activity of tritium decreased with continued pumping, which suggests that formation water surrounding the well contained lower activity of tritium than the water initially sampled from the well.

One mechanism by which the high initial tritium activities could occur is leakage down the well bore from the alluvium. The activity of tritium in the alluvial groundwater in Mortandad Canyon in 1995 was approximately 20,000 pCi/L (Figure 3.3.3-6). The activity of tritium observed in the initial well sample could be produced if only 0.2 gal. (0.8 L) of alluvial groundwater migrated down the well bore and mixed with approximately 200 gal. (757 L) or approximately 1 well bore volume (mixing ratio 1:1000) of formation water.



Source: Enviromental Survelance Program 1996, 55333

Figure 3.7.4-6. Results of time series sampling and analysis of TW-8.

That same rate of migration of alluvial groundwater down the well bore would result in concentrations of chloride and nitrate within the range of regional background levels observed in the regional aquifer. Sufficient amounts of ^{90}Sr would not be available to raise the activity of the regional aquifer above detection limits. Therefore, dilution of alluvial groundwater containing chloride and nitrate would produce concentrations similar to those normally observed in the regional aquifer; moreover, no decrease in concentration with purging would be expected. This model is consistent with the observed time series sampling and analysis results, which are shown on Figure 3.7.4-6. Therefore, the hypothesis of leakage of water down the well bore cannot be ruled out, especially when considering the concerns expressed by Baltz et al. (1963, 8402, p. 51) after the well was installed that leakage around the surface casings might occur.

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

3.7.5 Data Requirements for Understanding the Hydrogeology of Mortandad 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 (including bulk density, porosity, saturated hydraulic conductivity, and matric potential) are needed.

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

Water samples will be collected from the alluvial groundwater, the regional aquifer, and any other saturated zones encountered. The samples should be both filtered in the field and unfiltered 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 TW-8 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 Geochemistry of Surface Water and Groundwater in Mortandad Canyon

The purpose of this section is to discuss the geochemistry of surface water, alluvial groundwater, and regional aquifer groundwater within Mortandad Canyon. Since 1961, ESH-18 (or predecessor) personnel have routinely collected unfiltered water samples from various alluvial wells: currently wells MCO-3, MCO-4, MCO-4B, MCO-5, MCO-6, MCO-7, and MCO-7.5. Samples of the TA-50 RLWTF discharge are collected by TA-50 personnel as part of NPDES compliance monitoring. Average annual concentrations of constituents in the discharge are reported by TA-50 and ESH-18 personnel and are provided here for comparison with surface water and groundwater quality data.

As discussed in Section 2.4.6 in Chapter 2 of this work plan, during the 1980s the volume of water discharged from the TA-50 RLWTF decreased; however, concentrations of chloride, nitrate, and other constituents increased. Therefore, the total masses of solutes discharged from the TA-50 RLWTF remained fairly constant over time.

Historically, GS-1 has been the only semicontinuously operated surface water gaging station in Mortandad Canyon. (GS-2 was operated for brief periods only, and gaging stations installed in 1995 and 1996 in lower Mortandad Canyon have not recorded flows as of May 1997, see Section 3.6.) Surface water samples are collected and analyzed routinely in Mortandad Canyon only at GS-1. At times of routine sampling, the surface water usually is from a mix of sources, primarily storm runoff with lesser amounts of cooling water and TA-50 RLWTF discharges. All surface water flowing past GS-1 recharges alluvial groundwater within 1000 ft (305 m) east of the gaging station. For this reason, the data for surface water and alluvial groundwater are presented together in this section.

This discussion focuses on temporal variations in major ion chemistry, uranium, and radionuclide distributions in alluvial groundwater and the regional aquifer. This discussion also provides an interpretative summary of geochemical modeling using analytical results from filtered samples collected quarterly during 1995 in a special ESH-18 study (Environmental Surveillance Program 1996, 55333).

3.8.1 Major Ions and Total Dissolved Solids in Surface Water and Groundwater

The major cations in surface water and alluvial groundwater include calcium, magnesium, potassium, and sodium; the major anions include bicarbonate, chloride, fluoride, nitrate, and sulfate. Total dissolved solids (TDS) concentration is the summation of all separately-measured dissolved species.

Concentrations of total calcium in surface water at GS-1 and alluvial groundwater from 1973 to 1995 are shown in Figure 3.8.1-1. Concentrations range from less than 10 to 210 mg/L; most concentrations are less than 65 mg/L. During 1987, 1990, and 1991 the highest concentrations were measured at GS-1 and MCO-3. Concentrations are less than 65 mg/L at wells MCO-4, MCO-5, MCO-6, MCO-7, MCO-7.5, and MCO-8. Variations in calcium concentrations in alluvial groundwater could be due to variable amounts of calcium-bearing suspended material (clay minerals and calcium carbonate) as well as variable dissolved calcium (Ca^{2+}*). The TA-50 RLWTF discharge contains sufficient concentrations of calcium and bicarbonate for calcium carbonate to precipitate in alluvial groundwater.*

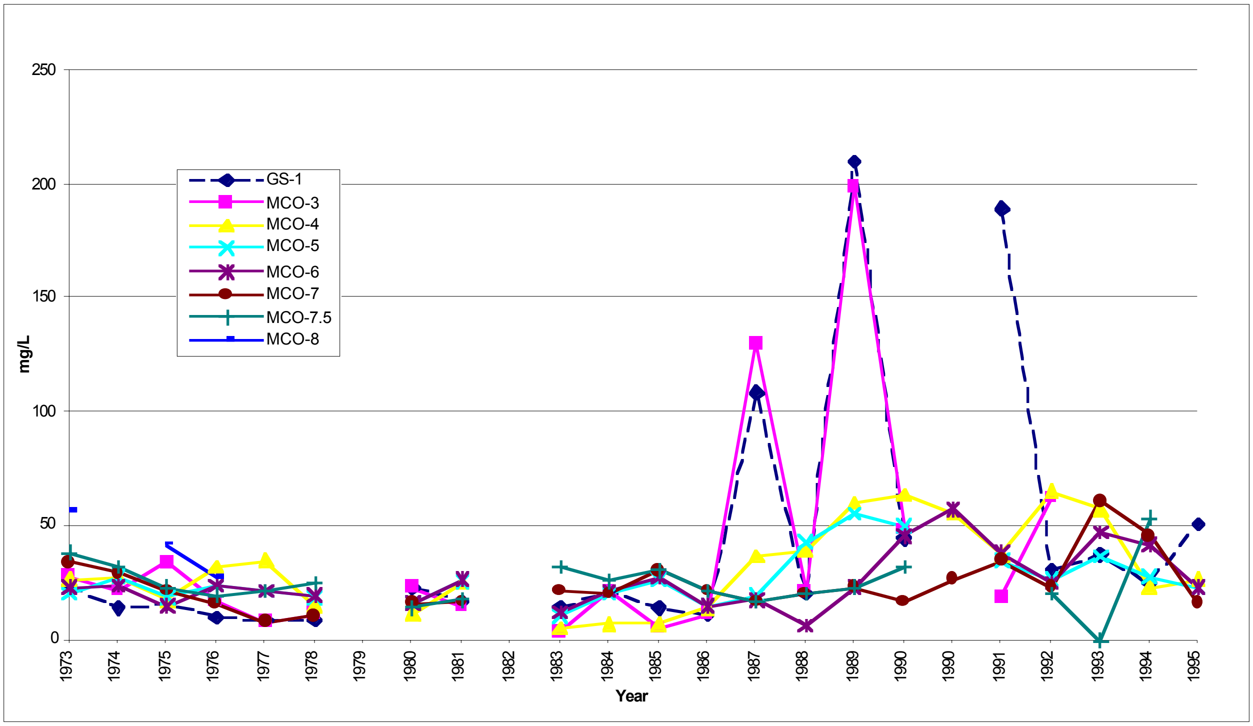
Concentrations of total magnesium in surface water at GS-1 and alluvial groundwater from 1973 to 1995 are shown in Figure 3.8.1-2. Concentrations fluctuate at GS-1 and along the groundwater flow path in Mortandad Canyon, ranging from less than 1 mg/L to 4.5 mg/L, whereas in 1993 concentrations in alluvial groundwater as high as 20 mg/L were reported in MCO-7. Variations in total magnesium concentrations in alluvial groundwater could be due to magnesium-bearing suspended material (clay minerals) as well as variable dissolved magnesium (Mg^{2+}*).*

Concentrations of total sodium in the TA-50 RLWTF discharge, surface water at GS-1, and alluvial groundwater from 1960 to 1995 are shown in Figure 3.8.1-3. Concentrations range from less than 10 mg/L to approximately 1060 mg/L. From 1980 through 1991 the highest concentrations of sodium were measured in the TA-50 RLWTF discharge. Concentrations are generally less than 350 mg/L in the alluvial groundwater with occasional spikes to more than 800 mg/L (as in MCO-3 in 1981). In the 1980s the concentration of sodium in the TA-50 RLWTF discharge increased, whereas volume discharged decreased (see Figure 2.4.6-1 in Chapter 2 of this work plan), and the total annual mass of sodium discharged did not change significantly. A concurrent increase in the concentration of sodium is not observed in the alluvial groundwater during this period.

Concentrations of total bicarbonate in surface water at GS-1 and alluvial groundwater from 1973 to 1995 are shown in Figure 3.8.1-4. Concentrations fluctuate widely in both surface water and alluvial groundwater, ranging from less than 70 mg/L to approximately 390 mg/L. Concentrations greater than 190 mg/L were measured in alluvial groundwater during 1973, 1977, 1980, 1987, 1989, and 1995. In addition, no pattern in concentrations is observed along the groundwater flow path in Mortandad Canyon. Variations in total bicarbonate concentrations in alluvial groundwater could be due to carbonates in the suspended material as well as variable dissolved calcium and bicarbonate (HCO_3^-*).*

Concentrations of total chloride in the TA-50 RLWTF discharge, surface water at GS-1, and alluvial groundwater from 1960 to 1995 are shown in Figure 3.8.1-5. The major source of chloride is probably hydrochloric acid (HCl) used in laboratories and ferric chloride used in the precipitation of ferric hydroxide at the TA-50 RLWTF. Concentrations in the TA-50 RLWTF discharge range from less than 20 mg/L to approximately 180 mg/L; the highest concentrations were measured during 1986, 1987, and 1989. Concentrations in surface water and alluvial groundwater are uniformly less than 80 mg/L. Uniform distributions of chloride, a nonsorbing species at neutral pH values, suggest that alluvial groundwater is hydrodynamically well mixed. In the 1980s the concentration of chloride in the TA-50 RLWTF discharge increased, whereas the volume discharged decreased (see Figure 2.4.6-1 in Chapter 2 of this work plan), and the total annual mass of chloride discharged did not change significantly. A concurrent increase in the concentration of chloride is not observed in the alluvial groundwater during this period.

Total chloride concentrations in alluvial groundwater at MCO-5 and the regional aquifer at TW-8 from 1960 to 1995 are shown in Figure 3.8.1-6. Concentrations at MCO-5 vary widely from 5 mg/L to 67 mg/L during the period; concentrations in TW-8 range from 2 to 8 mg/L. Background chloride concentrations in the regional aquifer are typically less than 5 mg/L (Environmental Protection Group 1995, 50285).



Source Enviromental Survellance Reports

Figure 3.8.1-1. Total calcium in Mortandad Canyon surface water and alluvial groundwater.

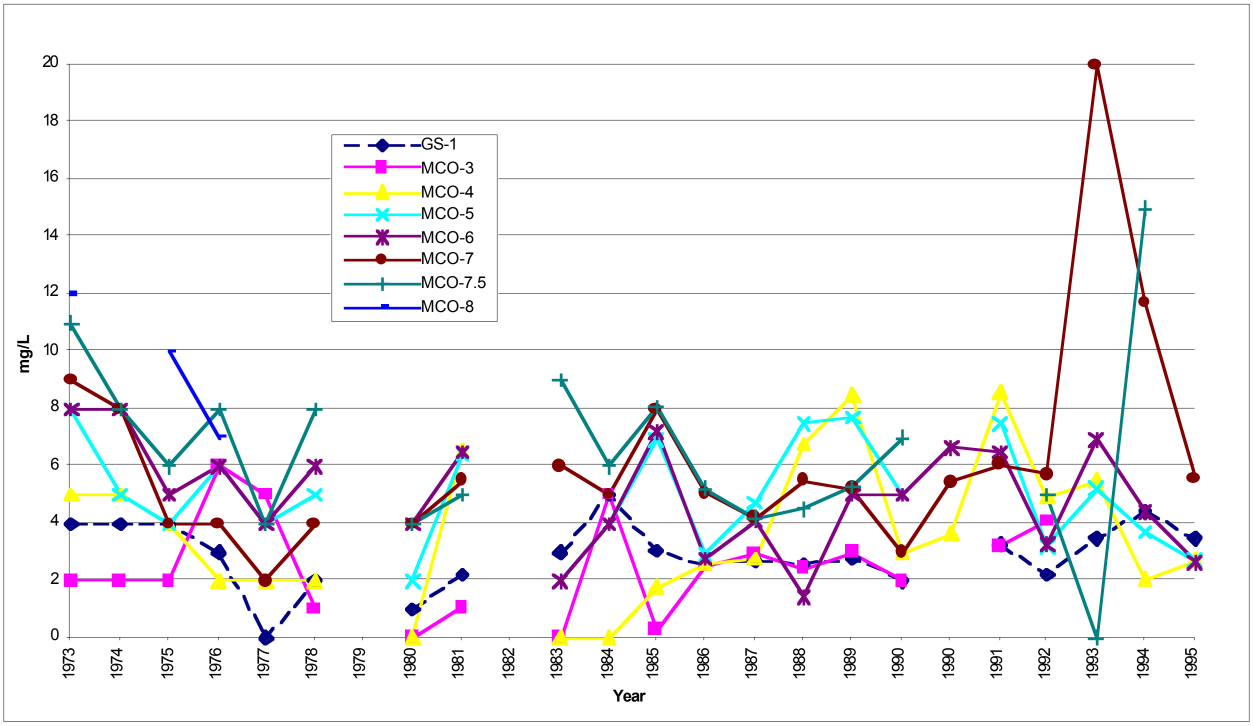


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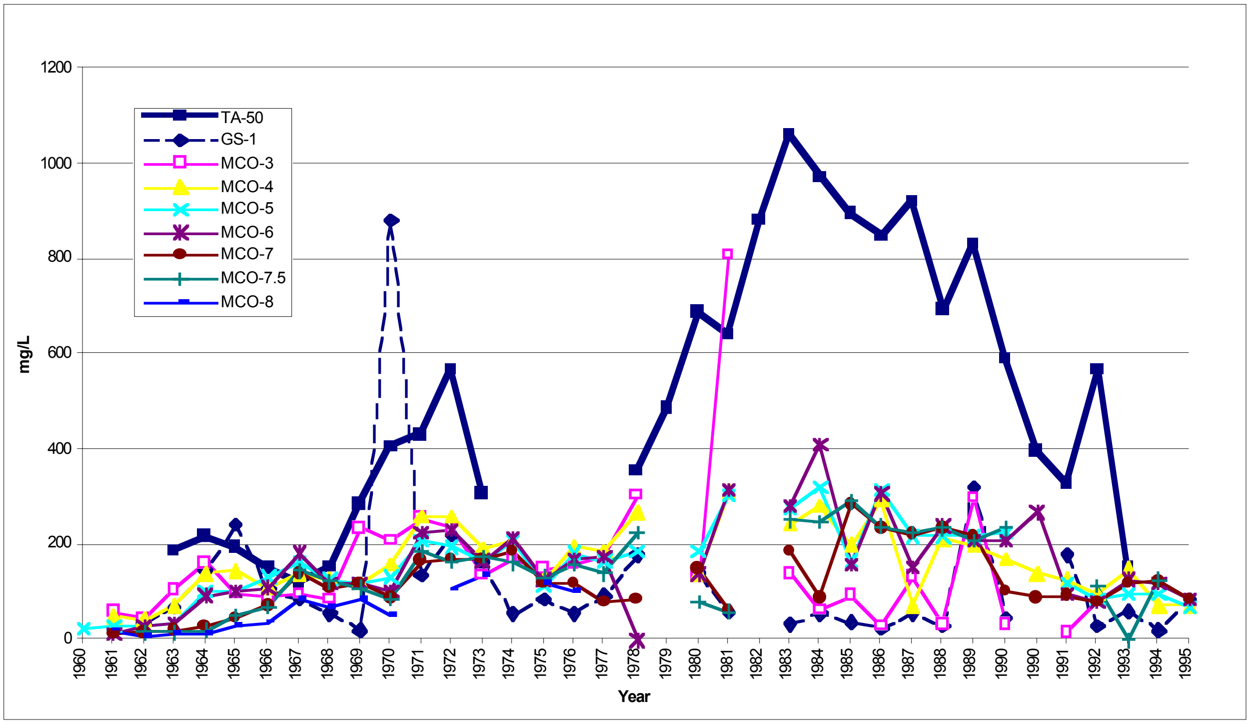
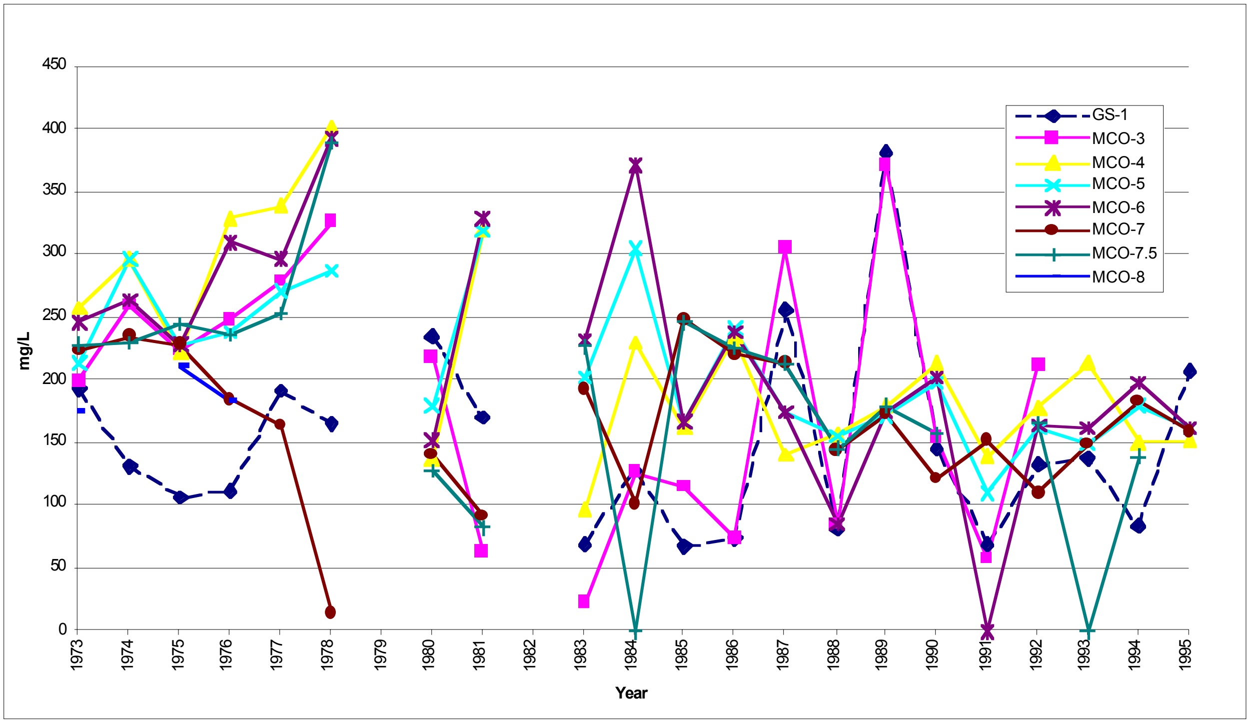
Figure 3.8.1-2. Total magnesium in Mortandad Canyon surface water and alluvial groundwater.



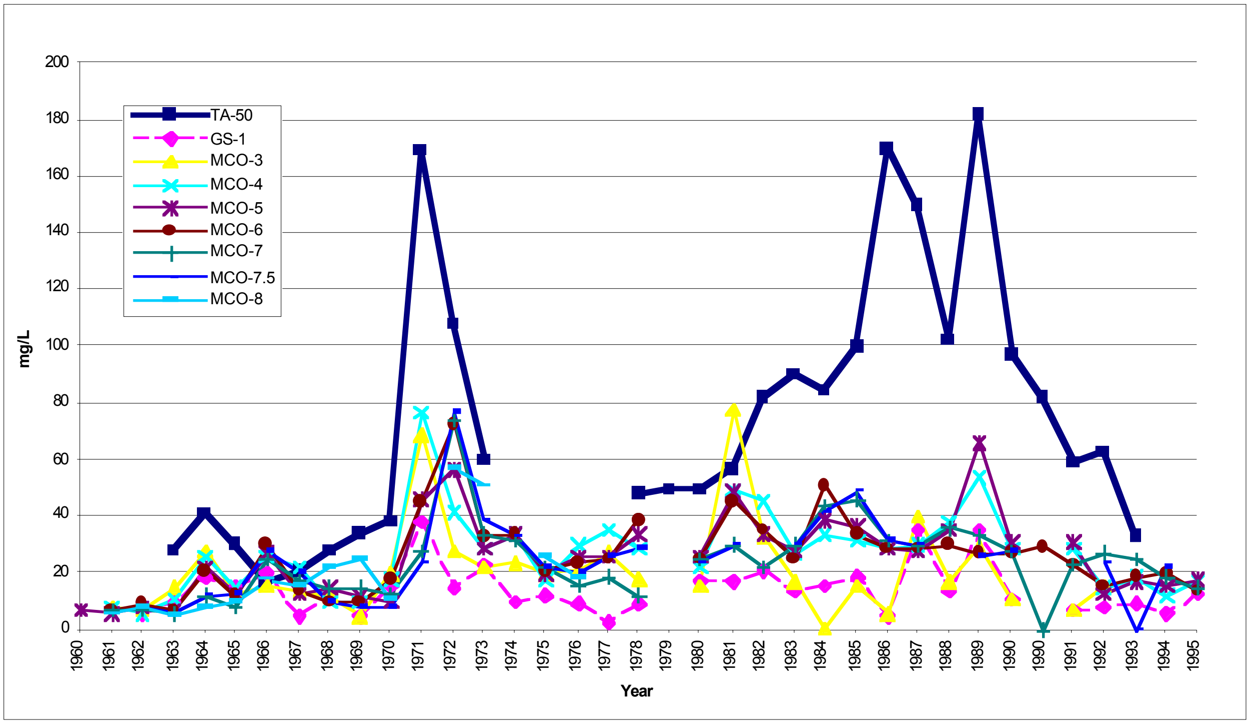
Source Enviornmental Survellance Reports

Figure 3.8.1-3. Total sodium in the TA-50 RLWTF discharge and Mortandad Canyon surface water and alluvial groundwater.



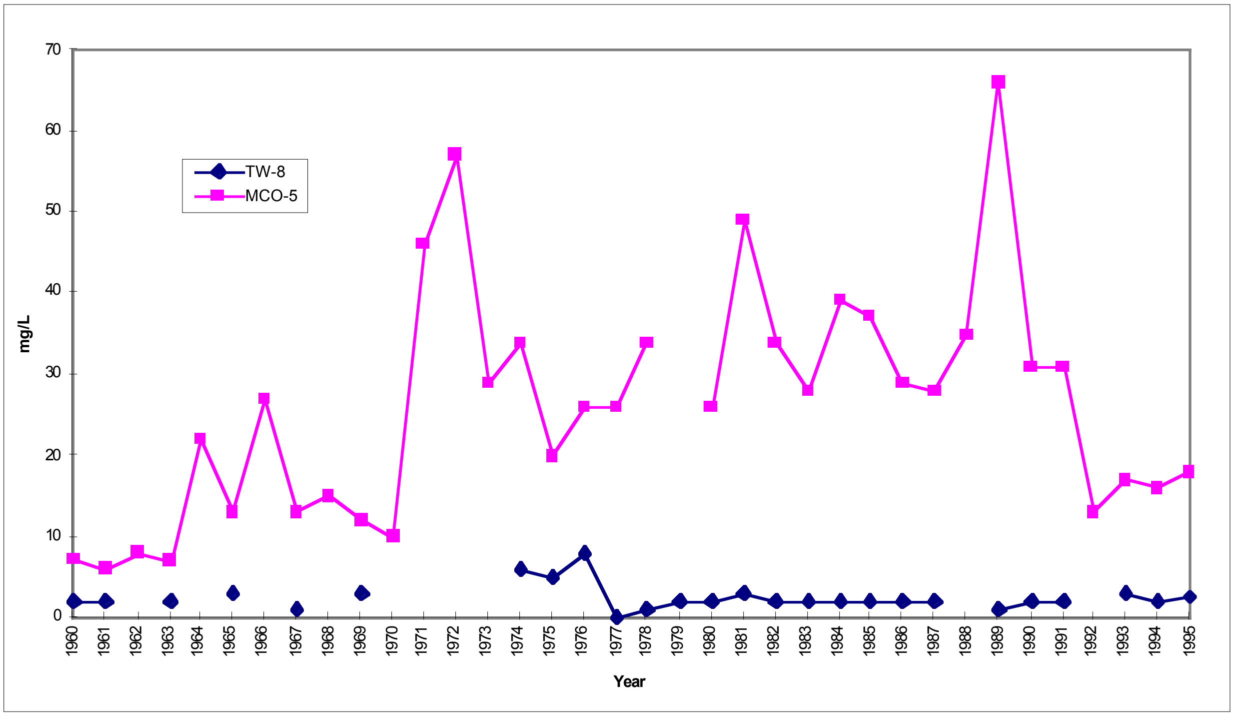
Source Enviornmental Survellance Reports

Figure 3.8.1-4. Total bicarbonate in Mortandad Canyon surface water and alluvial groundwater.



Source:EnvironmentalSurveillance Reports

Figure 3.8.1-5. Total chloride in the TA-50 RLWTF discharge and Mortandad Canyon surface water and alluvial groundwater.



Source:EnvironmentalSurveillance Reports

Figure 3.8.1-6. Total chloride in alluvial groundwater and the regional aquifer in Mortandad Canyon.

Concentrations of nitrate (as N) in the TA-50 RLWTF discharge, surface water at GS-1, and alluvial groundwater from 1961 to 1995 are shown in Figure 3.8.1-7. Concentrations in the TA-50 RLWTF discharge range from less than 50 mg/L to approximately 490 mg/L. The major source of nitrate is nitric acid (HNO_3) used in laboratories. Concentrations in surface water are significantly less (averaging about 20 mg/L) at GS-1 because of sampling during times of natural precipitation runoff. Concentrations in alluvial groundwater vary widely from nil to more than 200 mg/L; most concentrations are less than 100 mg/L. Variations in concentrations in alluvial groundwater through the period are probably due to variable mixing of discharge with natural runoff. The relatively narrow range of concentrations in alluvial groundwater compared with the TA-50 RLWTF discharge suggests that the alluvial groundwater is hydrodynamically well mixed. In the 1980s the concentration of nitrate in the TA-50 RLWTF discharge increased, whereas the volume discharged decreased (see Figure 2.4.6-1); the total annual mass of nitrate discharged increased but not proportionally to the increased concentration. A concurrent increase in the concentration of nitrate is not observed in the alluvial groundwater during this period.

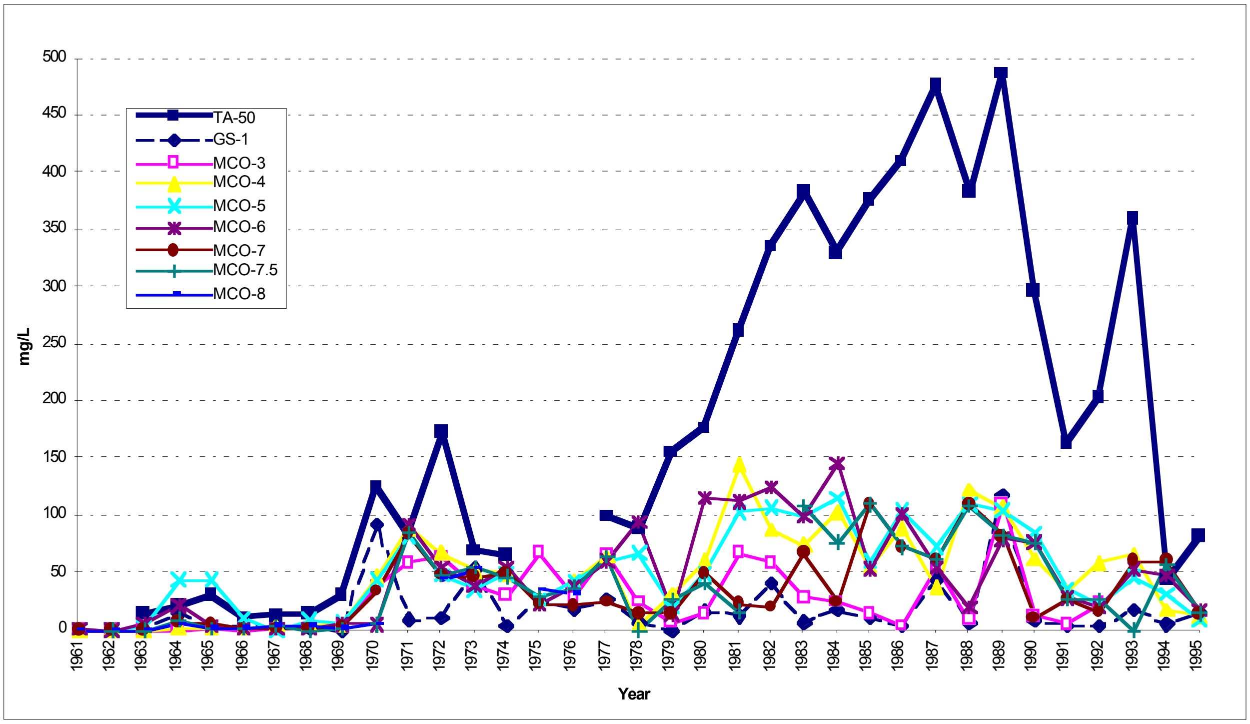
Variation in nitrate (as N) concentrations in alluvial groundwater at MCO-5 and in the regional aquifer at TW-8 from 1960 to 1995 are shown in Figure 3.8.1-8. Concentrations at MCO-5 vary widely from less than 0.6 mg/L to more than 700 mg/L; concentrations in TW-8 range from 0.02 to 5 mg/L, slightly higher than background levels in the regional aquifer, which are typically less than 0.1 mg/L (Environmental Protection Group 1995, 50285). Concentrations above background levels suggest a hydrologic connection between the regional aquifer and the alluvial groundwater in the Mortandad Canyon area. Similar to chloride concentrations observed in the two wells, the large differences in nitrate concentrations observed in MCO-5 and TW-8 suggest that leakage of alluvial groundwater down the TW-8 well annulus (if it occurs at all) is small and accompanied by substantial dilution (see the discussion in Section 3.7.4).

Concentrations of sulfate in surface water at GS-1 and alluvial groundwater from 1978 to 1995 are shown in Figure 3.8.1-9. Concentrations range from less than 10 mg/L to approximately 130 mg/L; most of the values are less than 40 mg/L. The major source of sulfate is probably sulfuric acid (H_2SO_4) used in laboratories. Historically, the highest concentrations of sulfate (128 mg/L) have been measured at well MCO-3. Concentrations are less than 100 mg/L at the other alluvial wells.

Concentrations of TDS in the TA-50 RLWTF discharge, surface water at GS-1, and alluvial groundwater from 1961 to 1995 are shown in Figure 3.8.1-10. It is important to note that before 1992 water samples for major cation analyses were field-acidified before filtration in the laboratory. This procedure will tend to bias the measurements of dissolved calcium and magnesium concentrations high because of dissolution of any suspended solids present in the sample. The TDS concentrations measured in the TA-50 RLWTF discharge range from 530 to more than 4000 mg/L; the highest concentrations occurred from 1980 to 1993. However, in surface water and alluvial groundwater TDS concentrations are generally less than 1600 mg/L; east of MCO-3 TDS concentrations are less than 1300 mg/L.

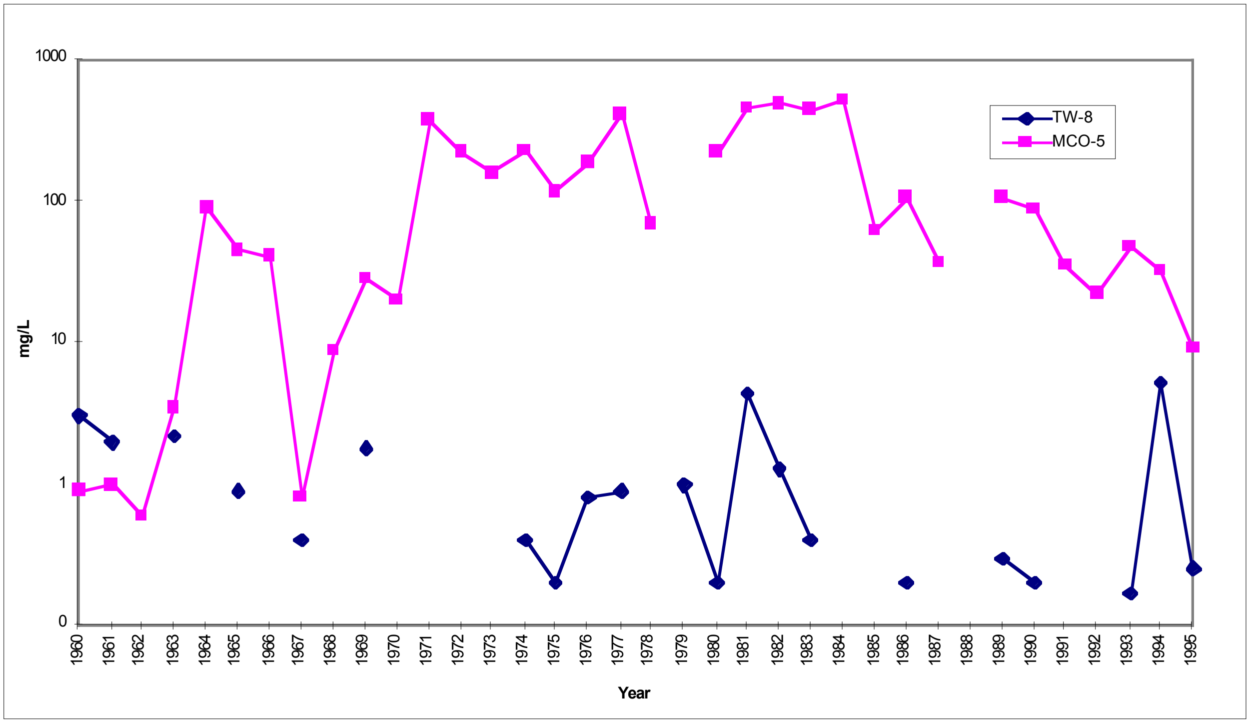
In the 1980s TDS in the TA-50 RLWTF discharge increased, whereas the volume discharged decreased (see Figure 2.4.6-1 in Chapter 2 of this work plan), and the total annual mass of TDS discharged did not change significantly. A concurrent increase in TDS was not observed in the alluvial groundwater during this period.

In October 1996 well MCO-13 was found to contain about 1 ft (0.30 m) of water. The well was bailed dry in February 1997 and sampled for water quality parameters on May 13, 1997, after the water level recovered about 2 ft (0.61 m). Water from this depth (105 ft [32.0 m]) in well MCO-13 is probably from the Cerro Toledo interval, as indicated on Figure A-3 in Appendix A of this work plan. Selected results of the analyses (listed in Table 3.8.1-1) showed anomalously high chloride (92.3 mg/L), sulfate (319 mg/L), and



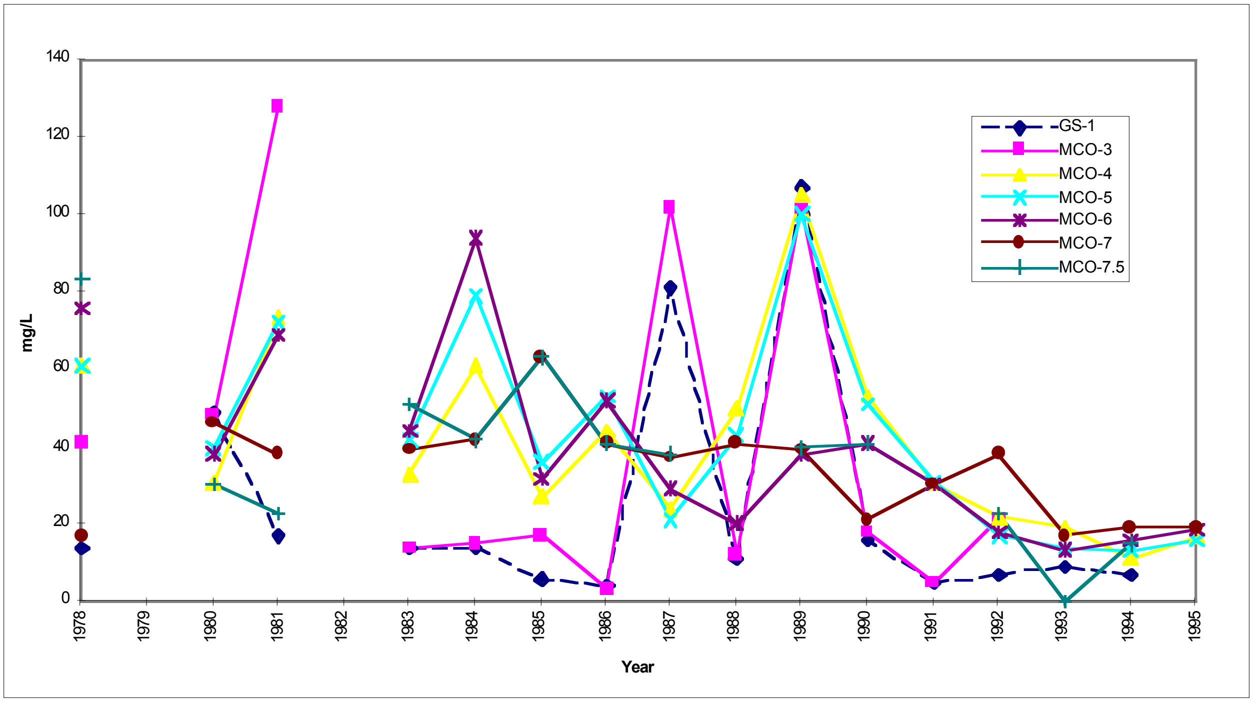
Source: Enviromental Survellance Reports

Figure 3.8.1-7. Nitrate in the TA-50 RLWTF discharge and Mortandad Canyon surface water and alluvial groundwater.



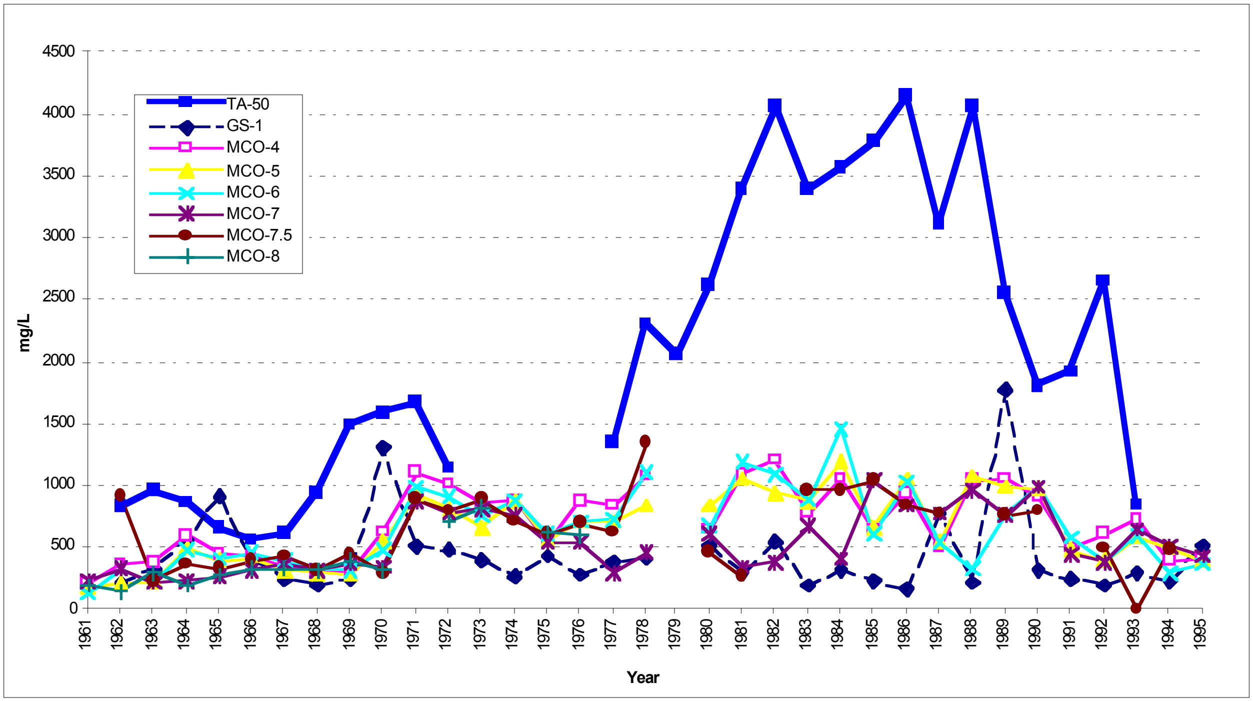
Source: Enviromental Survellance Reports

Figure 3.8.1-8. Nitrate in alluvial groundwater and the regional aquifer in Mortandad Canyon.



Source: Environmental Surveillance Reports

Figure 3.8.1-9. Sulfate in Mortandad Canyon surface water and alluvial groundwater.



Source: Environmental Surveillance Reports

Figure 3.8.1-10. Total dissolved solids in the TA-50 RLWTF discharge and Mortandad Canyon surface water and alluvial groundwater.

TABLE 3.8.1-1

ANALYSES OF GROUNDWATER AT MCO-13 AND COMPARISON WITH MAXIMUM CONCENTRATIONS PREVIOUSLY OBSERVED IN MORTANDAD CANYON ALLUVIAL GROUNDWATER

Constituent	MCO-13 May 13, 1997 (mg/L) *	Previously Observed Maximum (mg/L)
Ba	0.05 +/- 0.01	0.74
Be	<0.002	0.003
Cd	0.23 +/- 0.01	
Co	<0.002	0.060
Cr	<0.002	0.051
Cu	<0.002	
Fe	0.01	
Hg	<0.005	0.002
Mn	0.43	
Ni	0.007 +/- 0.002	
Pb	<0.002	
Sb	<0.0005	
Se	<0.005	
Sr (nonradiogenic)	0.65	
Zn	20.6	0.5
Ca	199	200
Mg	6.26	8.6
K	14.5	
Na	10.4	812
Cl	92.3	80
F	0.44	
HCO_3	32.2	403
NH_4	0.06	
NO_2	<0.02	
NO_3^-N	27	Since 1989 <100 NO_3^-N
PO_4	<0.05	3.5
SO_4	319	130
SiO_2	3.81	51
Hardness as $CaCO_3$	523	240
TDS	821	1459
Tritium	<370 pCi/L	>10,000 pCi/L

**Preliminary results obtained from Laboratory group EES-1*

Zn (20.6 mg/L) and anomalously low SiO_2 (3.81 mg/L) compared with results obtained in past years from alluvial groundwater in Mortandad Canyon. The pH of the water was slightly acidic (6.85). Maximum concentrations previously observed in the alluvial groundwater were 80 mg/L of chloride, 130 mg/L of sulfate, and 0.5 mg/L of Zn. The nitrate concentration (27 mg/L [as N]) was within the range of those observed in the alluvial groundwater during the past decade.

In addition, a sample collected from MCO-13 on February 11, 1997, by NMED DOE Oversight Bureau personnel contained tritium activity of <390 pCi/L. The 1995 average tritium activity in water from this well was 18,500 pCi/L. This result suggests that the groundwater sampled did not come from the TA-50 RLWTF discharge.

Solid and solution phase calculations using the computer code MINTEQA2 (Allison et al. 1991, 49930) were performed using water quality data collected from well MCO-13 (Table 3.8.1-1) to address the speciation of major cations, anions, and metals and to evaluate mineral stability. This groundwater may contain anthropogenic solutes such as cadmium, nitrate, and zinc. Results of speciation calculations suggest that the dominant cation, calcium, is stable as Ca^{2+} (84.9%) and $CaSO_4^0$ (14.9%). The dominant anion is sulfate, which is predicted to be stable as SO_4^{2-} (74.8%), $MgSO_4^0$ (1.0%), $CaSO_4^0$ (22.3%), and $ZnSO_4^0$ (1.5%). The nitrate (as N) concentration at 27 mg/L is within the range of nitrate concentrations recently observed in the alluvial groundwater upstream, but dissimilarities in the concentrations of major ions rule out upstream water as the source of nitrate in this sample.

Concentrations of cadmium and zinc in the groundwater collected from well MCO-13 are 0.23 and 20.6 mg/L, respectively, which are well above background levels for alluvial groundwater in Los Alamos Canyon. The maximum historical concentration of zinc observed in the alluvial groundwater associated with the TA-50 RLWTF discharge is 0.5 mg/L. Therefore, the source of these two metals in the groundwater at this location does not appear to be the TA-50 RLWTF discharge and is not known. However, these metal cations may be the result of dissolution of galvanized pipe possibly present within MCO-13. The dominant species of cadmium and zinc are predicted to occur as Cd^{2+} and Zn^{2+}, respectively.

The degree of saturation with respect to possible solid mineral phases was also calculated in terms of the saturation index (SI). The SI is a measure of the degree of undersaturation or oversaturation of a solid phase in water [$SI = \log_{10}$ {activity product/solubility product}; at equilibrium $SI = 0 \pm 0.5$]. These calculations do not consider rates of reactions; they consider only the thermodynamic feasibility. A precipitation reaction that is thermodynamically feasible or predicted to be in equilibrium with groundwater may actually take years to reach equilibrium.

This groundwater sample is predicted by the modeling to be slightly oversaturated (SI value $\leq$ +0.5) with respect to reactive geochemical phases including amorphous $Al(OH)_3$ and barite ($BaSO_4$), slightly undersaturated (SI value $\leq$ -0.5) with respect to quartz, and undersaturated (SI value $\leq$ -1.0) with respect to anhydrite, calcite, chalcedony, cristobalite, gypsum, and $ZnCO_3.H_2O$. The groundwater collected from well MCO-13 does not appear to be natural formation water; however, potential sources are not known but, based on concentrations of cadmium, chloride, sodium, sulfate, tritium, and zinc, this water does not appear to be derived from the TA-50 RLWTF discharge.

3.8.2 Uranium

Uranium is of interest in Mortandad Canyon because of its history of releases and its mobility under oxidizing conditions in the presence of complexing ligands including bicarbonate. Distributions of total uranium (unfiltered samples) in surface water at GS-1 and alluvial groundwater from 1973 to 1995 are shown in Figure 3.8.2-1. Concentrations measured at GS-1 have been fairly constant since 1965, ranging from 1 to 4 µg/L.

However, concentrations in alluvial groundwater increased with time until 1987. From 1976 to 1978 and again in 1984 total uranium concentrations greater than 7 µg/L were measured at MCO-4, MCO-5, MCO-6, MCO-7, and MCO-7.5. Since 1987 concentrations usually have been less than 5 µg/L.

3.8.3 Radionuclides

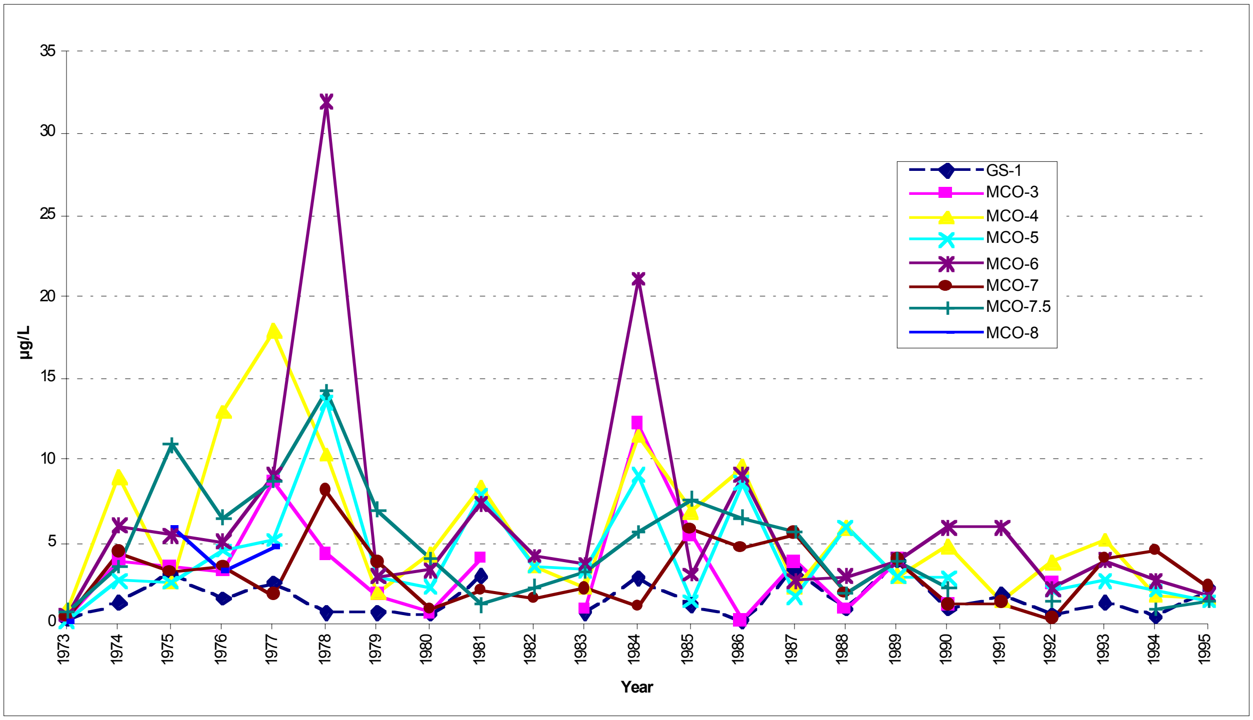
Activities of total ^{241}Am in the TA-50 RLWTF discharge, surface water at GS-1, and alluvial groundwater in Mortandad Canyon from 1967 to 1995 are shown in Figure 3.8.3-1. Activities in the TA-50 RLWTF discharge range from less than 20 pCi/L to approximately 1000 pCi/L. Activities of ^{241}Am decrease significantly to less than 20 pCi/L at GS-1. Activities are also much lower in the alluvial groundwater and generally decrease along the groundwater flow path. Typical activities of this isotope in unfiltered alluvial groundwater range from 0.05 to 5 pCi/L.

Activities of ^{137}Cs in the TA-50 RLWTF discharge, surface water at GS-1, and alluvial groundwater from 1968 to 1995 are shown in Figure 3.8.3-2. Activities in the TA-50 RLWTF discharge range from 20 pCi/L to approximately 7900 pCi/L. Activities of ^{137}Cs decrease to less than 6000 pCi/L at GS-1. Activities are also much lower in the alluvial groundwater and generally decrease along the groundwater flow path in the alluvium. Typical activities of this isotope in unfiltered alluvial groundwater range from 0.01 to 100 pCi/L.

Activities of total ^{238}Pu in the TA-50 RLWTF discharge, surface water at GS-1, and alluvial groundwater from 1968 to 1995 are shown in Figure 3.8.3-3. Activities in the TA-50 RLWTF discharge range from 10 pCi/L to approximately 500 pCi/L. Activities of ^{238}Pu decrease to between 0.2 and 150 pCi/L at GS-1. Activities are also much lower in the alluvial groundwater and generally decrease, with fluctuation, along the groundwater flow path in the alluvium. Activities of this isotope measured at MCO-7.5 typically are less than 1 pCi/L in unfiltered samples.

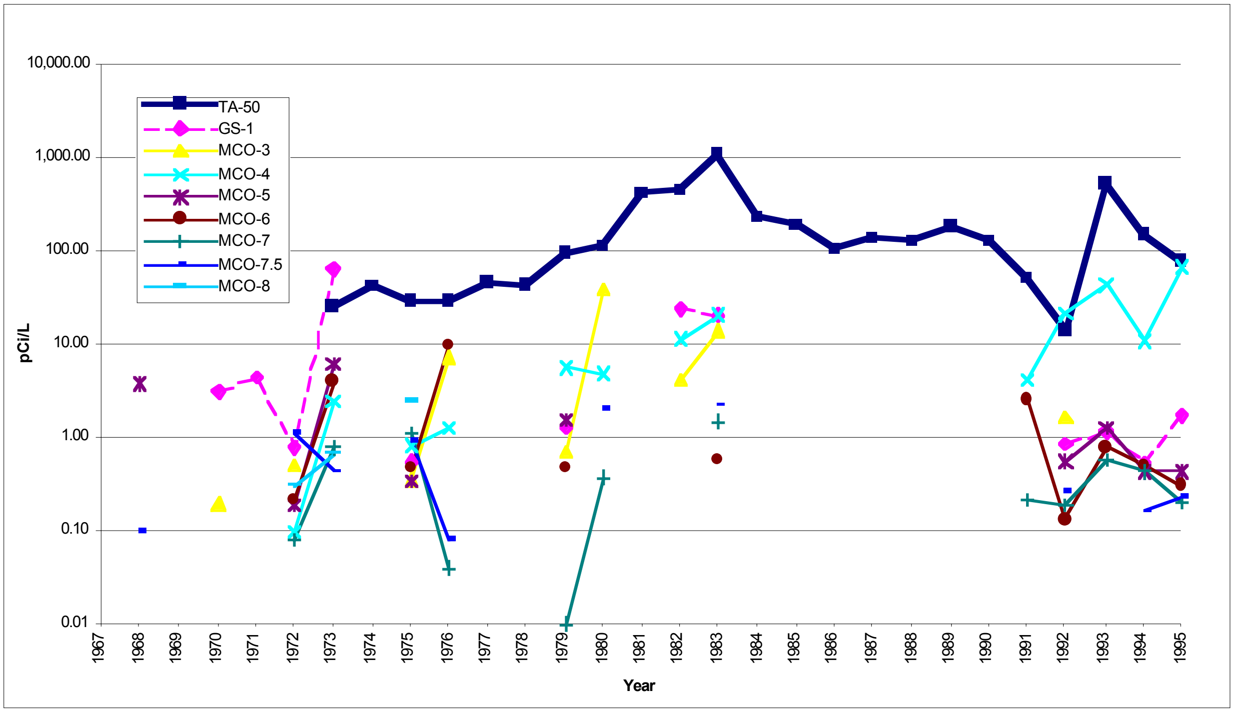
Activities of total ^{239,240}Pu in the TA-50 RLWTF discharge, surface water at GS-1, and alluvial groundwater from 1963 to 1995 are shown in Figure 3.8.3-4. Activities in the TA-50 RLWTF discharge range from 10 pCi/L to approximately 1000 pCi/L. Activities of ^{239,240}Pu decrease to between 0.5 and 100 pCi/L at GS-1. Activities are also much lower in the alluvial groundwater and generally decrease, with fluctuation, along the groundwater flow path in the alluvium. Activities of these plutonium isotopes measured at MCO-7.5 typically are less than 0.6 pCi/L in unfiltered samples.

The ^{239,240}Pu/^{238}Pu ratios in the TA-50 RLWTF discharge, at GS-1, and in alluvial groundwater from 1967 to 1995 are shown in Figure 3.8.3-5. In the TA-50 RLWTF discharge, the ratio is less than unity from 1972 to 1978 and greater than unity from 1979 to 1990. In alluvial groundwater, the ratio is less than unity from 1972 to 1979 but, beginning in 1980, becomes greater than unity at MCO-3, which is the closest downgradient well east of the TA-50 RLWTF outfall. Plutonium isotopic ratios greater than unity initially occur in water samples collected from wells progressively downgradient: MCO-4, MCO-5, MCO-6, and MCO-7 in successive years 1981, 1982, 1983, and 1984, respectively. This pattern suggests that the travel time, including both surface water and groundwater flows, for the plutonium isotopes in Mortandad Canyon is approximately one year along a distance of 1500 ft (457 m). However, the ratio in groundwater samples collected from MCO-7.5 was anomalous; it was greater than unity beginning in 1972. Surface water flow (including suspended material with adsorbed plutonium) and groundwater flow (possibly containing colloidal plutonium) contribute to the dispersion of plutonium isotopes observed in Mortandad Canyon.



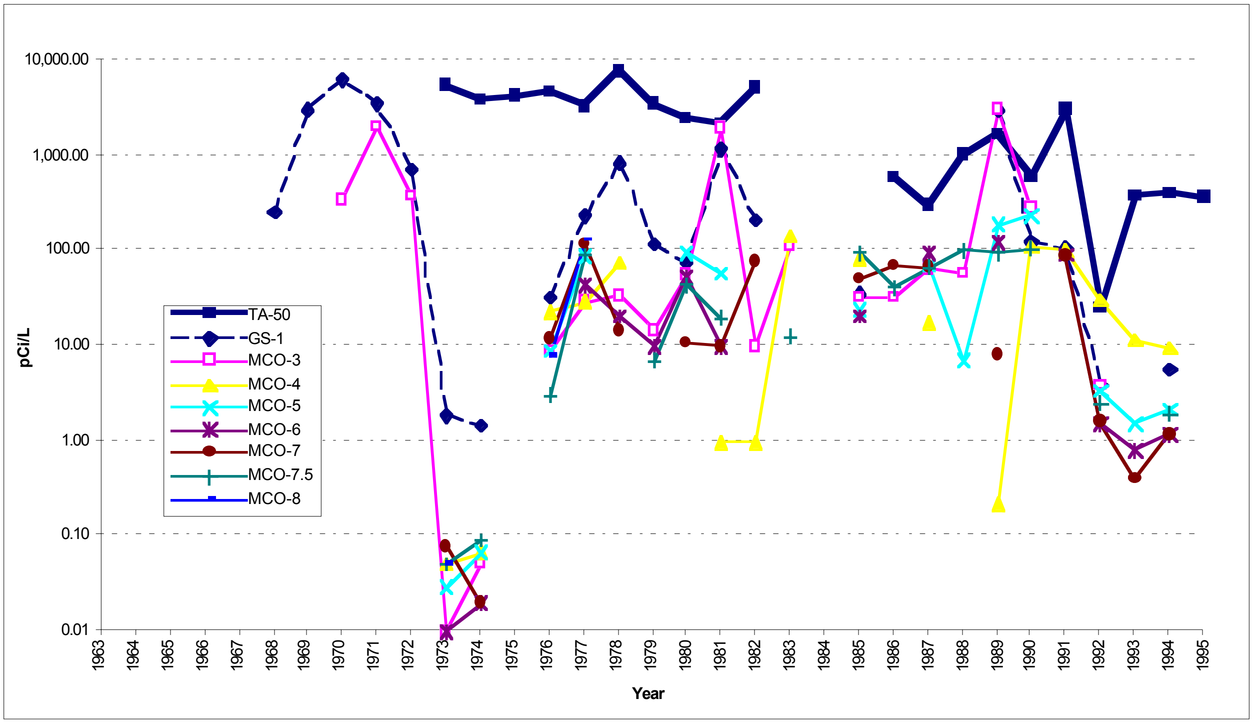
Source: Environmental Surveillance Reports

Figure 3.8.2-1. Distribution of total uranium in Mortandad Canyon surface water and alluvial groundwater.



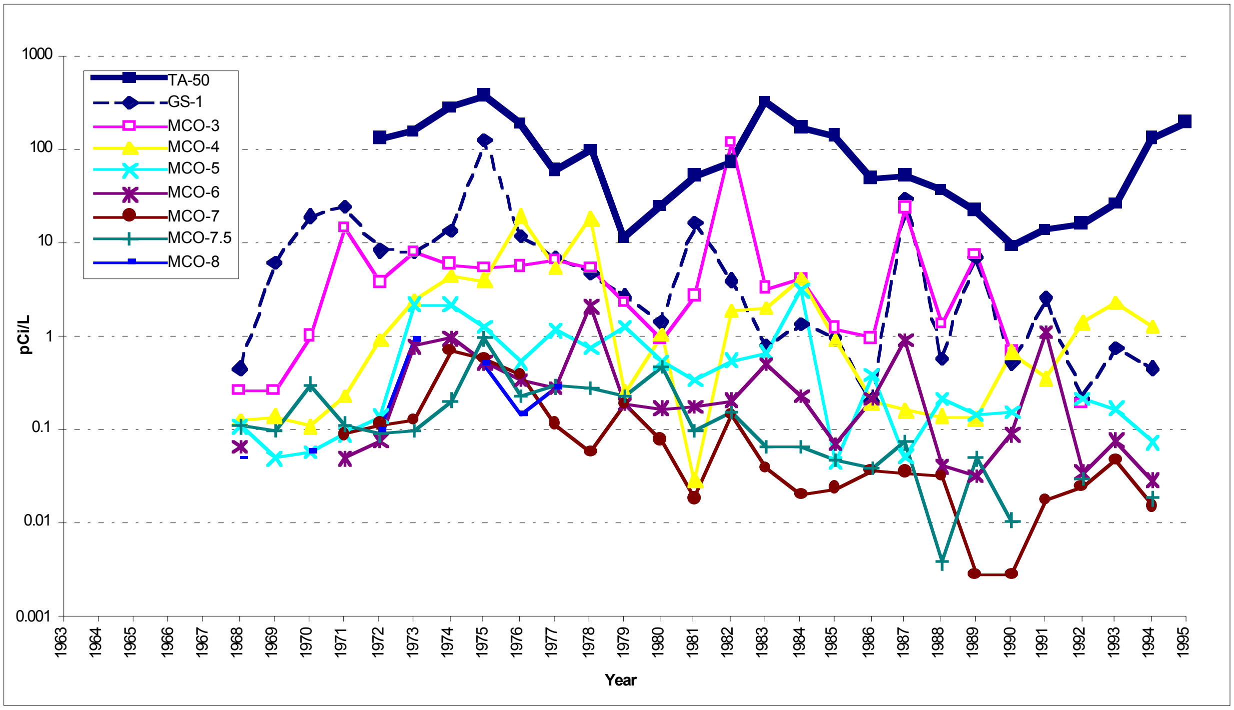
Source: Environmental Surveillance Reports

Figure 3.8.3-1. Americium-241 in the TA-50 RLWTF discharge and Mortandad Canyon surface water and alluvial groundwater.



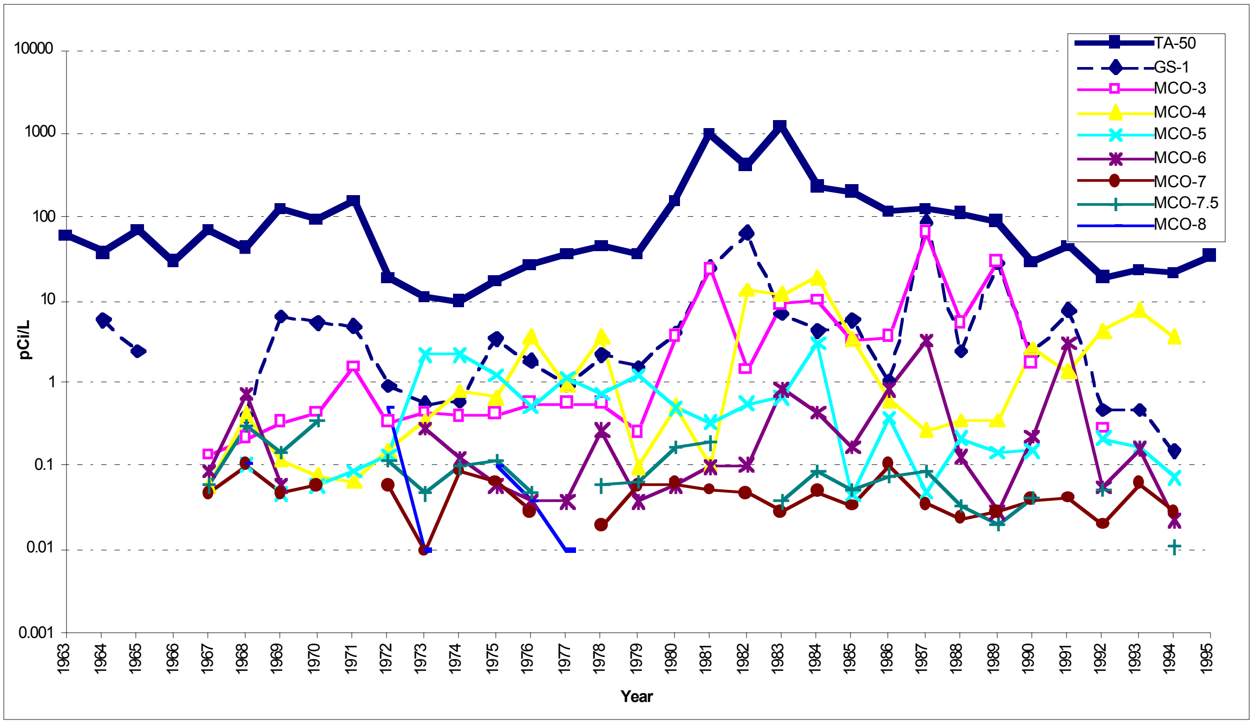
Source Enviornmental Survellance Reports

Figure 3.8.3-2. Cesium-137 in the TA-50 RLWTF discharge and Mortandad Canyon surface water and alluvial groundwater.



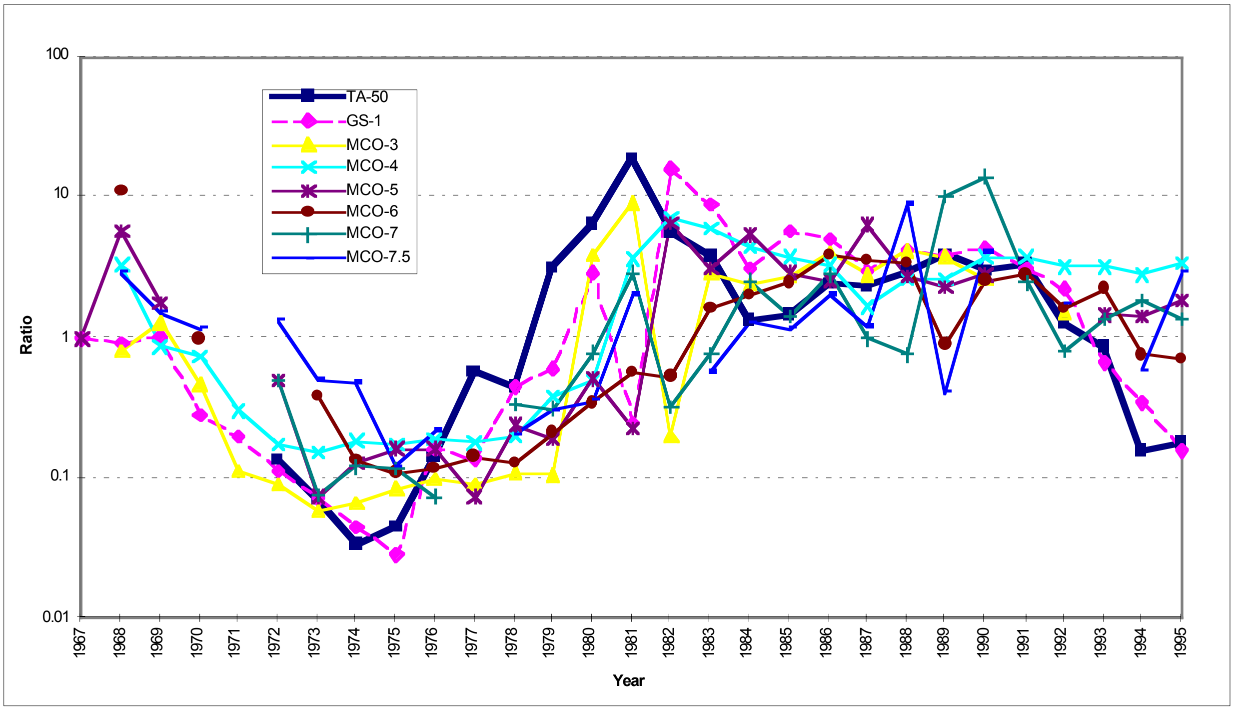
Source Enviornmental Survellance Reports

Figure 3.8.3-3. Plutonium-238 in the TA-50 RLWTF discharge and Mortandad Canyon surface water and alluvial groundwater.



Source: Environmental Survelance Reports

Figure 3.8.3-4. Plutonium-239,240 in the TA-50 RLWTF discharge and Mortandad Canyon surface water and alluvial groundwater.



Source: Environmental Survelance Reports (data only)

Figure 3.8.3-5. Ratios of ^{239,240}Pu/^{238}Pu in the TA-50 RLWTF discharge and Mortandad Canyon surface water and alluvial groundwater.

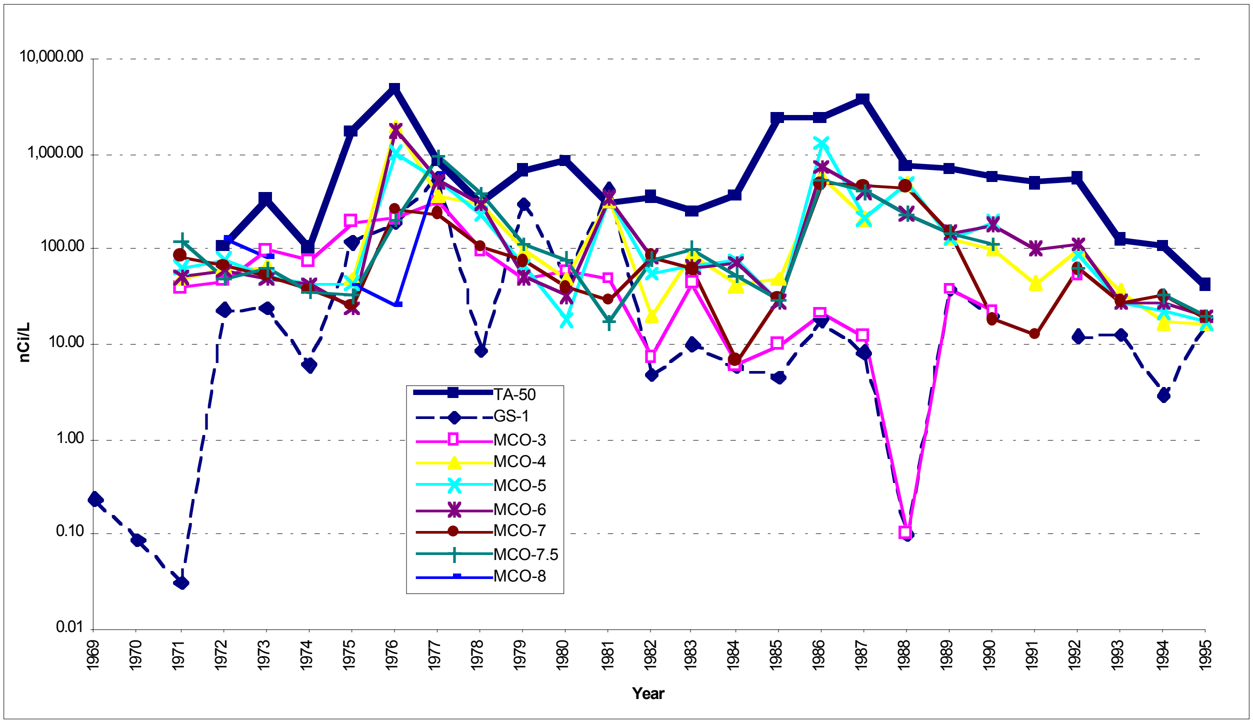
The occurrence of americium and plutonium in alluvial groundwater within Mortandad Canyon was investigated by Penrose et al. (1990, 11770). Results of their investigation suggest that americium and plutonium are tightly or irreversibly associated with colloidal material between 25 and 450 nm in size. The composition of the colloidal material is not known; it may consist of silica, ferric hydroxide, clay minerals, and solid organic matter. According to Penrose et al. (1990, 11770) these two colloidal-bound actinides could not be completely removed from groundwater by serial filtration. Moreover, the fraction of americium not associated with colloids is stable in a low-molecular weight form (≤2nm diameter) and may occur as an anion of unknown composition. Transport of americium and plutonium as colloidal-sized particulates may contribute to the widespread occurrences of these two actinides within both surface water and alluvial groundwater in Mortandad Canyon.

Activities of tritium in the TA-50 RLWTF discharge, surface water at GS-1, and alluvial groundwater from 1969 to 1995 are shown in Figure 3.8.3-6. Tritium occurs in the form of HTO and migrates at the same rate as groundwater. For the period of record, activities of tritium in the TA-50 RLWTF discharge range from a recent (and possibly anomalous) low value of 50 pCi/L to approximately 6,000,000 pCi/L. Activities measured at GS-1 are between 50 and 700,000 pCi/L, which reflects the primary sampling of runoff with some mixing of the TA-50 RLWTF discharge at the gaging station. Activities in alluvial groundwater are fairly constant over time, showing only minor fluctuations; they generally range from 20,000 to 1,000,000 pCi/L. Distributions of tritium, in addition to chloride and nitrate, suggest that alluvial groundwater is hydrodynamically well mixed in Mortandad Canyon.

Activities of tritium in both the alluvial groundwater at MCO-5 and in the regional aquifer at TW-8 from 1971 to 1995 are shown in Figure 3.8.3-7. Activities in alluvial groundwater range from 20,000 pCi/L to more than 1,000,000 pCi/L, whereas activities in TW-8 range from 100 to approximately 2000 pCi/L; most recent measurements are on the low end of the range. Before 1990 the quantitation limit for tritium using liquid scintillation is approximately 700 pCi/L, and tritium activities below this level are considered to be nondetections. Background tritium activities in the regional aquifer are typically less than 1.0 pCi/L (Environmental Protection Group 1995, 50285). Recent time series sampling of TW-8 by ESH-18 personnel and analysis for tritium using low-detection-level electrolytic enrichment confirm the presence of above background levels in the regional aquifer beneath Mortandad Canyon. As discussed in Section 3.7.4, activities of tritium in TW-8 from the time series sampling and analysis were initially approximately 16 pCi/L and declined with progressive pumping to approximately 5 pCi/L, an activity considered to be above background level (Environmental Protection Group 1996, 54769) (see Figure 3.7.4-5).

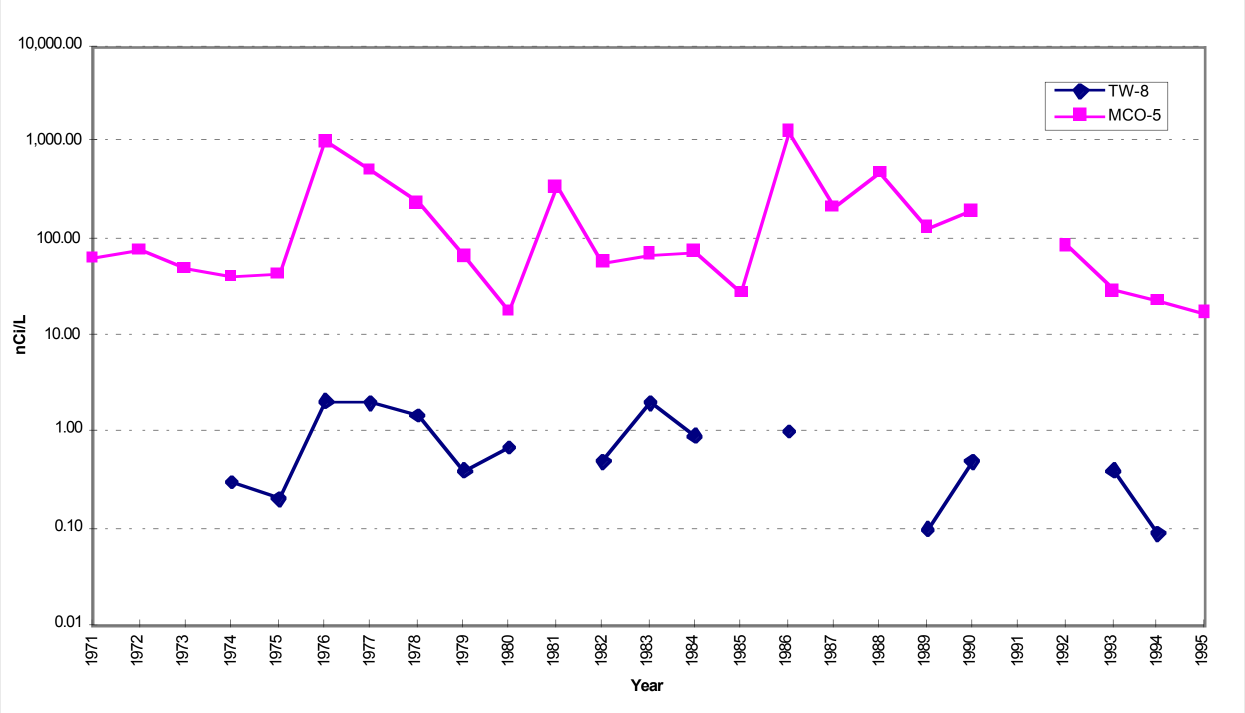
3.8.4 Low-Level Isotopic Analyses of Plutonium and Uranium

In 1994 ESH-18 personnel collected six alluvial groundwater samples (along with sediment samples discussed in Section 3.4.4.2.1) in Mortandad Canyon, and CST-7 personnel analyzed the samples using TIMS to determine the plutonium and uranium activities and isotopic ratios (Gallaher et al. 1997, 04-0329). The Laboratory plutonium component was evaluated relative to that from global fallout by measuring the ^{240}*Pu/*^{239}*Pu ratios. Laboratory-derived plutonium is easily distinguished from global fallout plutonium by the isotopic ratios. The relative abundance of* ^{235}*U and* ^{236}*U were also measured to identify anthropogenic sources. Anthropogenic uranium was identified in groundwater samples collected from the alluvial wells. The survey results indicate that the Laboratory-derived plutonium and uranium activities in alluvial groundwater decrease along a short distance downstream from Laboratory sources.*



Source: Enviromental Surveillance Reports

Figure 3.8.3-6. Tritium in the TA-50 RLWTF discharge and Mortandad Canyon surface water and alluvial groundwater.



Source: Enviromental Surveillance Reports

Figure 3.8.3-7. Tritium in alluvial groundwater and the regional aquifer in Mortandad Canyon.

3.8.5 Geochemical Modeling of Alluvial Groundwater

Solid and solution phase calculations were performed with the computer code MINTEQA2 (Allison et al. 1991, 49930) using results of analyses on filtered (<0.45 µm) alluvial groundwater samples collected on August 9 and 10, 1995, by ESH-18 personnel (Environmental Surveillance Program 1996, 55333) from alluvial wells MCO-4B, MCO-6, MCO-7, and MCO-7A.

The purpose of the calculations was to assess the importance of precipitation reactions and to determine speciation of the constituents that influence the degree of adsorption onto solid surfaces. Cations tend to adsorb onto solids to a greater extent than do anions at near-neutral pH.

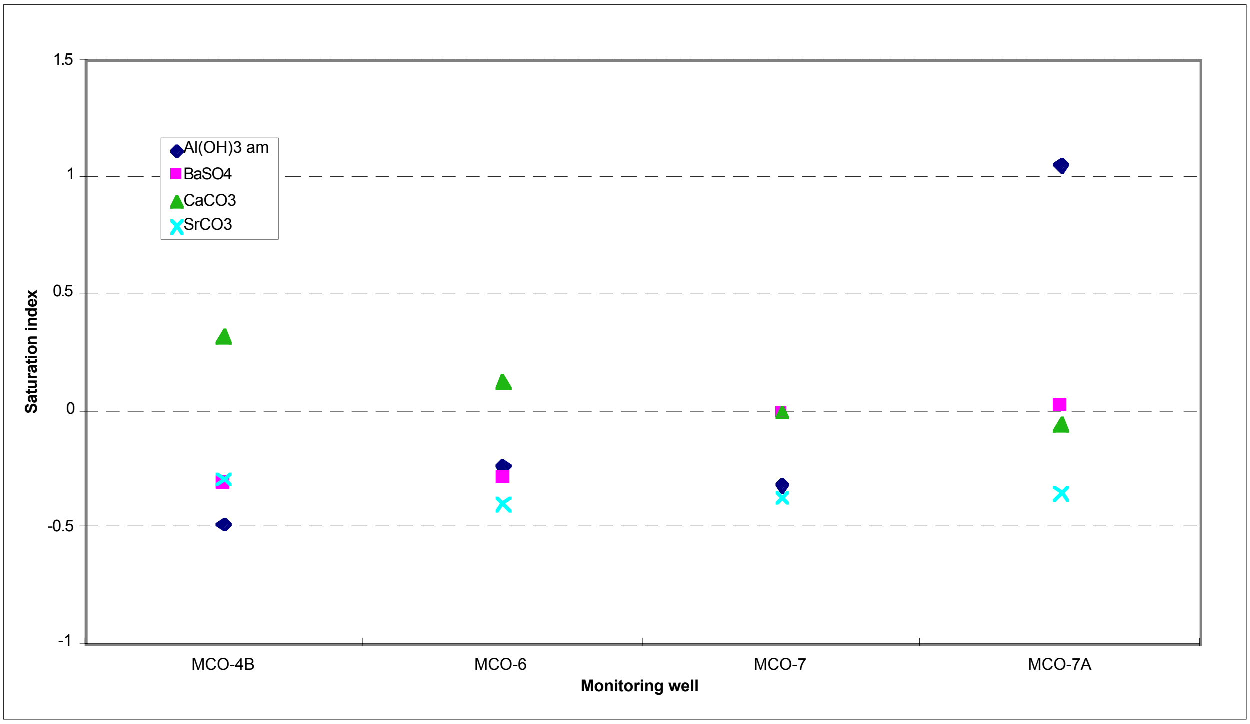
Based on mineral-solid phase SI calculations, alluvial groundwater in Mortandad Canyon is predicted to be in equilibrium with $BaSO_4$*,* $CaCO_3$*, and* $SrCO_3$ *(Figure 3.8.5-1). The radionuclide* ^{90}Sr *and stable strontium are predicted to precipitate from solution as a pure phase (*$SrCO_3$*) and/or as a coprecipitate with barite (*$BaSO_4$*). Barite is relatively insoluble (Ksp =* $10^{-9.98}$ *M, Allison et al. 1991, 49930) requiring less than 0.05 and 10 mg/L of dissolved barium and sulfate, respectively, to reach saturation. Coprecipitation of strontium with barium, as* $Ba_{1-x}Sr_xSO_4$*, is possible at low temperatures based on both model simulations using MINTEQA2 and experimental results reported by Felmy et al. (1993, 56036). Barite and celestite (*$SrSO_4$*) have the same crystal structure and show complete solid solution at low temperatures. Synthesized materials commonly have variable Ba-Sr mole fractions (Felmy et al. 1993, 56036).*

Alluvial groundwater approaches equilibrium with respect to amorphous $Al(OH)_3$ *along the flow path (Figure 3.8.5-1). This phase is predicted to precipitate from solution during the hydrolysis of aluminum-rich volcanic glass, with a composition of 12 wt %* Al_2O_3 *and 76 wt %* SiO_2 *present in the Bandelier Tuff, according to the following reaction:* $(0.12Al_2O_3, 1.27SiO_2)$*glass +* $2.90H_2O = 0.24\ Al(OH)_3am + 1.27H_4SiO_4^0$*.*

The adsorptive characteristics of amorphous $Al(OH)_3$*, which include its pH at point of zero charge (*$pH_{pzc} = 5.0$*, Stumm and Morgan 1996, 56042) and its large surface area, should enhance removal of cationic solutes (*$^{90}Sr^{2+}$*) under near-neutral pH conditions. At pH > 5, amorphous* $Al(OH)_3$ *has negative surface charge sites that are available for cation exchange. In addition, continued hydrolysis of the glass and amorphous* $Al(OH)_3$ *may enhance the precipitation of kaolinite and smectite, which are found as minor constituents in glass-rich portions of the Bandelier Tuff (Broxton et al. 1995, 50121; LANL 1995, 50290).*

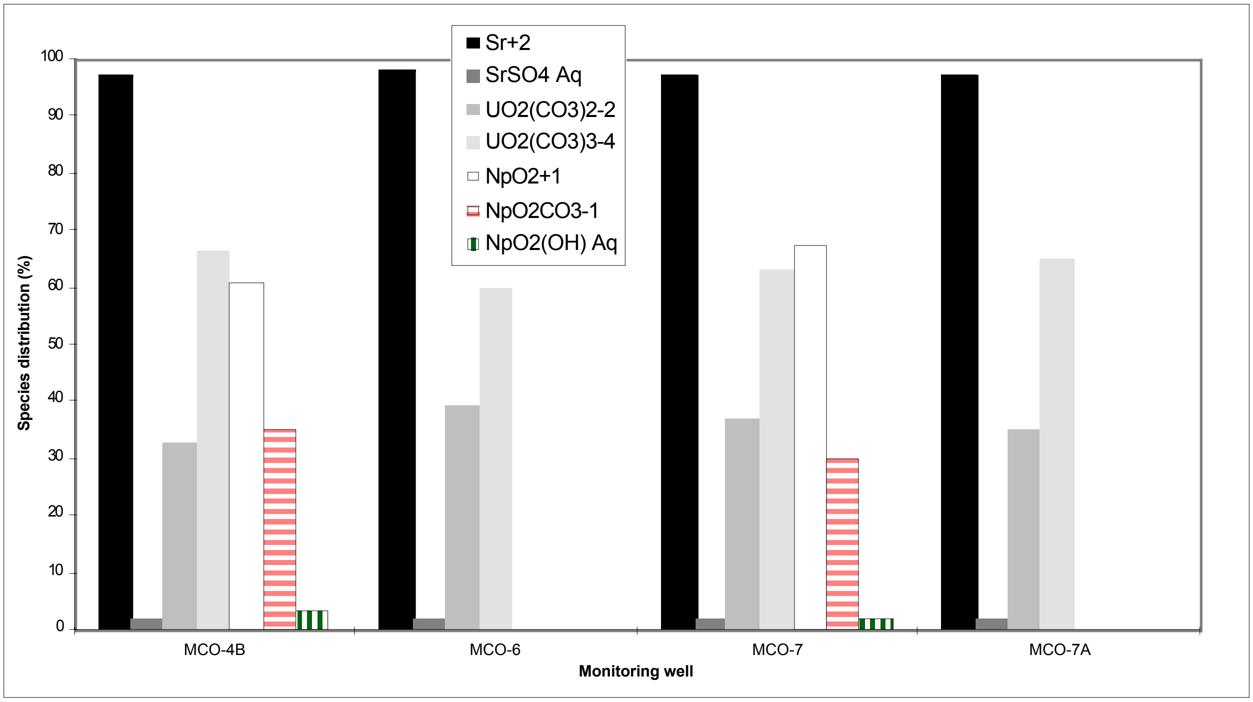
SI calculations suggest that alluvial groundwater is undersaturated with respect to $UO_2(OH)_2$*,* $AmOHCO_3$*, amorphous* $Am(OH)_3$*,* $Am(OH)_3$*, amorphous* PuO_2OH*,* $Pu(OH)_4$*,* PuO_2*,* $NaNpO_2CO_3$*, and other solid phases containing these actinide elements. Based on these calculations, adsorption processes are inferred to control the distribution of dissolved americium, neptunium, plutonium, and uranium in alluvial groundwater in Mortandad Canyon.*

Speciation calculations suggest that total dissolved strontium, consisting mainly of nonradiogenic strontium with small concentrations of ^{90}Sr *(50 pCi/L is equivalent to* $10^{-14.4}$ *M strontium), is mainly stable as* Sr^{2+} *with a small percentage of* $SrSO_4^0$ *present (Figure 3.8.5-2). Speciation calculations (assuming oxidizing conditions in the water) also suggest that total dissolved uranium (assuming uranyl, U[VI]) and neptunium (assuming neptunyl, Np[V]) are mainly stable as* $UO_2(CO_3)_3^{4-}$ *and* NpO_2^+*, respectively. However, smaller percentages of* $UO_2(CO_3)_2^{2-}$ *and* $NpO_2CO_3^-$ *are predicted to be present as well. The anionic species do not adsorb onto mineral surfaces at solution pH above their* pH_{pzc} *because the solid phases have a net negative surface charge. Cations such as* NpO_2^+ *tend to adsorb onto solid surfaces at near-neutral pH because of the adsorbents' net negative surface charge (Longmire et al. 1995, 48818; Langmuir 1997, 56037).*



Source: Environmental Protection Group 1996, 54769 (data only)

Figure 3.8.5-1. Results of saturation index calculations for alluvial groundwater in Mortandad Canyon.



Source: Environmental Protection Group 1996, 54769 (data only)

Figure 3.8.5-2. Results of speciation calculations for neptunium, strontium, and uranium in Mortandad Canyon alluvial groundwater.

Speciation calculations suggest that total dissolved americium (Am[III]) is mainly stable as $Am(CO_3)_2^-$; a smaller percentage of $AmCO_3^+$ is present (Figure 3.8.5-3). Speciation calculations for plutonium, assumed to be present in two oxidation states (Pu[IV] and Pu[V]), is predicted to be stable as $Pu(CO_3)_3^{2-}$, $Pu(CO_3)_4^{4-}$, and PuO_2^+ (Figure 3.8.5-3). The higher bicarbonate concentrations enhance the formation of $Pu(CO_3)_4^{4-}$ over that of $Pu(CO_3)_4^{2-}$ when plutonium is stable in the +IV oxidation state. However, hydrolysis reactions dominate when plutonium is stable in the +V oxidation state under near-neutral pH conditions. Furthermore, the anionic species do not adsorb onto mineral surfaces at solution pH above their pH_{pzc} because the solid phases have a net negative surface charge. However, PuO_2^+ will tend to adsorb. As a consequence of the speciation, small activities of dissolved plutonium and americium are expected to be present and, in fact, are present in alluvial groundwater in Mortandad Canyon (Longmire et al. 1995, 48818; Langmuir 1997, 56037).

3.8.6 Summary

Bicarbonate, chloride, magnesium, nitrate, and sodium are the major chemicals in the TA-50 RLWTF discharge and alluvial groundwater in Mortandad Canyon. Variations in TDS concentrations in both surface water and alluvial groundwater could be due to (1) mixing of TA-50 RLWTF discharge with surface water west of GS-1, (2) precipitation of solid phases (for example, calcium carbonate) from solution, and (3) varying amounts of suspended material in the samples analyzed for total constituents.

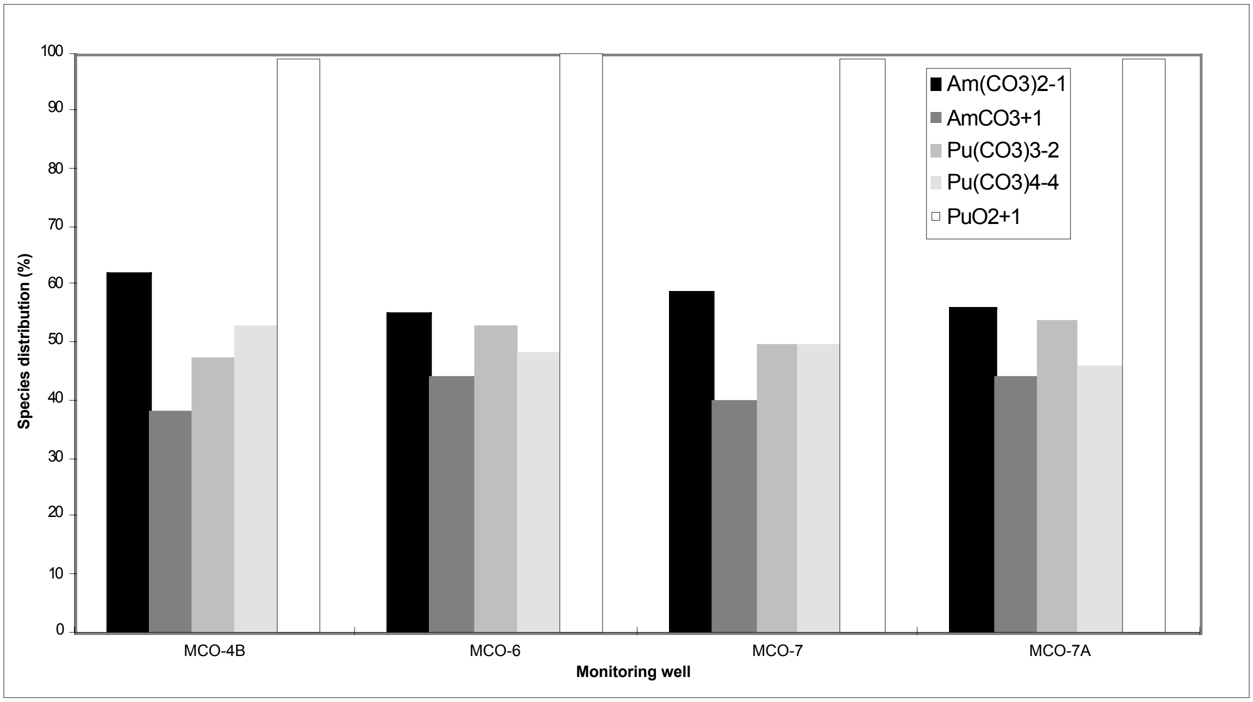
Concentrations of total uranium measured at GS-1 range from 1 to 4 µg/L. The maximum concentration of total uranium (33 µg/L) was measured at MCO-6 in 1978. Since 1987, concentrations of total uranium usually have been less than 5 µg/L in alluvial groundwater.

Activities of ^{241}Am in the TA-50 RLWTF discharge range from less than 20 pCi/L to approximately 1000 pCi/L. Activities of ^{137}Cs in the discharge range from 20 pCi/L to approximately 8000 pCi/L. Typical activities of ^{241}Am and ^{137}Cs range from 0.05 to 5 pCi/L and 0.01 to 100 pCi/L, respectively, in alluvial groundwater.

Activities of ^{238}Pu in the TA-50 RLWTF discharge range from 10 pCi/L to approximately 500 pCi/L. Activities measured in alluvial groundwater at MCO-7.5 are typically less than 1 pCi/L. Activities of ^{239,240}Pu in the TA-50 RLWTF discharge range from 10 pCi/L to approximately 1000 pCi/L. Activities measured at MCO-7.5 typically are less than 0.6 pCi/L.

Activities of tritium in alluvial groundwater in Mortandad Canyon are fairly constant over time and generally range from 20,000 to 1,000,000 pCi/L. Distributions of tritium, in addition to chloride and nitrate, suggest that alluvial groundwater is hydrodynamically well mixed. Recent time series sampling of TW-8 and analyses for tritium using low-detection-level electrolytic enrichment confirm the presence of tritium in the regional aquifer at approximately 5 pCi/L, which is above the background level of approximately 1 pCi/L (Environmental Protection Group 1996, 54769). The large differences in tritium activities observed between MCO-5 and TW-8 suggest that leakage of contaminated alluvial groundwater down the TW-8 well annulus (if it occurs at all) is small and accompanied by substantial dilution.

Using TIMS to determine the plutonium and uranium activities and isotopic ratios in sediment and water samples collected in Mortandad Canyon, Gallaher et al. (1997, 04-0329) suggest that Laboratory-derived plutonium and uranium activities in alluvial groundwater and sediments decrease along a short distance downstream of Laboratory outfalls. However, isotopic ratios suggest possible off-site transport of trace levels (fCi/g) of Laboratory-derived plutonium in stream sediments to distances approximately 2 mi (3.2 km) downstream of the Laboratory boundary to near state road NM4.



Source: Environmental Protection Group 1996, 54769 (data only)

Figure 3.8.5-3. Results of speciation calculations for americium and plutonium in Mortandad Canyon alluvial groundwater.

Based on mineral-solid phase SI calculations, alluvial groundwater in Mortandad Canyon is predicted to be in equilibrium with $BaSO_4$*,* $CaCO_3$*, and* $SrCO_3$*. Calculations suggest that alluvial groundwater is undersaturated with respect to* $UO_2(OH)_2$*,* $AmOHCO_3$*, amorphous* $Am(OH)_3$*,* $Am(OH)_3$*, amorphous* PuO_2OH*,* $Pu(OH)_4$*,* PuO_2*,* $NaNpO_2CO_3$*, and other solid phases containing these actinide elements. Based on these calculations, adsorption processes are inferred to control the distribution of dissolved americium, neptunium, plutonium, and uranium in alluvial groundwater in Mortandad Canyon.*

Speciation calculations in alluvial groundwater suggest that total dissolved strontium is mainly stable as Sr^{2+}*. Speciation calculations (assuming oxidizing conditions) also suggest that total dissolved uranium (assuming uranyl, U[VI]) and neptunium (assuming neptunyl, Np[V]) are stable mainly as* $UO_2(CO_3)_3^{4-}$ *and* NpO_2^+*, respectively. Total dissolved americium (Am[III]) is predicted to be stable mainly as* $Am(CO_3)_2^-$*. Speciation calculations for plutonium, assuming two different oxidation states (Pu[IV] and Pu[V]), suggest that it is stable as dissolved* $Pu(CO_3)_3^{2-}$*,* $Pu(CO_3)_4^{4-}$*, and* PuO_2^+*.*

3.8.7 Data Requirements for Understanding the Geochemistry of Surface Water and Groundwater

1. *To understand and model solid-solution phase interactions, both filtered and unfiltered surface water and groundwater samples should 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.*

2. *To understand the role of sorption reactions on the transport of radionuclides, batch sorption experiments should be performed on different aquifer material (alluvium, Bandelier Tuff, Cerro*

Toledo sediments, basalts, Puye Formation, and Santa Fe Group) using selected radionuclides (^{241}Am, ^{137}Cs, ^{238}Pu, ^{239,240}Pu, and ^{90}Sr).

3. *Geochemical modeling of surface water and groundwater is needed to quantify speciation, mineral stability, adsorption reactions, and mixing reactions between different media.*

3.9 Biological Setting

The general biological setting for the Los Alamos region and the canyons was discussed in Section 3.8 of the core document (LANL 1997, 55622). This section discusses unique aspects of the biological setting of the Mortandad Canyon system.

Several anthropogenic sources of surface water, as well as runoff, enter the Mortandad Canyon system. In the upper canyon NPDES-permitted cooling water discharges from TA-48 into Effluent Canyon maintain surface flow in Effluent Canyon to the TA-50 RLWTF outfall. These discharges plus natural runoff maintain small cattail wetlands at TA-48 and just upstream at the TA-50 RLWTF outfall. In addition, portions of Mortandad Canyon and Ten Site Canyon are designated on the national wetlands inventory maps as artificially and permanently flooded wetlands (Dunham 1992, 31726).

3.9.1 Potential Receptors

A summary of species thought to occur throughout the Laboratory canyons system can be found in Section 3.8 in Chapter 3 of the core document (LANL 1997, 55622). Only supplemental data specific to Mortandad Canyon will be presented here.

3.9.1.1 Flora

Within the Mortandad Canyon system, vegetation varies by elevation. Ponderosa pine-fir and Gambel's oak provide the dominant overstory, and wheatgrass is the dominant grass upstream of the TA-50 RLWTF outfall above 7185 ft (2190 m). Ponderosa pine-fir, Gambel's oak, and chokecherry provide the dominant overstory vegetation, and bluegrass and clematis are the dominant grass and forb species near the TA-50 RLWTF outfall between 7185 and 7105 ft (2190 and 2165 m) elevation. Ponderosa pine, piñon, and juniper provide the dominant overstory, and forbs and grasses include strawberry, dandelion, bluegrass, goosefoot, and bedstraw downstream of the TA-50 RLWTF outfall between 7105 and 6855 ft (2165 and 2090 m) elevation. Within the understory, grasses dominate at the higher elevations, whereas forbs dominate at lower elevations (Miera et al. 1977, 5569). A cursory examination indicated that many species used by humans as food and medicinal sources are abundant in the canyon including wild strawberries, raspberries, roses, mullein, currants, pussytoes, and juniper. Many species used as fuel by surrounding residents, including American Indians, can be found as well, including juniper and ponderosa pine. Many standing dead ponderosa pines are apparent in the lower canyon on Laboratory property, although fewer were observed during a 1997 tour than in the previous year, which suggests that some have been gathered for fuel in the intervening period.

3.9.1.2 Fauna

Mule deer, coyotes, and cottontail rabbits were documented as common to abundant throughout the canyon in 1973 (Hakonson et al. 1973, 4974), and brown bears were common as far as 0.5 mi (0.8 km) downstream of the TA-50 RLWTF outfall. Gonzales and Newell (1996, 56045) also refer to reports of Rocky Mountain elk and porcupines within Mortandad Canyon.

In a preliminary investigation of biota within Mortandad Canyon undertaken in 1977 (Miera et al. 1977, 5569), a maximum of six species of small mammals representing five families were identified at a single Mortandad Canyon location. The most common species trapped were the piñon mouse (Peromyscus truei), deer mouse (P. maniculatus), and least chipmunk (Eutamias minimus). Other species may have included the meadow vole (Microtus pennsylvanicus), Mexican woodrat (Neotoma mexicana), dwarf shrew (Sorex nanus), valley pocket gopher (Thomomys bottae), rock squirrel (Spermophilus variegatus), and cottontail rabbit (Sylvilagus sp.). Because data for these less frequent species were summed across sites in other canyons as well, Mortandad Canyon-specific incidence cannot be determined. The number of captures and number of species were highest in the ponderosa pine woodland upstream of the TA-50 RLWTF outfall and dropped dramatically (>4-fold) with distance downstream of the outfall over a 2.5 mi (4.0 km) study area. Although vegetation and precipitation levels also decline with distance downstream from the outfall, no significant correlations were found either between combined small mammal biomass per site and understory vegetation biomass or with the number of small mammal species and total vegetation estimates. However, the drop in small mammal numbers with elevation or distance from the outfall was not observed in either the DP Canyon/Los Alamos Canyon or Acid Canyon/Pueblo Canyon systems. Upstream of the outfall, an Abert's squirrel and a golden-mantled squirrel as well as incidental cotton rats and house mice were also observed.

In March 1994 a second study investigated small mammal species diversity in Mortandad Canyon (Raymer and Biggs 1994, 56038). This study was less inclusive; mammals were trapped only at outfalls in Mortandad Canyon and Effluent Canyon using fewer traps and a shorter trapping period. Five small mammal species were found including the long-tailed vole, white-throated woodrat, Mexican woodrat, brush mouse, and deer mouse. Although the species list differs, similar numbers of species are represented across the approximately 20-yr interval. The 1994 study does not report absolute numbers of animals trapped, so the abundance cannot be compared between the studies. Although the incidental species sited in the 1977 study were not observed, differences in the protocols could account for this.

No comprehensive investigation of avian or invertebrate species has been undertaken in Mortandad Canyon.

3.9.2 Threatened, Endangered, and Sensitive Species

Potential threatened and endangered species of concern in the canyon systems are listed in Chapter 3 of the core document (Section 3.8, Table 3-6) (LANL 1997, 55622). No detailed biological assessments of the Mortandad Canyon system have been completed but are scheduled for fiscal year (FY) 1998 by the Laboratory Ecology group (ESH-20). These assessments will include reconnaissance (Level 1) surveys, habitat evaluations (Level 2), and confirmatory identification of specific threatened and endangered species (Level 3).

Biological evaluations and wetland/floodplain assessments were performed by ESH-20 personnel in 1991 for technical areas bordering Mortandad Canyon (Dunham 1992, 31276). These investigations did not attempt to define boundaries of wetlands or floodplains because such boundaries are considered valid only within two years of determination. Such bounding will be included in the FY98 assessments. Level 2 surveys were conducted on the north canyon rim, the north canyon wall, and the canyon floor in the areas of Ten Site Canyon and Mortandad Canyon influenced by TAs -4, -35, -48, -52, and -55. Because the results of the 1991 assessment are summarized by operable unit, it is not clear what species identified are within the Mortandad Canyon/Ten Site Canyon region specifically. Although the introduction to the report (Dunham 1992, 31276) lists habitat for several sensitive species including the spotted bat, no confirmatory sightings were made.

The 1991 assessment and a subsequent 1993 survey (Cross 1996, 26071) note that suitable nesting areas for several raptors (including northern goshawks and bald eagles) occur in Mortandad Canyon. No detailed investigation of reptile and amphibian species has been undertaken.

3.9.3 Species Viability Studies

Mortandad Canyon is currently an area for reproductive studies on insectivorous ecological receptors, which measure nesting rates, reproductive capacity, fledgling viability, and renesting frequency. This is the only study currently identified that addresses species viability in Mortandad Canyon.

3.9.4 Contaminant Uptake

3.9.4.1 Radionuclide Concentrations in Biota

The most extensive investigation of radionuclide concentrations in plant and animal tissues was undertaken in 1972 through 1973 (Hakonson et al. 1973, 4974). This study examined concentrations of americium, cesium, plutonium, and tritium in plant and animal species as well as related soils and sediments in Mortandad Canyon. Individual animal tissues including liver, lungs, bones, kidney, lymph nodes, muscle, thyroid, carcass, and hide were analyzed, although not all tissues were examined in the smaller species. Animal species included small mammals, large herbivores, predator species, and birds. In addition, concentrations of radionuclides in honeybees and honey were examined. The detailed data tables presented in that report provide data that can be used to develop distributions for uptake of these radionuclides as well as useful information to evaluate human health risks that result from consumption of various animal and plant tissues. Data from these investigations have been reported in peer-reviewed literature and are summarized below, along with additional data on contaminant uptake in Mortandad Canyon species from more recent surveillance studies.

3.9.4.1.1 Flora

Concentrations of plutonium in plants in Mortandad Canyon ranged from 0.18 to 18 pCi/g dry weight at soil concentrations of 90 pCi/g. At ^{137}*Cs concentrations of 980 pCi/g in soil, concentrations in plants ranged from 0.94 to 110 pCi/g. The highest concentrations for both radionuclides were observed in grasses and lichens; the lowest concentrations were observed in trees (Hakonson and Bostick 1975, 29678). Later studies indicated that the higher concentrations on the low-growing grass (<40 cm) and lichen species were due to surface deposition from rain splash (Dreicer et al. 1984, 8592). However, these surface contaminants still represent a pathway for food chain transfer because they will be consumed along with the plant by many species. In addition, studies on surface deposition of airborne contaminants from Chernobyl have indicated that surface particulates can be systemically absorbed by plants, which indicates that this mechanism can result in food chain transfer of contaminants even when the plant surfaces are washed (Monte et al. 1990, 56046).*

Hakonson and Nyhan (1980, 8917) have also calculated transfer coefficients for plutonium in grasses in Mortandad Canyon ranging from 0.05 to 0.93 and 0.04 to 1.1 (unwashed samples). These transfer coefficients are reported to be linear with soil concentrations.

Concentrations of radionuclides in Mortandad Canyon plant species were studied more recently at three wetlands: (1) one that is maintained by the TA-48 NPDES outfall, (2) one that is 1.3 mi (2.1 km) downstream from the TA-50 RLWTF outfall, and (3) one that is 2.5 mi (4.0 km) downstream from the TA-50 RLWTF outfall. Although no statistical differences were observed in most concentrations, data were highly variable. Data *from understory plants downstream of the TA-48 outfall showed the highest mean concentrations for americium, cesium, plutonium, strontium, tritium, and uranium. Although no regression analysis between sediment and plant concentrations was performed, graphical representation of the data suggested low correlations in these samples (Bennett et al. 1996, 56035).*

3.9.4.1.2 Honeybees

Honeybees near the TA-50 RLWTF outfall showed concentrations of tritium that reflected the concentrations in their vegetation and surface water sources (Hakonson and Bostick 1976, 8912). Concentrations of tritium in honey were also elevated, although two to three times lower than those in the bees. Cesium and plutonium also were detected in the honeybees. Ratios of the radionuclides were consistent with primarily a water ingestion source. Data for cesium and plutonium in honey were not available.

3.9.4.1.3 Small Mammals

Contradictory data on tissue localization have been reported. In studies from the early 1970s, plutonium concentrations in rodents were highest in lung tissue and pelts; concentrations in liver and carcass tissue were at or below the detection limit (Hakonson and Bostick 1975, 29678). However, Hakonson and Nyhan (1980, 8917) later reported that 96% of the body burden of plutonium was localized to the pelts and gastrointestinal tracts; the lowest observed concentration in the tissues studied was in the lungs.

Subsequent studies of small mammals analyzed only tissues pooled across several animals and examined only carcasses and pelts (Bennett et al. 1996, 56035). Pelt samples showed concentrations consistently an order of magnitude greater than carcass samples for ^{241}*Am,* ^{137}*Cs,* ^{238}*Pu,* ^{239,240}*Pu, and uranium. However,* ^{90}*Sr concentrations were equivalent in both carcasses and pelts. For all but uranium, tissue concentrations were correlated with sediment concentrations in the region of trapping. Results of these studies further indicated that concentrations of radionuclides in small mammals sampled in Mortandad Canyon were greater than in rodents sampled at the waste burial site at TA-54, Area G. In general, concentrations reflected elevation in contaminant concentrations in sediments near the trapping sites; mammals collected near the TA-50 RLWTF outfall showed the greatest elevation.*

3.9.4.2 Inorganic Contaminant Uptake

No data were found on specific inorganic contaminant uptake in biota in the Mortandad Canyon system.

3.9.4.3 Bioaccumulator Uptake

No data on uptake of bioaccumulators have been reported for species in the Mortandad Canyon system, although data on mercury concentrations in sediments have been reported (Hakonson et al. 1980, 8924).

3.9.5 Data Needs for Understanding Biota Uptake of Contaminants

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. Mercury was reported to be present in sediments downstream of the TA-50 RLWTF outfall (Hakonson et al. 1980, 8924). However, the article has a discrepancy between tabular and graphic results. Table values report concentrations of mercury in µg/kg, whereas the graphic presentation in is mg/kg. A value of 1800 µg/kg *is reported near the outfall with mean concentrations of 100 to 150 µg/kg as far as 1640 ft (500 m) downstream (Hakonson et al. 1980, 8924). Because mercury bioaccumulates, these concentrations could present significant risks to humans and other species. In addition, portions of the Mortandad Canyon/Ten Site Canyon region appear on the national wetlands inventory maps as artificially and permanently flooded wetlands (Dunham 1992, 31276). Therefore, bioaccumulators (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 also may be important for food-chain transfer to higher trophic levels.*

No data were found on tissue concentrations of contaminants for predator species such as coyotes, owls, and raptors in Mortandad Canyon, which makes it difficult to evaluate food chain transfer effects. Related to this, no data for pocket gophers have been found. Because of the extensive burrowing of this species and their localized range, this species could present a more significant pathway for contaminant dispersion and transfer than indicated by the small mammal data collected thus far.

Only very limited data are available for avian species. These data may prove important in evaluating food chain effects as well as in determining impacts on species survival. Although many avian species have broad ranges, foraging may be localized during breeding and fledging only to regions proximal to the nest site. In addition, many species can ingest significant amounts of soil while foraging.

Questions remain on values for potential transfer of contaminants through biota to humans. Uptake in species used by American Indians for medicinal and dietary purposes has not been systematically investigated and represents a data gap. In addition, apparent harvesting of firewood from standing dead trees in lower Mortandad Canyon suggests a potential human health risk from inhalation of contaminants in combustion products. Analysis of this risk will require concentration factors for contaminants in tree trunks where contaminants may be localized in particular growth rings that develop during periods of higher sediment or groundwater contaminant concentrations. Current data have primarily represented contaminant concentrations in trees determined by examination of branches, which may have developed relatively recently and, therefore, show lower concentrations. The presence of abundant berries suggests a potential exposure pathway not only for individuals who regularly gather plants in the canyon but also for those who use the canyon for recreational purposes (such as joggers, hikers, and cyclists). Because such use is currently unlimited and many people use the canyon, investigation of contaminant concentrations in these potential food sources is necessary.

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. Moreover, some of the previous data reflect unwashed samples, whereas some do not specify whether samples were washed or unwashed. Depending on the scenario being evaluated, pooling of these data may inflate or deflate the transfer coefficient. For example, if plants are washed before human consumption, using data from unwashed samples will overestimate the risk. However, data from washed samples will underestimate the risk for situations where materials are consumed without washing. Therefore, some confirmatory samples should be taken and analyzed to update and validate the applicability of previously calculated transfer coefficients.

Because recent data have pooled tissues and animals before analysis, no estimate of variability in the population can be determined. Such measures of variability are essential to evaluate uncertainty in both *human health and ecological risk estimates. Also, because most contaminants localize within specific tissues in fauna, the prior practice of pooling tissues obscures variations among critical organs, making assessment of the impact of contaminants on the health of the population difficult.*

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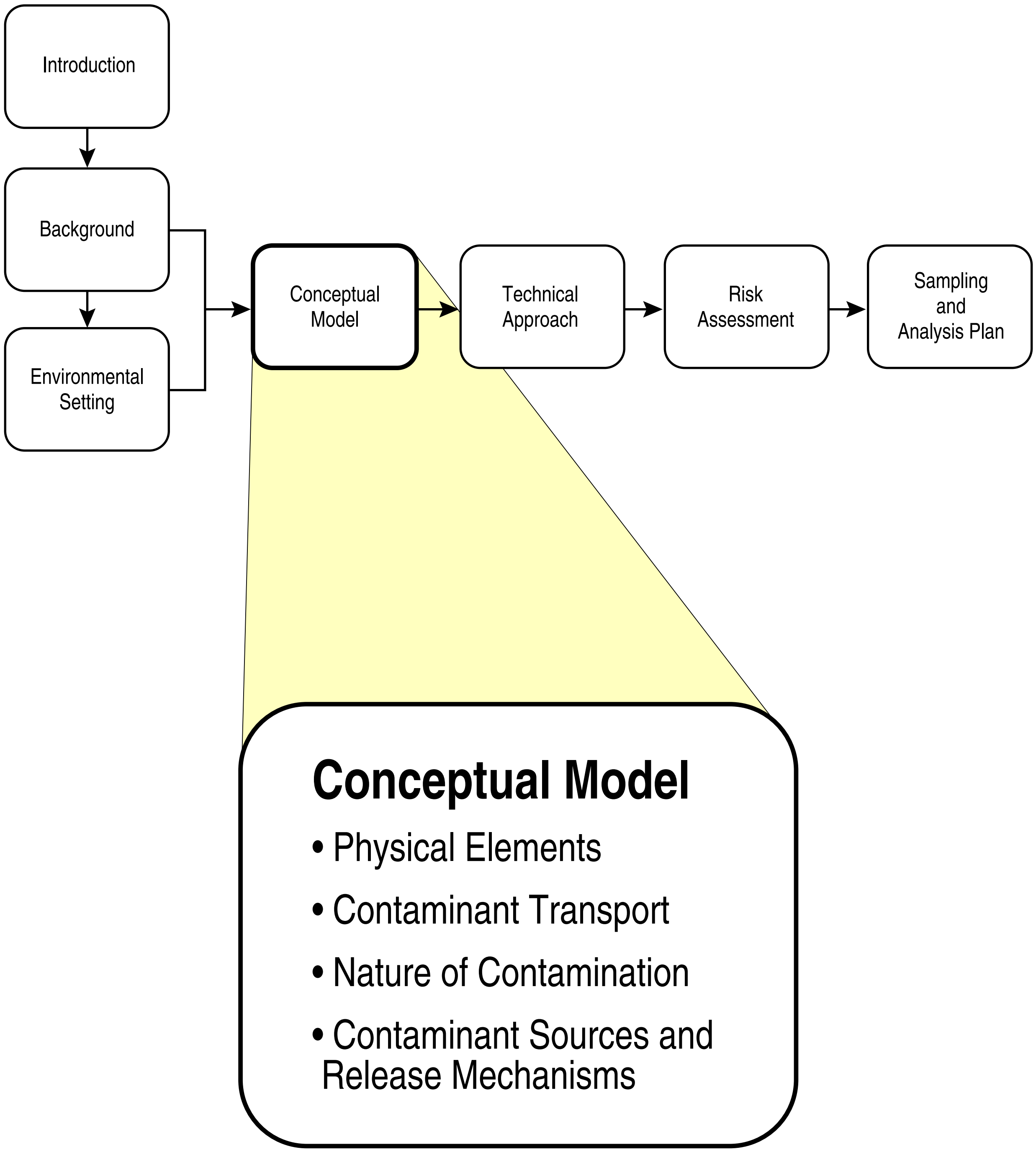
Chapter 4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4.0 CONCEPTUAL MODEL

4.1 Introduction

This chapter summarizes the significant geologic, hydrologic, and biological features, events, and processes operating in the Mortandad Canyon system that could reasonably affect estimates of human and ecological risk from Laboratory-derived contaminants. This chapter places these features, events, and processes (which are described in greater detail in the preceding chapters of this work plan) within a conceptual framework that is intended to support a credible human health risk assessment for current contamination conditions and to project trends of reasonable future impacts. The human health risks will be evaluated for personnel who work in the canyon system and for the public who visit the canyon system for a variety of purposes. In addition, impacts to the ecological system will be assessed.

The conceptual model of contaminant occurrence, transport, and exposure route for the Mortandad Canyon system (hereafter "the conceptual model") presented in this chapter is modified from the conceptual model for the canyon systems in general, which is discussed in Chapter 4 of the Core Document for Canyons Investigations (hereafter "the core document") (LANL 1997, 55622). With respect to the general conceptual model, this modification adds detail that is specific to the Mortandad Canyon system and eliminates from consideration some processes that are known not to occur in the Mortandad Canyon system. It also incorporates findings that are relevant to the conceptual model of the studies currently underway in Los Alamos Canyon and Pueblo Canyon pursuant to the work plan for those investigations (LANL 1995, 50290).

The conduct of this investigation and other canyon investigations will involve working with the neighboring Indian Pueblos (Cochiti, Jemez, San Ildefonso, and Santa Clara) to define and evaluate the impacts to cultural resources that are valued by the American Indian population. This commitment fulfills part of the Laboratory's responsibility for stakeholder involvement. The approach to evaluating present-day risks is being defined, and this conceptual model may not yet fully reflect American Indian concerns. The term "present-day risks," which is discussed further in Section 5.1.3 in Chapter 5 of the core document (LANL 1997, 55622), means human health risk assessment using present-day contamination levels for exposure scenarios now and in the near future. Section 4.3 discusses how the conceptual model will be revised to reflect investigation data as well as changing impact assessment objectives.

4.1.1 Purpose

The purpose of the conceptual model is to incorporate known significant features, events, and processes (as described in Chapter 2 and Chapter 3 of this work plan) into a comprehensive view that is then used to guide the development of the technical rationale for investigations in the Mortandad Canyon system. The conceptual model articulates the major assumptions (some of which need to be tested), the features that need to be described more accurately, and the models of processes that might need to be refined to adequately evaluate impacts. The conceptual model description helps define the investigations (including field measurement activities) and the interpretation and analysis of both new and existing data that are needed to refine risk assessments. These investigations are described in the sampling and analysis plans in Chapter 7 of this work plan.

4.1.2 Relationship of the Conceptual Model to Impact Assessment

The conceptual model describes the major contaminant sources in Mortandad Canyon and the adjacent watershed area and the mechanisms by which those contaminants could be transported to potential receptors. It identifies interactions among these transport pathways and their relationship to exposure pathways to humans, plants, and wildlife.

The exposure pathways are part of the human health risk assessment model and ecological risk assessment model described in Chapter 6 of the core document (LANL 1997, 55622). The selection of potential receptors and exposure pathways depends on the structure and assumptions of the assessment models. The conceptual model discussed in this chapter addresses the exposure pathways in the Mortandad Canyon system that were selected for consideration using the assessment models described in Chapter 6 of the core document.

Human health and ecological risk will be quantitatively evaluated based on current contamination levels. Changes in those evaluations over time, considering water and sediment transport of contaminants, will be evaluated qualitatively.

The potential human exposure scenarios for the Mortandad Canyon system include the following:

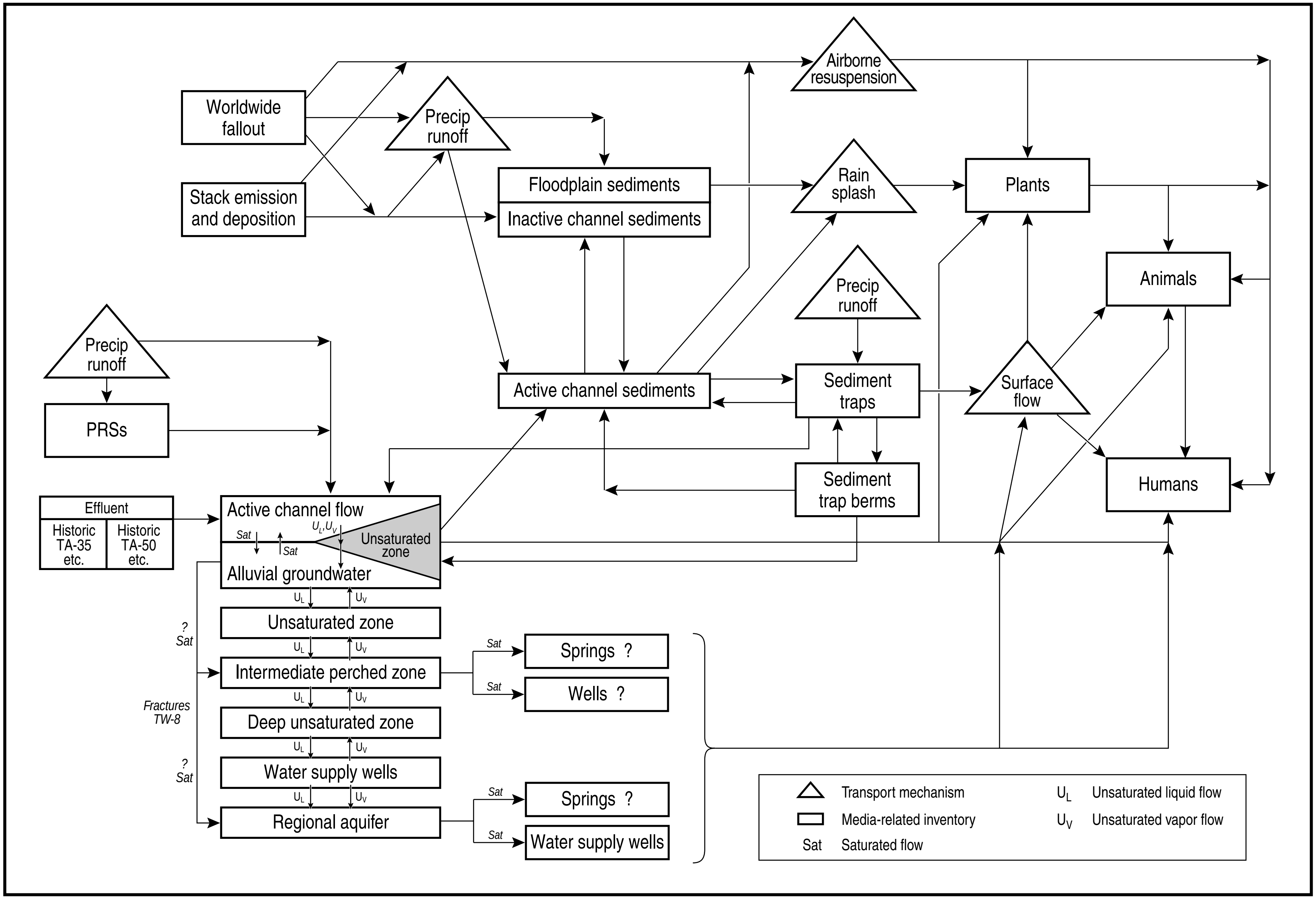
- *use by Laboratory workers;*
- *recreational use by the public and Laboratory workers;*
- *restricted use by workers and/or public imposed by access control (such as the "institutional control scenario" contemplated by proposed interagency guidance on cleanup);*
- *use by the American Indian population for residential, cultural, and religious purposes and for farming, ranching, and hunting;*
- *habitation by the local biological community, which considers whether complete exposure pathways exist; and*
- *use of the Rio Grande, including integrity of that biological community.*

Chapter 6 of the core document (LANL 1997, 55622) describes these exposure scenarios in detail except the "institutional control scenario" which is being developed. Therefore, they are not repeated in this work plan.

4.1.3 Development of the Mortandad Canyon Conceptual Model

The conceptual model for the Mortandad Canyon system was developed from the data and information presented in Chapter 2 and Chapter 3 of this work plan and the general conceptual model presented in Chapter 4 of the core document (LANL 1997, 55622). Variations in stratigraphy and hydrogeology from the general representation in the core document are discussed in Chapter 3 of this work plan and in Section 4.3.7.2 of the Hydrogeologic Workplan (LANL 1996, 55430). The elements of the contaminant occurrence and the transport and exposure pathway interactions in the Mortandad Canyon system are illustrated in Figure 4.1.3-1.

The conceptual model identifies potential sources of contamination, relevant pathways for transport, and likely pathways for exposure. The conceptual model and the hypotheses it represents are based on a synthesis of current knowledge of the canyon system, geology, geochemistry, hydrology, and distribution of contaminants in and adjacent to the canyon system. The transport pathway descriptions include the predominant release mechanisms, transport processes, and the contaminated media for each transport pathway. The conceptual model includes those elements that are likely to influence decisions about remediation in the canyon system environment. In many cases the model and hypotheses need to be further tested or verified to optimize confidence in understanding of processes and future trends in human health and ecological risks.



F4.1.3-1 / MORTANDAD WP / 072497

Figure 4.1.3-1. Elements of the Mortandad Canyon system conceptual model.

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

4.2 Contaminant Transport Conceptual Model

The major elements of the conceptual model are discussed in the expected order of their ability to disperse and transport contaminants in the Mortandad Canyon system.

- *Surface water and sediment transport*
- *Groundwater transport*
- *Biological/food chain transport*
- *Atmospheric transport*

The elements of the conceptual model are summarized in Table 4.2-1. Italicized terminology refers to graphic elements that are depicted in Figure 4.1.3-1. The assumptions, features, events, and processes related to transport are described in greater detail in Chapter 2 and Chapter 3 of this work plan. Cross-references to Chapter 2 and Chapter 3 are included in this discussion to facilitate the location of additional detail in other parts of this work plan.

4.2.1 Surface Water and Sediment Transport and Resultant Exposures

Sediment transport by surface flow is believed to be the predominant contaminant transport mechanism in the Mortandad Canyon system. In most cases more than 90% of total inventories of radioactive contaminants having low solubility and high sorptive properties are associated with the sediments in the active channel, inactive channel, floodplain, and the sediment traps (see Section 3.4 in Chapter 3 of this work plan). Precipitation runoff, especially that from the larger thunderstorms, has redistributed sediments and associated contaminants in Mortandad Canyon, generally within the Laboratory boundaries. Sequential precipitation runoff and other surface flow events have transported a small portion of these contaminants off-site (see Section 3.4). Most contaminants were discharged primarily as dissolved or particulate components in liquid effluent discharges and have been adsorbed from the liquid phase onto sediment particles. The sediments carrying the adsorbed contaminants are redistributed by sediment transport processes that occur after the original effluent discharge. Because most of the radioactive contaminant inventory is associated with the sediments, major future precipitation runoff events hold the greatest potential for significant redistribution on Laboratory land and off-site. Therefore, understanding sediment transport processes is fundamental to understanding contaminant transport.

Sediment transport occurs during large precipitation runoff events (floods) and during sustained effluent discharges from outfalls, although most transport probably occurs during floods produced by summer thunderstorms. Sediment transported by these surface flows has been deposited downstream at various locations along Effluent Canyon, Ten Site Canyon, and Mortandad Canyon but generally not much farther than the sediment traps. One effect of continued sediment transport over time is to move older contaminants from upstream areas and increase their inventory in some downstream areas.

TABLE 4.2-1

ELEMENTS OF THE CONCEPTUAL MODEL FOR MORTANDAD CANYON

Pathway/Mechanism	Concepts/Hypotheses
Surface water and sediment transport	
A. Surface water runoff and discharges	*A1. Precipitation will partition among evaporation, transpiration, infiltration, and runoff. Precipitation runoff is a function of soil and vegetation properties, precipitation intensity, and initial soil moisture content.*
	A2. Precipitation runoff is concentrated by natural topographic features and man-made diversions.
	A3. 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 radionuclides and metals. However, some radionuclide contamination, such as tritium and ^{90}Sr, can also be transported in solution.
	A4. The dissolved contaminants of major importance to surface water quality (for example, tritium, nitrate, chloride, and fluoride) are relatively conservative species.
	A5. Movement of some contaminants as dissolved species may be partly retarded by adsorption onto organic matter, clay, metal hydrous oxides, and other highly sorptive phases in porous alluvial media when surface flow infiltrates and then either returns to surface flow in some portions of the upper canyon or moves laterally or downward out of the alluvium by saturated or unsaturated flow.
B. Erosion and transport of soils and sediments	*B1. Surface soil erosion and sediment transport are a function of precipitation runoff intensity and frequency, vegetative cover, topography, soil properties, and land use.*
	B2. Contaminants tend to adsorb onto soil and sediment particles, which can be transported by surface flow and concentrated in depositional areas of the canyon system (such as the sediment traps).
	B3. Precipitation runoff and effluent discharges have redistributed contaminants on both suspended and bedload sediments substantial distances downstream from their original sources. Most of this redistribution has occurred within Laboratory boundaries; however, some contaminants may have been carried onto San Ildefonso Pueblo land, predominantly between the Laboratory boundary and state road NM4. Presently there is no evidence of contaminant transport to the Rio Grande in Mortandad Canyon.
	B4. Concentrations of contaminants in sediments generally decrease downstream because of dilution with clean sediments. Dilution will also tend to decrease contaminant concentrations over time if contaminant releases are stopped or reduced. However, higher concentrations may occur in fine-grained sediments in the sediment traps because impoundment of surface flow allows the fine-grained suspended sediments to settle. In the absence of impoundments, the tendency is for the fine-grained sediment to be deposited farthest downstream and in other locations where surface flow decreases.
	B5. The deposition and storage of contaminated sediments generally increase downstream. Contaminants carried by floods can be dispersed over progressively wider areas of the canyon floor downstream, which results in relatively high contaminant inventories in some downstream locations. These deposits are potentially subject to remobilization.
	B6. Concentrations of contaminants in sediments can be highly variable in any part of a canyon because of variations in deposit age and type of sediment deposit (for example, active channel versus floodplain sediments). Sediment deposits of similar age and particle size distributions that vary in relative contributions from different source areas (for example, Effluent Canyon versus upper Mortandad Canyon) contribute to the variations.

TABLE 4.2-1 (continued)

ELEMENTS OF THE CONCEPTUAL MODEL FOR MORTANDAD CANYON

Pathway/Mechanism	Concepts/Hypotheses
	B7. Contaminant concentrations vary with sediment particle size; the highest concentrations are generally found in the finer-grained fractions of sediments of a given age. However, the highest contaminant inventories in a given reach may be found in coarse-grained sediment fractions due to their larger volume.
	B8. Locally, sediment contaminant concentrations at depth may be significantly higher than at the surface due to burial by younger and cleaner sediments.
	B9. Residence times for contaminated sediments deposited at different canyon locations could range up to several years in active channels and hundreds or thousands of years in some inactive channels and floodplains.
	B10. Channel incision, lateral bank erosion, and sediment redistribution will be most active during floods that may have return periods of years to decades or longer.
	B11. Contaminant transport in the active channel occurs predominantly by bedload and suspended sediment transport with lesser transport in the dissolved phase. Coarse- to medium-grained sand and gravel are generally transported as bedload. Fine sand, silt, and clay are generally transported as suspended load.
	B12. The area near the sediment traps has experienced substantial deposition of alluvium during the last 10,000 years, and future floods may tend to deposit more sediment and progressively bury contaminated sediment layers. However, infrequent, large-magnitude floods could result in channel incision, excavation of sediments, and transport of some sediments downstream.
	B13. The transport distance and lateral dispersion of contaminants during floods depend on the characteristics of both floods and channels. Longer transport and less lateral dispersion occur in deeply incised channels. Concentrations of contaminants carried and deposited by such floods would depend on the amount of mixing of contaminated and uncontaminated sediments.
	B14. Sediment transport segregates sediments by size, which might reconcentrate contaminants in low-energy depositional areas; this process has been observed in the sediment traps.
	B15. Flooding extends the area of contaminant dispersal in the canyon floor away from the channel, especially as the canyon widens and the gradient decreases.
Groundwater transport	
C. Alluvial groundwater	*C1. Alluvial groundwater, which is present in Mortandad Canyon, is maintained perennially by precipitation runoff and surface flow.*
	C2. The alluvium contains distinct zones; some may cause limited perching within the alluvium and/or limited confinement of some deeper zones. When well MCO-8 was installed in 1960, the alluvial groundwater exhibited slight artesian conditions (see Section 3.7.2 in Chapter 3 of this work plan).
	C3. Perennial alluvial groundwater is augmented in the portions of Mortandad Canyon that receive discharges from Laboratory sources within or adjacent to the canyons.
	C4. Maximum concentrations of contaminants are initially associated with alluvial groundwater close to source effluent discharges. Maximum concentrations of contaminants are observed in the alluvial groundwater wells immediately below the Technical Area (TA) -50 RLWTF outfall.
	C5. Alluvial groundwater is recharged in the middle canyon (Effluent Canyon eastward to test well [TW] -8) by infiltration of surface water from the stream channel and in the lower canyon (TW-8 eastward to the sediment traps) predominantly by groundwater moving downgradient from upstream reaches.

TABLE 4.2-1 (continued)

ELEMENTS OF THE CONCEPTUAL MODEL FOR MORTANDAD CANYON

Pathway/Mechanism	Concepts/Hypotheses
	C6. Dilution and attenuation by geochemical processes leads to generally decreased contaminant concentrations (relative to conservative species such as chloride and tritium) downgradient within a water-bearing zone. Lowest concentrations of contaminants are observed in the alluvial groundwater in lower Mortandad Canyon downstream of the sediment traps. Colloidal transport through the alluvium is possible based on the distribution of actinides and the fission products observed.
	C7. Alluvium is generally more permeable than the underlying tuff units. Surface water infiltrates until downward movement is impeded by less permeable units; at that point moisture accumulates, possibly leading to saturation.
	C8. Tritium and other conservative dissolved species move into underlying stratigraphic units. The migration process (for example, saturated and unsaturated liquid-film or unsaturated vapor-phase flows) and rate depend on the properties of the interface between the stratigraphic units, which may be highly variable both spatially and temporally.
	C9. Saturated conditions appear to be confined to the alluvium and/or to the Tsankawi Pumice Bed/Cerro Toledo interval where they are in contact with the alluvium.
	C10. The thickness and longitudinal extent of the alluvial saturated zone varies seasonally; the maximums occur after spring snowmelt and/or summer thunderstorms.
	C11. Groundwater flows downgradient in the alluvium relatively rapidly (30 to 40 ft per day), taking about a year to move from the TA-50 RLWTF outfall in Effluent Canyon to lower Mortandad Canyon near well MCO-8.2.
	C12. Groundwater flow processes downgradient in the alluvium can be approximated by a porous medium model, which can account for changing gradients, variation in permeability and, probably, anisotropy in vertical and horizontal permeability.
	C13. The rate of migration of geochemically active contaminants (not including conservative species such as tritium and nitrate) will be retarded relative to the groundwater flow rate primarily by sorption in the alluvium onto mineral, organic, or organic-coated mineral particles. However, colloidal transport of contaminants may occur in the alluvium and other hydrogeologic units beneath Mortandad Canyon. Colloids may consist of silica, ferric oxyhydroxides, clay minerals, and solid organic matter.
	C14. Evapotranspiration removes approximately 20% of the water that is added to Mortandad Canyon each year. Most water (possibly 80 to 90%) is lost from the alluvium by moving downward into underlying units. Contaminated alluvial groundwater infiltrates into the underlying Bandelier Tuff and possibly other hydrogeologic units. Neither the mechanism nor the location of the loss is known. Two principal water-balance models present alternate hypotheses: one indicates that most losses occur upstream of the confluence with Ten Site Canyon; the other suggests that most losses occur downstream of the confluence.
	C15. West of the sediment traps, the alluvium and the Cerro Toledo interval are distinct hydrogeologic units separated by the Tshirege Member of the Bandelier Tuff. Near the sediment traps and eastward these two units may merge into a single hydrogeologic unit.
	C16. West of the sediment traps the Cerro Toledo interval may contain one or more intermediate perched zones.
	C17. Because the alluvium and the Cerro Toledo interval are similar in lithology, identification of the Cerro Toledo interval beneath the alluvium may be difficult in boreholes. Groundwater in the alluvium east of the sediment traps may infiltrate directly into the Cerro Toledo interval.

TABLE 4.2-1 (continued)

ELEMENTS OF THE CONCEPTUAL MODEL FOR MORTANDAD CANYON

Pathway/Mechanism	Concepts/Hypotheses
	C18. It is not known whether losses from alluvium recharge any intermediate perched zone(s). Based on logs of the boreholes for TW-8 and nearby water supply wells (PM-3 and PM-5), no saturated zones have been observed in any unit beneath the alluvium until the depth of the regional aquifer. However, when the boreholes for these wells were drilled, intermediate perched zones were not anticipated, and any perched water may not have been recognized because of drilling methods (fresh water and mud rotary drilling). Moreover, the drilling for TW-8 was conducted in 1960 before discharges from the TA-50 RLWTF began; intermediate perched zones could have developed subsequent to and as a result of these discharges.
D. Infiltration and unsaturated zone flow and transport	*D1. Infiltration into the surface soils depends on the rate of rainfall or snowmelt, proportion of discharges added, existing soil moisture, depth of soil, rate of evapotranspiration, and properties of soil and bedrock.*
	D2. Precipitation runoff and discharges infiltrate the alluvium. Dissolved contaminants infiltrate more readily than contaminants that are adsorbed onto sediment particles. Nonsorbing species (for example, tritium and anionic species) migrate in solution virtually as fast as the water physically moves.
	D3. Transport of normally insoluble or strongly-sorbed contaminants in the unsaturated zone can occur by movement of colloidal-size suspended solids. Nonsorbing species (for example, tritium or anionic species) migrate in solution.
	D4. 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 Mortandad Canyon.
	D5. Transient and steady-state liquid flow at depth can be very slow in unsaturated tuff and other bedrock units under low moisture contents.
	D6. Both liquid-film and vapor-phase unsaturated flow occur at varying depths in unsaturated tuff beneath the alluvial groundwater in Mortandad Canyon.
	D7. 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.
	D8. Fractures contribute to liquid flow and transport at moisture contents above some as yet undefined critical value. Below this value, flow in the rock matrix will predominate.
	D9. Mineral precipitation and sorption onto mineral surfaces will cause retardation of contaminant migration.
E. Perched groundwater and lateral flow at unit contacts beneath alluvium	*E1. Intermediate-depth units within the Bandelier Tuff (Guaje Pumice Bed), Cerro Toledo interval, basalts, and the Puye Formation in the Mortandad 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 (Pueblo Canyon, Los Alamos Canyon, and Sandia Canyon).*
	E2. Intermediate perched zones could be expected in areas where a sufficient water source is present to maintain saturation; the annual losses from the Mortandad Canyon alluvium are sufficient to warrant further investigation of potential intermediate perched zones, especially within the Guaje Pumice Bed.
	E3. If present, intermediate perched zones may receive some recharge from watersheds farther westward or northward; however, currently there is no indication that this occurs upgradient from Mortandad Canyon.

TABLE 4.2-1 (continued)

ELEMENTS OF THE CONCEPTUAL MODEL FOR MORTANDAD CANYON

Pathway/Mechanism	Concepts/Hypotheses
	E4. Intermediate perched zones have not been observed to extend laterally beneath mesas. However, lateral spreading of such perched zones could occur downgradient if the canyon course and the gradient of the perched zone do not coincide. There is some indication of the presence of paleosurfaces beneath Mortandad Canyon, which suggests the possibility of movement south-southeast from the axis of the canyon if intermediate perched zones occur.
	E5. 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 either the losses from the alluvium or the apparent dilution of tritium in some locations.
	E6. Contrast in hydraulic properties between the Guaje Pumice Bed and the underlying Puye Formation or Cerros del Rio basalts may create locations for intermediate-depth perched groundwater.
	E7. Buried paleotopographic surfaces and the dip of stratigraphic contacts may influence the direction of laterally diverted flow. Other factors influencing flow direction include grain size, flux through the system, faults, and fractures. The buried paleosurfaces of the pre-Tshirege (Tsankawi Pumice Bed/Cerro Toledo interval) and pre-Otowi (Guaje Pumice Bed) may be particularly important beneath Mortandad Canyon.
	E8. Laterally diverted groundwater flow may return to the surface as springs or seeps, as is observed in other canyons, although none are known to be associated with Mortandad Canyon.
	E9. Contaminant concentrations of adsorbing species are expected to decrease with depth because of dispersion, dilution, and/or geochemical attenuation along flow paths. Contaminant concentrations of nonsorbing species could potentially increase with depth due to past Laboratory effluent discharges that contained higher concentrations of contaminants than recent effluent discharges.
F. Vapor transport	*F1. Vapor-phase transport is important for some volatile contaminants and is a viable mechanism by which tritium may have moved much deeper than any other contaminant (except chloride and nitrate).*
	F2. Vapor-phase transport is controlled by the vapor pressure of the contaminant and the porosity, permeability, moisture content, and moisture characteristic properties of the unsaturated medium (soil, sediment, or rock) and the properties of the contaminants (except chloride and nitrate).
G. Regional aquifer and saturated zone flow and transport	*G1. Numerous permeable units in the Puye Formation, the Tschicoma Formation, and the Santa Fe Group compose the regional aquifer.*
	G2. 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. 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 as regards layering and the influence of anisotropy in the vertical and horizontal permeability.
	G3. The hydraulic gradient of the regional aquifer averages about 60 to 80 ft per mile within the Puye Formation and increases to 80 to 100 ft per mile along the eastern edge of the plateau as groundwater enters the more permeable sediments of the Santa Fe Group.
	G4. Based on aquifer tests, the rate of groundwater movement in the upper potion of the regional aquifer ranges from 20 ft per year in the Tesuque Formation to 345 ft per year in the more permeable Puye Formation.

TABLE 4.2-1 (continued)

ELEMENTS OF THE CONCEPTUAL MODEL FOR MORTANDAD CANYON

Pathway/Mechanism	Concepts/Hypotheses
	G5. The upper saturated zones of the regional aquifer may be recharged in part from the west, possibly from the Jemez Mountains. Alluvial groundwater may contribute to regional aquifer recharge including infiltration along fault and fracture zones or possibly along well boreholes on the Pajarito Plateau. Natural recharge through undisturbed Bandelier Tuff on the mesa tops is believed to be possible but is probably insignificant.
	G6. A portion of the regional aquifer discharges into the Rio Grande through springs and seeps. Springs fed by the regional aquifer discharge an estimated 4300 to 5000 acre-feet of water annually to the portion of the Rio Grande in White Rock Canyon.
	G7. Contamination of the regional aquifer beneath Mortandad Canyon by at least tritium and nitrate has occurred at low levels as observed at TW-8. The mechanism for this contamination is not fully understood, but it may be related to a pathway along the well borehole itself or possibly to infiltration of contaminants through an intermediate perched zone or the vadose zone(s).
	G8. The regional aquifer in the Los Alamos area is the only aquifer capable of producing a large-scale water supply.
	G9. The regional aquifer exhibits artesian conditions in the eastern portion of the Pajarito Plateau, especially near the mouth of Los Alamos Canyon. Recharge for this portion of the aquifer may originate in the Sangre de Cristo Mountains. It is not known whether such conditions extend near the confluence of Mortandad Canyon and the Rio Grande. The regional aquifer exhibited slight artesian conditions at TW-8 when the borehole for this well was drilled in 1960.
	G10. Where present, Laboratory-derived contaminants in the regional aquifer would be expected to be highly diluted compared with potential recharge sources such as the contaminated alluvial groundwater. This is the observation near TW-8 where contaminant concentrations are factors of 1000 to 100,000 lower than in the alluvial groundwater.
Biological pathways/transport and exposure	
H. Plant uptake	*H1. The ability of plants to absorb contaminants depends on soil and water chemistry, soil microflora activities, contaminant characteristics, climatic conditions, and the characteristics of individual plant species.*
	H2. Contaminants in the rooting zone can be assimilated into the roots and redistributed throughout plant tissues. The rooting zone can include alluvial groundwater.
	H3. Contaminants in plant tissues can be redistributed by herbivore feeding and by erosional transport of dying leaves, branches, stems, and roots, and by wind.
	H4. Tritium is transpired to the atmosphere by ponderosa pines in Mortandad Canyon at essentially the same concentration as the water in the alluvial groundwater.
	H5. Plant surfaces are contaminated by deposition from rain splash of contaminated soil onto stems and leaves. Deposition of atmospheric contaminants, such as worldwide fallout, also contributes to contamination.
I. Animal uptake	*I1. Animals can ingest contaminants by consuming water from the active channel or from water ponded for limited periods at locations such as the sediment traps.*
	I2. Animals consume leaves, stems, and roots; surficial contamination is the largest contribution. Bees consume both water and plant products (such as nectar) and the contaminants they contain, especially tritium.
	I3. Animals also consume contaminants that adhere to the surfaces of plant tissues. Predators ingest contaminants that are in or on their prey.
	I4. Animals can ingest soil intentionally or incidentally while grooming, inhale contaminants absorbed to airborne particles, and absorb contaminants through abraded or injured skin while bathing or swimming in contaminated water.

TABLE 4.2-1 (continued)

ELEMENTS OF THE CONCEPTUAL MODEL FOR MORTANDAD CANYON

Pathway/Mechanism	Concepts/Hypotheses
	I5. Animal behavior patterns and the elimination of feces and urine can disperse contaminants away from source areas.
	I6. Humans can consume the flesh from contaminated wildlife that have moved away from contaminated areas.
	I7. Behavior can decrease the degree of exposure to environmental contaminants because food or water might not be obtained from a single site or behavior might cause wildlife to be exposed to multiple, antagonistic contaminants.
	I8. Bioaccumulation of contaminants from the ingestion of animals and plants is an important process for certain metals and anthropogenic organic compounds.
J. Bioturbation	*J1. Burrowing invertebrates (such as earthworms) and vertebrates (such as pocket gophers) redistribute contaminants vertically and horizontally.*
K. Biotic/abiotic interaction	*K1. Vegetative cover affects erosion by both water and wind. Wildlife feeding behaviors affect vegetative cover.*
	K2. Disturbance of the soil surface by vertebrates also affects the rates of erosion processes.
Atmospheric transport	
L. Wind-borne dust	*L1. Entrainment is limited to contaminants in surface sediments.*
	L2. Entrainment, dispersal, and deposition are affected by moisture content, wind speed, stability of the wind direction, and precipitation.
	L3. Entrainment, dispersal, and deposition are controlled by sediment properties, surface roughness, vegetative cover, and terrain.
	L4. Resuspended particulates from Mortandad Canyon during the past 5 to 10 years will have characteristic isotopic ratios of certain contaminants, especially plutonium. This knowledge should permit statistical determination of at least a maximum possible contribution of resuspended contaminants to the adjacent mesa-top areas where air sampling stations collect continuous monitoring data. Measurements of airborne contaminants at the air sampling stations closest to Mortandad Canyon show levels no more than a few percent of any present guidelines or standards. Therefore, even if all such radioactive contaminants were attributable to Mortandad Canyon deposits, from a regulatory standpoint there is no significant risk on the mesa tops.
M. Gas/vapor dispersion	*M1. Gas exchange between the subsurface and the atmosphere provides a release mechanism for volatile contaminants. Controlling factors include temperature and pressure gradients; fracture and joint patterns; wind speed and direction; and precipitation. Gaseous contaminants are not believed to occur in Mortandad Canyon at any significant levels.*

Sediments and associated contaminants deposited in different geomorphic locations, such as active channels, inactive channels, and floodplains or low terraces, will remain in place for varying lengths of time. Transport of sediments in the active channel occurs during relatively frequent, small- to moderate-sized storm flows. Flows sufficient to redistribute sediment as far as the sediment traps have occurred about six times in the last two decades (see Section 3.6). Only one precipitation event in the last 45 years is believed to have caused surface flow from middle and lower Mortandad Canyon to extend uninterrupted past the Laboratory boundary. Infrequent major precipitation events could result in sufficient precipitation runoff to transport accumulated sediments off-site onto San Ildefonso Pueblo land. Such events have been estimated by numeric modeling as having a very low probability. The probability is even lower of a single event large enough to fill the sediment traps completely, exceed the infiltration capacity of the *broad channel west of state road NM4, and transport contaminants to the Rio Grande (see Section 3.6.3 in Chapter 3 of this work plan).*

Contaminants that are associated with sediment and transported by surface flow can be available for uptake by humans through the following pathways:

- *ingestion of unfiltered water from stream flow or ponding,*
- *ingestion of sediments either directly or as rain splash deposition on vegetation,*
- *inhalation of airborne particulates resuspended from the sediments,*
- *dermal contact,*
- *consumption of plants and animals that have been contaminant receptors, and*
- *direct exposure to sediments containing gamma-emitting radioactive contaminants.*

4.2.2 Groundwater Transport and Resultant Exposures

The transport of contaminants in sediment or bedrock under saturated and/or unsaturated flow conditions is considered a potentially significant transport pathway in the Mortandad Canyon system. Groundwater under saturated conditions has been observed in two zones in Mortandad 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 in the Los Alamos area. Saturated conditions may also exist at some intermediate depth(s), as has been observed beneath Pueblo Canyon and Los Alamos Canyon (see Section 3.7 in Chapter 3 of this work plan).

In upper Mortandad Canyon, 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. The streamflow is supported by discharges and precipitation runoff. Occasional ponding occurs in the sediment traps for limited periods after major precipitation runoff events. In the reach of Mortandad Canyon from approximately its confluence with Ten Site Canyon eastward to the sediment traps, the saturated alluvium is deeper, and no alluvial groundwater has been observed returning to streamflow because the water table is 40 to 50 ft (12 to 15 m) below ground surface. An unsaturated zone is located between the ephemeral stream channel and the alluvial groundwater. The groundwater in the alluvium supplies some water to deeper rooted plants as indicated by the high concentration of tritium in transpirate.

Hydraulic connections among the saturated zones and the groundwater flow rates in the unsaturated zone are not well understood. Figure 4.1.3-1 shows the conceptual flow pathways between the different possible zones of saturation. Contaminants are present in the alluvial groundwater that could migrate to deeper zones of saturation. Hydraulic interconnections between the alluvium and intermediate perched zones are known to exist in adjacent canyons; the Cerro Toledo interval and the Guaje Pumice Bed may contain intermediate perched zones beneath Mortandad 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.

Historically alluvial groundwater in Mortandad Canyon has contained the largest number and highest concentrations of contaminants of any groundwater at the Laboratory because of the number, volume, *and proximity of effluent discharges. Contaminant occurrence is due to Laboratory discharges into Mortandad Canyon (see Chapter 2 of this work plan). Groundwater in the regional aquifer appears to be uncontaminated at most of the locations of water supply wells. Laboratory-derived tritium is the contaminant of main concern because of its mobility. In specific locations, such as at TW-8, the regional aquifer shows low (but above background) levels of tritium ($\leq$100 pCi/L) and nitrate.*

The occurrence of alluvial groundwater in relation to alluvial stratigraphy is not completely understood. The following hypotheses for the occurrence of alluvial groundwater that have been developed for the observed water levels and degree of saturation in the Mortandad Canyon system. Hypotheses 1, 3, and 4 are considered most likely, and hypothesis 2 is presented as a possibility, recognizing that a special depositional environment might be required to create the necessary conditions.

1. *The "Bathtub" Model (see Figure 4.2.2-1) applies to lower Mortandad Canyon, which receives infrequent surface flow. When flow occurs, water infiltrates rapidly from the stream directly downward to a confining zone and gradually fills available pore spaces. Groundwater levels would respond rapidly to changes in streamflow head but, because of the large volume of available pore spaces, a large volume of flow is necessary to increase water levels significantly.*

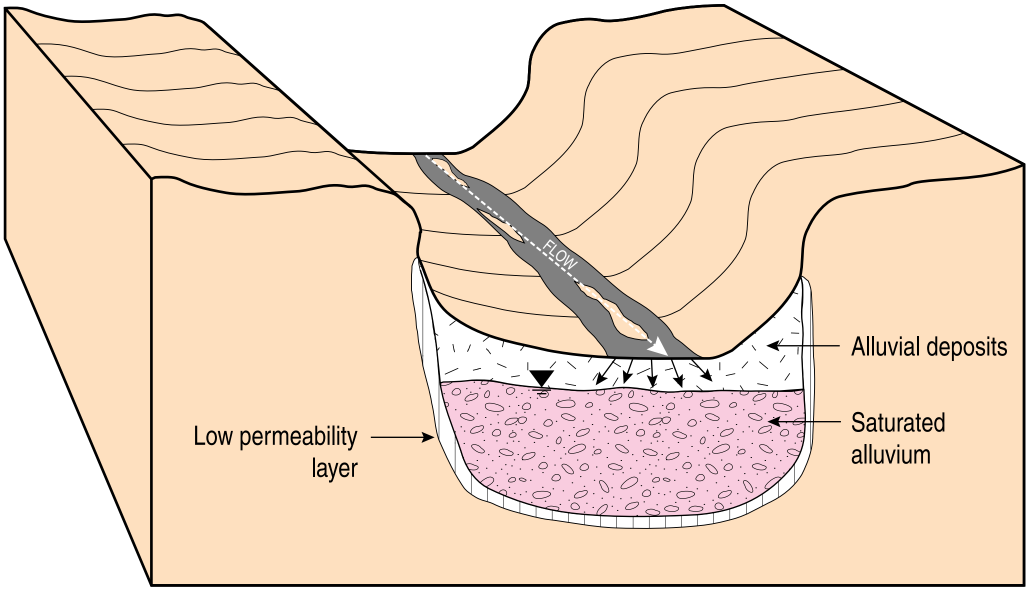
2. *The "Sausage" Model (see Figure 4.2.2-2) devolves from the "Bathtub" Model under seasonally dry conditions into a gradation from a saturated center to an unsaturated exterior. When surface flow is again present, water would infiltrate rapidly, filling available pore spaces outside the "sausage," and groundwater levels would respond slowly to changes in the streamflow head.*

3. *The "Interleaved Card" or Layer Model (see Figure 4.2.2-3) applies to the reach between the sediment traps and wells MT-2 and MT-3. The structure of the alluvium consists of interleaved aquitards in a sand and gravel matrix. Water spills downward from one clayey aquitard layer to another but moves mainly horizontally downgradient rather than vertically. Groundwater levels would respond variably to changes in the streamflow head.*

4. *The "Saturated Mound" Model (see Figure 4.2.2-4) applies to middle and lower Mortandad Canyon from upstream of the confluence with Ten Site Canyon near wells MCO-4, -5, and -6 downstream to at least the sediment traps. The structure of the alluvium consists of low-permeability deposits partially confining coarse alluvium at depth and the saturated zone forming a convex upper surface. Groundwater levels would respond rapidly to changes in the streamflow head.*

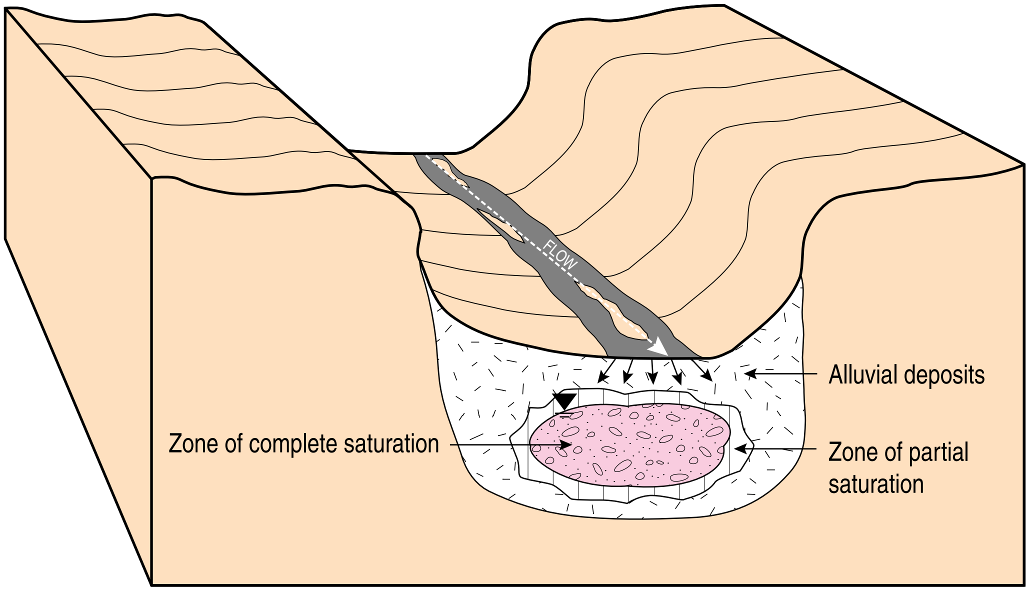
It will be necessary to understand the mechanisms that govern the occurrence of the saturated alluvial groundwater in Mortandad Canyon sufficiently well to determine if any significant exposure pathway potential exists for future use scenarios. Currently the alluvial groundwater is not consumed by humans, but soil moisture does support vegetation that is used as forage by animals and for fuel and ritual or medicinal purposes by American Indians from San Ildefonso Pueblo.

Groundwater in the regional aquifer beneath the Pajarito Plateau provides municipal and industrial water to Los Alamos County. Contamination has been observed in the regional aquifer beneath Mortandad Canyon at TW-8 (see Section 3.7). The Los Alamos production wells closest to Mortandad Canyon are PM-3 and PM-1 in Sandia Canyon about 7500 ft (2290 m) and 13,000 ft (3960 m), respectively, east of the sediment traps and PM-5 on the mesa about 1800 ft (550 m) southwest of TW-8. Farther east of the Laboratory, wells and springs in the regional aquifer provide water to residents, livestock, wildlife, and plants at San Ildefonso Pueblo. Therefore, groundwater is considered to be important as both a transport and an exposure pathway.



F4.2.2-1 / MORTANDAD WP / 072997

Figure 4.2.2-1. The "Bathtub" Model for alluvial groundwater in lower Mortandad Canyon.



F4.2.2-2 / MORTANDAD WP / 091997

Figure 4.2.2-2. The "Sausage" Model for alluvial groundwater in Mortandad Canyon.

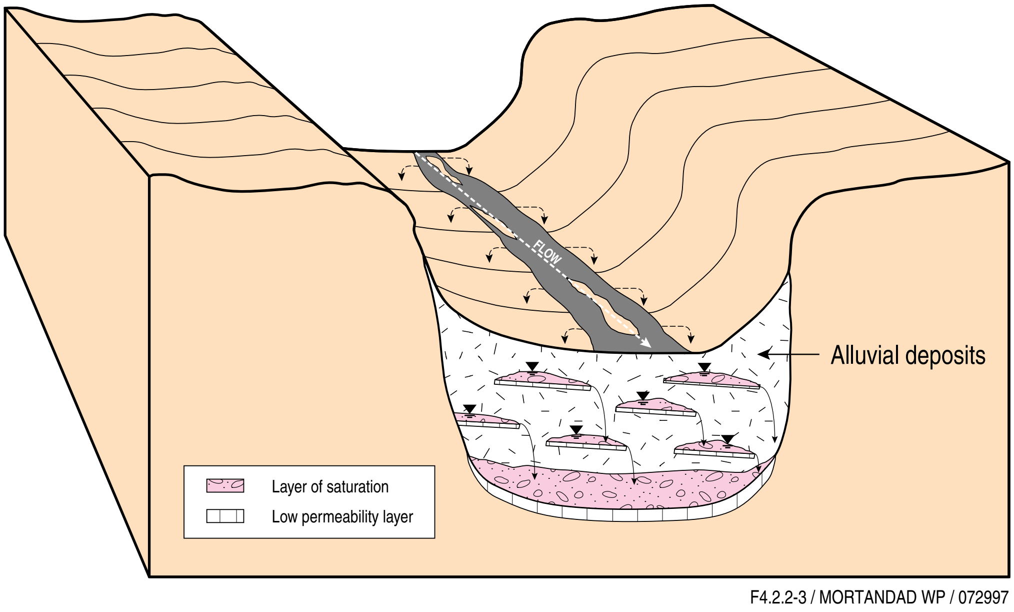


Figure 4.2.2-3. The "Interleaved Card" or Layer Model for alluvial groundwater in Mortandad Canyon.

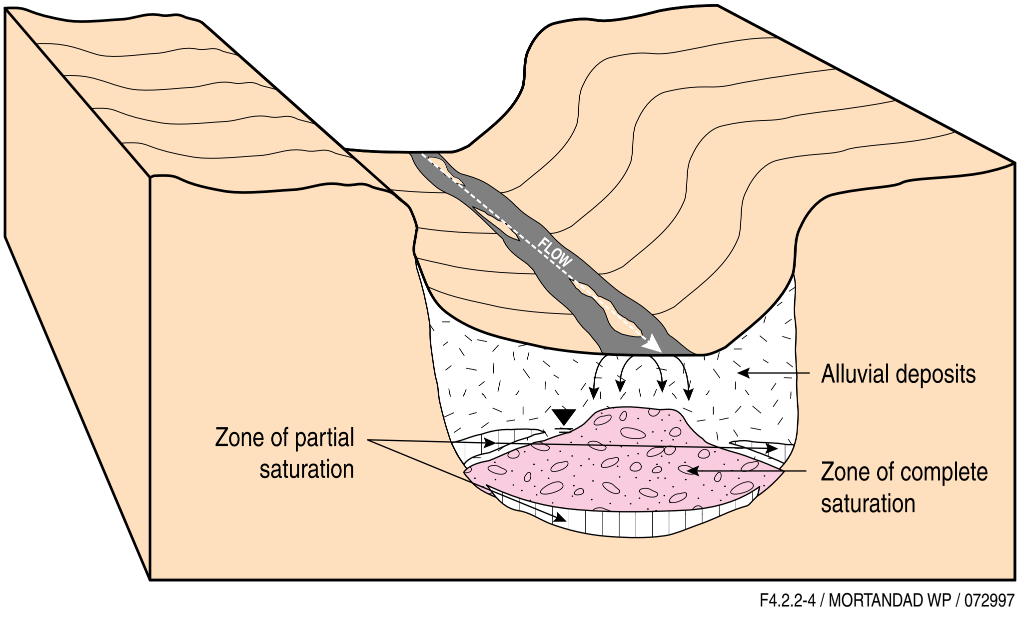


Figure 4.2.2-4. The "Saturated Mound" Model for alluvial groundwater in middle Mortandad Canyon.

The hydrologic processes connecting the alluvium and any intermediate perched zones are not yet understood. Without such an understanding, the possibility of multiple connections, including saturated flow pathways to the regional aquifer, must be considered as working hypotheses to be evaluated.

Some of the mechanisms that are known to function in Mortandad Canyon to transport water and contaminants from the stream flow down to the unsaturated zones in the Otowi Member are

- **direct infiltration as saturated flow** *that transports dissolved contaminants and very small particulates and colloids,*
- **unsaturated liquid and liquid-film flow** *that transport dissolved contaminants and possibly some colloids, and*
- **unsaturated, vapor-phase flow** *that transports only contaminants that can occur as vapor (such as tritiated water and some volatile organic compounds).*

Saturated flow (Sat) shown in Figure 4.1.3-1 operates between stream flow and shallow alluvial groundwater. It may also occur along well boreholes, fractures, and downdip interfaces or contacts between strata with different properties. Saturated flow within the alluvium of Mortandad Canyon may extend laterally off-site along the channel. There is recent indication at well MCO-13 that saturation occurs farther downgradient than previously observed. Saturation at MCO-13 may be located in the combined alluvial/Cerro Toledo hydrogeologic unit (see Figure A-3 in Appendix A of this work plan). Downward saturated flow may be responsible for the observed tritium and nitrate contamination in the regional aquifer at TW-8. Saturated matrix flow and/or fracture flow along stratigraphic contacts or in paleochannels needs to be further evaluated as a possible mechanism for understanding the significant loss of water from the alluvium.

Unsaturated liquid and liquid-film flow (U_L) shown in Figure 4.1.3-1 operates between the stream channel and the deeper saturated alluvial groundwater in the reach of Mortandad Canyon from about well MCO-5 eastward to the sediment traps. There is some evidence that this mechanism has also transported some contaminants beneath the base of the alluvium in the unsaturated zone vertically to the interface of the Tshirege Qbt 1g unit with the Tsankawi Pumice Bed and/or the Cerro Toledo interval.

Unsaturated vapor-phase flow (U_V) may have transported tritiated water as a contaminant in the two deepest boreholes (for moisture access tubes MCM-5.9A and MCC-8.2) to depths of about 200 ft (61m). This mechanism requires further investigation to determine how far the vapor-/aqueous-phase transport of tritiated water may extend or to determine at which point it no longer needs to be considered a significant risk potential.

4.2.3 Biological Transport and Resultant Exposures

Biological transport is considered to be less important than surface water and sediment transport or groundwater transport as a means of dispersing contaminants. However, uptake and transport of contaminants by plants and animals 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.

The availability of soil- or sediment-borne contaminants to plant tissues depends on soil and pore water chemistry, which are influenced by soil microflora, mineralogy, and the chemical and physical characteristics of the contaminants. Contaminants in the root zone of plants can be assimilated by roots and redistributed to different parts (such as leaves, stems, seeds, or fruits) or products (such as nectar or pollen) and become available for ingestion by biological receptors. After certain contaminants (such as tritium in the form of tritiated water) have been assimilated by the roots, the contaminants can be transpired to the atmosphere.

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

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

While obtaining food and shelter, certain burrowing vertebrates and invertebrates cause soils to be redistributed laterally and vertically. This process, called bioturbation, can cause surface contaminants to become buried and underground contaminants to be brought to the surface. Currently its potential significance in the Mortandad Canyon system is unknown.

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

4.2.4 Atmospheric Transport and Resultant Exposures

Transport of fine-grained contaminated particles by wind can be a means of contaminant dispersal in the Mortandad Canyon system. Resuspension of sediment by winds is considered to be one of the predominant pathways for radiological exposure to humans because dust can easily be lifted high enough to be inhaled by humans (see Chapter 6 of the core document [LANL 1997, 55622] for a discussion of exposure pathways and scenarios). Current understanding of wind patterns in the canyon system and the interaction between mesa-top and canyon winds is preliminary; however, airborne resuspension and transport of sediments out of the canyons is not expected to be a significant contaminant transport pathway.

The predominant wind direction across Mortandad Canyon is from the south/southwest. Diurnal variations are important, with local east winds during the day and local west winds (drainage winds) at night. Wind directions on the mesa tops are considered to be at least partially independent of those in the canyons. For example, during the warmer months south or southwest winds on the mesa tops can induce north or northwest winds in the canyons.

Wind speed on the mesa tops is sufficient to transport contaminated dust from the mesa tops to the canyons, especially during the spring when the winds are strongest. However, this is not a significant source of contamination in the Mortandad Canyon system. Airborne resuspension of sediments by wind is *affected by the distribution of grain sizes in the sediment, moisture content, snow cover, and vegetative cover. All these factors suggest that airborne resuspension of sediments will be less effective in the canyons (which are typically well-vegetated and moist) than is airborne resuspension of dust on the mesa tops (which are typically thinly vegetated and dry). The broader and shallower reaches of the canyons are more favorable sites for airborne resuspension of sediments. Wind-borne transport of contaminants out of Mortandad Canyon to the adjacent mesa tops is probably relatively insignificant. Local airborne resuspension may be important for land use scenarios in reaches that contain greater contaminant inventories (such as the sediment traps). Direct radiation exposure from contaminated sediments may be the most significant exposure in terms of doses received by occupants of the canyon.*

4.3 Refinement of the Conceptual Model

The conceptual model will be refined by interpretation and analysis of new data from the sampling and analyses proposed in Chapter 7 of this work plan, work at other operable units, the site-wide studies of the Environmental Restoration Project Earth Science Council, and investigations coincident with new well installations proposed under the Laboratory's Groundwater Protection Management Program Plan (LANL 1995, 50124) and the Hydrogeologic Workplan (LANL 1996, 54430).

The following major areas will 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. These 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 of the water loss from alluvium with sufficient confidence to know if it represents a pathway with a significant exposure potential.*
- *Improved understanding of the mechanisms for observed contamination in the regional aquifer with sufficient confidence to know if the mechanism represents a pathway with a significant exposure potential.*
- *Actual data to document possible exposure of canyon occupants by resuspension.*
- *Other conceptual model components, as needed.*

REFERENCES FOR CHAPTER 4

LANL (Los Alamos National Laboratory), October 25, 1995. "Groundwater Protection Management Program Plan" (draft), Revision 2.0, Los Alamos, New Mexico. **(LANL 1995, ER ID Number 50124)**

LANL (Los Alamos National Laboratory), November 1995. "Task/Site Work Plan for Operable Unit 1049: Los Alamos Canyon and Pueblo Canyon," Los Alamos National Laboratory Report LA-UR-95-2053, Los Alamos, New Mexico. **(LANL 1995, ER ID Number 50290)**

LANL (Los Alamos National Laboratory), December 6, 1996. "Hydrogeologic Workplan" (draft), Revision 1.0, Los Alamos, New Mexico. **(LANL 1996, ER ID Number 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 Number 55622)**

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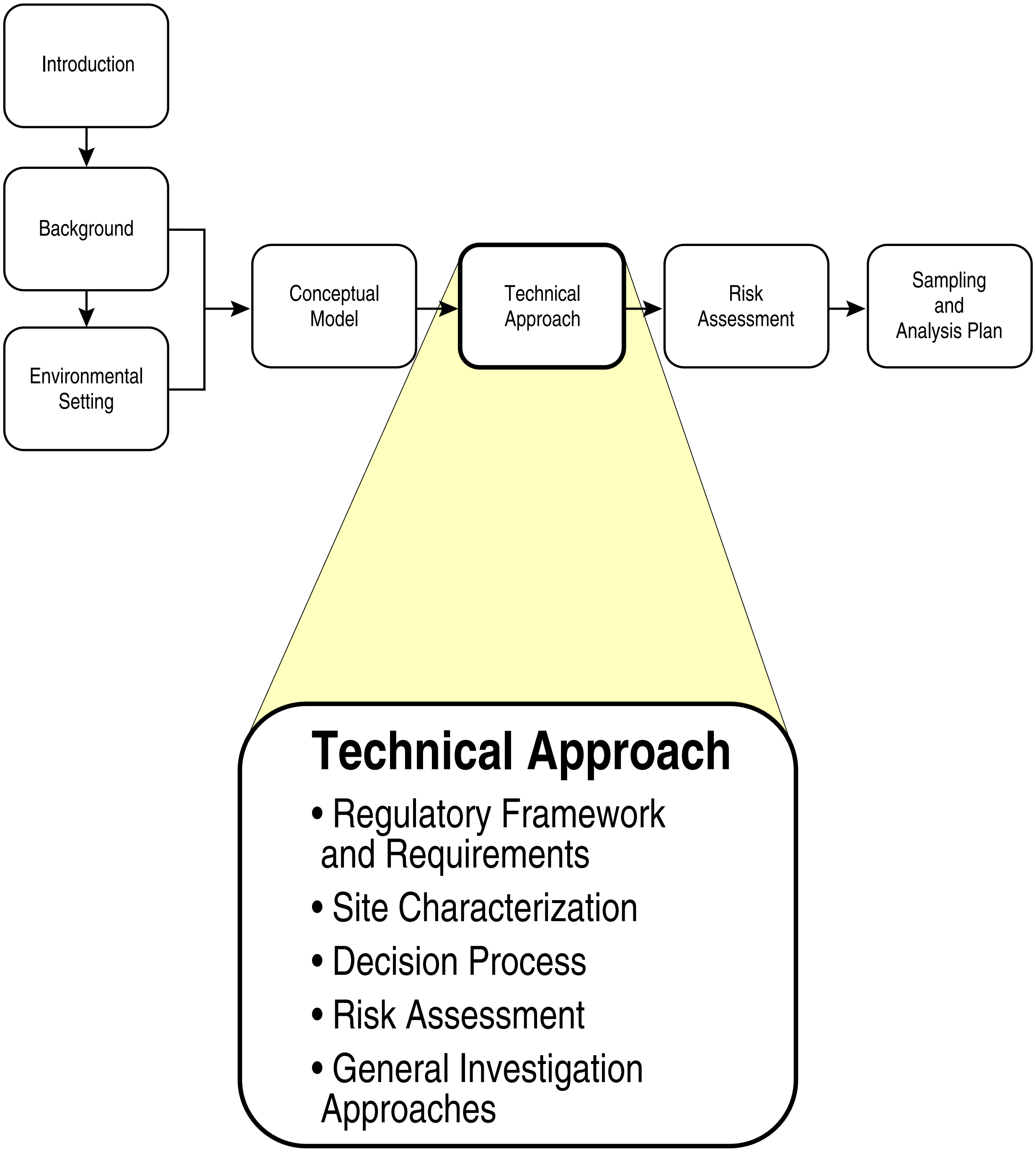
Chapter 5



Technical Approach

- Regulatory Framework and Requirements
- Site Characterization
- Decision Process
- Risk Assessment
- General Investigation Approaches

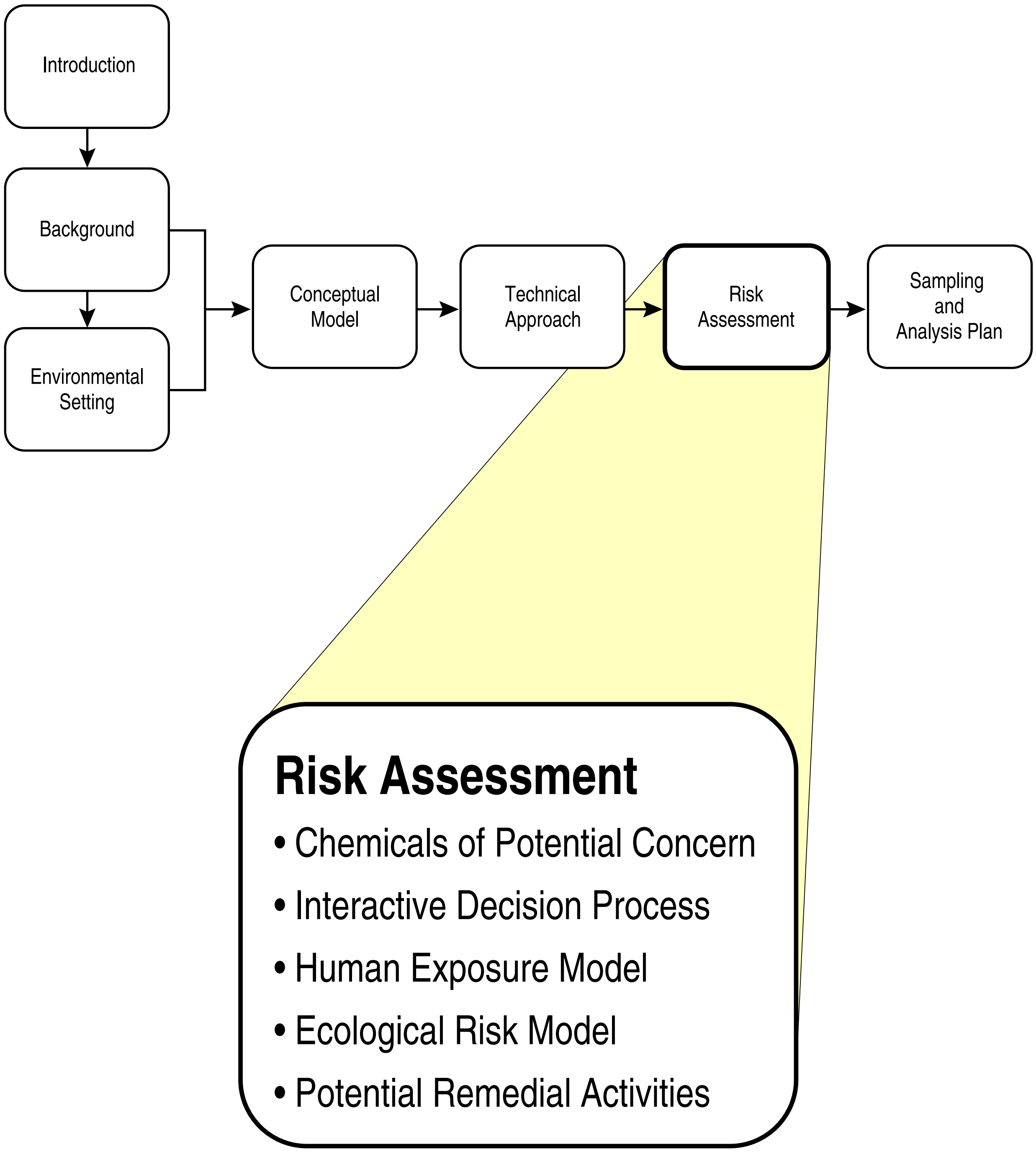
5.0 TECHNICAL APPROACH

The technical approach employed in the Mortandad Canyon investigations is identical to that described in Chapter 5 of the Core Document for Canyons Investigations (LANL 1997, 55622).

REFERENCE FOR CHAPTER 5

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 Number 55622)**

Chapter 6



Risk Assessment

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

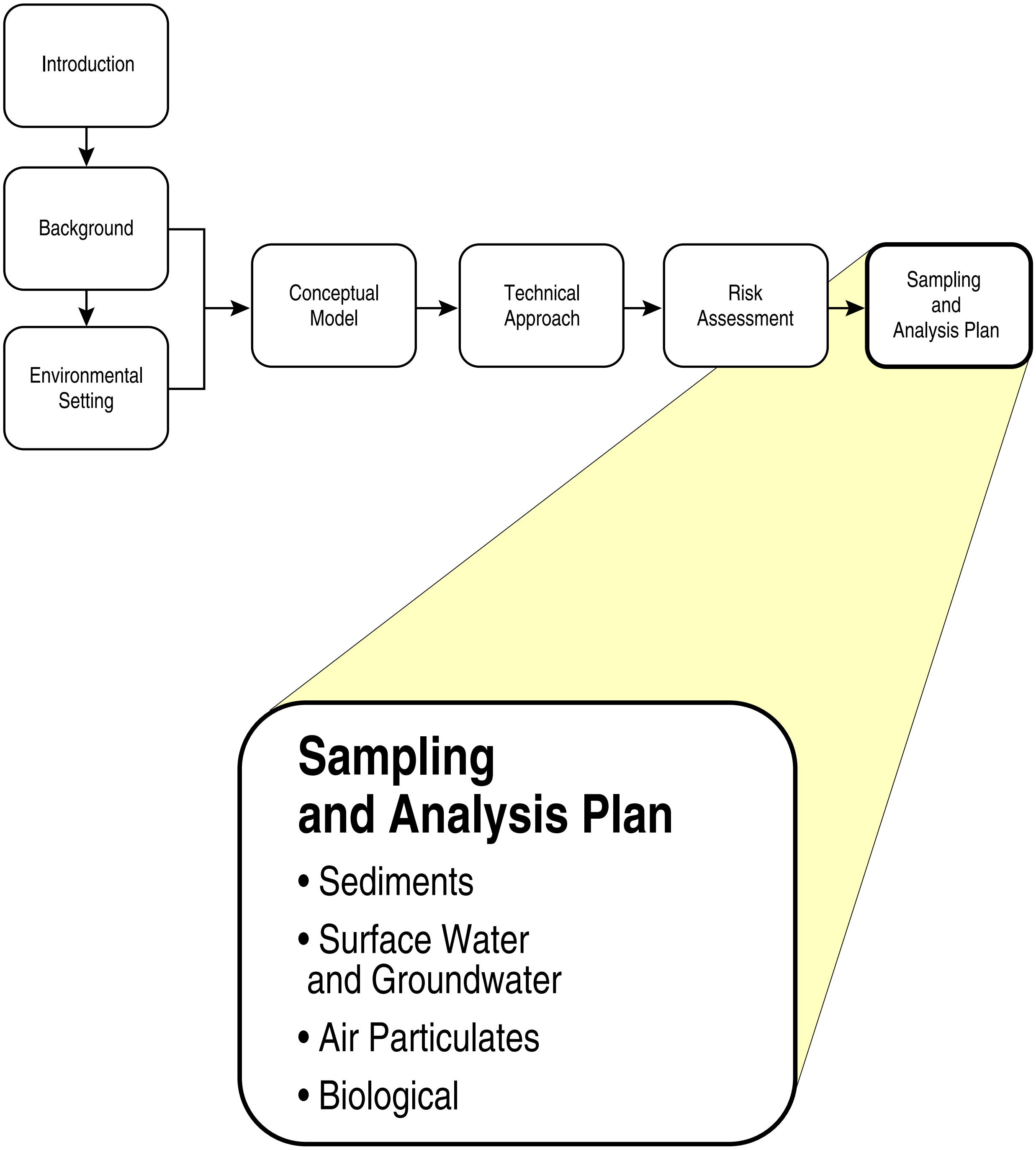
6.0 RISK ASSESSMENT

The approach to risk assessment employed in the Mortandad 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

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 Number 55622)**

Chapter 7


Introduction
Background
Environmental Setting
Conceptual Model
Technical Approach
Risk Assessment
Sampling and Analysis Plan
Sampling and Analysis Plan
• Sediments
• Surface Water and Groundwater
• Air Particulates
• Biological

7.0 SAMPLING AND ANALYSIS PLAN FOR THE MORTANDAD CANYON SYSTEM

7.1 Introduction

This chapter describes the rationale and plans for collecting and analyzing samples and field survey data to characterize the Mortandad 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 Mortandad 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 Mortandad Canyon system (hereafter "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 "the core document") (LANL 1997, 55622), results of field surveys and sample analyses conducted initially will be used in conjunction with comparison to and reinterpretation of extensive existing data to revise subsequent sampling and analyses. Sampling and analysis plans 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 sampling and analysis plan, and the data quality objectives for the investigations. Section 7.2 describes plans for sediment characterization. Section 7.3 describes plans for characterizing the hydrologic system including (1) surface water and alluvial groundwater (and the alluvium that contains it), (2) Bandelier Tuff groundwater, and (3) the regional aquifer. Section 7.4 describes plans for characterizing the air exposure pathway. Section 7.5 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 Mortandad 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 Mortandad 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 MORTANDAD CANYON AND SOURCE AREAS*

Known COPCs	Source Areas
Radionuclides	
^{241}Am	TA-35, TA-48, TA-50
^{60}Co	TA-48, TA-50
^{137}Cs	TA-3, TA-35, TA-48, TA-50
^{238}Pu	TA-3, TA-35, TA-42, TA-48, TA-50
^{239}Pu	TA-3, TA-35, TA-42, TA-48, TA-50
Rare earth elements or lanthanides	TA-35
^{90}Sr	TA-3, TA-35, TA-42, TA-48, TA-50
Tritium	TA-35, TA-48, TA-50
Uranium	TA-4, TA-5, TA-48, TA-50, TA-52
Organic Chemicals	
High explosives	TA-4, TA-5
Hydrocarbons	TA-35, TA-48
PCBs	TA-35, TA-48, TA-50
Pesticides	General
Photographic chemicals (organic acids)	TA-4, TA-5, TA-35
SVOCs	TA-35, TA-48
Inorganic Chemicals	
Arsenic	TA-50
Barium	TA-50
Beryllium	TA-50
Chromium	TA-50
Fluoride	TA-50
Lead	TA-50
Mercury	TA-48, TA-50
Nickel	TA-50
Nitrate	TA-50
Selenium	TA-50
Silver	TA-4, TA-5, TA-35

*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	Mortandad Canyon	Effluent Canyon	Ten Site Canyon	Unnamed Canyon (MCW)	Total
Sediment[a] and Core					
Full-suite[b] sediment	*16*	*4*	*8*	*8*	*36*
Limited-suite[c] sediment	*TBD[d]*	*TBD*	*TBD*	*TBD*	*TBD*
Key contaminants[e] sediment	*TBD*	*TBD*	*TBD*	*TBD*	*TBD*
Geochemical analysis sediment	*60*	*N/A[f]*	*N/A*	*N/A*	*60*
Alluvial borehole core[g]	*72*	*N/A*	*14*	*N/A*	*86*
Intermediate borehole core	*66*	*N/A*	*N/A*	*N/A*	*66*
PRS characterization[c]	*142*	*16*	*N/A*	*N/A*	*158*
Groundwater[h] and Surface[i] Water					
Surface water	*20*	*N/A*	*N/A*	*N/A*	*20*
Alluvial (upgradient well)	*2*	*N/A*	*N/A*	*N/A*	*2*
Alluvial (observation wells)	*12*	*N/A*	*2*	*N/A*	*14*
Intermediate perched zones (observation wells)	*6*	*N/A*	*N/A*	*N/A*	*6*
Regional aquifer	*36*	*N/A*	*N/A*	*N/A*	*36*
Air Particulate[j]					
Total suspended particulate (annual)	*4*	*N/A*	*N/A*	*N/A*	*4*
PM10/PM2.5[k] fraction (annual)	*4*	*N/A*	*N/A*	*N/A*	*4*
Biological					
Wild plant species[l]	*TBD*	*TBD*	*TBD*	*TBD*	*TBD*
Livestock forage plants[m]	*TBD*	*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, ^{241}Am, ^{137}Cs, ^{238}Pu, ^{239,240}Pu, and ^{90}Sr) to obtain information about contaminant concentrations, contaminant distributions, and sediment transport processes. Actual number collected will be decided by the technical team on the basis of initial survey and sampling results. (The collection of approximately 50 samples per canyon is anticipated.)

f. N/A = not applicable

g. 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 7.3.4-2).

h. Alluvial well upgradient from the TA-50 RLWTF will be sampled twice. All observation wells will be sampled at completion and after six months.

i. If surface water is present, samples will be collected during storm events and snowmelt.

j. Air-particulate samples will be collected approximately bimonthly, depending on filter loading, and will be composited to obtain an annual sample for each sampling site.

k. PM10 fraction is the inhalable particulate fraction (10 µm diameter or less); PM2.5 is the respirable fraction that can penetrate to deep lungs.

l. Two samples each of four different wild plant species will be collected.

m. 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 Mortandad Canyon system (excluding mesa-top 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 contamination 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 contamination? 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.*

3. *As a result of Mortandad Canyon contaminants, are any threats present to sites of cultural or historic significance to the Indian Pueblos or other affected populations such as northern New Mexico Hispanic communities or those using adjacent sites for recreational purposes?*

7.1.2 Site Description

A detailed description of Mortandad 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 contamination, and current environmental conditions in the Mortandad Canyon system are provided in Chapter 2 and Chapter 3 of this work plan.

Mortandad Canyon and/or its tributaries have received radioactive liquid waste from Laboratory operations since 1951. The major discharges have been treated radioactive liquid wastes. The former radioactive liquid waste treatment plant was located at Technical Area (TA) -35 from 1951 until 1963. This plant routinely discharged treated waste and occasionally discharged raw wastes (unintentionally) to Pratt Canyon and Ten Site Canyon. A summary of discharges from the former treatment plant is provided in Section 2.4.4 in Chapter 2 of this work plan. The current Radioactive Liquid Waste Treatment Facility (RLWTF) at TA-50 began operations in 1963; it discharges to Effluent Canyon and Mortandad Canyon. A summary of these discharges is provided in Section 2.4.6 in Chapter 2 of this work plan. The principal contaminants are radionuclides (including ^{241}*Am,* ^{137}*Cs,* ^{238}*Pu,* ^{239,240}*Pu,* ^{90}*Sr, tritium, and activation products) and inorganic contaminants (including fluoride, mercury, and nitrate).*

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). Specifically relevant to Mortandad Canyon, the HSWA Module Section C.3 also requires, through maintenance of existing sediment traps or construction of new ones, that all residual sediment contamination be contained within the facility boundary. 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; the Department of Energy (DOE) (DOE 1990) 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 Mortandad 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 Mortandad Canyon system specifically in Chapter 4 of this work plan. 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 contaminant sources such as the TA-50 RLWTF discharge.*

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 culturally and historically significant locations within or adjacent to the Mortandad Canyon system that may be of concern to the Indian Pueblos*

5. *Refinement of the assessment of potential human exposure and ecological risk by improving confidence in the upper limits of risk to present and future land users (including Indian Pueblos), recreational users, and animals that could result from the migration of contaminants*

6. *Identification of risks to biological communities (including humans) inhabiting or using the Rio Grande (now and in the future) as a result of transport of contaminants from Mortandad Canyon*

7. *Identification of remediation strategy(ies) for cleanup of specific area(s) in Mortandad Canyon, as determined in these investigations*

8. *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.*

7.1.6 Data Quality Objectives

The objectives for data quality 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.

The quality objectives for data to address objectives 1, 2, and 3 listed in Section 7.1.5 will be met by summarizing existing data (Chapter 3 of this work plan), using the data to develop preliminary distributions of parameters, and designing appropriate field sampling and analysis plans to iteratively reduce uncertainties in the preliminary distribution of those parameters that contribute most to the uncertainty in human health risk assessment and contaminant transport evaluation. These parameters might be 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 depth 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 human health risk and remediation decisions with a high degree of confidence.

The quality objectives for data to address objectives 4 and 5 listed in Section 7.1.5 will include survey information from population samples considered representative of the Indian Pueblo concerns. The survey will require review of a proposed plan by the tribal council. A more extensive survey may be necessary for those parameters that contribute major uncertainty to potential exposure pathways that are discussed in Chapter 6 of the core document (LANL 1997, 55622) (for example, species and gathering locations for plants used for medicinal or dietary purposes).

7.2 Sediment Sampling and Analysis Plan

This section presents the sampling and analysis plan for investigating potentially contaminated sediment in the Mortandad Canyon system. Thirteen reaches downstream of known Laboratory sources of contamination have been selected for detailed investigation; 4 of the 13 reaches will be investigated contingent upon the findings of investigations in other canyon systems or other operable units as discussed in each reach description below. These reaches will be characterized by radiological and geomorphic surveys and by chemical analysis of sediment samples collected from potentially contaminated geomorphic units. Some geomorphic characterization of pre-1943 sedimentary deposits *will 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 contamination associated with post-1942 sediment deposits;*
- *evaluate the present-day risk to human health and ecosystems from contaminated sediments on-site, off-site, and at the Rio Grande;*
- *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 projecting trends in risk estimates that may result from migration of contaminants off-site, identifying the nature and amount of contamination that has migrated beyond Laboratory boundaries, and identifying processes that could result in future migration.*

The following sections present the data quality objectives for the sediment investigation and describe the technical approach adopted to achieve these objectives.

7.2.2 Data Quality Objectives for Sediment Investigation

This section briefly describes the data quality objectives process (EPA 1994, 50288) as completed for the geomorphic and radiological surveys and the sediment sampling and analysis portion of this chapter.

7.2.2.1 Geomorphic and Radiological Survey Data Quality Objectives

1. *State the problem.*

   What areas in the selected reaches represent the distribution of contaminants in the various sedimentary facies defined for the canyons?

2. *Identify the decision(s).*

   Determine whether the geomorphic units are adequate to delineate the major spatial variations in contaminant concentrations and sedimentary facies or whether further subdivision of mapping units is necessary. 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 contaminant concentrations, the units may be subdivided into two or more distinct stratigraphic layers. Radiation screening results and laboratory analyses will be examined to determine whether the original geomorphic units 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).

3. *Identify inputs to decision(s).*

   From geomorphic mapping

   - *Identified mapping units*
   - *Characteristics of post-1942 sedimentary deposits*
   - *Areal extent of units*

   From radiation survey

   - *Gross-alpha, -beta, and -gamma readings at selected locations*

4. *Define the study boundaries.*

   - *Temporal*

     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.

   - *Spatial*

     The sampling will be restricted to the stream channel and its floodplain in Mortandad Canyon and selected tributary canyons and to areas downstream of the first identified location of Laboratory-derived contamination.

5. *Develop decision rules.*

   - *Geomorphic*

     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 7.2.6.1 for full-suite, key contaminant, and limited-suite analyses.

   - *Radiation*

     Any locations with radiation levels above the decision level, as established from the distribution of the radiation survey data, will be candidates for full-suite or key contaminant analysis as described in Section 7.2.5.1. Radiation screening results will be examined to determine whether the original geomorphic units are adequately delineated to define the risks using weighted average values for these units. The need to subdivide units into a *more detailed level of identification may be established by the judgment of the technical team.*

Decision Rule #1

If the field mapping or the radiation screening data indicate mappable subdivisions within any geomorphic unit (definable areas with either higher or lower radiation), then the site geomorphologist will identify appropriate subdivisions of the unit.

Decision Rule #2

Field screening 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 radiation levels and geomorphic units observed but will be biased to sample most intensively the units with the highest radiation levels.

Decision Rule #3

Localized areas showing high radiation levels (based on field screening) that occur in geomorphic units will be investigated further by laboratory analyses of samples.

6. *Specify tolerable limits on decision errors.*

   Limits on decision errors will be based on the degree of overlap in uncertainty with 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 Data Quality Objectives

1. *State the problem.*

   What is the nature, extent, and inventory of contamination in the Mortandad 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, off-site, or at the Rio Grande and (2) model contaminant transport to quantitatively evaluate future risks.

2. *Identify the decision(s).*

   Determine what contaminants are present in the sediments in Mortandad 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.

3. *Identify inputs to decision.*

   - *Archival information*
   - *Sample location*
   - *Sample unit*

- *Concentrations of contaminants in each sample*

4. *Study boundaries.*

   Spatial boundaries will be determined by the boundary of each specified reach. No limits are set on temporal boundaries.

5. *Develop a decision rule.*

   Decision Rule #1

   Field screening 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 radiation levels and geomorphic units observed but will be biased to sample most intensively the units with the highest radiation levels.

   Decision Rule #2

   Any contaminant identified at concentrations exceeding the 95% upper tolerance limit (UTL) of the current background (McDonald et al. 1997, 04-0328) or whose distribution is different from that of the background data in the full-suite or key contaminant analyses will be added to the limited-suite analytical protocol for all samples from that reach (see Table 7.2.6-3 and Table 7.2.6-4 for 95% UTLs for background levels in sediments).

   Decision Rule #3

   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.

6. *Specify tolerable limits on decision errors.*

   Limits on decision errors will be based on the degree of overlap in uncertainty with 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 Technical Approach for Sediment Investigation

The technical approach 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 Mortandad Canyon system, which are discussed in Chapter 4 of this work plan. The investigation will focus on potentially contaminated sediment deposits but will also include supplemental characterization of pre-1943 deposits.

The sediment sampling and analysis plan focuses on selected areas of the Mortandad Canyon system downstream of known contaminant sources. Field surveys and mapping, as well as sampling and analysis tasks, will concentrate on up to 13 canyon reaches, each approximately 0.5 to 1 km long. A “reach” refers to a specific area of a canyon that will be treated as a single unit for sampling, analysis, and present-day human health and ecosystem risk assessment. The reaches of the main canyon and selected tributary *canyons proposed for detailed investigation are shown in Figure A-2 (Appendix A of this work plan) and in individual reach maps. The precise length and area of each canyon reach will be defined by the geomorphic survey to encompass the local variability in geomorphic units and to constitute a reasonable area for use in the risk assessments. Between 5 and 9 km (3.1 and 5.6 mi) of a total canyon length of 22 km (13.7 mi) downstream of the contaminant sources will be studied in detail. Focusing on relatively short reaches will allow the collection of high-quality data in an efficient manner. Supplemental measurements, such as field radiological data and the sizes of sediment deposits, may be made 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;*
- *areas with a variety of present-day or reasonably possible future land uses (recreational, residential, or ranching);*
- *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;*
- *institutional boundaries, to define contamination that has migrated off Laboratory property; and*
- *areas of concern to San Ildefonso Pueblo.*

Each reach will be used to address particular issues regarding potential contamination of the Mortandad 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.

In addition to the field survey and mapping tasks (which are described in Section 7.2.4), the sediment sampling and analysis plan includes three types of sampling tasks.

- *Collect samples for “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 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*

  Purpose: analyze for the limited suite of COPCs to define the degree of colocation 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 among 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

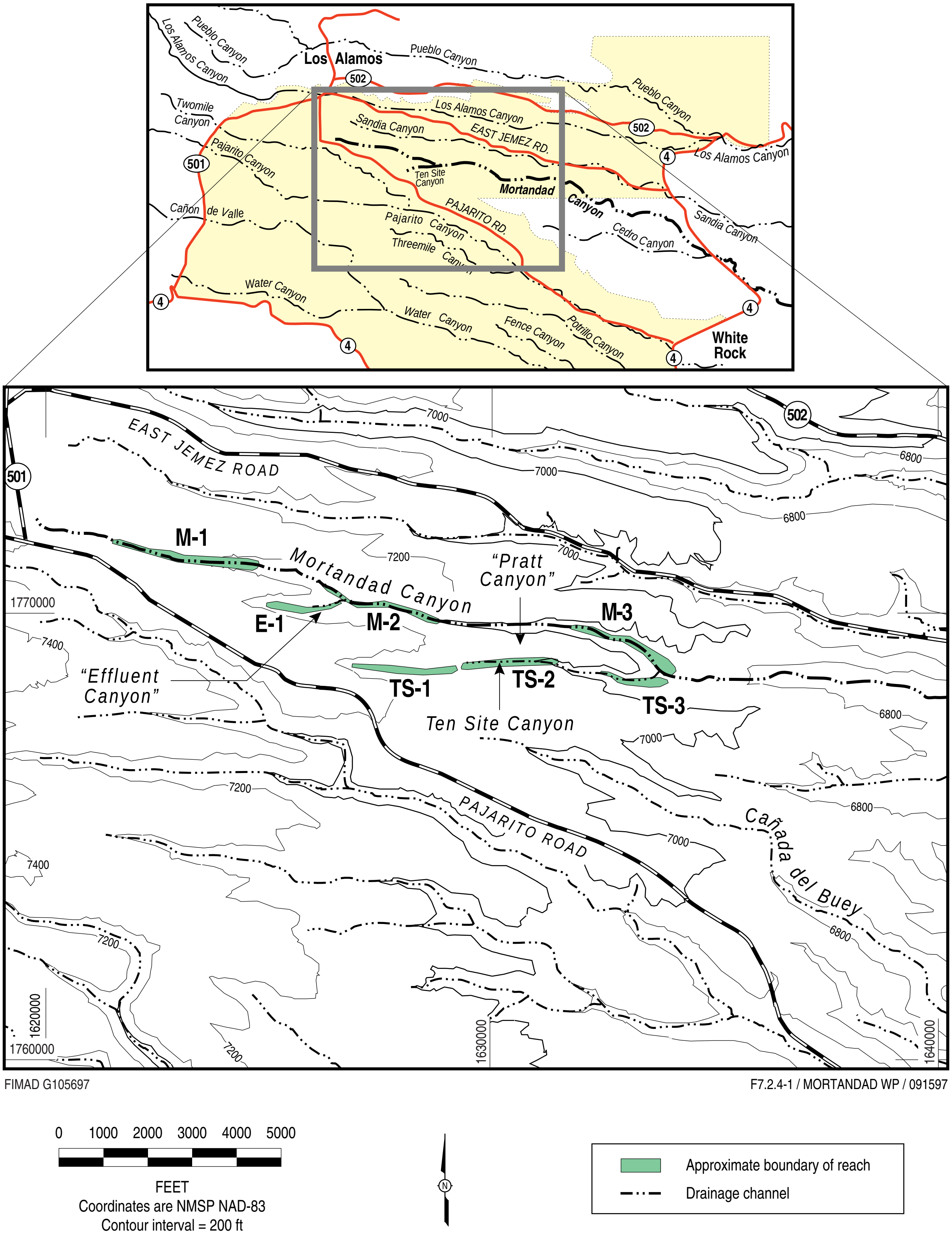
- *data to support an assessment of the present-day risk to on-site (within Laboratory boundaries) receptors and the potential for off-site exposure from deposits of contaminated sediments in the canyon system;*
- *a description of contaminant transport by sediment within the canyon system; and*
- *an assessment of the potential future trends in risk estimates due to existing contaminated sediments moving downstream on Laboratory property, across San Ildefonso Pueblo land, and to the Rio Grande.*

7.2.4 Canyon Reaches Proposed for Investigation

The following sections describe each of the reaches proposed 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 7.2.4-1 and Figure 7.2.4-2). The reaches chosen for the sediment investigation are as follows:

- *three reaches in Ten Site Canyon (TS-1 through TS-3),*
- *one reach in Effluent Canyon (E-1),*
- *three reaches in upper Mortandad Canyon (M-1 through M-3),*
- *two reaches in lower Mortandad Canyon (M-4 and M-5) on Laboratory property and adjacent San Ildefonso Pueblo land, and*
- *up to two reaches in lower Mortandad Canyon (M-6 and M-7) on San Ildefonso Pueblo land.*

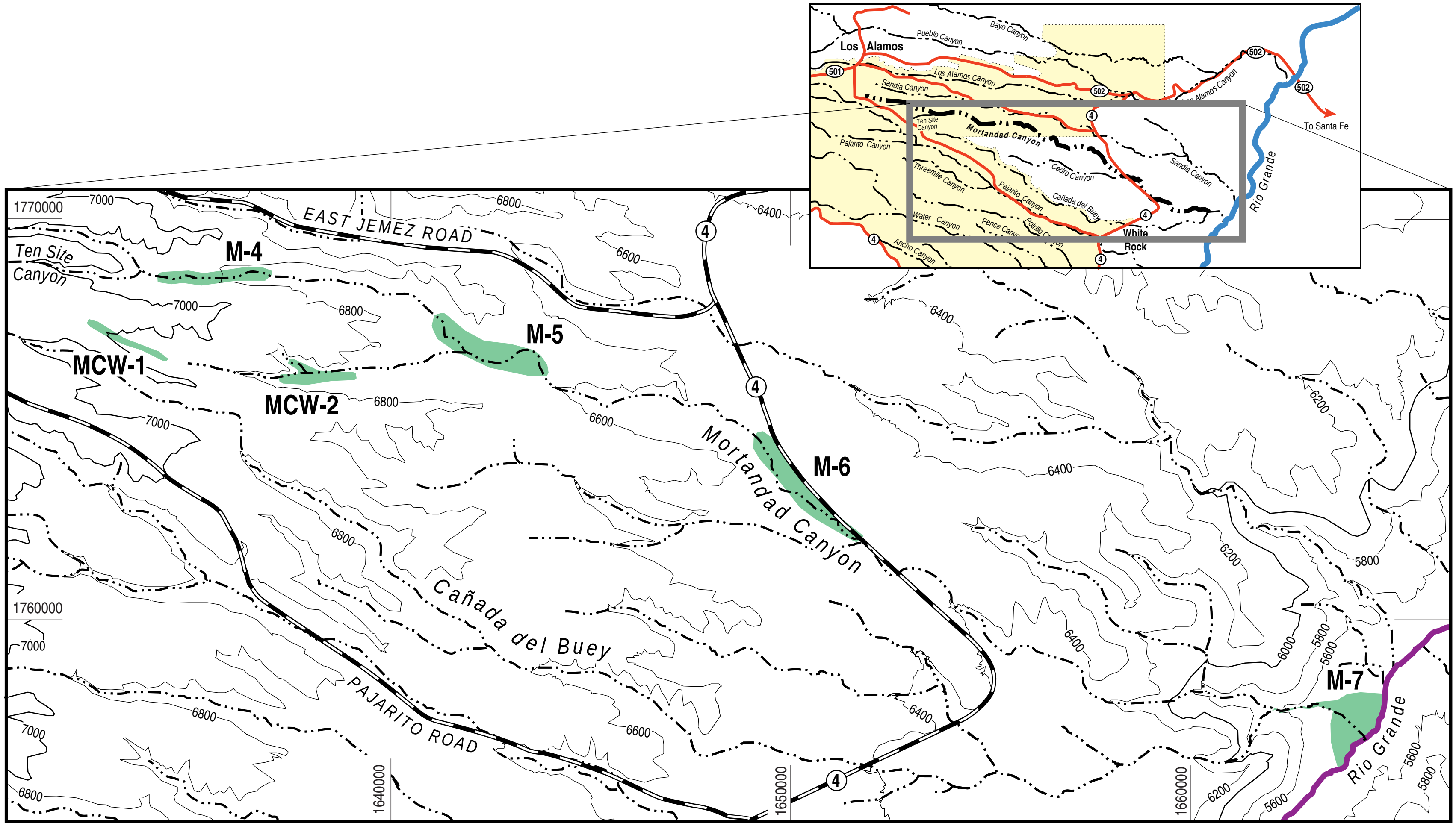
Investigation of M-6 and M-7 will depend on the results of investigations in upstream reaches. One of these investigations, downstream of the confluence with Cañada del Buey, will be deferred until the investigation of Cañada del Buey. Possible investigation of two additional reaches in an unnamed tributary to Mortandad Canyon (reaches MCW-1 and MCW-2) will depend on results of prior sampling and analysis of mesa-top potential release sites (PRSs). General maps of each reach are included with the individual descriptions. The boundaries shown on the maps of each reach indicate the general area 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 be focused on those geomorphic units that are most likely to contain Laboratory-derived contaminants, supplemented by geomorphic characterization of pre-1943 sediment deposits.



FIMAD G105697

F7.2.4-1 / MORTANDAD WP / 091597

Figure 7.2.4-1. Locations of reaches TS-1, TS-2, TS-3, E-1, M-1, M-2, and M-3 within the Mortandad Canyon watershed.



Source: FIMAD G105697

F7.2.4-2 / MORTANDAD WP / 091597

Coordinates are NMSP NAD-83
Contour interval = 200 ft

🟩 Approximate boundary of reach
–·–·– Drainage channel

Figure 7.2.4-2. Locations of reaches M-4, M-5, M-6, M-7, MCW-1, and MCW-2 within the Mortandad Canyon watershed.

7.2.4.1 Ten Site Canyon Reaches

Reach TS-1: Upstream of Pratt Canyon

Reach TS-1, located upstream of Pratt Canyon (Figure 7.2.4-3), is expected to have the highest concentrations of contaminants derived from TA-50 discharges into the headwaters of Ten Site Canyon. Previous sampling and analysis by Field Unit 5 personnel has indicated that contaminated sediments in this reach are up to several feet thick below the grassy canyon floor, which suggests that a significant inventory of contaminants may be present. PRS No. 50-006(a) will be further characterized by investigations in this reach.

Reach TS-2: Downstream of Pratt Canyon

Reach TS-2, located downstream of Pratt Canyon (Figure 7.2.4-4), is expected to have the highest concentrations of contaminants derived from the former TA-35 wastewater treatment plant in addition to contaminants from farther upstream in Ten Site Canyon. The reach includes a grassy area of sediment deposition and the beginning of a steeper, rock-bound channel with little sediment deposition. TS-2, in combination with reach TS-1, will allow the determination of the relative contributions of contaminants from these different sources and the contaminant inventory of upper Ten Site Canyon.

Reach TS-3: Immediately upstream of the confluence with Mortandad Canyon

Reach TS-3, located immediately upstream of the confluence with Mortandad Canyon (Figure 7.2.4-5), is an area where the channel gradient decreases and the canyon floor widens, which provides greater opportunity for sediment deposition than is typical of upstream reaches. This reach could contain a significant part of the total contaminant inventory in Ten Site Canyon, although probably at lower concentrations than in reaches TS-1 and TS-2. The width of the canyon floor may also permit more land use scenarios at TS-3 than at the upstream reaches.

7.2.4.2 Effluent Canyon Reach

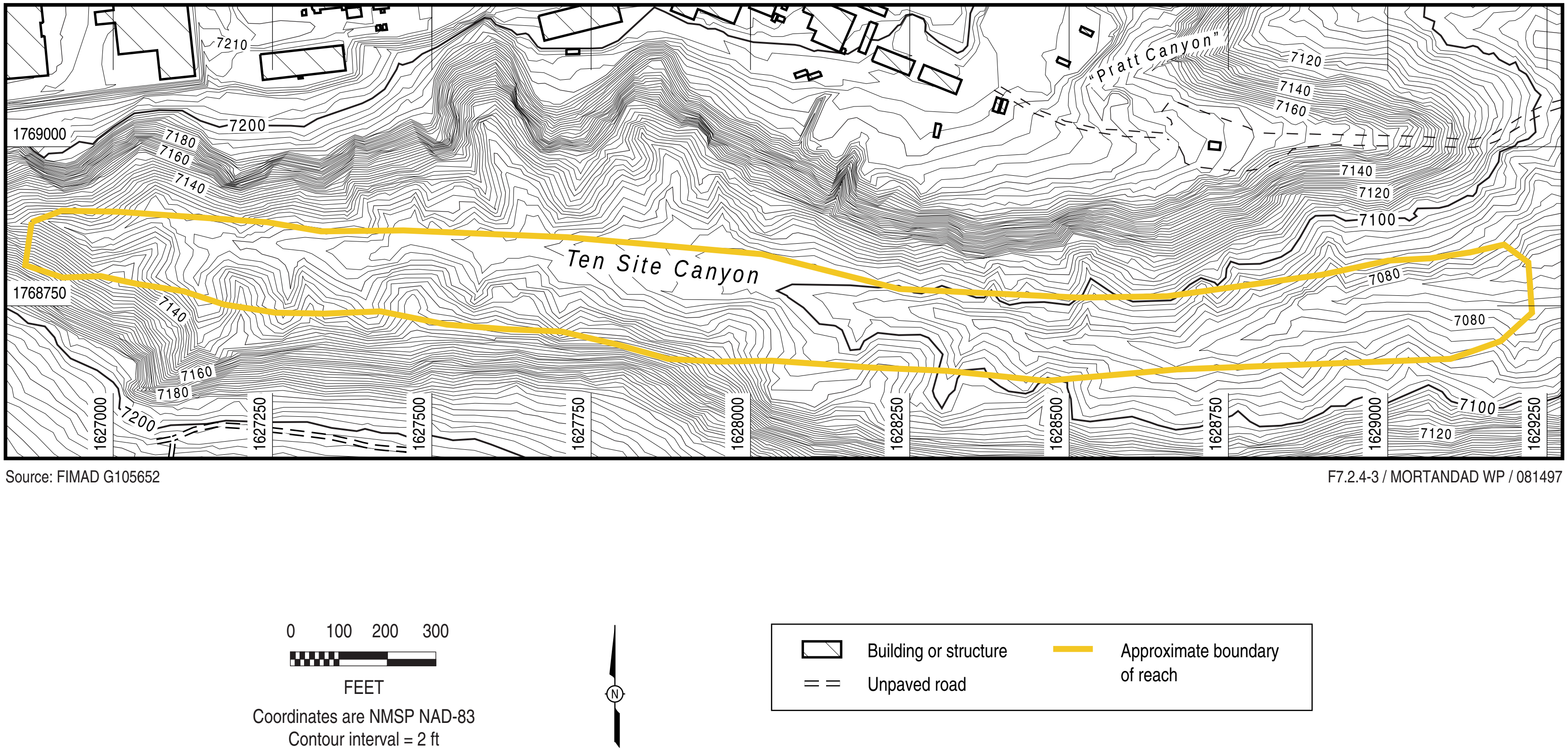
Reach E-1: Effluent Canyon

Reach E-1, located in Effluent Canyon between TA-48 and Mortandad Canyon (Figure 7.2.4-6), is expected to contain contaminants derived from PRSs in TAs -42, -48, and -50. This reach will allow the determination of the contribution of Effluent Canyon to contaminants in Mortandad Canyon and the determination of the contaminant inventory in Effluent Canyon.

7.2.4.3 Upper Mortandad Canyon Reaches

Reach M-1: Below outfalls from TAs -3, -59, and -60 and west of the confluence with Effluent Canyon

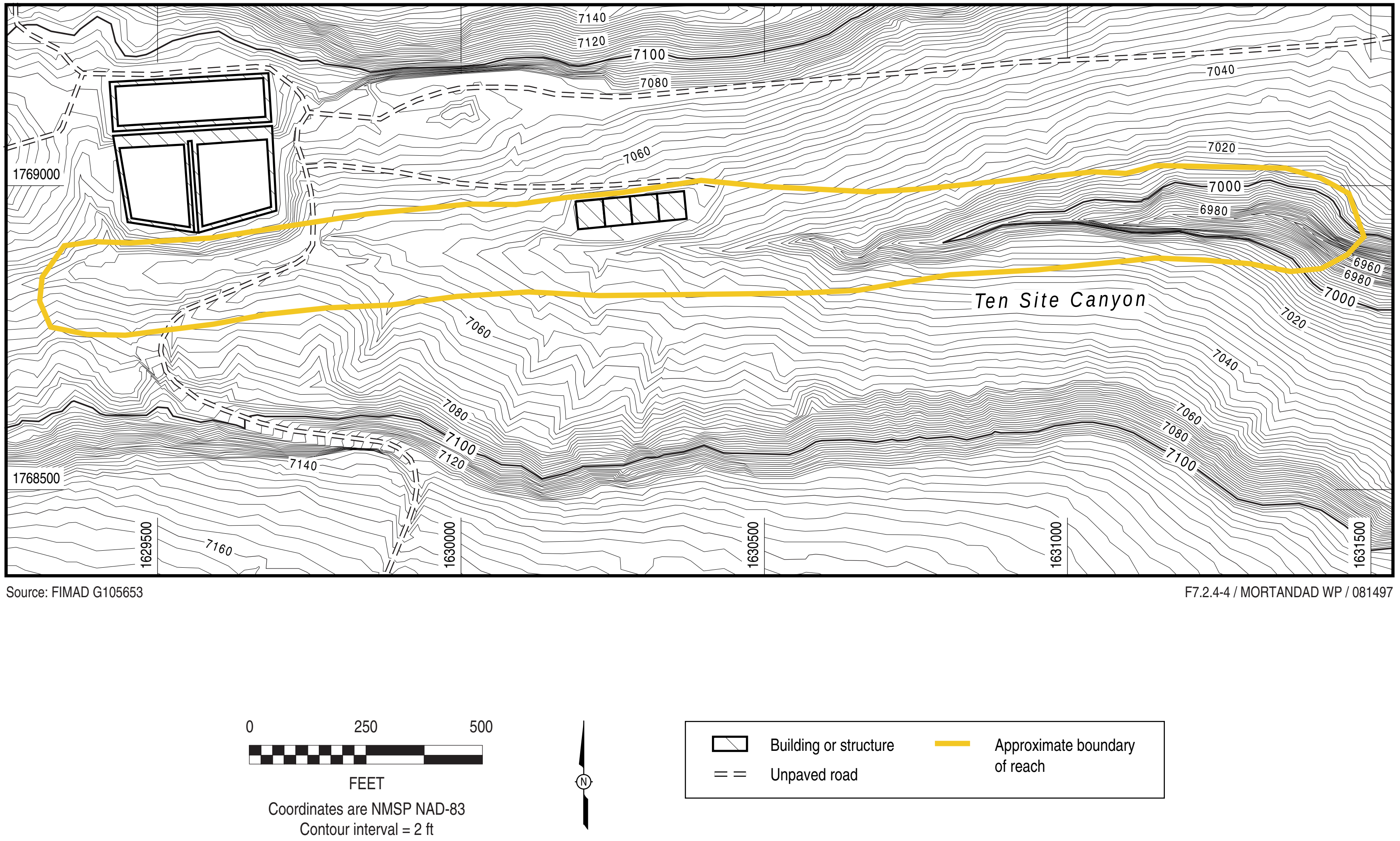
Reach M-1 includes an area with a moist, grassy canyon floor in the headwaters of Mortandad Canyon (Figure 7.2.4-7) that may have received contaminants from a variety of sources. The combination of a relatively gentle channel gradient and abundant vegetation provides opportunities for the storage of contaminated sediments derived from these upstream sources. Reach M-1 will allow definition of the types and concentrations of contaminants that result from discharges upstream of TA-48 and TA-50.



Source: FIMAD G105652

F7.2.4-3 / MORTANDAD WP / 081497

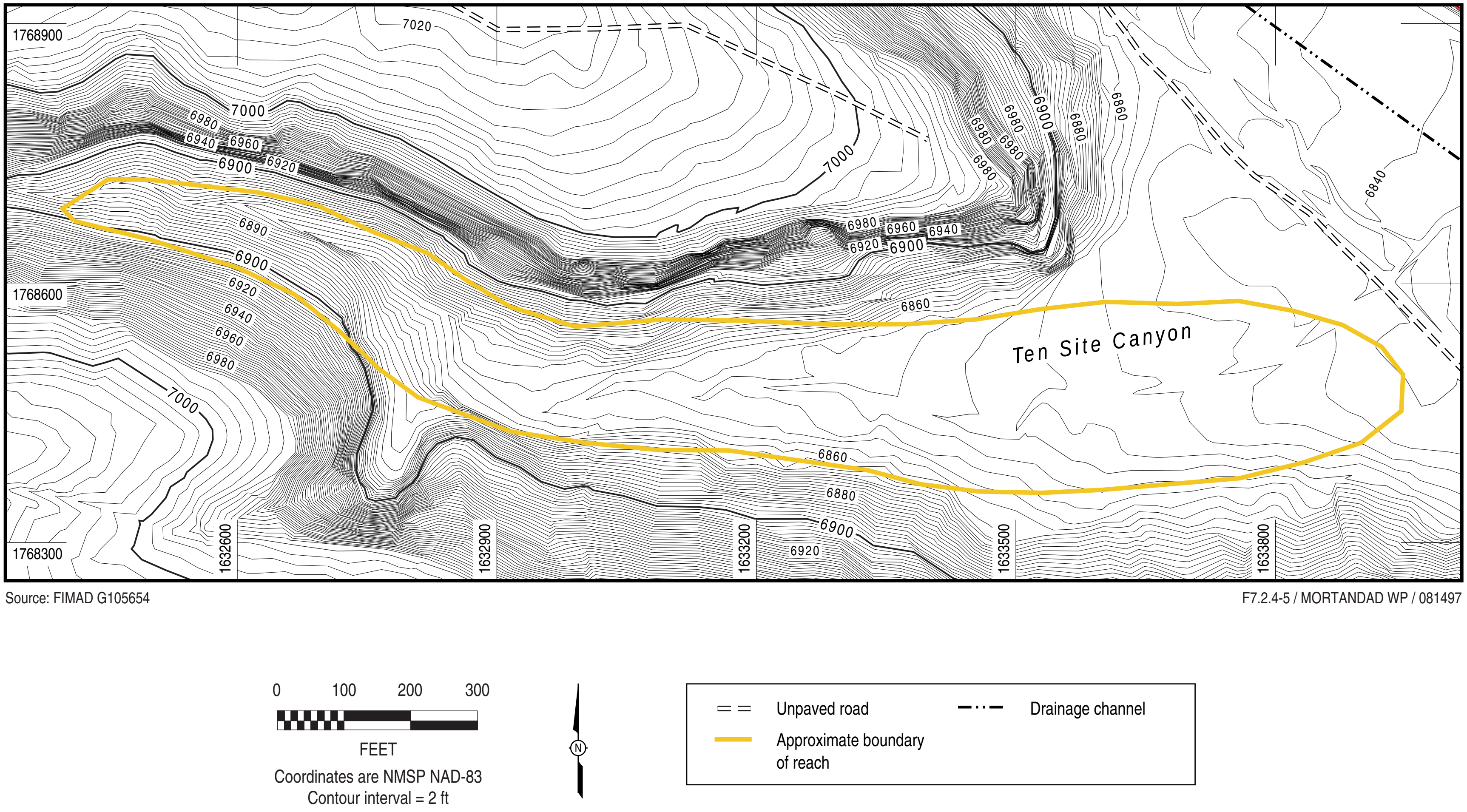
Figure 7.2.4-3. Location of reach TS-1 in Ten Site Canyon.



Source: FIMAD G105653

F7.2.4-4 / MORTANDAD WP / 081497

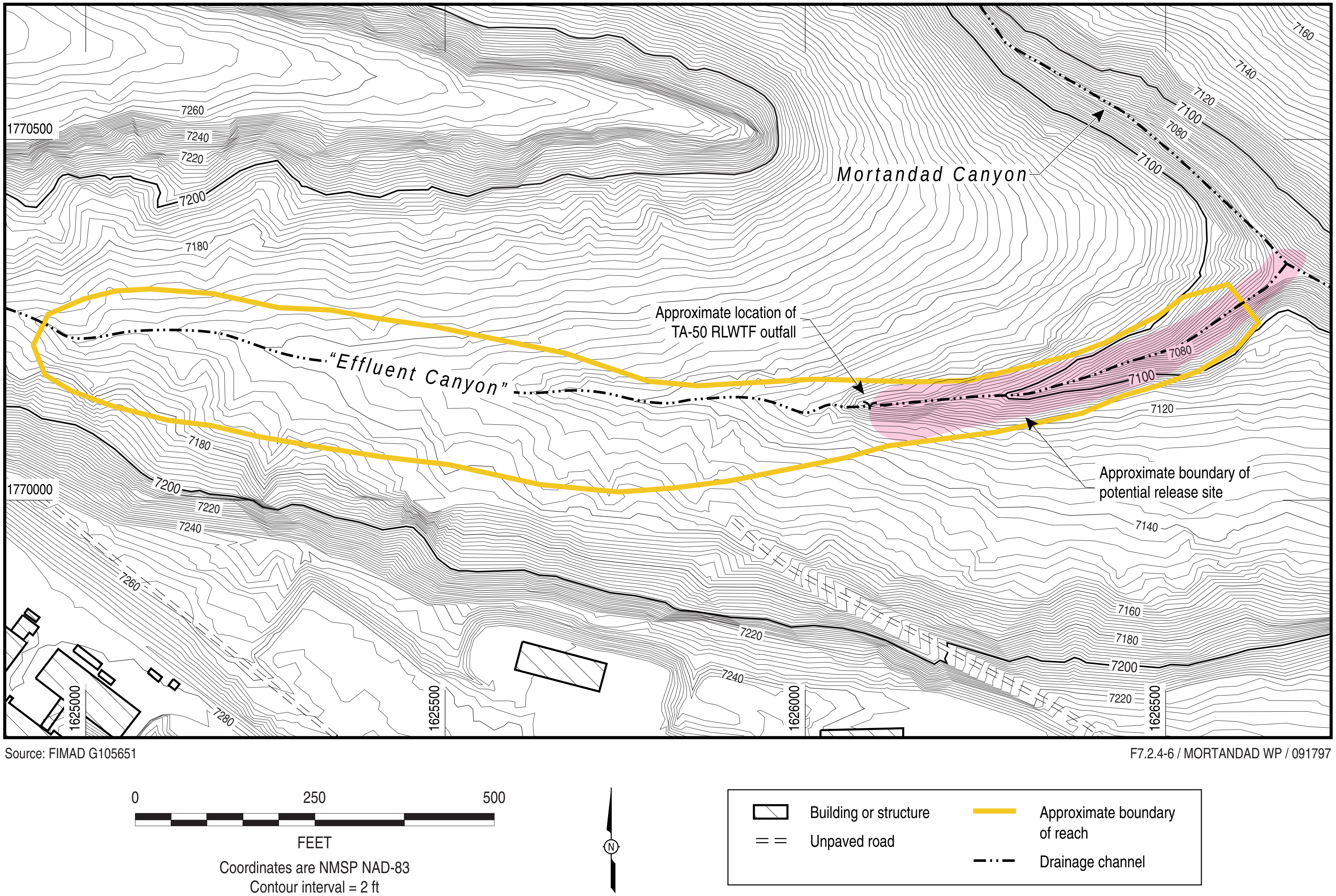
Figure 7.2.4-4. Location of reach TS-2 in Ten Site Canyon.



Source: FIMAD G105654

F7.2.4-5 / MORTANDAD WP / 081497

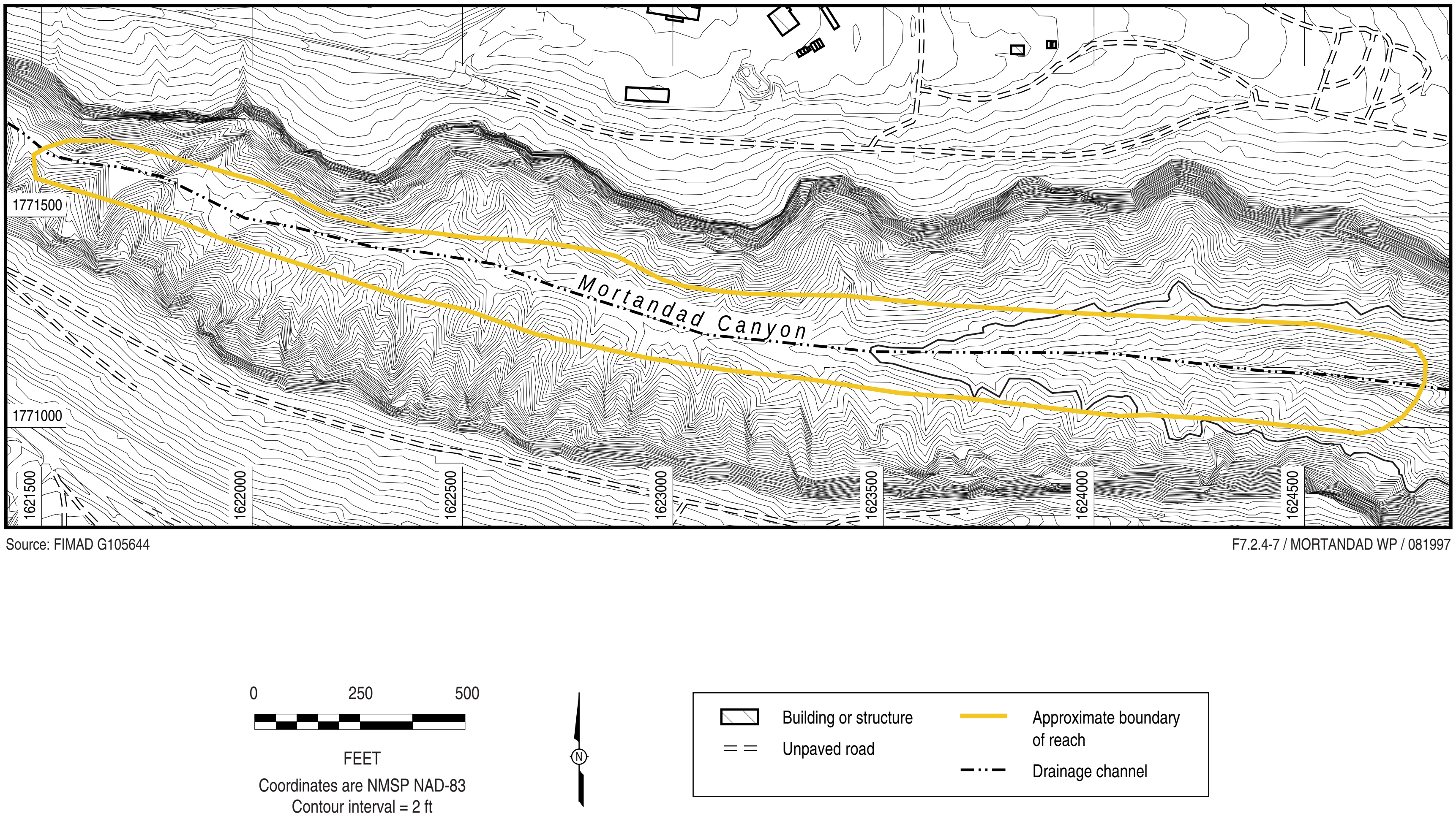
Figure 7.2.4-5. Location of reach TS-3 in Ten Site Canyon.



Source: FIMAD G105651

F7.2.4-6 / MORTANDAD WP / 091797

Figure 7.2.4-6. Location of reach E-1 in Effluent Canyon.



Source: FIMAD G105644

F7.2.4-7 / MORTANDAD WP / 081997

Figure 7.2.4-7. Location of reach M-1 in Mortandad Canyon.

Reach M-2: East of the confluence with Effluent Canyon

Reach M-2 is expected to have the highest concentrations of contaminants in Mortandad Canyon derived from the TA-50 RLWTF outfall (Figure 7.2.4-8) as well as the potential for lower concentrations of contaminants derived from farther upstream in Mortandad Canyon. This reach will allow definition of downstream trends in contaminant concentration, although it is a relatively steep and narrow reach with relatively little opportunity for sediment deposition; it may contain a relatively small contaminant inventory.

Reach M-3: Upstream of the confluence with Ten Site Canyon

Reach M-3 includes the area where Mortandad Canyon widens dramatically upstream of Ten Site Canyon (Figure 7.2.4-9), which provides greater opportunity for deposition of sediment and storage of contaminants. It is expected that this reach will contain a significant inventory of contaminants, although at lower concentrations than upstream. The reach includes sediments in a segment of channel that was abandoned after the engineering diversion discussed in Section 3.6.1 in Chapter 3 of this work plan. The width of the canyon floor may also permit more land use scenarios at M-3 than at the upstream reaches.

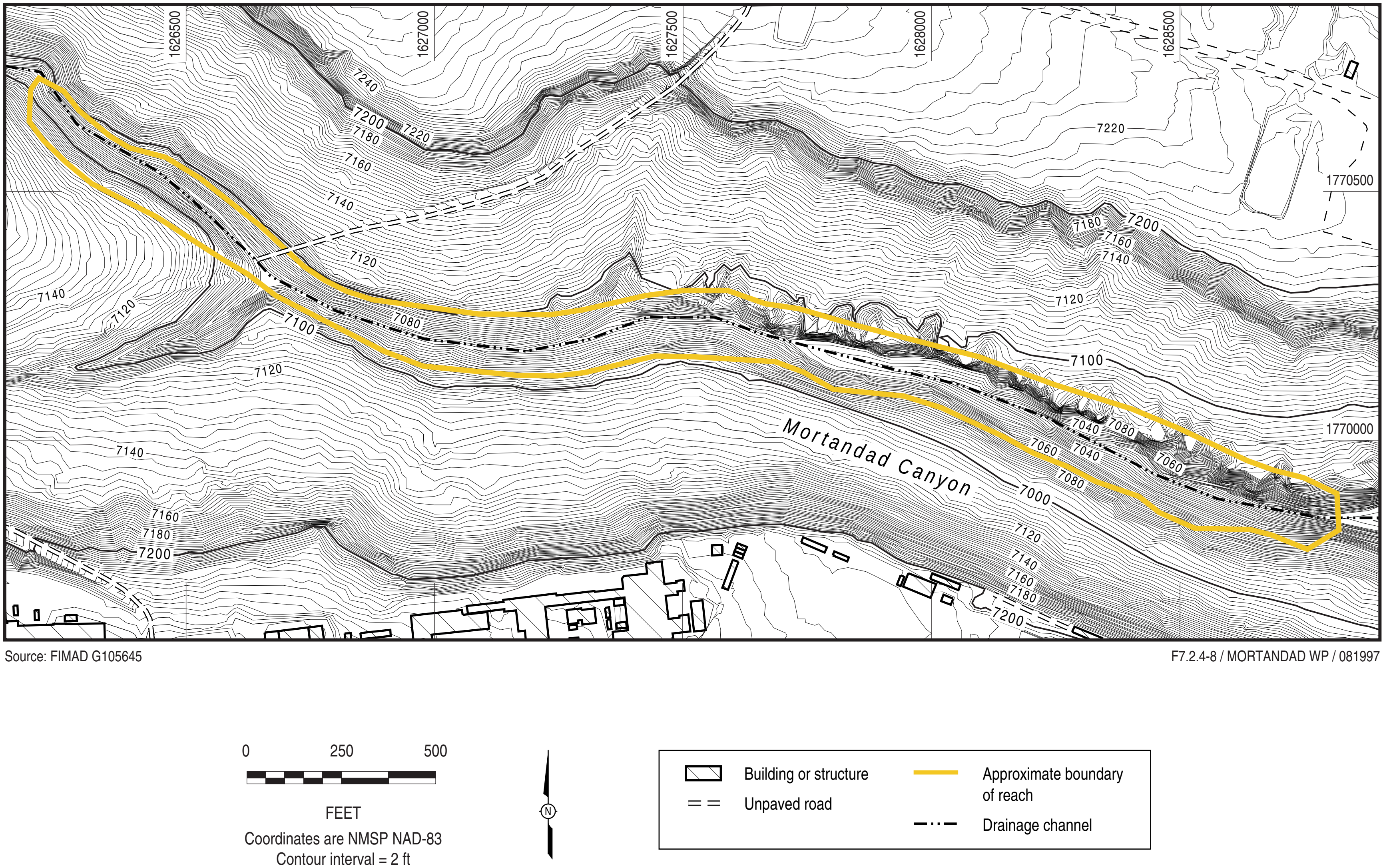
7.2.4.4 Lower Mortandad Canyon Reaches

Reach M-4: Near Ten Site Canyon to past the sediment traps

Reach M-4 is located immediately downstream of Ten Site Canyon and includes the Mortandad Canyon sediment traps (PRS No. 00-001) (Figure 7.2.4-10). This was an area of sediment deposition before the sediment traps were constructed in 1976. Since that time the area has constituted the downstream extent of floodwaters and the downstream extent of sediment deposition. Reach M-4 may contain the highest inventory of contaminants along stream channels in the Mortandad Canyon system, both in natural sedimentary deposits and in the clean-out piles adjacent to the sediment traps. The reach extends a short distance downstream from the sediment traps to allow the evaluation of contaminant dispersion before 1976. The width of the canyon floor could permit a relatively wide variety of land use scenarios. Like the nearby reaches TS-3 and M-3, the canyon floor is known to be used by American Indians for, at least, gathering firewood. The characterization of PRS No. 00-001 is discussed in Section 7.2.7. PRS No. 00-001 will be further characterized by drilling the borehole for proposed well MCO-7.2 as discussed in Section 7.3.4.1.2.

Reach M-5: Near MCO-13 to past the boundary with San Ildefonso Pueblo

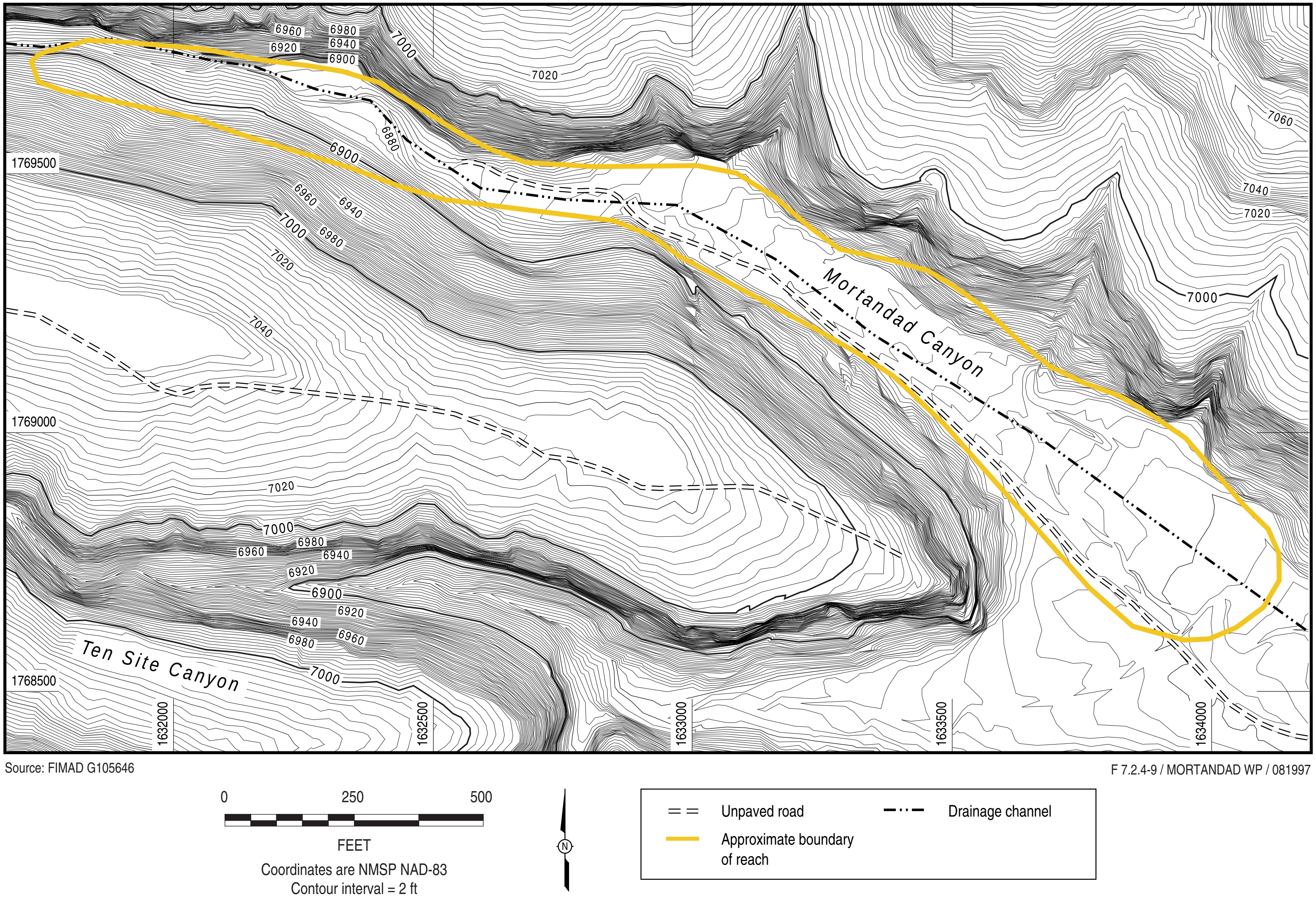
Reach M-5 spans the boundary between the Laboratory and San Ildefonso Pueblo (Figure 7.2.4-11). This reach will allow definition of the types and maximum concentrations of contaminants that have crossed the Laboratory boundary along the Mortandad Canyon channel. This reach also includes the confluence with an unnamed tributary canyon to the west-southwest that potentially contains contaminants derived from mesa-top PRSs at TA-5. Contaminants above background levels have not yet been identified there and, if present, contaminant inventories are expected to be low. The width of the canyon floor indicates that residential land use could occur.



Source: FIMAD G105645

F7.2.4-8 / MORTANDAD WP / 081997

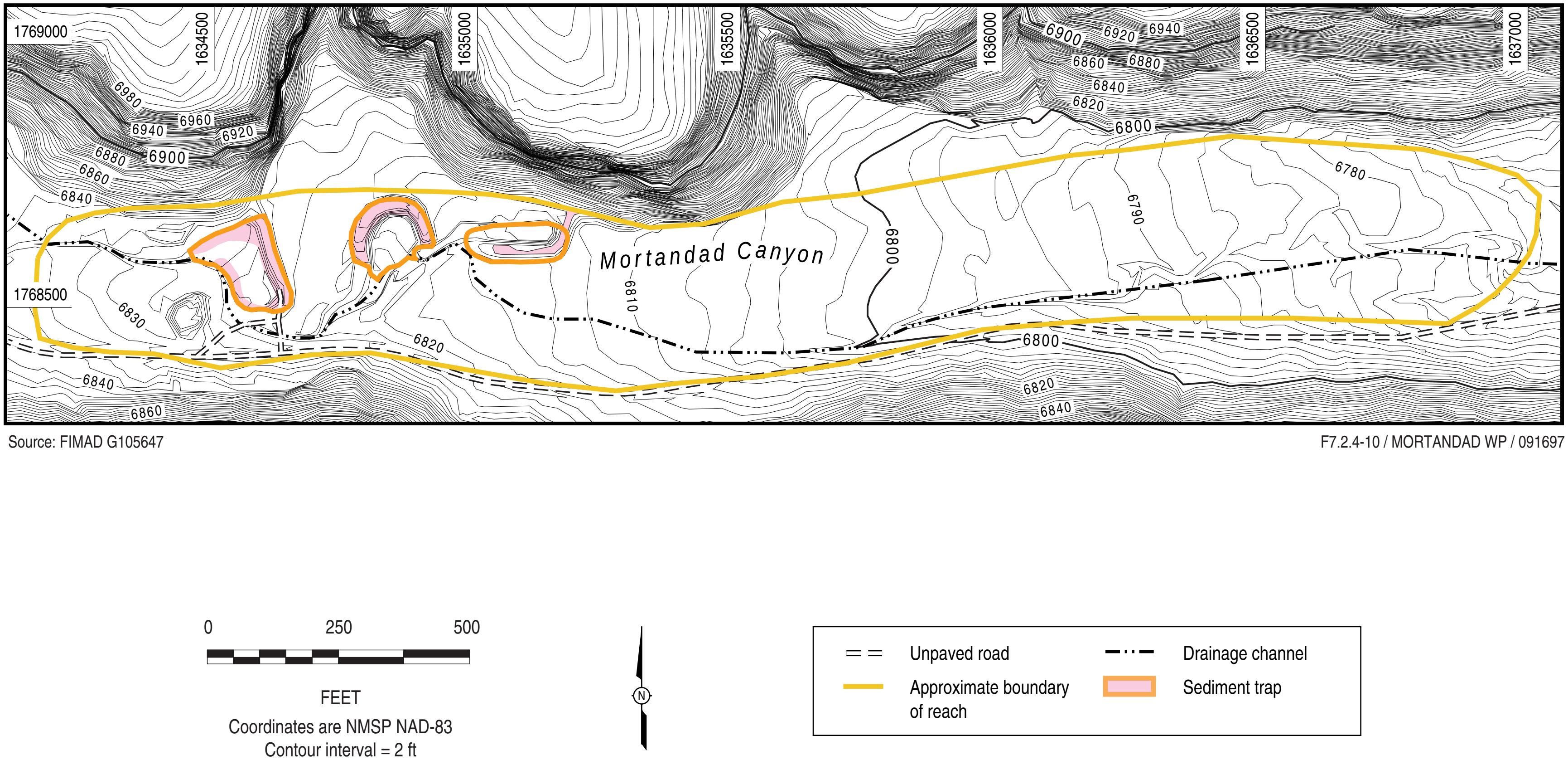
Figure 7.2.4-8. Location of reach M-2 in Mortandad Canyon.



Source: FIMAD G105646

F 7.2.4-9 / MORTANDAD WP / 081997

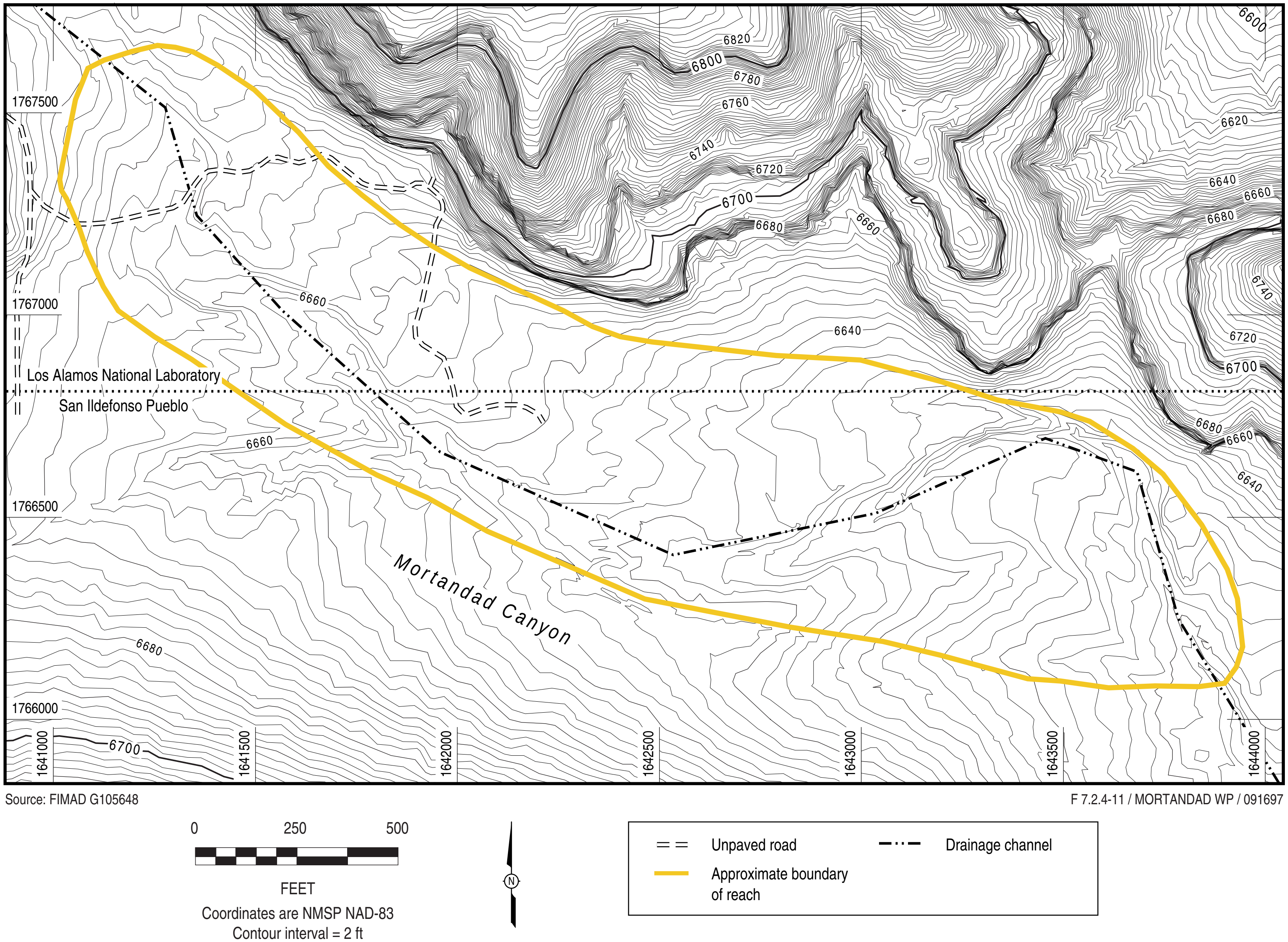
Figure 7.2.4-9. Location of reach M-3 in Mortandad Canyon.



Source: FIMAD G105647

F7.2.4-10 / MORTANDAD WP / 091697

Figure 7.2.4-10. Location of reach M-4 in Mortandad Canyon.



Source: FIMAD G105648

F 7.2.4-11 / MORTANDAD WP / 091697

Coordinates are NMSP NAD-83
Contour interval = 2 ft

Figure 7.2.4-11. Location of reach M-5 in Mortandad Canyon.

7.2.4.5 Lower Mortandad Canyon Reaches off Laboratory Property

Reach M-6: Below the Laboratory boundary downstream to state road NM4 on San Ildefonso Pueblo land

Reach M-6 is on San Ildefonso Pueblo land adjacent to state road NM4 in the area where the stream channel has the lowest gradient, which increases the potential for sediment deposition (Figure 7.2.4-12). Archival information suggests that surface runoff from one flood in 1952, which possibly carried Laboratory contaminants, came at least this far downstream. Plutonium concentrations are near worldwide fallout levels, although isotopic ratios indicate some Laboratory contribution. Inventories of all contaminants are expected to be very low. The area is used by San Ildefonso Pueblo residents for a variety of purposes, and the width of the canyon floor indicates that residential land use could occur. Surveys and sampling of this reach will be contingent on results of sampling and analysis in reach M-5; if no contaminants are found in reach M-5, no investigations will be conducted in this reach.

Reach M-7: Immediately upstream of the Rio Grande

Reach M-7 is located immediately upstream of the Rio Grande on San Ildefonso Pueblo land and consists of a steep, rocky, alluvial fan (Figure 7.2.4-13). Located downstream of the confluence of Mortandad Canyon and Cañada del Buey, this reach could contain contaminants from either canyon. Surveys and sampling of this reach will be deferred until the investigation of Cañada del Buey and will be contingent on identification of contaminants in upstream reaches in either canyon.

7.2.4.6 Other Reaches in the Mortandad Canyon Watershed

Reach MCW-1: Immediately downstream of TA-5 PRS

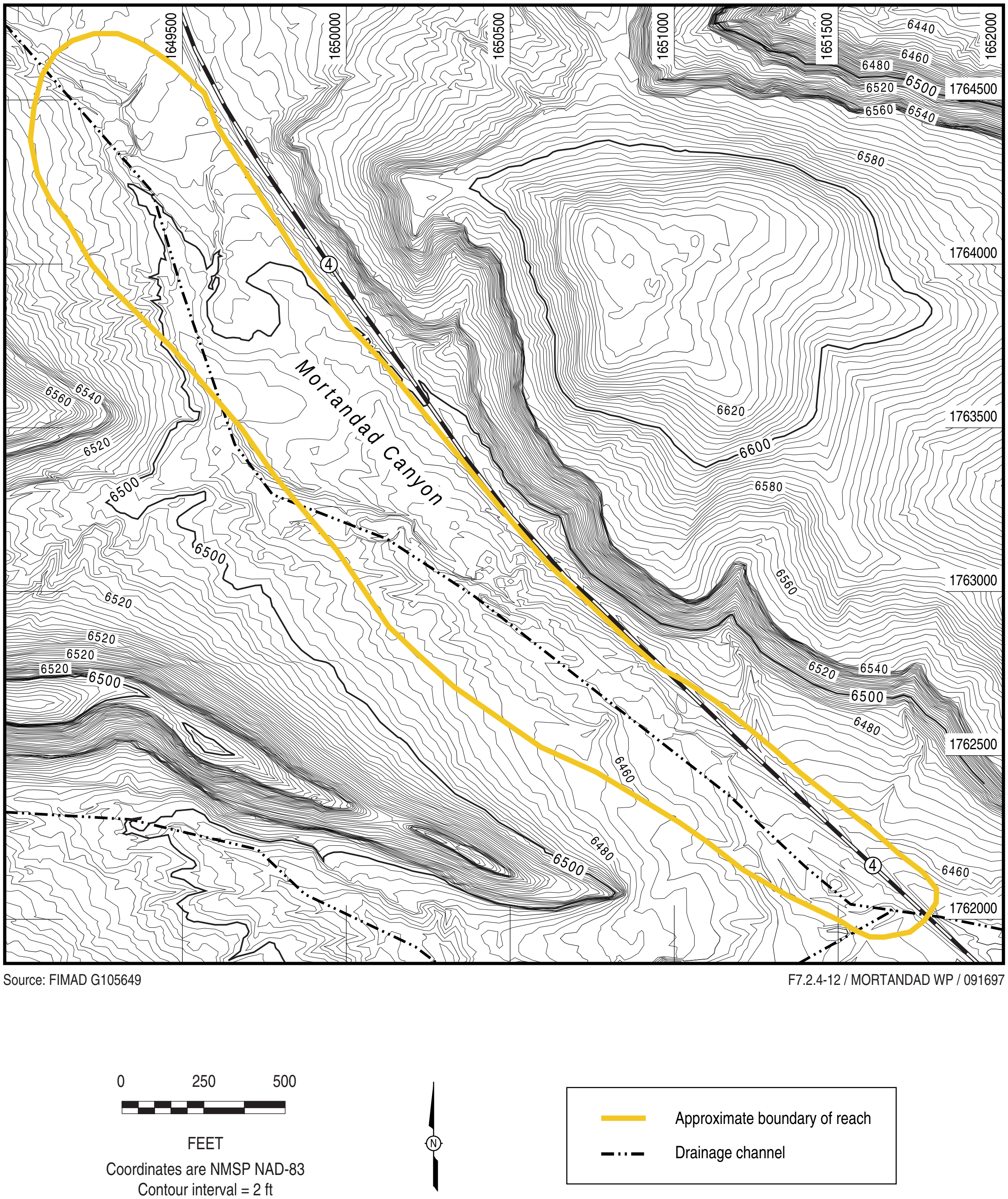
Reach MCW-1 is located immediately downstream of a mesa-top PRS in TA-5 (Figure 7.2.4-14), which drains into an unnamed tributary to Mortandad Canyon on San Ildefonso Pueblo land. This reach may have received contaminants from Laboratory activities, but contamination has not been confirmed. Surveys and sampling of this reach will be contingent on results of sampling and analysis at the mesa-top PRS.

Reach MCW-2: Downstream of TA-5 PRSs

Reach MCW-2 is located downstream of mesa-top PRSs in TA-5 (Figure 7.2.4-15) and downstream of Reach MCW-1 in an unnamed tributary to Mortandad Canyon on San Ildefonso Pueblo land. This reach also may have received contaminants from Laboratory activities, but contamination has not been confirmed. Surveys and sampling of this reach will be contingent on results of sampling and analysis at the mesa-top PRSs.

7.2.5 Field Surveys and Mapping of the Canyon Reaches

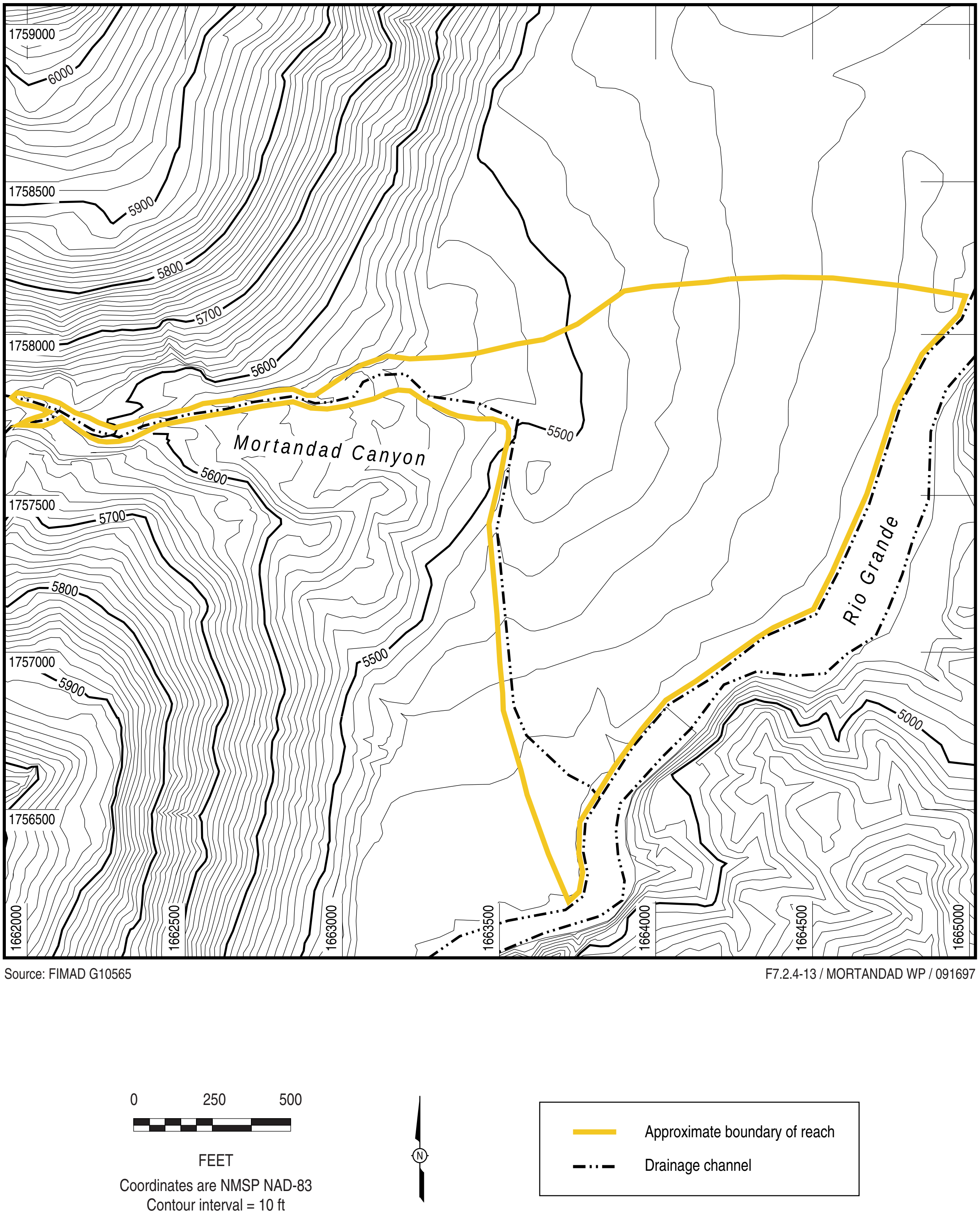
The canyon reaches described in Section 7.2.4 will be surveyed and mapped, relying primarily on nonintrusive techniques. The survey and mapping tasks include land, radiological, and geomorphic surveys. The general strategy that will be followed and the techniques that will be employed are discussed in Section 5.6.2 in Chapter 5 of the core document (LANL 1997, 55622). The techniques that will be used in the radiological survey and the objective of that survey differ from those discussed in Section 5.6.2.3 of the core document. However, they are discussed below.



Source: FIMAD G105649

F7.2.4-12 / MORTANDAD WP / 091697

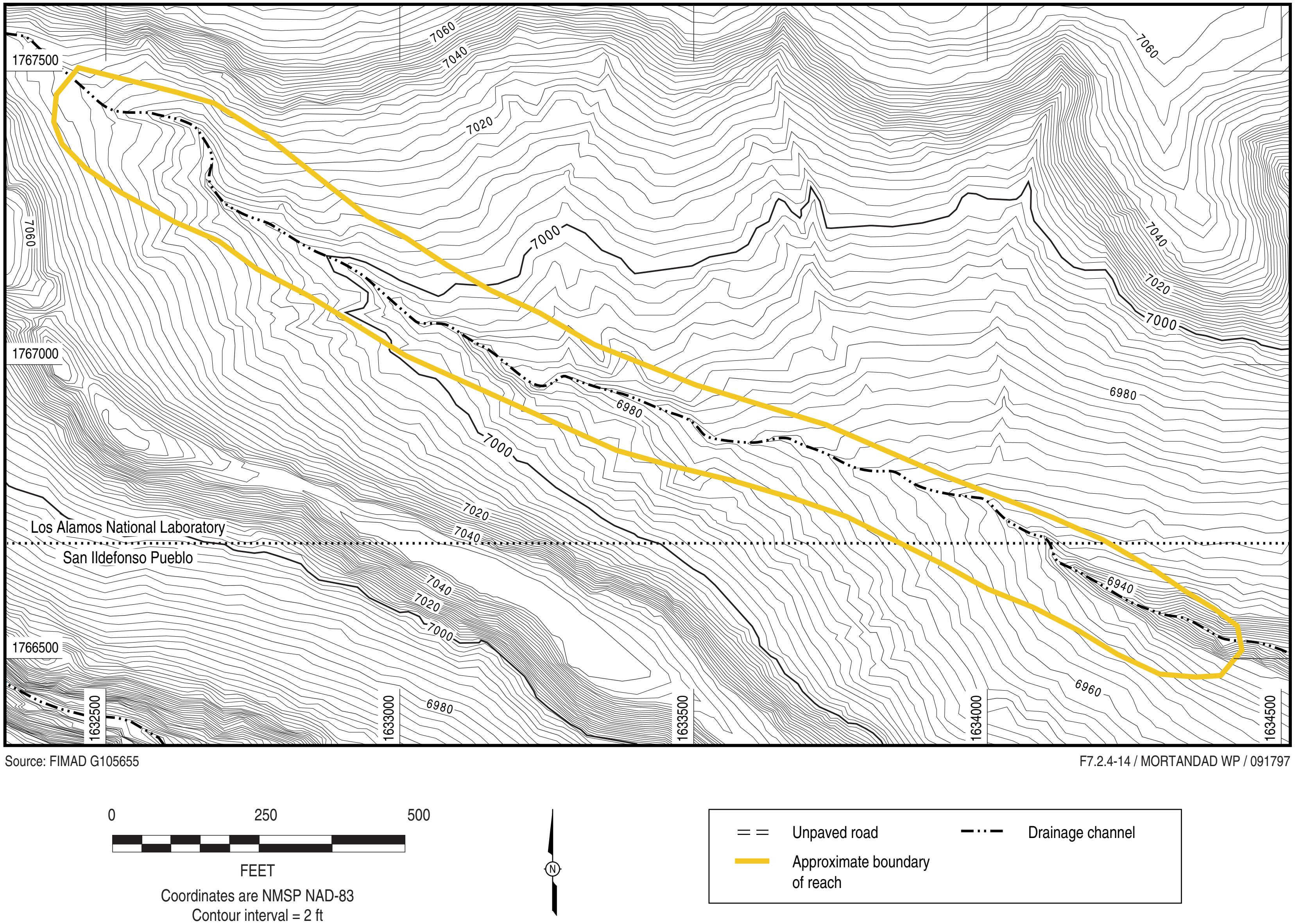
Figure 7.2.4-12. Location of reach M-6 in Mortandad Canyon.



Source: FIMAD G10565

F7.2.4-13 / MORTANDAD WP / 091697

Figure 7.2.4-13. Location of reach M-7 in Mortandad Canyon.

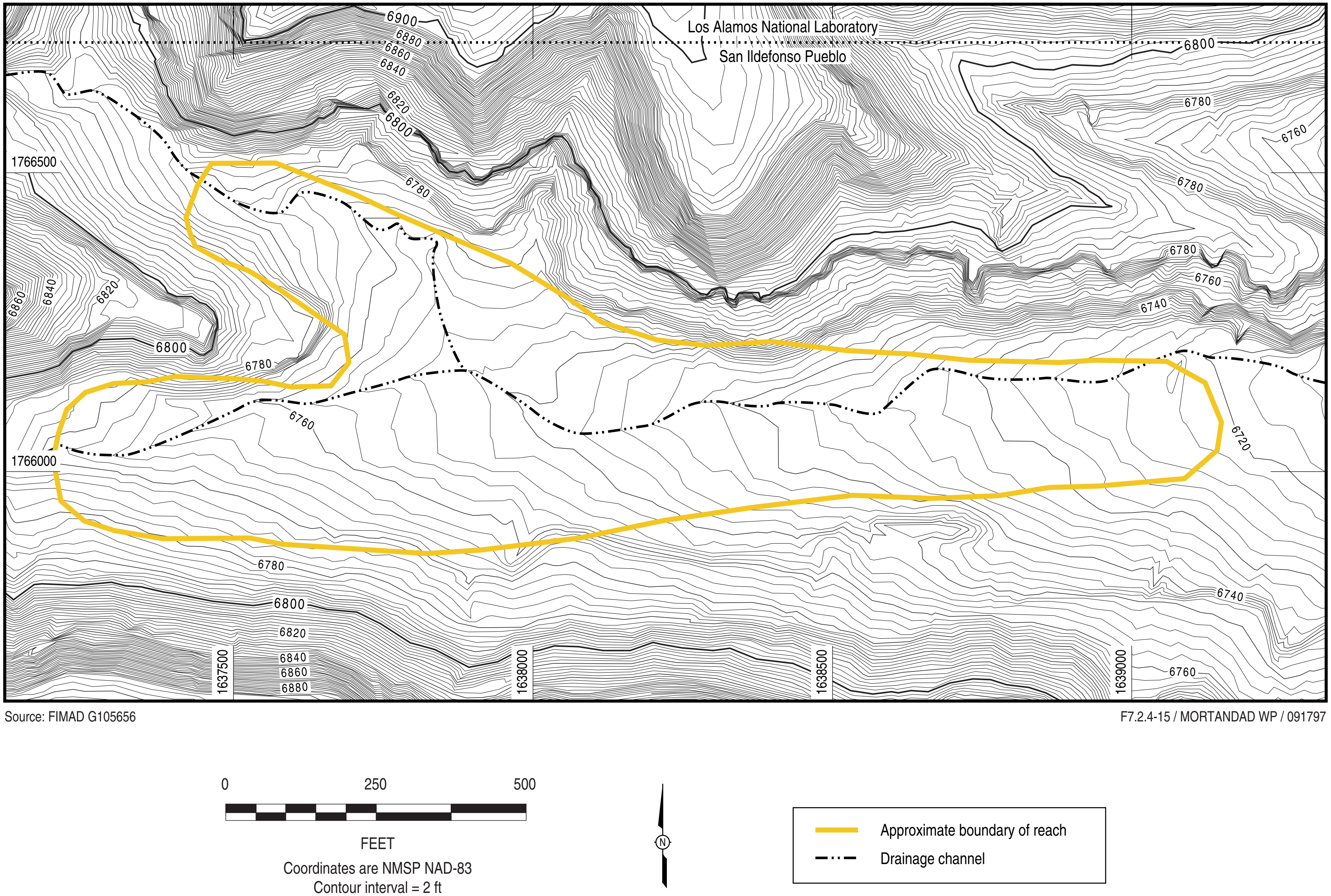


Source: FIMAD G105655

F7.2.4-14 / MORTANDAD WP / 091797

Coordinates are NMSP NAD-83
Contour interval = 2 ft

Figure 7.2.4-14. Location of reach MCW-1 in the Mortandad Canyon watershed.



Source: FIMAD G105656

F7.2.4-15 / MORTANDAD WP / 091797

Figure 7.2.4-15. Location of reach MCW-2 in the Mortandad Canyon watershed.

The objectives of the radiological survey are to

- *provide information about the surface distribution of radiological contaminants across geomorphic units,*
- *provide information about the heterogeneity of contaminant distribution within geomorphic units,*
- *identify areas or spots where radioactivity is highest, and*
- *provide information about radioactivity in subsurface (depths greater than 1 to 2 cm [0.4 to 0.8 in.]) sediment.*

The first iterations of the radiological surveys will consist of gross-gamma radiation walkover surveys to provide information about radiation that originates in the upper part of the sediments from gamma-emitting contaminants such as ^{137}*Cs and many of the activation products derived from Laboratory activities. Subsequent fixed-point measurements with longer count times will be used to obtain more precise field measurements of alpha, beta, and/or gamma radiation at a series of points within each geomorphic unit. Measurements will be taken both at the surface and at different depths that are exposed in stream bank cuts or shallow excavations.*

The proposed instrumental techniques and their applications are summarized in Table 7.2.5-1. Alpha particles can be detected at levels greater than 20 to 40 pCi/g with 15- to 30-minute count times by placing a zinc sulfide scintillator probe directly into a clean sediment surface. Gross-beta or gross-beta/-gamma measurements can be made using a Geiger-Müller pancake probe. Detection of gross-gamma radiation can be achieved using a sodium iodide scintillator detector. Other instruments may also be used as appropriate, including the Phoswich detector, which will detect the x-radiation emissions that accompany the decay of transuranic particles (particularly ^{241}*Am,* ^{239}*Pu, and* ^{235}*U), the LEHPGe, and the FIDLER (field instrument for detecting low-energy radiation) or the VIOLINIST, which is a much improved automated version of the FIDLER and can provide spectroscopic measurements to identify particular isotopes. It is expected that concentrations of radionuclides in many reaches will be too low to recognize with field instruments; therefore, these field measurements may not be taken in all reaches.*

TABLE 7.2.5-1

DESCRIPTION OF RADIOLOGICAL SURVEY INSTRUMENTATION

Instrument/Detector	Emission Detected	Applications
Zinc sulfide (ZnS) scintillator	α	*Gross-alpha radiation screening*
Geiger-Müller pancake	β/γ	*Gross-beta/-gamma radiation screening, field surveys, and point source detection*
Plastic scintillator	β	*Gross-beta radiation screening*
Sodium iodide (NaI[Tl]) scintillator	γ	*Gamma radiation screening, field surveys, and point source detection*
FIDLER/VIOLINIST	*Low-energy x-radiation*	*Transuranics (Am, Pu, U) field screening and sub-surface (1–2 cm) detection*
LEHPGe	γ*/Low-energy x-radiation*	*Spectroscopic identification and quantification of transuranics (Am, Pu, U) and* ^{137}*Cs*

A simplified schematic view of the radiological survey measurement strategy is shown in Figure 7.2.5-1. The initial walkover survey will take many short count-time (1 to 10 seconds) measurements for gamma radiation because previous field screening measurements indicate that ^{137}Cs concentrations are high enough to be detected with this approach (see Section 3.4.5 in Chapter 3 of this work plan). The short count-time measurements will provide low-resolution, qualitative data over a large area and allow rapid identification of small-area sources of radioactivity. Longer count-time (60 seconds or longer) measurements will be taken at locations where radiological anomalies are detected and at selected locations within each geomorphic unit to achieve higher resolution data.

The gross-gamma walkover survey may use (1) a global positioning system where tree cover is minimal; (2) radiotelemetry techniques, such as the Ultrasonic Ranging and Data System (USRADS) environmental surveying instrument (Chemrad Tennessee Corporation, Oak Ridge, Tennessee) for high-resolution spatial data logging; or (3) a compass and surveyed locations with a data logger to mark locations. Advantages of the more expensive radiotelemetry technique include the ability to collect data under heavy tree cover and the ability to visualize the radiological survey data in real time. Geodetic measurements will also be taken to provide locations for mapping of the radiological survey data.

The radiological survey is designed to provide enough data to distinguish different levels of radioactive contamination between different geomorphic units and to refine the geomorphic mapping where possible. The density of measurements within a unit will vary depending on the degree and variability of radioactive contamination; a higher density of measurements will be taken in the most contaminated units or those units showing high variability in measurements.

7.2.6 Sediment Sample Collection and Analysis

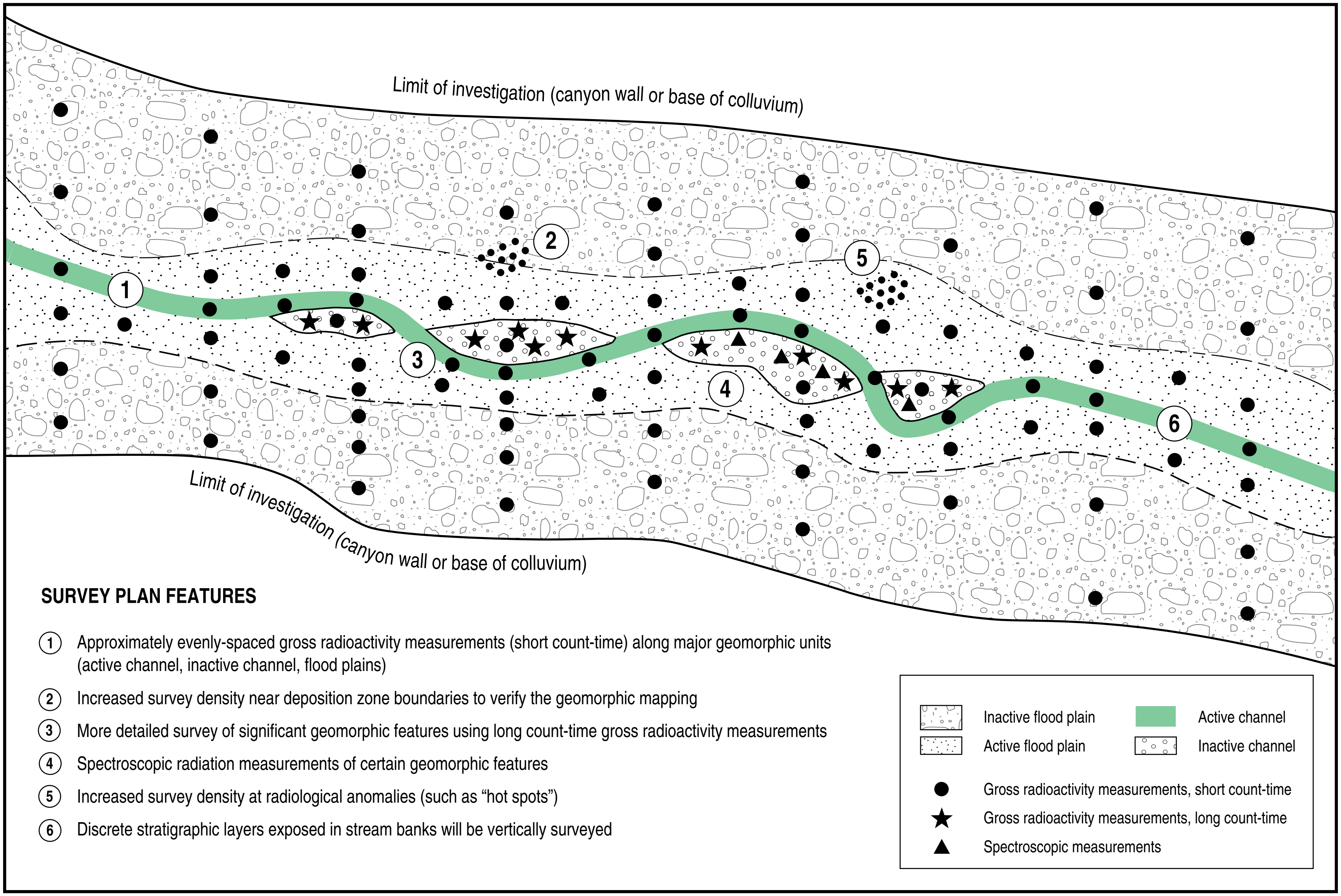
This section describes the sediment sample collection process in the canyon reaches. Particular emphasis is given to the criteria for selecting sample locations within each reach and the rationale for the choice of analytical suites. The methods for sample collection and for the chemical, radiochemical, and geotechnical analyses are also provided in this section.

7.2.6.1 Sampling Design

Samples of sediments from potentially contaminated geomorphic units will be collected in each of the reaches proposed for investigation (see Section 7.2.4). 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 Sample Management Office, 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).



SURVEY PLAN FEATURES

① Approximately evenly-spaced gross radioactivity measurements (short count-time) along major geomorphic units (active channel, inactive channel, flood plains)

② Increased survey density near deposition zone boundaries to verify the geomorphic mapping

③ More detailed survey of significant geomorphic features using long count-time gross radioactivity measurements

④ Spectroscopic radiation measurements of certain geomorphic features

⑤ Increased survey density at radiological anomalies (such as “hot spots”)

⑥ Discrete stratigraphic layers exposed in stream banks will be vertically surveyed

F7-2.5-1 / MORTANDAD WP / 091597

Figure 7.2.5-1. Simplified schematic view of the proposed radiological survey strategy.

Because of the abundance of information available on radionuclide contaminants in the Mortandad Canyon system, the initial round of sampling and analysis will consist of extensive determinations of key contaminant concentrations within geomorphic units. Key contaminants analyzed for could include ^{241}Am, ^{137}Cs, ^{238}Pu, ^{239,240}Pu, and ^{90}Sr as suggested by historical data from each reach. In addition, mercury and other metals have been identified as contaminants in the TA-50 RLWTF discharge and will be analyzed for as key contaminants in the inorganic chemicals analyses.

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. These full-suite analyses will include short-lived radionuclides with half-lives less than 180 days (to be specified) that are routinely discharged from the TA-50 RLWTF in samples from two of the proposed reaches. These radionuclides may prove to be useful tracers during the evaluation of transport mechanisms and rates.

7.2.6.1.1 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 except as noted above.

In addition, sediment samples for full-suite analysis will be collected from the canyon reaches closest to known source areas, with the widest distribution of contaminants, and immediately upstream of the eastern Laboratory boundary: specifically, reaches TS-1 and TS-2 in Ten Site Canyon and reaches M-1, M-2, and M-5 in Mortandad Canyon. Reaches MCW-1 and MCW-2 may also be sampled for full-suite analyses if those reaches are investigated, as discussed in Section 7.2.4.5.

7.2.6.1.2 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 except as noted in Section 7.2.6.1.

The key contaminant analyses are critical to the sediment investigations because they will be either of analytes that are most important for evaluating risk or of analytes shown to be colocated with the risk drivers.

7.2.6.1.3 Sample Collection for Limited-Suite Analysis

Because the database on radionuclide and metal contaminants in Mortandad Canyon is extensive, contaminants known to be present have been identified with confidence, enabling the parameters for limited-suite analyses to be selected a priori, subject to change by any unexpected contaminant found in the full-suite analyses. Sediment samples for limited-suite analysis will be collected from most or all of the canyon reaches proposed for investigation. The sampling strategy will focus on evaluating the colocation of contaminants in the potentially contaminated geomorphic units. The specific sampling locations will be selected after the analysis of key contaminants to allow sampling for a range of contaminant concentrations. 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. For example, in reaches where different contaminants have substantially different discharge histories, more analyses may be required to evaluate colocation. 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 significant risk drivers from the full-suite analyses.

7.2.6.2 Sampling Methods

Sediment samples will be collected using the methods and ER Project standard operating procedures (SOPs) listed in Table 7.2.6-1 (LANL 1991, 21556). 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 7.2.6-1

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 applicable ER Project SOPs for the collection, preservation, identification, storage, transport, and documentation of environmental samples (LANL 1991, 21556). 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."

7.2.6.3 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 well-mixed 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 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.

7.2.6.3.1 Organic Chemicals

Sediment samples collected in accordance with criteria outlined in Section 7.2.6.1.1 will undergo full-suite analyses for organic 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 7.2.6-2. The analytical suites include semivolatile organic compounds (SVOCs), organochlorine pesticides, and polychlorinated biphenyl compounds (PCBs), which will be analyzed for in each sample. All analyses for organic chemicals will be performed in accordance with the EPA SW-846 protocols (EPA 1986, 31733). 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 7.2.6-2

ANALYTE SUITES AND ANALYTICAL METHODS FOR ANALYSIS OF ORGANIC CHEMICALS IN SEDIMENT SAMPLES[a]

Analyte Suite	Analytical Method	Analytical Protocol[b]
Organochlorine pesticides	*GC/ECD*	*SW-8081A*
PCBs	*GC/ECD*	*SW-8081A or SW-8082*
SVOCs	*GC/MS*	*SW-8270*

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 1986, 31733)

7.2.6.3.2 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 7.2.6-3. 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 (MDAs), analytical methods, and background levels in sediments are listed in Table 7.2.6-4. Before chemical separation and counting for alpha or high-energy beta emissions, samples will undergo a complete digestion or fusion procedure. Measurements of ^{90}*Sr will be performed by beta-counting of* ^{90}*Y 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 7.2.6-3

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*	*13260*	*ICPES*	*SW-6010B*
Antimony	*1.0*	*5.0*	*ICPMS*	*SW-6020*
Arsenic	*2*	*3.98*	*ETVAA*	*SW-7060A*
Barium	*40*	*127*	*ICPES*	*SW-6010B*
Beryllium	*1*	*1.31*	*ICPES*	*SW-6010B*
Boron	*10*	*N.A.*[c]	*ICPES*	*SW-6010B*
Cadmium	*1*	*0.18*	*ICPES*	*SW-6010B*
Calcium	*500*	*3850*	*ICPES*	*SW-6010B*
Chromium	*2*	*10.5*	*ICPES*	*SW-6010B*
Cobalt	*10*	*4.73*	*ICPES*	*SW-6010B*
Copper	*5*	*9.97*	*ICPES*	*SW-6010B*
Iron	*20*	*13800*	*ICPES*	*SW-6010B*
Lead	*0.6*	*19.7*	*ETVAA or ICPMS*	*SW-7421 or SW-6020*
Magnesium	*1000*	*2130*	*ICPES*	*SW-6010B*
Manganese	*3*	*543*	*ICPES*	*SW-6010B*
Mercury	*0.1*	*0.03*	*CVAA*	*SW-7470A*
Nickel	*8*	*9.38*	*ICPES*	*SW-6010B*
Potassium	*500*	*2690*	*ICPES*	*SW-6010B*
Selenium	*1*	*<0.2*	*ETVAA*	*SW-7740*
Silver	*2*	*0.28*	*ICPES*	*SW-6010B*
Sodium	*500*	*1470*	*ICPES*	*SW-6010B*
Thallium	*2*	*3.2*	*ICPMS*	*SW-6020*
Titanium	*10*	*N.A.*	*ICPES*	*SW-6010B*
Uranium	*0.5*	*1.62*	*ICPMS*	*SW-6020*
Vanadium	*10*	*19.7*	*ICPES*	*SW-6010B*
Zinc	*4*	*60.2*	*ICPES*	*SW-6010B*
Other Inorganic Chemicals				
Total cyanide	*0.05*	*N.A.*	*Colorimetry*	*SW-9012A*

a. *Background for canyon sediment samples from McDonald et al. 1997, 04-0328*

b. *EPA SW-846 Method (EPA 1986, 31732)*

c. *N.A. = not available*

TABLE 7.2.6-4

ANALYTE LIST, MINIMUM DETECTABLE ACTIVITIES, AND ANALYTICAL METHODS FOR RADIONUCLIDES IN SEDIMENT SAMPLES

Analyte	Half-Life (yr)	Detected Emission	MDA (pCi/g)	Background[a] (pCi/g)	Analytical Method
^{241}Am	432.2	α	0.05	0.139	α-Spectrometry
^{238}Pu	87.7	α	0.05	0.006	α-Spectrometry
^{239,240}Pu[b]	2.411×10^4	α	0.05	0.197	α-Spectrometry
^{90}Sr	28.7	β	0.5	1.0	GPC
Tritium	12.3	β	250 pCi/L	0.068	LSC
^{234}U	2.46×10^5	α	0.1	2.39	α-Spectrometry
^{235}U	7.04×10^8	α	0.1	0.16	α-Spectrometry
^{236}U	2.34×10^7	N/A[c]	0.001	N.A.[d]	TIMS
^{238}U	4.47×10^9	α	0.1	2.29	α-Spectrometry
Gamma spectroscopy[e]	N/A	γ	0.2[f]	N/A	γ-Spectroscopy
Gross-alpha	N/A	α	1.0	N.A.	GPC
Gross-beta	N/A	β	1.0	N.A.	GPC
Gross-gamma	N/A	γ	2.0	N.A.	NaI(Tl) or HPGe detection

a. Background for canyon sediment samples from McDonald et al. 1997, 04-0328. Background values may include 95% UTLs or maximum observed values.

b. The ^{239}Pu and ^{240}Pu isotopes cannot be distinguished by alpha spectrometry. The half-life of ^{239}Pu is given.

c. N/A = not applicable

d. N.A. = not available

e. The gamma spectroscopy analyte list is given in Table 7.2.6-5.

f. The MDA for ^{137}Cs is 0.2 pCi/g; the MDA 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 7.2.6-5) includes the decay series of the naturally occurring radionuclides ^{232}Th, ^{235}U, and ^{238}U 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 ^{40}K 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 ^{40}K gamma emission peak provides a qualitative indicator of the accuracy and precision of the gamma spectroscopy measurement, but ^{40}K is not considered to be a potential contaminant in Mortandad Canyon sediments.

The required QC procedures and acceptance criteria for both the inorganic and radiochemical analyses (except ^{236}U) 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 7.2.6-5

ANALYTE LIST AND HALF-LIVES OF RADIONUCLIDES MEASURED USING GAMMA SPECTROSCOPY

Radionuclide	Half-life*	Emissions
^{232}Th decay series (Thorium series)		
^{212}Pb	10.64 h	β,γ
^{208}Tl	3.053 m	β,γ
^{235}U decay series (Actinium series)		
^{211}Bi	2.14 m	α,β,γ
^{227}Th	18.72 d	α,γ
^{235}U	7.04 x 10^{8} y	α,γ
^{238}U decay series (Uranium series)		
^{214}Bi	19.9 m	α,β,γ
^{214}Pb	26.8 m	β,γ
^{234}Th	24.10 d	β,γ
Activation products (and their decay products)		
^{241}Am	432.7 y	α,γ
^{60}Co	5.271 y	β,γ
^{22}Na	2.605 y	β,γ
^{233}Pa	27.0 d	β,γ
Fission products		
^{134}Cs	2.065 y	β,γ
^{137}Cs	30.17 y	β,γ
^{152}Eu	13.48 y	β,γ
^{106}Ru	372.6 d	β
Other		
^{40}K	1.25 x 10^{9} y	β,γ
**m = minutes, h = hours, d= days, y = years*		

7.2.6.3.3 Geotechnical Analysis

In addition to the chemical and radiochemical analyses, selected sediment samples will undergo geotechnical analysis for particle size distribution using the American Society for Testing and Materials (ASTM) methods described in LANL-ER-SOP-11.02, "Particle Size Distribution of Soil/Rock Samples" (LANL 1991, 21556). ASTM Method D-422-63 will be used to determine the 10-µm size fraction (respirable particulate) in sediment samples. Other geotechnical analyses, such as mineralogy, may be performed at the discretion of the technical team geologists.

7.2.6.3.4 Geochemical Analysis

The distributions of ^{241}Am, ^{137}Cs, ^{238}Pu, ^{239,240}Pu, ^{90}Sr, ^{234}U, ^{235}U, ^{238}U, fission products, activation products, *and nonradioactive species associated with different solid phases including organic matter, clay minerals, and ferric oxyhydroxides present as separate phases or as coatings on sediment particles are important considerations in assessing the mobility of the contaminants.*

More than 99% of the radionuclides discharged into the Mortandad Canyon system are associated with channel and active floodplain sediments (Stoker et al. 1991, 7530). Contaminant distributions in the sediments are controlled by sorption and desorption processes, which are inferred to include cation exchange (most important for ^{137}*Cs and* ^{90}*Sr) and surface complexation (most important for* ^{241}*Am,* ^{238}*Pu,* ^{239,240}*Pu,* ^{234}*U,* ^{235}*U,* ^{238}*U, and various nonradioactive metals) (Longmire et al. 1996, 48818). For risk analysis, it is important to determine what solid phases contain the contaminants as functions of geomorphic setting, sediment age, particle size, and mineralogy or composition (solid organic matter) because the mobility and bioavailability of contaminants are controlled by these parameters. Mobilization of contaminants in dissolved form to surface water and groundwater is partly controlled by the mineralogy, surface area, and amount of organic matter that coats the sediments. This information will provide insight into the sorption capacity of the different solid phases present in sediments by identifying the solid phases associated with the radionuclides.*

Sediment samples will be collected from the three different geomorphic settings (active channel, inactive channel, and active floodplain) within each of several reaches to perform both particle-size analysis and chemical extractions. Sediment samples will be sieved and separated into at least two size fractions: the clay plus silt-sized fraction and the sand-sized fraction. In addition, a separate aliquot of sediment samples (bulk samples) will not be sieved. However, both bulk sediment samples and sieved samples will have twigs and leaves removed before the extraction tests. Standard soil extraction tests will be performed as follows.

- *Dithionite extractions to selectively dissolve total (nonstructural) iron in the forms of ferric oxyhydroxide, organic-bound iron, amorphous ferric hydroxide, and hematite (*Fe_2O_3*)*
- *Oxalate extractions to selectively dissolve iron in the forms of amorphous ferric hydroxide and ferrihydrite*
- *Pyrophosphate extractions to selectively oxidize solid organic matter that coats the sediment particles*

Before chemical analysis, extracts will be acidified with HNO_3 *to pH 2 to prevent mineral precipitation. The different extracts will be analyzed for mercury and other metals by appropriate methods discussed in Section 7.2.6.3.2 and for* ^{241}*Am,* ^{137}*Cs,* ^{238}*Pu,* ^{239,240}*Pu,* ^{90}*Sr,* ^{234}*U,* ^{235}*U,* ^{236}*U, and* ^{238}*U using alpha spectrometry, gas-flow proportional counting, and gamma spectroscopy. The analytical data will be used to evaluate contaminant distributions and activities of radionuclides within the different size fractions (clay, silt-sized, and sand-sized) as functions of age and geomorphic setting. Approximately 60 samples will be collected for particle-size analysis and chemical extraction.*

7.2.7 Characterization of Potential Release Sites in Mortandad Canyon

This section describes the sampling plan for characterizing the PRSs located within Mortandad Canyon and its tributaries: PRS No. 00-001 (the sediment traps), PRS No. 50-006(d) (the TA-50 RLWTF outfall in Effluent Canyon), and PRS No. 50-006(a) (contamination associated with a spill at the head of Ten Site Canyon). These PRSs are described in detail in Chapter 2 and Chapter 3 of this work plan.

The approach to sample collection and analysis and the analytical methods will be similar to those described in Section 7.2.6 except that hollow-stem auger drilling and sampling techniques and/or *hand-auger drilling and sampling techniques will be followed. The required procedures are listed in Table 7.2.7-1. The best method for existing field conditions will be determined by the field team leader.*

TABLE 7.2.7-1

REQUIRED PROCEDURES FOR BOREHOLE SAMPLING

Title	LANL-ER-SOP No.
Drilling Methods and Drill Site Management	*4.01, R1*
General Borehole Logging	*4.04, R0*
Monitor Well and RFI Borehole Abandonment	*5.03, R0*
Collection of Sand, Packed Powder, or Granule Samples Using the Hand Auger	*6.18, R0*
Sample Collection From Split-Spoon Samplers and Shelby Tube Samplers	*6.24, R0*
Core Barrel Sampling for Subsurface Earth Materials	*6.26, R0*
Management of Environmental Restoration Project Wastes	*1.06, R1*
Field Decontamination of Drilling and Sampling Equipment	*1.08, R0*
Radioactive Waste Management for ER Project Field Operations	*1.11, R0*

Boreholes will be drilled and samples will be collected to determine the distribution of contamination associated with each PRS. The samples will be analyzed for COPCs, as determined from the preliminary sampling and analysis described in Section 3.4 in Chapter 3 of this work plan. The analytes and analytical methods are listed in Tables 7.2.6-3, 7.2.6-4, and 7.2.6-5. Field screening for volatile organic compounds (VOCs) will be performed; if the presence of VOCs is indicated, samples will be collected for VOC analysis.

This investigation will be performed in conjunction with the sediment investigations described in Section 7.2.6 and the alluvial groundwater investigations described in Section 7.3.4.1.2.

7.2.7.1 Characterization of PRS No. 00-001

PRS No. 00-001 comprises the old and current sediment traps, the clean-out piles, the sediment shafts, and the sediment trap berms in Mortandad Canyon (Figure 3.4.4-11 and Figure 7.2.7-1). The site is approximately 900 ft (274 m) long and 200 ft (61 m) wide downstream from the confluence of Mortandad Canyon and Ten Site Canyon. The sediment traps are located approximately 1.75 mi. (2.82 km) downstream from the TA-50 RLWTF outfall and approximately 1.4 mi. (2.3 km) upstream from the Laboratory boundary. A historical description of the sediment traps is provided in Section 2.3.1 in Chapter 2 of this work plan, and the results of previous sampling at the site are provided in Section 3.4.4.2.4 in Chapter 3 of this work plan.

The sediment traps have been designated as a PRS although the traps are required by the HSWA Module (EPA 1990, 1585) to be maintained and operated so that contaminated sediments do not leave Laboratory property (see Section 2.3.2 in Chapter 2 of this work plan). Because the sediment traps are operational and routinely (although infrequently) receive contaminated sediments, the approach described in this section will focus on characterizing them at a specific point in time. The sediment shafts, the old sediment traps, and the clean-out piles are not currently operational; characterization of these structures will focus on determining the vertical distribution of contaminants and the contaminant inventory. For the most part, the nature of the contaminants has been determined by preliminary investigations, as described in Section 3.4.4.2.4 in Chapter 3 of this work plan.

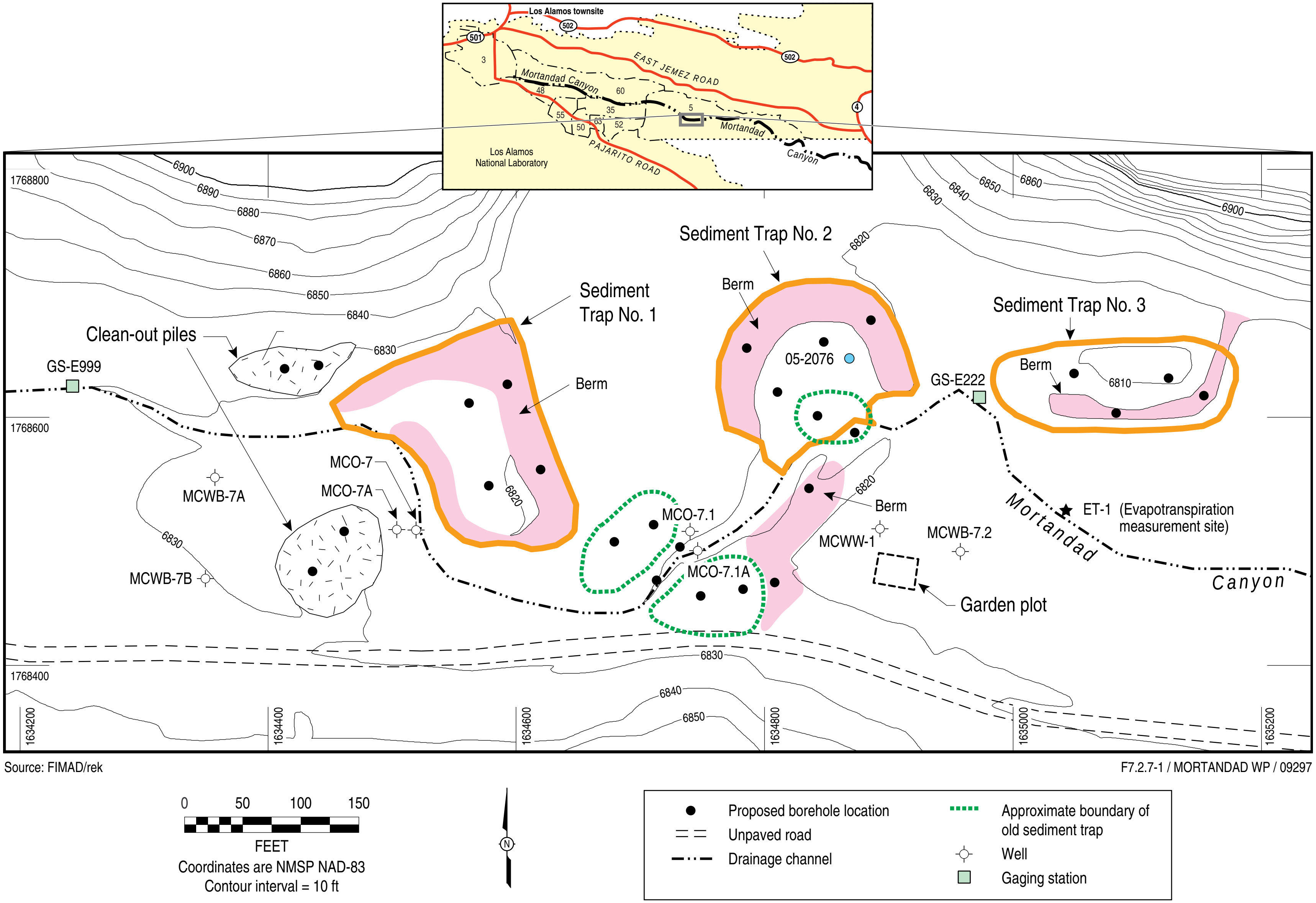


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Figure 7.2.7-1. Locations of the proposed boreholes at PRS No. 00-001 in Mortandad Canyon.

Investigations proposed for reach M-4 (defined in Section 7.2.4.4) as described in Section 7.2.5 and Section 7.2.6 will provide geomorphic mapping and sampling and analysis, respectively, of the active channel and inactive bank deposits. The investigation described in this section focuses primarily on characterizing the sediment trap structures and alluvial material beneath the structures. The investigations proposed for characterizing the alluvial sediments and alluvial groundwater, as described in Section 7.3.4.1.2, include drilling two boreholes (MCO-6.8 and MCO-7.2) near the sediment traps.

Boreholes are proposed to be drilled into the sediment traps, and samples will be collected to determine the vertical extent of contamination associated with each sediment trap. Core samples will be collected from each borehole as described below for the different sediment traps. The samples of the sediments associated with the sediment traps may be sieved before analyses to determine contaminant concentrations within each sediment size fraction. For example, samples may be sieved into two size fractions: one greater than 0.05 mm (very fine sand size and larger) and one less than 0.05 mm (silt and clay size). Samples of the alluvial material beneath the sediment traps will not be sieved.

The following issues will be addressed by the characterization of PRS No. 00-001.

Issue Number 1

What is the distribution of contamination at each of the old sediment traps? What is the vertical distribution of the contamination, and does the contamination extend into the alluvial material beneath the old sediment traps?

Importance

The old sediment traps were constructed in 1976; within 7 to 10 years they had filled with contaminated sediments. At that time the sediments probably contained higher concentrations of contaminants than present-day sediments in the canyon because of higher concentrations of contaminants in the TA-50 RLWTF outfall (see Section 2.4.6 in Chapter 2 of this work plan). The results of preliminary sampling and analyses at the old sediment traps showed that higher activities of radionuclides were detected in the old sediment traps than in the current sediment traps and clean-out piles (see Section 3.4.4.2.4 in Chapter 3 of this work plan). Additionally, the samples collected from both the 0 to 1-ft (0 to 0.30-m) and 2- to 3-ft (0.61- to 0.91-m) intervals in the old sediment traps contained significantly elevated activities of radionuclides, unlike the current sediment traps, which appear to contain significantly elevated activities only within the 0 to 2-ft (0 to 0.61-m) intervals (the 2- to 3-ft [0.61- to 0.91-m] intervals in the current sediment traps contain lower activities of radionuclides, see Section 3.4.4.2.4 in Chapter 3 of this work plan).

Approach

The precise locations of the old sediment traps will be determined to the extent possible using geomorphic mapping, review of aerial and ground photographs, and archival research. The boundaries of the old sediment traps will be delineated and documented on site maps. This effort will be conducted as part of the geomorphic mapping and sediment sampling for reach M-4. One of the old sediment traps located near Sediment Trap No. 2 may have been partially or completely destroyed by excavation of Sediment Trap No. 2. Efforts will be made to locate and characterize this old sediment trap; however, characterization of the old sediment trap may be performed in conjunction with the characterization of Sediment Trap No. 2.

A minimum of two boreholes will be drilled in each of the old sediment traps to collect samples in the sediments within the traps and the alluvial material beneath the traps. The boreholes will be located such that an estimate of the size, shape, and volume of sediments in each sediment trap can be obtained. Additional boreholes may be drilled to delineate the location and size of the sediment traps, if needed. Core samples will be obtained from split-spoon core barrel samplers that will be lithologically examined; detailed logs of the sediments will be maintained to identify the base of the sediment trap.

Four samples will be collected from each borehole. Two samples will be collected from the sediment material within the trap: one from the 1-ft (0.30-m) interval immediately above the base of the sediment trap and one from near the center of the sediment trap. Two samples will be collected from the alluvial material beneath the sediment trap: one from the 1-ft (0.30-m) interval immediately beneath the sediment trap and one from the bottom of the borehole. To obtain information on the depth of migration of contamination beneath the old sediment traps, one of the boreholes at each sediment trap will be drilled to a depth of at least 3 ft (0.91 m) beneath the trap, and the other borehole will be drilled to at least 5 ft (1.5 m) beneath the sediment trap. Table 7.2.7-2 summarizes the samples to be collected in the old sediment traps; Figure 7.2.7-1 shows the locations of the proposed boreholes.

TABLE 7.2.7-2

SUMMARY OF SAMPLES TO BE COLLECTED AT PRS No. 00-001

Issue No.	Location	No. of Boreholes	No. of Samples Collected	No. of Samples Sieved	No. of Samples Analyzed
1	*Old sediment traps*	*6*	*24*	*12*	*36*
2	*Current sediment traps*	*6*	*24*	*0*	*24*
3	*Sediment shafts*	*2*	*8*	*2*	*10*
4	*Clean-out piles*	*4*	*16*	*8*	*24*
	Berms	*8*	*32*	*16*	*48*
	Total	*26*			*142*

Core samples will be field screened for VOCs and gross-alpha, -beta, and -gamma radiation; the results will be used to select samples from the core and to guide advancement of the borehole to depths greater than 5 ft (1.5 m) beneath the sediment trap, if warranted. Drilling deeper than 20 ft (6.1 m) beneath the sediment traps is not anticipated. As discussed in Section 7.3.4.1.2, the boreholes for proposed wells MCO-6.8 and MCO-7.2 are designed to characterize the alluvial sediments and alluvial groundwater near the sediment traps.

Issue Number 2

What is the distribution of contamination at each of the current sediment traps? What is the vertical distribution of the contamination, and does the contamination extend into the alluvial material beneath the sediment traps?

Importance

The current sediment traps were constructed in 1986 and cleaned out and enlarged in 1991. Since 1991 Sediment Trap No. 1 has partially filled with water several times and has received a relatively small volume *of sediment that exists as a small alluvial fan extending from the mouth of the stream channel to near the center of the sediment trap. Since 1991 flow into Sediment Trap No. 2 and Sediment Trap No 3 has not been observed.*

The results of preliminary sampling and analyses showed that the activities of the plutonium isotopes in the samples from the surface of the sediment traps averaged more than 100 times higher than the activities at the 2- to 3-ft (0.61- to 0.91-m) depth. The activities of the plutonium isotopes in the samples from the 2- to 3-ft (0.61- to 0.91-m) depth were 5 to 10 times higher than background levels (see Section 3.4.4.2.4 in Chapter 3 of this work plan). Investigations to characterize the alluvial material beneath the sediment traps have not been performed.

Approach

The precise locations of recent sediments and the associated contaminant inventory within the sediment traps will be determined to the extent possible using geomorphic mapping. This effort will be conducted as part of the geomorphic mapping and sediment sampling for reach M-4.

A minimum of two boreholes will be drilled in each of the current sediment traps, and samples will be collected to characterize the alluvial sediments beneath the traps. Core samples will be obtained from split-spoon core barrel samplers that will be lithologically examined; detailed logs of the sediments will be maintained to identify the effects of water infiltration and contaminant migration beneath the sediment traps. One borehole will be drilled to a depth of 10 ft (3.0 m), and the other borehole will be drilled to a depth of 20 ft (6.1 m) beneath each sediment trap. The drilling will be performed during a dry time of the year to insure that water will not be present.

Four samples will be collected from each borehole. Samples in the 10-ft-deep boreholes will be collected from the from following intervals: 2 to 2.5 ft (0.61 to 0.76 m), 4.5 to 5 ft (1.37 to 1.52 m), 7 to 7.5 ft (2.13 to 2.29 m), and 9.5 to 10 ft (2.90 to 3.05 m). Samples in the 20-ft-deep (6.1-m-deep) boreholes will be collected from the following intervals: 4.5 to 5 ft (1.37 to 1.52 m), 9.5 to 10 ft (2.90 to 3.05 m), 14.5 to 15 ft (4.42 to 4.57 m), and 19.5 to 20 ft (5.94 to 6.10 m). Table 7.2.7-2 summarizes the samples to be collected in the sediment traps; Figure 7.2.7-1 shows the locations of the proposed boreholes.

Core samples will be field screened for VOCs and gross-alpha, -beta, and -gamma radiation; the results will be used to guide advancement of the borehole to depths greater than planned beneath the sediment trap, if warranted. Drilling deeper than 20 ft (6.1 m) beneath the sediment traps, or deeper than 40 ft (12.2 m), is not anticipated.

Issue Number 3

What is the distribution of contamination at the location of the sediment shafts? What is the aerial and vertical distribution of the contamination, and does the contamination extend into the alluvial material beneath the sediment shafts?

Importance

Five sediment shafts were installed in 1974; within two years they had filled with contaminated sediments. At that time the sediments contained higher concentrations of contaminants than present-day sediments in the active stream channel because of higher concentrations in the TA-50 RLWTF outfall. The sediment shafts are each 12 in. (0.30 m) in diameter and 20 ft (6.1 m) deep. Although they have been filled with *sediment since 1976, they have probably continued to infiltrate surface water. Determining the inventory of contaminants associated with the sediment shafts is an important part of the overall inventory of contaminants at PRS No. 00-001.*

No preliminary sampling was performed at the location of the sediment shafts.

Approach

The exact location of the sediment shafts will be determined to the extent possible using geomorphic mapping, archival research, and possibly geophysical techniques such as ground penetrating radar. The location of the sediment shafts will be documented on site maps. This effort will be conducted as part of the geomorphic mapping and sediment sampling for reach M-4. Efforts will be made to locate and characterize the sediment shafts, but if the exact locations of the shafts cannot be determined, boreholes will be drilled to characterize the alluvial sediments in the area where the shafts were installed.

A minimum of two boreholes will be drilled near the sediment shafts, and samples will be collected and analyzed to characterize the sediments within the shafts and the alluvial material adjacent to and beneath the shafts. One borehole will be located within a shaft, and one borehole will be located approximately 5 ft (1.5 m) from a shaft to provide a comparison with the amount of contamination in the alluvial material. The borehole drilled into a shaft will be drilled to a depth of at least 3 ft (0.91 m) beneath the shafts, and the other borehole will be drilled to at least 5 ft (1.5 m) beneath the shafts to obtain information on the depth of migration of contamination beneath the sediment shafts. Additional boreholes may be drilled to delineate the locations and area impacted by the sediment shafts, if needed. Core samples obtained from split-spoon core barrel samplers will be lithologically examined; detailed logs of the sediments will be maintained to identify the base of the sediment shaft(s).

Four samples will be collected from each borehole. From the borehole drilled into a sediment shaft, two samples will be collected from the sediment material within the shaft, one sample will be collected from the 1-ft (0.30-m) interval immediately above the base of the shaft (approximately 19- to 20-ft [5.8- to 6.1-m] depth), and one sample will be collected from near the center of the shaft, (approximately 10-ft [3.0-m] depth). These samples will be sieved to remove particles larger than 2 mm, which will exclude the gravel materials that were placed in the shafts to maintain stability. Two samples will be collected from the alluvial material beneath the shaft: one from the 1-ft (0.30-m) interval immediately beneath the shaft and one from the interval 3 to 5 ft (0.91 to 1.52 m) below the shaft. The exact sample locations will be determined by the results of field screening. The locations of samples from the borehole drilled adjacent to the sediment shafts will be determined by field screening; however, at least one sample will be collected from each 6-ft (1.83-m) depth interval. Tentatively, the samples are proposed to be collected from the following depth intervals: 5 to 6 ft (1.52 to 1.83 m), 11 to 12 ft (3.35 to 3.66 m), 17 to 18 ft (5.18 to 5.49 m), and 24 to 25 ft (7.32 to 7.62 m). Table 7.2.7-2 summarizes the samples to be collected in the sediment shaft; Figure 7.2.7-1 shows the locations of the proposed boreholes.

Core samples will be field screened for VOCs and gross-alpha, -beta, and -gamma radiation; the results will be used to guide advancement of the borehole to depths greater than 5 ft (1.5 m) beneath the sediment shafts, if warranted. Drilling deeper than 40 ft (12.2 m) beneath the sediment shafts is not anticipated.

Issue Number 4

What is the distribution of contamination in the clean-out piles and berms adjacent to each sediment trap? What is the vertical distribution of the contamination, and does the contamination extend into the alluvial material beneath the clean-out piles and berms?

Importance

The sediment traps were constructed in 1986 and cleaned out and enlarged in 1991. The berms surrounding the sediment traps contain alluvial material from the initial excavation and possibly additional materials from the clean-out in 1991. The two clean-out piles adjacent to Sediment Trap No. 1 are the result of removing sediment material from this sediment trap during the clean-out and enlargement in 1991. An old berm is present at the east end of one of the old sediment traps, which extends from near this old sediment trap to Sediment Trap No. 2. This old berm has not previously been investigated. A total of four berms are present at PRS No. 00-001.

During the preliminary investigation in 1995, samples were collected at the two clean-out piles from depths up to 3 ft (0.91 m). The results of the analyses indicated that significantly elevated activities of radionuclides are located in the northern clean-out pile; however, radionuclide activities in samples collected from the larger, southern clean-out pile were not as elevated (see Section 3.4.4.2.4 in Chapter 3 of this work plan). Most of the contaminated material cleaned out of Sediment Trap No. 1 may be located near the base of the clean-out piles, and cleaner alluvial material from the enlargement of the sediment traps may be located on the top of the clean-out piles and/or on the berms that surround the sediment traps. Samples were not collected from the berms during the preliminary investigation. Therefore, additional sampling and analysis is necessary to determine the distribution of contamination associated with the clean-out piles and berms.

Approach

A minimum of two boreholes will be drilled in each clean-out pile and each berm, and samples will be collected to characterize the sediments comprising the piles and berms and to characterize the alluvial material beneath the piles and berms. The boreholes will be located such that an estimate of the size, shape, and volume of sediments in each pile and berm can be obtained. Additional boreholes may be drilled to further characterize the piles and berms, if needed. Core samples obtained from hand-augers or split-spoon core barrel samplers will be lithologically examined; detailed logs of the sediments will be maintained to identify the base of the piles and berms.

Four samples will be collected from each borehole. Two samples will be collected from the sediment material from within the pile or berm, one sample will be collected from the 1-ft (0.30-m) interval immediately above the base of the pile or berm, and one sample will be collected from near the center of the pile or berm. Two samples will be collected from the alluvial material beneath each pile or berm: one from the 1-ft (0.30-m) interval immediately beneath the pile or berm and one from the bottom of the borehole. One of the boreholes at each pile or berm will be drilled to a depth of at least 3 ft (0.91 m) beneath the pile or berm, and the other borehole will be drilled to at least 5 ft (1.5 m) beneath the pile or berm to obtain information on the depth of migration of contamination beneath the pile or berm. Table 7.2.7-2 summarizes the samples to be collected in the clean-out piles and berms; Figure 7.2.7-1 shows the locations of the proposed boreholes.

Core samples will be field screened for VOCs and gross-alpha, -beta, and -gamma radiation; the results will be used to guide advancement of the borehole to depths greater than 5 ft (1.5 m) beneath the pile or berm, if warranted. Drilling deeper than 10 ft (3.0 m) beneath the piles or berms is not anticipated.

7.2.7.2 Characterization of PRS No. 50-006(a)

PRS No. 50-006(a) is located at the head of Ten Site Canyon and is associated with past spills from an outfall from TA-50, as described in Section 2.4.6 in Chapter 2 of this work plan. The site was partially *decontaminated in 1981, and in 1996 and 1997 personnel from Field Unit 5 of the Environmental Restoration Project performed an interim action at the site to remove a small volume of contaminated sediments. The geomorphic mapping and sampling proposed for reach TS-1, as discussed in Section 7.2.4.1, will determine if contaminant migration from this site has occurred in upper Ten Site Canyon. Because this PRS was a one-time release and contaminants at the site have probably been adequately cleaned up, no subsurface investigations are presently proposed for PRS No. 50-006(a).*

7.2.7.3 Characterization of PRS No. 50-006(d)

PRS No. 50-006(d) is contamination associated with the TA-50 RLWTF outfall in Effluent Canyon, as described in Section 2.4.6 in Chapter 2 of this work plan. This outfall is designated as National Pollutant Discharge Elimination System outfall 051 and has operated regularly since 1963. Contaminants discharged from this outfall are discussed further in Section 3.8 in Chapter 3 of this work plan. Samples were collected as part of the investigation for this site in 1993, and the preliminary results are presented and discussed in Section 3.4.4.2.2 in Chapter 3 of this work plan.

A groundwater discharge plan for this outfall was submitted to the New Mexico Environment Department (NMED) in August 1996 as part of the Groundwater Discharge Plan Application (LANL 1996, 55688). The investigations proposed for reach E-1 (defined in Section 7.2.4.2) as described in Section 7.2.5 and Section 7.2.6 will provide geomorphic mapping and sediment sampling and analysis, respectively. The surface water and groundwater investigations proposed in Section 7.3.4 will supplement the investigation proposed in this section. Collectively, the investigations proposed in Effluent Canyon and Mortandad Canyon will contribute to the monitoring requirements of the TA-50 Groundwater Discharge Plan.

Issue

What is the distribution of contamination in the sediments below the TA-50 RLWTF outfall in Effluent Canyon? What is the vertical distribution of the contamination, and does the contamination extend into the bedrock units beneath the outfall area?

Importance

The results of the preliminary investigation show that activities of some radionuclides are elevated up to more than 2000 times background levels in the sediments below the TA-50 RLWTF outfall (see Section 3.4.4.2.2 in Chapter 3 of this work plan). Concentrations of nine metals are elevated approximately five to seven times background levels. The preliminary samples were collected from depths up to 4 ft (1.2 m). Additional investigations are needed to determine the distribution of contamination associated with this outfall.

Approach

The channel and bank sediments will be mapped using geomorphic mapping, and the associated contaminant inventories in the stream channel below the TA-50 RLWTF outfall will be determined using radiometric surveying and sediment sampling. This will be performed as part of the geomorphic mapping and sediment sampling plan for reach E-1.

A minimum of two boreholes will be drilled in the stream channel in lower Effluent Canyon, and samples will be collected to characterize the sediments beneath the outfall area. Core samples obtained from split-spoon core barrel samplers will be lithologically examined; detailed logs of the sediments will be maintained to identify the effects of water infiltration and contaminant migration beneath the outfall area.

One borehole will be drilled to a depth of 40 ft (12.2 m), and the other borehole will be drilled to a depth of 80 ft (24.4 m).

A minimum of eight samples will be collected from each borehole. Samples will be collected from each 5-ft (1.52 m) interval from the 40-ft-deep (12.2-m-deep) borehole and from each 10-ft (3.05-m) interval in the 80-ft-deep (24.2-m-deep) borehole. Figure 7.2.7-2 shows the locations of the proposed boreholes.

Core samples will be field screened for VOCs and gross-alpha, -beta, and -gamma radiation; the results will be used to guide advancement of the borehole to depths greater than planned beneath the outfall area, if warranted. Drilling deeper than 100 ft (30.5 m) beneath the outfall area is not anticipated. The boreholes for proposed wells MCOBT-4.4 and R-13, as discussed in Section 7.3.4.1.4 and Section 7.3.4.1.5, respectively, are designed to characterize the alluvial and bedrock sediments and to determine if intermediate perched groundwater is present below the TA-50 RLWTF outfall.

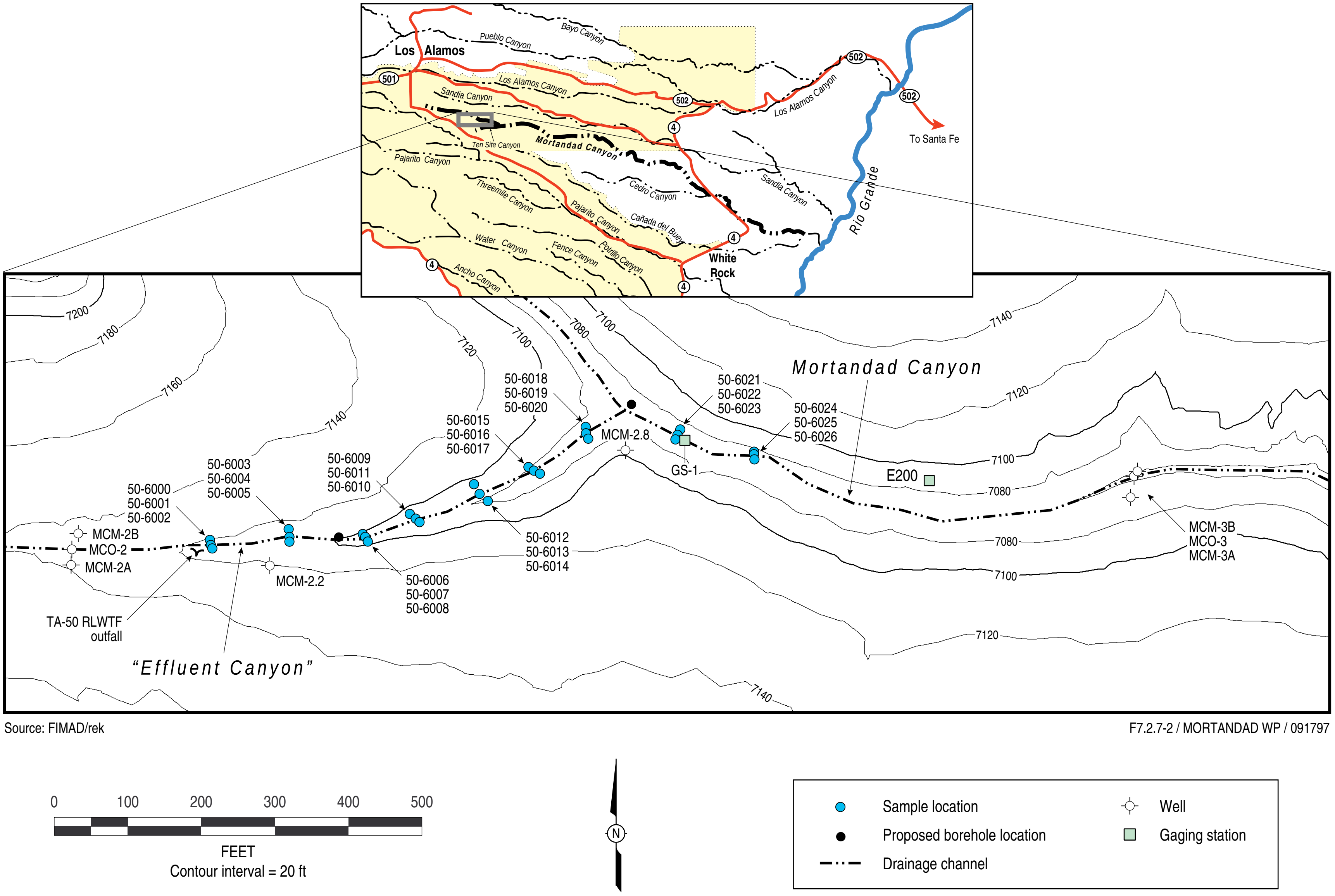
7.3 Surface Water and Groundwater Sampling and Analysis Plan

This section presents the sampling and analysis plan for investigating surface water and groundwater in the Mortandad Canyon system. Surface water sampling and analysis is included with the groundwater investigation because surface water in the canyon channel recharges the alluvial groundwater. The strategy for sampling surface water, alluvial groundwater, Bandelier Tuff groundwater, 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, 12 wells are proposed: 7 alluvial wells, 2 Bandelier Tuff wells, and 3 regional aquifer wells. Sampling and analysis of surface water and groundwater will focus on characterizing the hydrogeology of the Mortandad Canyon system as well as characterizing the nature of Laboratory-derived contaminants present in both surface water and groundwater.

7.3.1 Objective

The objective of the surface water and groundwater sampling and analysis plan is to address the HSWA Module (EPA 1990, 1585) requirements for characterizing the hydrogeology of the Mortandad Canyon system to determine the Laboratory's impact on surface water and groundwater. These requirements are discussed in detail in Chapter 1 of the core document (LANL 1997, 55622). This work plan also addresses, in part, the requirements of the groundwater discharge plan for the TA-50 RLWTF (LANL 1996, 55688) for characterizing contamination of groundwater in Mortandad Canyon. 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 sampling and analysis plan consists of three phases: (1) a field investigation phase, (2) a data analysis phase, and (3) a 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 both conceptual and computer models that quantitatively 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.



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F7.2.7-2 / MORTANDAD WP / 091797

Figure 7.2.7-2. Locations of the proposed boreholes at PRS No. 50-006(d).

The field investigation phase includes the following:

1. *sample and analyze surface water and alluvial, intermediate perched zone, and regional aquifer groundwater to characterize nature and extent of contamination;*
2. *collect surface water flow data from gaging stations;*
3. *measure evapotranspiration (ET) time series data from the canyon floor for water-balance calculations;*
4. *collect water level time series data from each groundwater zone;*
5. *measure field parameters in water samples (pH, temperature, specific conductance, alkalinity, dissolved oxygen, and turbidity); and*
6. *collect hydrogeologic data to characterize the vadose zone and other hydrologic zones.*

The data analysis phase includes the following:

1. *evaluate surface water infiltration losses into the alluvium,*
2. *evaluate ET losses from the canyon system,*
3. *measure infiltration into the Bandelier Tuff,*
4. *compare and contrast the geochemistry of all water samples, and*
5. *evaluate the potential for hydraulic and mass transport among all water-bearing zones.*

Development of a detailed conceptual model includes the following:

1. *validate and refine the conceptual model by integrating the results of field investigations and data analyses into a flow-transport model(s),*
2. *evaluate present-day and future exposure at various locations,*
3. *evaluate potential contaminant migration pathways and future concentrations, and*
4. *identify contamination problems that require remediation.*

After all three phases have been successfully completed, the Laboratory will satisfy the following requirements: (1) hydrogeological and geochemical characterization of the Mortandad Canyon system; (2) evaluation of historical, present, and future exposure risks; and (3) detailed recommendations for a long-term environmental surveillance program plan that optimizes future water sample collection and the frequencies and locations of water level measurements.

The sampling and analysis plan 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 *four 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 Data Quality Objectives for Surface Water and Groundwater Investigations

7.3.2.1 Surface Water and Alluvial Groundwater Data Quality Objectives

This section describes the data quality objectives process (EPA 1994, 50288) as completed for the surface and groundwater sampling and analysis portion of this chapter.

1. *State the problem.*

   What is the present-day risk posed by contaminants in the surface water and alluvial groundwater in Mortandad Canyon? How will that risk change with time?

2. *Identify the decision(s).*

   - *What is the flux of water moving out of the alluvium west of MCO-5 and TW-8?*
   - *What is the areal extent of groundwater in the alluvium and Cerro Toledo interval?*
   - *Is there a process or pathway for exposure?*
   - *Are there or could there be contaminant levels above the maximum contaminant levels (MCLs), New Mexico Water Quality Control Commission standards (1995, 54406), or UTLs for background or at levels posing unacceptable human health or ecological risks in appropriate land use scenarios?*
   - *What is the extent of contamination in sediments beneath the sediment traps?*

3. *Identify inputs to decision(s).*

   - *Infiltration rate of surface water and alluvial water below GS-1*
   - *Moisture content/saturation, water levels, saturated thickness, and temporal variations*
   - *Analyses of core and/or water samples for geochemical parameters and species, including contamination indicators, temporal water quality variations, and a validated conceptual model of groundwater geochemistry*
   - *Hydrologic properties, geologic structure, hydraulic gradients and predicted flow directions, land use scenarios, spring discharge information, current/proposed well-withdrawal points, and a validated conceptual model of the hydrologic system*

4. *Define the study boundaries.*

   - *Spatial*

     For initial planning use, the study will be limited by the boundaries for the Mortandad Canyon investigation.

- *Temporal*

  Two sampling events will be conducted approximately six months apart

  Chemical indicators sufficient to determine seasonal effects will be analyzed

  Sampling of the upgradient alluvial well will be conducted semiannually

- *Interpretive Study*

  Interpretive study will be a major component of the investigation because of the extensive 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.

- *Risk Assessment*

  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 investigation, 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]).

5. *Develop a decision rule.*

   Present-day human health risk assessments will include evaluation of alluvial groundwater with the following assumptions.

   Drinking water pathways

   - *Contaminants with concentrations above standards or UTLs for background or that show trends (observed or predicted) in concentrations over time, which indicates that contaminants may exceed standards or UTLs in the future, will be evaluated.*

   - *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 Pueblo 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.*

6. *Specify limits on uncertainty.*

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).

7.3.2.2 Bandelier Tuff and Regional Aquifer Groundwater Data Quality Objectives

1. *State the problem.*

   Does the potential exist for contaminants to move into Bandelier Tuff intermediate perched zones (Guaje Pumice Bed) and the regional aquifer? Does it pose a potential risk?

2. *Identify the decision(s).*

   - *Is intermediate perched zone groundwater present in the Bandelier Tuff (Guaje Pumice Bed)?*
   - *Is there a process or pathway for exposure?*
   - *Are there or could there be contaminant levels at or above the MCLs, New Mexico Water Quality Control Commission standards (1995, 54406), or UTLs for background or at levels that pose unacceptable human health or ecological risks in appropriate land use scenarios?*

3. *Identify inputs to decision(s).*

   - *Moisture content/saturation, water levels, saturated thickness, and temporal variations*
   - *Analyses of core and/or water samples for geochemical parameters and species including contamination indicators, distribution coefficients, temporal water quality variations, and a validated conceptual model of aquifer chemistry*
   - *Hydrologic properties, geologic structure, hydraulic gradients and predicted flow directions, land use scenarios, spring discharge information, current/proposed well-withdrawal points, and a validated conceptual model of hydrologic system*

4. *Define the study boundaries.*

   - *Spatial*

     For initial planning use, the study will be limited by the boundaries for the Mortandad Canyon investigation. Decisions 1 and 3 may require extension of the study area east and south of the limits of the canyons and possibly deeper toward the regional aquifer, depending on the actual observations.

- *Temporal*
  - *Field Study*

    Continuous groundwater levels will be recorded for two years in wells containing pressure transducers.

    Chemical indicators sufficient to determine seasonal effects will be analyzed.
  - *Interpretive Study*

    Interpretive study will be a major component of the investigation because of the extensive 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.
  - *Risk Assessment*

    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]).

5. *Develop a decision rule.*

   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 with concentrations above standards or UTLs for background or that show trends (observed or predicted) in concentrations over time, which indicates that contaminants may exceed standards or UTLs in the future, will be evaluated.*
   - *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 Pueblo 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.*

6. *Specify limits on uncertainty.*

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 Technical Approach for Surface Water and Groundwater Investigation

The technical approach to the surface water and groundwater investigation follows the decision logic discussed in Chapter 5 of the core document (LANL 1997, 55622).

The key hypotheses of the current conceptual model (discussed in Chapter 4 of this work plan) that will be tested during the groundwater investigation are as follows in order of importance.

- *(C14) ET removes approximately 20% of the water that is added to Mortandad Canyon each year. Most water (possibly 80 to 90%) is lost from the alluvium by moving downward into underlying units. Contaminated alluvial groundwater infiltrates into the underlying Bandelier Tuff and possibly other hydrogeologic units. Neither the mechanism nor the location of the loss is known. Two principal water-balance models present alternate hypotheses: one indicates that most losses occur upstream of the confluence with Ten Site Canyon; the other suggests that most losses occur downstream of the confluence.*

- *(C5) Alluvial groundwater is recharged in the middle canyon (Effluent Canyon eastward to test well [TW] -8) by infiltration of surface water from the stream channel and in the lower canyon (TW-8 eastward to the sediment traps) by groundwater moving downgradient from upstream reaches.*

- *(C18) It is not known whether losses from alluvium recharge any intermediate perched zone(s). Based on logs of the boreholes for TW-8 and nearby water supply wells (PM-3 and PM-5), no saturated zones have been observed in any unit beneath the alluvium until the depth of the regional aquifer. However, when the boreholes for these wells were drilled, intermediate perched zones were not anticipated, and any perched water may not have been recognized because of drilling methods (fresh water and mud rotary drilling). Moreover, the drilling for TW-8 was conducted in 1960 before discharges from the TA-50 RLWTF began; intermediate perched zones could have developed subsequent to and as a result of these discharges.*

- *(C8) Tritium and other conservative dissolved species move into underlying stratigraphic units. The migration process (for example, saturated and unsaturated liquid-film or unsaturated vapor-phase flows) and rate depend on the properties of the interface between the stratigraphic units, which may be highly variable both spatially and temporally.*

- *(C2) The alluvium contains distinct zones; some may cause limited perching within the alluvium and/or limited confinement of some deeper zones. When well MCO-8 was installed in 1960, the* *alluvial groundwater exhibited slight artesian conditions (see Section 3.7.2 in Chapter 3 of this work plan).*

- *(C6) Dilution and attenuation by geochemical processes leads to generally decreased contaminant concentrations (relative to conservative species such as chloride and tritium) downgradient within a water-bearing zone. Lowest concentrations of contaminants are observed in the alluvial groundwater in lower Mortandad Canyon downstream of the sediment traps. Colloidal transport through the alluvium is possible based on the distribution of actinides and the fission products observed.*

- *(D4) 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 Mortandad Canyon.*

- *(D7) 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.*

- *(E4) Intermediate perched zones have not been observed to extend laterally beneath mesas. However, lateral spreading of such perched zones could occur downgradient if the canyon course and the gradient of the perched zone do not coincide. There is some indication of the presence of paleosurfaces beneath Mortandad Canyon, which suggests the possibility of movement south-southeast from the axis of the canyon if intermediate perched zones occur.*

- *(E1) Intermediate-depth units within the Bandelier Tuff (Guaje Pumice Bed), Cerro Toledo interval, basalts, and the Puye Formation in the Mortandad 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 (Pueblo Canyon, Los Alamos Canyon, and Sandia Canyon).*

- *(E2) Intermediate perched zones could be expected in areas where a sufficient water source is present to maintain saturation; the annual losses from the Mortandad Canyon alluvium are sufficient to warrant further investigation of potential intermediate perched zones, especially within the Guaje Pumice Bed.*

- *(E5) 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 either the losses from the alluvium or the apparent dilution of tritium in some locations.*

- *(F1) Vapor-phase transport is important for some volatile contaminants and is a viable mechanism by which tritium may have moved much deeper than any other contaminant (except chloride and nitrate).*

- *(G2) 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. 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 as regards layering and the influence of anisotropy in the vertical and horizontal permeability.*

The hydrodynamics of the loss of groundwater from the alluvium in Mortandad Canyon is not well understood (as discussed in Chapter 3 of this work plan). The conceptual model of groundwater loss (as discussed in Chapter 4 of this work plan) includes vertical or lateral infiltration of alluvial groundwater to the Bandelier Tuff units including the Tshirege Qbt 1g unit west of Ten Site Canyon and the Cerro Toledo interval east of Ten Site Canyon. Groundwater may move downgradient 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 Mortandad Canyon between well MCO-6 and well MCO-7. 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.

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.*

- *Investigations in the alluvium will focus on determining (1) the potential for recharge from the alluvium to deeper zones, (2) the nature and extent of contamination, and (3) the physical and geochemical nature of perching layers at the alluvium/Bandelier Tuff interface.*

- *Water-balance studies for the alluvium will be performed by the Field Unit 4 technical team and the Laboratory Water Quality and Hydrology group (ESH-18) concurrently with the investigations described herein. The water-balance studies will use existing water-balance wells equipped with pressure transducers, which were installed in 1996 at the request of and with the support of the ER Project, plus the existing and proposed gaging stations and the two proposed 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). These studies will address key hypothesis C14 listed above.*

- *Investigations in the Bandelier Tuff (Guaje Pumice Bed) will focus on determining (1) the nature and vertical extent of contamination from tritium, chloride, and other solutes documented by Stoker et al. (1991, 7530); and (2) the geochemical and hydrogeologic features that control contaminant distributions within the Bandelier Tuff.*

- *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 three regional aquifer characterization wells within and south of Mortandad Canyon.*

- *The three new regional aquifer wells and the existing well TW-8 completed in the regional aquifer will be sampled for analyses of 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 (regional aquifer) in Mortandad Canyon.*

- *Recommendations will be made regarding corrective measures to groundwater zones and monitoring strategies for the ER Project and/or Laboratory environmental surveillance.*

Proposed alluvial wells, Bandelier Tuff wells, and regional aquifer wells are listed in Table 7.3.3-1, Table 7.3.3-2, and Table 7.3.3-3, respectively. Locations of the wells are shown in Figure 7.3.3-1 and Figure 7.3.3-2 (and also in Figure A-2 in Appendix A of this work plan).

TABLE 7.3.3-1

DESCRIPTION OF PROPOSED SURFACE WATER GAGING STATION AND ALLUVIAL/CERRO TOLEDO INTERVAL WELLS[a]

Well Designation[b]	Location[c]
GS-1.3	*Proposed gaging station 1000 ft east of GS-1*
MCO-3	*Proposed replacement well for old MCO-3*
MCO-0.6	*Proposed observation well west of TA-50 RLWTF outfall*
MCO-4B	*Existing observation well east of TA-50 RLWTF outfall*
TSCO-6A	*Proposed well for lower Ten Site Canyon*
MCO-7.2	*Proposed well between MCO-7 and MCO-8 at sediment traps*
MCO-6.8	*Proposed well between MCO-6 and MCO-7 below confluence with Ten Site Canyon*
MCO-13A and MCO-13B	*Proposed wells near MCO-13*

a. Alluvial/Cerro Toledo interval wells are listed in order of priority.
b. GS = gaging station, MC = Mortandad Canyon, O = observation, TSC = Ten Site Canyon
c. See Figure 7.3.3-1 for proposed locations.

TABLE 7.3.3-2

DESCRIPTION OF PROPOSED BANDELIER TUFF WELLS

Well Designation[a]	Location[b]
MCOBT-4.4	*West of TW-8, near MCWB-4*
MCOBT-8.5	*East of MCC-8.2*

a. MC = Mortandad Canyon, O = observation, BT = Bandelier Tuff
b. See Figure 7.3.3-2 for proposed locations.

TABLE 7.3.3-3

DESCRIPTION OF PROPOSED REGIONAL AQUIFER WELLS[a]

Well Designation[b]	Location[c]
R-15	*Southeast of sediment traps*
R-13	*Downstream of TA-50 RLWTF outfall, near MCO-3*
R-14	*North-northwest of supply well PM-5, south of MCO-4*

a. Regional aquifer wells are listed in order of priority.
b. R = regional aquifer
c. See Figure 7.3.3-2 for proposed locations.

7.3.4 Surface Water and Groundwater Characterization

This section describes the sampling design for collecting surface water and groundwater (alluvium, Bandelier Tuff, and regional aquifer) samples and borehole core samples. Particular emphasis is given to the criteria for selecting the locations of the proposed 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 seven alluvial observation wells and two Bandelier Tuff wells. The regional aquifer will be sampled through existing wells and three new wells.

7.3.4.1 Alluvial, Bandelier Tuff, and Regional Groundwater Investigations

The proposed alluvial wells are listed in Table 7.3.3-1 in order of priority for installation. In addition, a new surface water gaging station is proposed. The rationale for these is introduced briefly below in order of priority. The rationale for each well is discussed in greater detail in the following sections.

1. *Install one alluvial well in lower Ten Site Canyon (TSCO-6A) to determine whether alluvial groundwater is present and to characterize contaminant distributions in alluvium and bedrock. Split-spoon samples sealed in moisture protection bags will be analyzed for moisture content and contaminants. This well will complement existing water-balance well TSWB-6 and replace the lost observation well TSCO-1.*

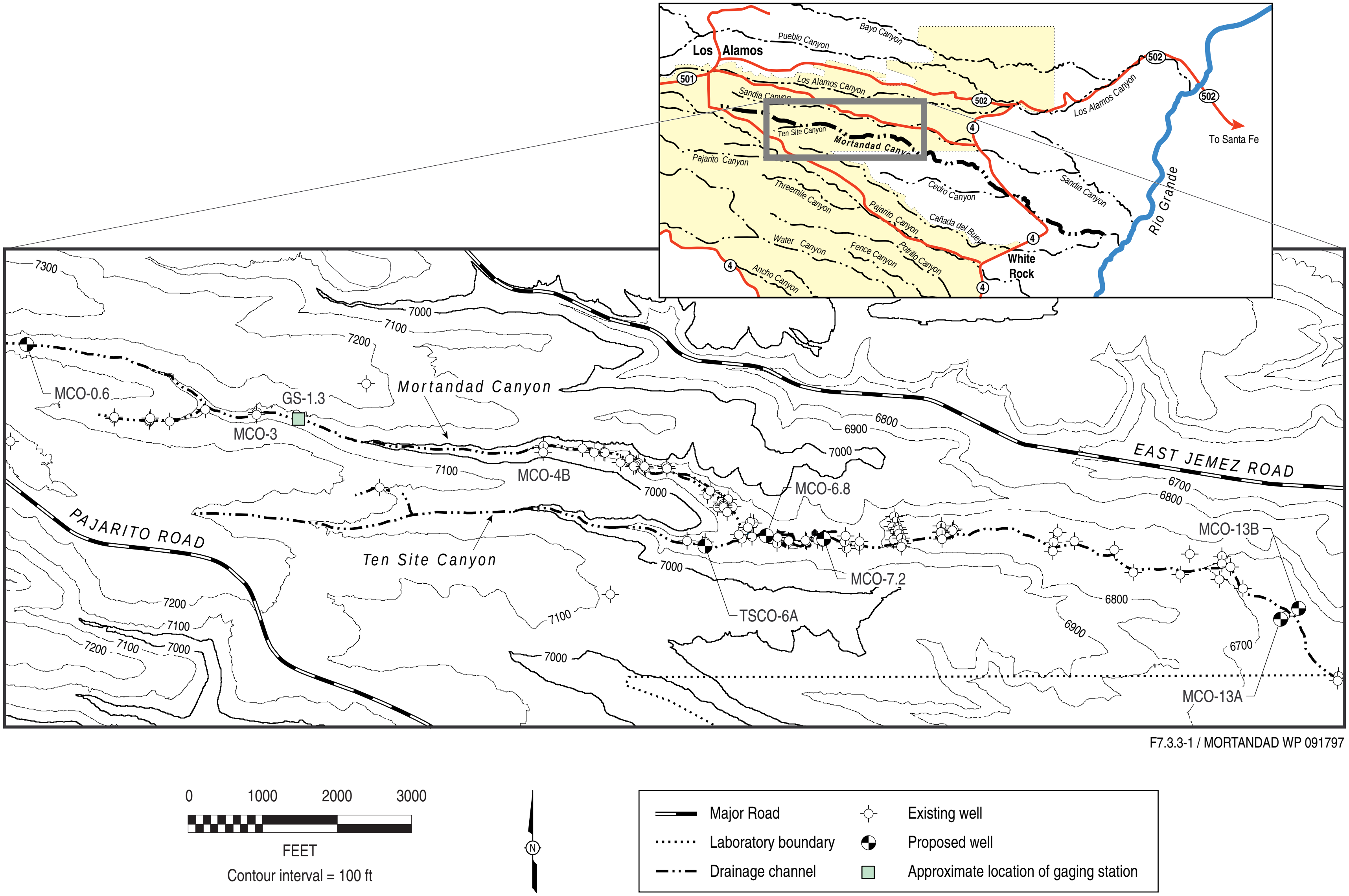
2. *Install one well in upper Mortandad Canyon (MCO-0.6) above the confluence with Effluent Canyon, which will provide both groundwater samples representing the upstream contributions and water level data.*

3. *Replace or upgrade alluvial well MCO-3 to provide adequate monitoring data.*

4. *Substitute alluvial well MCO-4B for MCO-4 to provide future monitoring data; abandon MCO-4.*

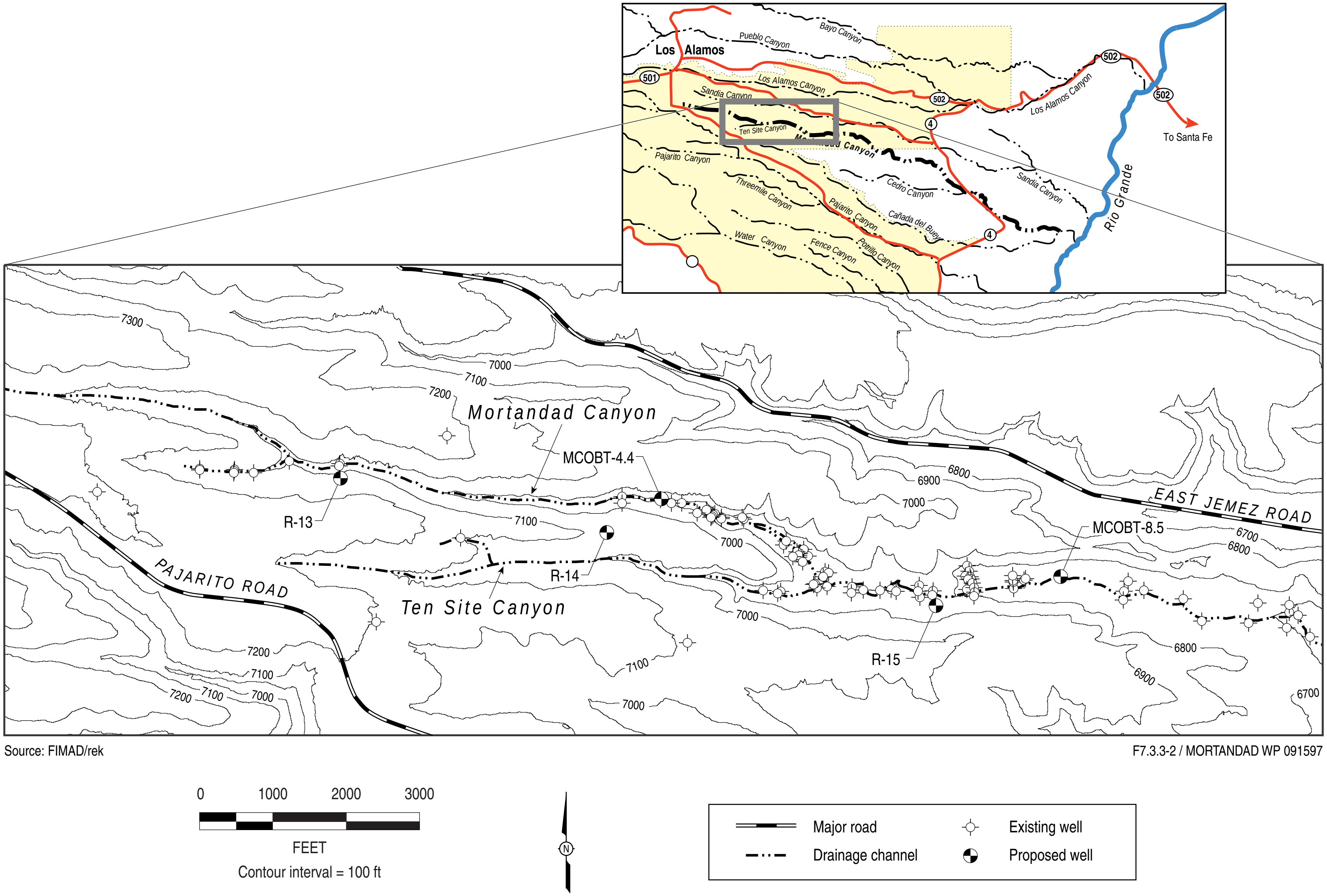
5. *Given suitable terrain, install a surface water gaging station (GS-1.3) approximately 1000 ft (304 m) east of GS-1.*

6. *Install one alluvial/Cerro Toledo interval well (MCO-7.2) near the sediment traps to characterize the subsurface stratigraphy, collect and analyze groundwater samples, and establish the extent of saturation.*



F7.3.3-1 / MORTANDAD WP 091797

Figure 7.3.3-1. Locations of proposed alluvial/Cerro Toledo interval wells.



Source: FIMAD/rek

F7.3.3-2 / MORTANDAD WP 091597

Figure 7.3.3-2. Locations of proposed Bandelier Tuff wells and regional aquifer wells.

7. *Install one alluvial/Cerro Toledo interval well (MCO-6.8) between MCO-6 and MCO-7.*

8. *Install two wells (MCO-13A and MCO-13B) north and south of MCO-13 near the Laboratory boundary to characterize core samples and evaluate groundwater chemistry within the alluvium/Cerro Toledo interval.*

In addition, pressure transducers are proposed to be installed in selected alluvial/Cerro Toledo interval wells in Mortandad Canyon to provide water level data in real time.

The proposed Bandelier Tuff characterization wells are listed in Table 7.3.3-2.

The purposes of MCOBT-4.4 and MCOBT-8.5 are to (1) characterize the vertical extent of a known tritium plume within the Otowi Member, (2) determine the degree of saturation of the Guaje Pumice Bed, and (3) determine whether the Guaje Pumice Bed is contaminated. The boreholes for these wells will be continuously cored in the tuff, and the cores will be analyzed to characterize the alluvial and bedrock structure and stratigraphy. Information will be collected on the moisture and/or tritium vapor-phase movement beneath the alluvium as a possible pathway to a potential intermediate perched zone. The wells will be completed within the Guaje Pumice Bed of the Bandelier Tuff. The two wells will provide hydrogeologic and geochemical data and information, which support discharge plan requirements in accordance with the New Mexico Water Quality Control Commission regulations that apply to TA-50 discharges (LANL 1996, 55688).

The proposed regional aquifer characterization wells are listed in Table 7.3.3-3 in order of priority. Well R-15 will be located in lower Mortandad Canyon near the sediment traps. The location of well R-13 will be determined based on stratigraphic, hydrologic, and geochemical data collected from the other regional aquifer wells and the Bandelier Tuff well. Well R-14 will be located between TW-8 and supply well PM-5. These wells will characterize subsurface bedrock units and regional structure, and provide characterization; selection as a monitoring well for the regional aquifer will be made after evaluating the data.

Table 7.3.4-1 summarizes the surface water and groundwater sample collection design; Table 7.3.4-2 summarizes the proposed borehole core samples. The sampling strategy for each of the hydrogeologic zones is described in detail in the following sections as is the strategy for the collection of borehole core samples. Where new wells are proposed, 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.

TABLE 7.3.4-1

SUMMARY OF COLLECTION DESIGN FOR SURFACE WATER AND GROUNDWATER SAMPLES

Hydrological Zone	No. of Wells	Sampling Frequency	Annual No. of Samples
Surface water	*1 station*	*During snowmelt and summer storm events*[a]	*40 (20 filtered, 20 unfiltered)*
Alluvial, observation wells[b]	*8*	*At completion and six months*	*32 (16 filtered, 16 unfiltered)*
Bandelier Tuff, observation wells[b]	*2*	*At completion and six months*	*8 (4 filtered, 4 unfiltered)*

a. *If surface water is present, samples will be collected twice during snowmelt and three times during summer storm events (six samples each storm event) at one operating gaging station (see Section 7.3.4.1.1). Numbers of samples are the maximum that will be collected if water is available.*

b. *See Table 7.3.4-2 for proposed core collection and analysis.*

TABLE 7.3.4-2

SUMMARY OF CORE AND WATER SAMPLES PROPOSED FOR MORTANDAD CANYON BOREHOLES

Borehole	Proposed Depth (ft)	Formation	Proposed Depth Beginning (ft)	Proposed Depth Ending (ft)	Core Sampling Frequency (ft)	Analytical Suite/ Proposed No. of Core Samples			Proposed No. of Water Samples	Comment
						a	b	c		
MCO-0.6	*<30*	*Qal*	*0*	*5*	*5*	*1*				
		Perched water	*4*	*5*	*N/A*[d]				*2*	*Water sample*[e,f]
		Qbt	*5*	*20*	*10*	*2*				
MCO-3	*<30*	*Qal*	*0*	*7*	*5*	*2*				
		Perched water	*4*	*7*	*N/A*				*2*	*Water sample*[e,f]
		Qbt	*7*	*20*	*10*	*1*	*1*			
MCO-6.8	*130*	*Qal*	*0*	*45*	*10*	*1*	*4*			
		Perched water	*40*	*45*	*N/A*				*2*	*Water sample*[e,f]
		Qbt 1g(?)	*45*	*50*	*5*		*1*			*Thickness unknown*
		Qct	*50*	*130*	*10*		*3*	*5*		
MCO-7.2	*130*	*Qal*	*0*	*60*	*10*	*1*	*3*	*3*		
		Qbt 1g(?)			*5*		*1*			*Presence questionable*
		Qct	*60*	*130*	*10*		*2*	*5*		
		Perched water	*60*	*65*	*N/A*				*2*	*Water sample*[e,f]
MCO-13A	*120*	*Qal*	*0*	*65*	*10*	*1*	*5*			
		Qct	*65*	*110*	*10*		*2*	*3*		
		Perched water	*105*	*110*	*N/A*				*2*	*Water sample*[e,f]
		Qbo	*110*	*120*	*10*		*1*			
MCO-13B	*120*	*Qal*	*0*	*65*	*10*	*1*	*5*			
		Qct	*65*	*110*	*30*		*2*	*5*		
		Perched water	*105*	*110*	*N/A*				*2*	*Water sample*[e,f]
		Qbo	*110*	*120*	*10*		*1*			
TSCO-6A	*120*	*Qal*	*0*	*35*	*10*	*1*	*3*			
		Qbt 1g	*35*	*50*	*5*		*3*			

a. Full-suite core sample analysis listed in Table 7.3.4-5

b. Limited-suite core sample analysis, including the following: trace elements, ^{90}Sr, tritium (high detection limit), hydrologic properties, and anions

c. Minimal analyses on core samples for moisture, tritium, chloride, and nitrate only

d. N/A = not applicable

e. Water sample analysis includes those analytes listed in Table 7.3.4-4 and Table 7.3.4-7

f. Water samples will be collected twice yearly (see text)

TABLE 7.3.4-2 (continued)

SUMMARY OF CORE AND WATER SAMPLES PROPOSED FOR MORTANDAD CANYON BOREHOLES

Borehole	Proposed Depth (ft)	Formation	Proposed Depth Beginning (ft)	Proposed Depth Ending (ft)	Core Sampling Frequency (ft)	Analytical Suite/ Proposed No. of Core Samples			Proposed No. of Water Samples	Comment
						a	b	c		
TSCO-6A	*120*	*Qct*	*50*	*120*	*10*		*3*	*4*		
		Perched water?	*80*	*90*	*N/A*[d]				*2*	*Water sample*[e,f]
MCOBT-4.4	*510*	*Qal*	*0*	*25*	*10*	*1*	*1*	*1*		
		Qbt 1g	*25*	*70*	*10*		*2*	*2*		
		Qbtt	*70*	*73*	*5*		*1*			
		Qct	*73*	*140*	*10*		*3*	*4*		
		Qbo	*140*	*450*	*20*		*3*	*12*		
		Qbog	*450*	*490*	*10*		*2*	*2*		
		Perched water?	*480*	*490*	*N/A*				*3*	*Water sample*[e,g]
		Tp (basalt)	*490*	*510*	*10*		*1*	*1*		
		Pore water in vadose zone?							*5*	*Water sample*[e,h]
MCOBT-8.5	*420*	*Qal*	*0*	*65*	*10*	*1*	*3*	*3*		
		Qct	*65*	*125*	*10*		*3*	*4*		
		Qbo	*125*	*360*	*20*		*3*	*10*		
		Qbog	*360*	*400*	*10*		*2*	*2*		
		Perched water?	*390*	*400*	*N/A*				*3*	*Water sample*[e,g]
		Tp (basalt)	*400*	*420*	*10*		*1*	*1*		
		Pore water in vadose zone?							*5*	*Water sample*[e,h]
R-13	*1330*	*Qbt 2*	*0*	*70*	*20*		*4*			
		Qbt 1v	*70*	*140*	*10*		*3*	*4*		
		Qbt 1g	*140*	*210*	*10*		*3*	*4*		
		Qbtt	*210*	*213*	*5*	*1*				
		Qct	*213*	*300*	*10*		*3*	*4*		
		Qbo	*300*	*570*	*20*		*3*	*11*		

a. Full-suite core sample analysis listed in Table 7.3.4-5

b. Limited-suite core sample analysis, including the following: trace elements, ^{90}Sr, tritium (high detection limit), hydrologic properties, and anions

c. Minimal analyses on core samples for moisture, tritium, chloride, and nitrate only

d. N/A = not applicable

e. Water sample analysis includes those analytes listed in Table 7.3.4-4 and Table 7.3.4-7

f. Water samples will be collected twice yearly (see text)

g. Water samples will be collected at time of drilling and twice thereafter; zonal samples may include up to five samples per event

h. Pore water samples will be obtained from the vadose zone for analysis of analytes listed in Table 7.3.4-6

TABLE 7.3.4-2 (continued)

SUMMARY OF CORE AND WATER SAMPLES PROPOSED FOR MORTANDAD CANYON BOREHOLES

Borehole	Proposed Depth (ft)	Formation	Proposed Depth Beginning (ft)	Proposed Depth Ending (ft)	Core Sampling Frequency (ft)	Analytical Suite/ Proposed No. of Core Samples			Proposed No. of Water Samples	Comment
						a	b	c		
R-13		Qbog	570	600	10	1	1	1		
		Perched water?	590	600	N/A[d]				3	Water sample[e,f]
		Tp (basalt)	600	1240	20		5	23		
		Pore water in vadose zone?							5	Water sample[g]
		Regional aquifer	1230	1330	N/A				15	Zonal water sampling[e,f]
		Tsf	1230	1330	100		5			
R-14	1670	Qbt 3	0	30	20		2			
		Qbt 2	30	95	20		2	1		
		Qbt 1v	95	160	20		2	1		
		Qbt 1g	160	225	10		2	5		
		Qbtt	225	228	5	1				
		Qct	228	300	10		3	4		
		Qbo	300	600	20		3	12		
		Qbog	600	645	10	1	1	2		
		Perched water?	600	645	N/A				3	Water sample[e,f]
		Tp (basalt)	645	1240	20		5	20		
		Tsf	1240	1670	100		6			
		Pore water in vadose zone							5	Water sample[g]
		Regional aquifer	1170	1670	N/A				15	Zonal water sampling[e,f]
R-15	1140	Qal	0	20	10		2			
		Qbt 1g	20	60	10		2	2		
		Qct	60	130	10	1	3	3		
		Qbo	130	420	20		3	12		
		Qbog	420	460	10	1	1	2		

a. *Full-suite core sample analysis listed in Table 7.3.4-5*

b. *Limited-suite core sample analysis, including the following: trace elements, ^{90}Sr, tritium (high detection limit), hydrologic properties, and anions*

c. *Minimal analyses on core samples for Moisture, tritium, chloride, and nitrate only*

d. *N/A = not applicable*

e. *Water sample analysis includes those analytes listed in Table 7.3.4-4 and Table 7.3.4-7*

f. *Water samples will be collected at time of drilling and twice thereafter; zonal samples may include up to five samples per event*

g. *Pore water samples will be obtained from the vadose zone for analysis of analytes listed in Table 7.3.4-6*

TABLE 7.3.4-2 (continued)

SUMMARY OF CORE AND WATER SAMPLES PROPOSED FOR MORTANDAD CANYON BOREHOLES

Borehole	Proposed Depth (ft)	Formation	Proposed Depth Beginning (ft)	Proposed Depth Ending (ft)	Core Sampling Frequency (ft)	Analytical Suite/ Proposed No. of Core Samples			Proposed No. of Water Samples	Comment
						a	**b**	**c**		
R-15		*Perched water?*	*450*	*460*	*N/A*[d]				*3*	*Water sample*[e,f]
		Tp (basalt)	*460*	*1010*	*20*		*4*	*20*		
		Tsf	*1010*	*1140*	*100*		*5*			
		Pore water in vadose zone							*5*	*Water sample*[g]
		Regional aquifer	*940*	*1140*	*N/A*				*15*	*Zonal water sampling*[e,f]
					Totals	*19*	*138*	*198*	*99*	

a. Full-suite core sample analysis listed in Table 7.3.4-5

b. Limited-suite core sample analysis, including the following: trace elements, ^{90}Sr, tritium (high detection limit), hydrologic properties, and anions

c. Minimal analyses on core samples for Moisture, tritium, chloride, and nitrate only

d. N/A = not applicable

e. Water sample analysis includes those analytes listed in Table 7.3.4-4 and Table 7.3.4-7

f. Water samples will be collected at time of drilling and twice thereafter; zonal samples may include up to five samples per event

g. Pore water samples will be obtained from the vadose zone for analysis of analytes listed in Table 7.3.4-6

7.3.4.1.1 Surface Water Sampling and Analysis

Streamflow at GS-1 and GS-1.3 will be measured to determine the amount of loss into the Bandelier Tuff in the reach between these two gaging stations. Surface water samples will be collected during snowmelt (two events) (one sample per snowmelt) and summer storm events (three events) (six samples per storm event) at one operating gaging station (either GS-1 or GS-1.3) in Mortandad Canyon. Although no springs have been identified in the Mortandad Canyon system, if any are found during the investigation, samples will be collected from them.

Samples will be collected in the middle of the stream to provide representative surface water chemical data for each reach or spring. Samples will be both filtered to remove particulates larger than 0.45 µm and unfiltered to include suspended material in the analysis. The differences in analytical results will enable the evaluation of chemicals residing on suspended particles. Surface water samples will undergo the same chemical analyses as alluvial groundwater samples. The analytical data will be confirmed, where appropriate, with analyses of unfiltered samples collected annually for environmental monitoring by ESH-18 to reduce uncertainty in the distributions of surface water quality data for contaminant transport and risk model inputs.

7.3.4.1.2 Alluvial Groundwater 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 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 contamination.*

Continuity

The alluvium in Mortandad Canyon is saturated from approximately the confluence with Effluent Canyon to the general vicinity of well MCO-8. However, saturation has been recently observed in well MCO-13. The alluvium may intersect the Cerro Toledo interval near well MCO-7.5, which results in saturated conditions with migration of contaminants being controlled by both the geometry and the hydraulic properties of the combined alluvial/Cerro Toledo interval hydrogeologic unit. Investigations at wells MCO-6.8 and MCO-7.2 are designed to determine the possible interaction of the alluvial and Cerro Toledo interval units. The alluvium in lower Ten Site Canyon may contain zones of saturation of unknown thickness and extent. Investigations are proposed to determine the presence of saturation in the alluvium and bedrock units in lower Ten Site Canyon (at well TSCO-6A) and the extent of any contribution to the saturated alluvium in Mortandad Canyon. Saturation is not expected to occur east of state road NM4 downstream to the confluence with Cañada del Buey 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 Mortandad 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 Contamination

The highest levels of contaminants (including ^{137}Cs, nitrate, plutonium isotopes, ^{90}Sr, and tritium) occur in alluvial groundwater closest to the discharge points (for example, the TA-50 RLWTF outfall) in Mortandad Canyon, based on Laboratory monitoring data (LANL 1981, 6059) (see Section 3.7.2 in Chapter 3 of this work plan).

Groundwater will be sampled and analyzed from new and existing wells two times, 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 Mortandad Canyon responds rapidly to seasonal variations in streamflow, which 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, which are not routinely sampled for environmental monitoring, may be sampled twice for chemical analysis. These wells include MCO-13, MT-1, MT-2, MT-3, MT-4, and possibly some MCWB wells. New wells will be sampled twice to assess water chemistry and contaminant distributions. Water level measurements will be recorded for two years using pressure transducers that have been or will be installed in the new and existing water-balance wells. 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 staff or for environmental monitoring by ESH-18 to reduce uncertainty in the distributions of alluvial groundwater quality for contaminant transport and risk model inputs.*

Proposed Alluvial/Cerro Toledo Interval Wells and Hydrologic and Geochemical Investigations

This section describes the rationale for the proposed hydrologic and geochemical investigations of the alluvial groundwater in Mortandad Canyon. The most fundamental questions to be addressed for the alluvial system are identified as follows.

- *Where does the groundwater loss from the alluvial system occur in Mortandad Canyon and what is the flux?*
- *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 proposed technical approach to addressing the issue. Each technical approach to an issue also addresses one or more of the key hypotheses. Table 7.3.4-3 summarizes the relationship between the key hypotheses from Table 4.2-1 in Chapter 4 of this work plan and the issues addressed.

Issues that are important in upper Mortandad Canyon are presented first followed by issues that are important for the middle and lower canyon.

Unless otherwise noted, all wells and the gaging station discussed below are listed in Table 7.3.3-1 and shown in Figure 7.3.3-1. The analytical suite for alluvial groundwater samples is presented in Table 7.3.4-4. The analytical suite for borehole core samples is presented in Table 7.3.4-5. Methods for analysis of water samples are described in Section 7.3.4.3.1. Methods for analysis of borehole core samples are described in Section 7.3.4.3.2.

Issue Number 1

What is the chemical composition of alluvial groundwater in Mortandad Canyon west of the confluence with Effluent Canyon?

Importance

To define the levels of contamination in alluvial groundwater that result from Laboratory activities, specifically from the TA-50 RLWTF outfall, it is necessary to define the baseline chemical characteristics of groundwater upgradient of the discharge.

It is unlikely that continuous saturation occurs in the alluvium west of TA-48 except during storm events because this reach is near the head of Mortandad Canyon and receives no Laboratory discharges.

However, alluvial groundwater downgradient of outfalls at TA-3 and TA-48 is contaminated by the discharge.

TABLE 7.3.4-3

RELATIONSHIP BETWEEN KEY HYPOTHESES AND ISSUES ADDRESSED

Hypothesis	Issues Addressed													
	Alluvium									Bandelier Tuff		Regional Aquifer		
	1	2	3	4	5	6	7	8	9	1	2	1	2	3
C14	√	√	√	√	√	√	√		√					
C5	√		√	√	√	√	√	√[a]						
C18	√		√		√	√	√		√	√	√	√	√	√
C8	√		√		√	√	√		√	√	√	√	√	√
C2	√		√		√	√	√		√					
C6	√		√	√	√	√	√		√					
D4	√		√		√	√	√		√	√	√	√	√	√
D7	√		√		√	√	√		√	√	√	√	√	√
E4										√	√	√	√	√
E1										√	√	√	√	√
E2										√	√	√	√	√
E5										√	√	√	√	√
F1										√	√	√	√	√
G2										√[b]	√	√[b]	√[b]	√[b]

a. Also addresses hypotheses B2 through B8 in Table 4.2-1 in Chapter 4 of this work plan

b. Also addresses hypotheses G1, G3, G4, G5, G7, and G10 in Table 4.2-1 in Chapter 4 of this work plan

Existing alluvial well LAO-B in Los Alamos Canyon may provide surrogate background data for Mortandad Canyon assuming that the background water chemistry of upper Los Alamos Canyon upgradient of the Laboratory is similar to pre-Laboratory water chemistry in Mortandad Canyon. There is no direct way to verify this assumption. However, natural groundwater flowing through the alluvium, which is derived from the Tshirege Member of the Bandelier Tuff, does not vary significantly in major ion and trace element composition except for bicarbonate (Blake et al. 1995, 49931; Longmire et al. 1996, 54168). In addition, the short residence time of natural alluvial groundwater (with flow velocities on the order of several hundreds of feet per year) does not allow for significant alteration of the water composition. Adsorption/desorption and precipitation/dissolution reactions control the composition of natural water.

Approach

One well (MCO-0.6) will be installed in the alluvium west of both the TA-50 RLWTF outfall and the confluence with Effluent Canyon in upper Mortandad Canyon assuming that a location that contains saturated alluvium can be found. The well is expected to be less than 30 ft (9.1 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 7.3.4.2.1.

TABLE 7.3.4-4

ANALYTICAL SUITE FOR ALLUVIAL GROUNDWATER SAMPLES[a]

Field-Measured Parameters		
Alkalinity	*pH*	*Temperature*
Dissolved oxygen	*Specific conductance*	*Turbidity*
Major and Minor Ions		
Aluminum	*Fluoride*	*Nitrite*
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 Compounds		
VOCs		
SVOCs		
Dissolved Organic Carbon (fractionation analysis)		
Total Suspended Solids		
Total Dissolved Solids		
Neutral Species (SiO_2)		
Hardness		
Cyanide		
Radionuclides		
^{241}Am	^{90}Sr	^{238}U
^{137}Cs	^{234}U	*Gamma spectroscopy*
^{238}Pu	^{235}U	*Gross-alpha, -beta, and -gamma*
^{239,240}Pu	^{236}U	*Tritium*[b]

a. *Filtered (<0.45 µm) and unfiltered water samples will be collected.*

b. *Low-detection-limit at MCO-0.6, TSCO-6, MCO-13A, and MCO-13B only; high-detection-limit for other alluvial and Cerro Toledo interval groundwater samples*

TABLE 7.3.4-5

ANALYTICAL SUITE FOR BOREHOLE CORE SAMPLES

Hydrologic Analyses		
Moisture content		
Moisture potential		
Saturated hydraulic conductivity		
Anions		
Bromide		
Chloride		
Fluoride		
Nitrate		
Sulfate		
Trace Elements		
Aluminum	*Cobalt*	*Selenium*
Antimony	*Copper*	*Silver*
Arsenic	*Iron*	*Thallium*
Barium	*Lead*	*Titanium*
Beryllium	*Manganese*	*Uranium*
Cadmium	*Mercury*	*Vanadium*
Chromium	*Nickel*	*Zinc*
Organic Compounds		
VOCs		
SVOCs		
Total Organic Carbon		
Cyanide		
Radionuclides		
^{241}Am	^{90}Sr	^{238}U
^{137}Cs	^{234}U	*Gamma spectroscopy*
^{238}Pu	^{235}U	*Gross-alpha, -beta, and -gamma*
^{239,240}Pu	^{236}U	*Tritium*[b]
Selected Samples for the Following		
Petrography		
X-ray fluorescence		
X-ray diffraction		
K/Ar or ^{39}Ar/^{40}Ar *isotopic dating*		

a. *Subsurface units only*

b. *Low-detection-limit in subsurface units only; high-detection-limit for alluvium and Cerro Toledo interval samples*

Groundwater samples will be collected two times, once in the fall or winter when the TA-50 RLWTF discharge typically dominates surface flow and once in the spring or summer when runoff typically dominates surface flow. Samples will be analyzed for the parameters listed in Table 7.3.4-4.

Issue Number 2

How much ET occurs in the Mortandad Canyon system?

Importance

Groundwater is lost from the alluvial groundwater system in Mortandad Canyon by two primary mechanisms: infiltration and ET. Previous studies of ET in Mortandad Canyon suggest that 20% of water is lost via this mechanism (Purtymun 1967, 8987). Accurate estimates of ET are critical to estimates of overall water balance in Mortandad Canyon. Moreover, tritium (as tritiated water) uptake into plants followed by transpiration is an important transport pathway for this radionuclide, and accurate estimates of ET can be used to estimate tritium (as tritiated water vapor) transport as well.

Approach

Two solar-powered ET measurement stations will be installed in Mortandad Canyon to obtain canyon-specific information about water loss through this mechanism. Continuous instrument measurements will include three-dimensional wind velocity, air temperature, and air moisture. These measurements will be used to calculate evaporative heat fluxes, which are then converted to ET values. The Laboratory currently records similar data on the mesa tops at TA-6 (7380 ft [2249 m] elevation) and TA-54 (6380 ft [1945 m] elevation). The ET values from Mortandad Canyon will be compared with ET values from these existing stations so that the effects of different environmental settings can be evaluated. Important factors that affect ET include altitude, vegetation, and soil type. These site-specific comparisons should reduce similar data requirements in adjacent canyons during future ER Project work efforts.

Issue Number 3

Alluvial well MCO-3 has been damaged by erosion from storm events during the past 30 years and should be replaced; hydrologic and geochemical data need to be collected at this location.

Importance

Well MCO-3 does not meet current NMED and EPA well completion guidelines (LANL 1996, 55688). This well is also the closest well downstream and downgradient of the TA-50 RLWTF discharge. Water level measurements and groundwater samples are needed from this well to evaluate hydrologic and geochemical processes that influence contaminant transport.

Approach

Replace MCO-3 with a new alluvial well of similar dimensions that meets current well completion guidelines. The well will be installed and completed as described in Section 7.3.4.2.1.

Groundwater samples will be collected two times, once in the fall or winter when the TA-50 RLWTF discharge typically dominates surface flow and once in the spring or summer when runoff typically *dominates surface flow. Samples will be analyzed for the parameters listed in Table 7.3.4-4. Borehole core samples will be collected and analyzed for the parameters listed in Table 7.3.4-5.*

Issue Number 4

How much surface water infiltrates into the alluvium in Mortandad Canyon immediately east of gaging station GS-1 and well MCO-3?

Importance

Surface water and alluvial groundwater in Mortandad Canyon represent both a source of water and a mechanism for transporting contaminants to human and ecosystem receptors. The extent and volume of saturation, the spatial and temporal distribution of contaminants, the general contaminant inventory, and the residence time of groundwater in this area of the alluvial system are all reasonably well understood. Moreover, alluvial water-balance estimates in this area suggest that approximately 80% of the annual input to the perennial alluvial groundwater infiltrates to the Bandelier Tuff (Purtymun 1967, 8987). However, it is not known where the alluvial groundwater infiltrates the Bandelier Tuff or the mechanisms by which the alluvial groundwater loss occurs.

Approach

One additional stream gaging station (GS-1.3) may be installed approximately 1000 ft (305 m) downstream (east) from the existing gaging station (GS-1) on bedrock similar to GS-1 to determine the infiltration from the stream into the bedrock per unit channel length. The feasibility of installing this gaging station depends on access and terrain; the proposed location is within a thickly-wooded, steep-walled canyon reach, which may pose problems.

Streamflow measurements will be made with continuous recorders during flow events for a two-year period, and established hydrologic and hydraulic routing techniques will be applied to quantify channel infiltration. The streamflow loss in the reach that contains an ET station will be combined with water storage information obtained from water-balance studies to estimate the loss from the alluvium and the amount transported down the channel as surface flow.

In addition, to provide supplemental data to that collected routinely at GS-1, surface water samples will be collected two times, once in the fall or winter when the TA-50 RLWTF discharge typically dominates surface flow and once in the spring or summer when runoff typically dominates surface flow. Samples will be analyzed for the parameters listed in Table 7.3.4-4.

Issue Number 5

Is alluvial/Cerro Toledo interval groundwater present in lower Ten Site Canyon? If so, what is the vertical extent of the alluvial groundwater and what contaminants are present?

Importance

As discussed in Chapter 2 of this work plan, the former radioactive liquid wastewater treatment plant at TA-35 discharged into Ten Site Canyon from about 1951 through 1963. Radionuclides (primarily ^{90}Sr) in the discharges are known to have contaminated sediments in Mortandad Canyon before 1960. Other

PRSs present at TA-35 (such as the former sanitary septic sewage lagoons that were operated from 1975 through 1992) may have been a source of recharge to groundwater in lower Ten Site Canyon and may have contained contaminants. A well (TSCO-1) installed in 1960 and a water-balance well (TSWB-6) installed in 1994 in lower Ten Site Canyon have never contained water but may not have been properly placed to encounter saturation. Moreover, TSCO-1 could not be located in 1991 and may have been plugged or removed.

Approach

One well (TSCO-6A) will be installed in the alluvium/Cerro Toledo interval in lower Ten Site Canyon to determine the presence, depth, and thickness of potential saturation and to evaluate the composition of any groundwater encountered. The well will be installed and completed as described in Section 7.3.4.2.1. The alluvium at the proposed location is projected to be approximately 40 to 50 ft (12 to 15 m) thick; the well will be installed with a 10-ft (3.0-m) screen at the alluvial water table to account for variations in saturated thickness. If no water is encountered, the screen will be placed above the base of the alluvium/Cerro Toledo interval; it will be checked quarterly to detect intermittent groundwater.

Groundwater samples will be collected two times, once in the fall or winter when the TA-50 RLWTF discharge typically dominates surface flow and once in the spring or summer when runoff typically dominates surface flow. Samples will be analyzed for the parameters listed in Table 7.3.4-4. Borehole core samples will be collected at the alluvium/bedrock interface and in other zones, if appropriate, and analyzed for the parameters listed in Table 7.3.4-5.

Issue Number 6

What hydrologic and geochemical processes contribute to the major differences in groundwater chemistry observed between well MCO-6 and well MCO-7?

Importance

Chemical data collected from well MCO-6 and well MCO-7 suggest that alluvial groundwater may be mixing with a new source of more dilute groundwater that possibly originates from the Cerro Toledo interval. Well MCO-6 is screened in the alluvium, whereas well MCO-7 may be screened in the Cerro Toledo interval. Mixing could explain the significant concentration decreases in ^{90}Sr, ^{236}U, and other solutes that are observed between the wells (see Section 3.8). If present, the source of mixing groundwater is not known, but it is possible that significant recharge to the Bandelier Tuff occurs in upper Mortandad Canyon near well MCO-3 (Purtymun 1967, 8987) and that this groundwater infiltrates to the Cerro Toledo interval followed by lateral flow down-dip. Dissolved radionuclides, including ^{90}Sr and ^{236}U, partly adsorb onto the Bandelier Tuff as groundwater infiltrates. Between well MCO-6 and well MCO-7, concentrations of these two radionuclides significantly decrease (up to a factor of 100) in the groundwater. However, the concentrations of conservative species such as chloride and tritium in the mixing zones would not be significantly reduced because both source groundwaters probably contain about the same concentrations; both potentially have the same original sources in treated wastewater discharges to the alluvium.

Approach

A new well (MCO-6.8) will be installed between well MCO-6 and well MCO-7 to evaluate hydrologic and chemical characteristics of both the alluvial groundwater and any Cerro Toledo interval groundwater and to establish the extent of saturation in the alluvium and/or suballuvial units. The well will be installed and *completed within the alluvium/Cerro Toledo interval if one continuous saturated zone occurs within both geologic strata. If separate zones of saturation occur, multiple completions of a single well or additional wells completed in different zones will be considered, depending on the conditions encountered. Details of well construction are described in Section 7.3.4.2.1. A 10-ft (3.0-m) screen will be installed near the top of the water table to account for variations in saturated thickness.*

Borehole core samples collected at this location will provide subsurface stratigraphic information. The alluvium is expected to be about 45 ft (14 m) thick at this location. Suballuvial stratigraphy may include a thin section of the Tshirege Member Qbt 1g unit and the Cerro Toledo interval.

Groundwater samples will be collected two times, once in the fall or winter when the TA-50 RLWTF discharge typically dominates surface flow and once in the spring or summer when runoff typically dominates surface flow. Samples will be analyzed for the parameters listed in Table 7.3.4-4. Borehole core samples will be collected and analyzed for the parameters listed in Table 7.3.4-5.

Issue Number 7

What is the stratigraphy beneath the sediment traps (PRS No. 00-001) and the extent of saturation and contamination in the alluvium/Cerro Toledo interval?

Importance

When well MCO-6 and well MCO-7 were installed in 1960, changes in the subsurface stratigraphy were noted between these wells. The thickness of the alluvium apparently increases abruptly near the sediment traps.

The revised interpretation of subsurface stratigraphy in this area suggests that the Cerro Toledo interval probably underlies the alluvium. It has been observed that ponded water in the sediment traps recharges the alluvium and possibly the Cerro Toledo interval (see Section 3.7.2 in Chapter 3 of this work plan). As outlined in the conceptual model, alluvial groundwater near the sediment traps probably infiltrates into bedrock stratigraphic units and/or moves downstream within the alluvium. Groundwater that infiltrates into the Cerro Toledo interval may move downgradient and/or continue to infiltrate. Because sediments in the Cerro Toledo interval may have similar mineralogy and texture as the alluvium in Mortandad Canyon, it may be difficult to distinguish the two strata in borehole samples. An understanding of the alluvial and bedrock stratigraphy near the sediment traps is imperative to an understanding of the potential migration pathways for contaminants.

Approach

One additional well (MCO-7.2) will be installed near the sediment traps to evaluate hydrologic and geochemical characteristics of the alluvial groundwater, establish the extent of saturation in the alluvium and/or bedrock units, and obtain subsurface stratigraphic information. The well will be installed and completed as described in Section 7.3.4.2.1 and screened through the saturated zone. Core will be obtained and archived to determine the alluvial and bedrock stratigraphy. The alluvium is expected to be approximately 60 ft (18 m) thick at this location. Suballuvial stratigraphy may include the Cerro Toledo interval.

Groundwater samples will be collected two times, once in the fall or winter when the TA-50 RLWTF discharge typically dominates surface flow and once in the spring or summer when runoff typically *dominates surface flow. Samples will be analyzed for the parameters listed in Table 7.3.4-4. Borehole core samples will be collected and analyzed for the parameters listed in Table 7.3.4-5.*

Issue Number 8

Colloids are present in alluvial groundwater in Mortandad Canyon. What is their composition and particle size distribution? What contaminants (actinides) are associated with the colloids?

Importance

Penrose et al. (1990, 11770) report on the occurrence of americium and plutonium in alluvial groundwater within Mortandad Canyon. Results of their investigation suggest that americium and plutonium are tightly or irreversibly associated with colloidal material between 25 and 450 nm in diameter. Colloidal transport may be a major mechanism for dispersal of these contaminants. Laboratory surveillance data collected since 1967 generally support this hypothesis because these two actinides are measured in most of the alluvial wells in Mortandad Canyon.

The composition of the colloidal material is not known; it may consist of silica, ferric hydroxide, clay minerals, and solid organic matter. According to Penrose et al. (1990, 11770) americium and plutonium colloids could not be completely removed from groundwater by serial filtration. Moreover, the fraction of americium not associated with colloids is stable in a low-molecular weight form (≤2nm in diameter) and may occur as an anion of unknown composition (see Section 3.8.5 in Chapter 3 of this work plan for a discussion of americium speciation).

Approach

Groundwater samples will be collected two times from alluvial wells MCO-4B and MCO-6.8, once in the fall or winter when the TA-50 RLWTF discharge typically dominates surface flow and once in the spring or summer when runoff typically dominates surface flow. Samples will be both filtered and unfiltered for evaluation of total colloids. The analyses will be used to assess the particle size distribution in groundwater. The apparatus used in the sample collection as described by Triay et al. (1996, 56031) incorporates serial filters of three different sizes. Before and after each filtration, samples will be stored in borosilicate glass bottles to minimize adsorption of colloids onto the container surface.

All samples will be collected in duplicate, which includes both unacidified and acidified samples (pH 4). Both types of samples will provide information on mineral precipitation potentially induced during sample collection (for example, precipitation of calcium carbonate or other solids that may change the amount of colloids to be measured in the alluvial groundwater).

After dilution in ultrapure water, particles will be counted with a Horiba (PLC311) unit and analyzed with respect to size according to the intensity of the scattered light that the particles produce in the unit laser beam. Colloid concentration for a given size range will be calculated using the Paul Scherrer Institute computer code COLIAT (for colloid linear analytical treatment) (Triay et al. 1996, 56031). Activities of americium, neptunium, plutonium, and uranium in the various size fractions will be determined by liquid scintillation counting (LSC) and/or alpha spectrometry.

Issue Number 9

Is alluvial groundwater present east of well MCO-13 and, if so, how much infiltrates into the Bandelier Tuff and stratigraphic units in lower Mortandad Canyon?

Importance

Alluvial groundwater in lower Mortandad Canyon may move along the canyon axis; therefore, groundwater represents a potential source of recharge to the Cerro Toledo interval and deeper units. Groundwater may also move laterally at contacts or other surfaces where hydraulic characteristics change. Data obtained from boreholes (Stoker et al. 1991, 7530) show the presence of americium, plutonium, tritium, and uranium at varying depths; tritium has been found at depths of at least 194 ft (59.1 m). However, the activities of tritium observed had not reached background levels in the deepest penetration.

Recent measurements from well MCO-13 indicate for the first time the presence of groundwater at this location. Analyses show the presence of chloride, nitrate, sulfate, and other solutes. However, the concentrations of sulfates did not match those of any other groundwater previously analyzed in Mortandad Canyon (see Table 3.8.1-1 in Chapter 3 of this work plan); therefore, the source(s) of the water is unknown.

In addition, activities of tritium were below detection (300 to 370 pCi/L) in three samples collected by the Agreement in Principle staff. Activities of tritium in TA-50 RLWTF discharges have been substantially higher. During borehole advancement for the installation of previous wells near the Laboratory boundary, the presence of the Cerro Toledo interval beneath the alluvium in lower Mortandad Canyon was not recognized; therefore, the existing wells probably did not penetrate through the complete thickness of the Cerro Toledo interval and potentially missed deeper perched zones of saturation.

Approach

A north-south transect of at least two additional wells (MCO-13A and MCO-13B) completed in the alluvium/Cerro Toledo interval will be installed in lower Mortandad Canyon north of the Laboratory boundary to further characterize groundwater in the combined stratigraphic unit. The boreholes will be continuously cored or sampled by split-spoon, if possible, to obtain samples for both stratigraphic identification and contaminant characterization. Borehole core samples will be analyzed for metals, radionuclides, and organic compounds. Water level measurements will be continuously recorded using pressure transducers, if possible, for two years. The wells are expected to be less than 150 ft (46 m) deep and will have a screened interval (minimum of 10 ft) installed through the saturated zone. Wells will be installed as described in Section 7.3.4.2.1.

Groundwater samples will be collected two times, once in the fall or winter when the TA-50 RLWTF discharge typically dominates surface flow and once in the spring or summer when runoff typically dominates surface flow. Samples will be analyzed for the parameters listed in Table 7.3.4-4. Borehole core samples will be collected at the alluvium/bedrock interface, and in other zones, if appropriate, and analyzed for the parameters listed in Table 7.3.4-5.

7.3.4.1.3 Bandelier Tuff Groundwater and Borehole Sampling and Analysis

Stoker et al. (1991, 7530) documented the movement of tritium and other contaminants within the Otowi Member beneath Mortandad Canyon. Contaminants may have reached the Guaje Pumice Bed and deeper strata. Preliminary results of hydrologic modeling by ESH-18 personnel, using hydrologic and recharge data from Purtymun (1967, 8987), suggest that the Guaje Pumice Bed may be >90% saturated. The possible perched water-bearing zone in the Guaje Pumice Bed lies between the known sources of contamination and the deeper regional aquifer in Mortandad Canyon. This intermediate perched zone may serve either as a pathway or as a barrier to the long-term transport of contaminants to the regional aquifer, *depending on the geochemical properties of the water-bearing material (sorption capacity), hydraulic conductivities, and the degree of saturation of the perching layer(s). Individual zones could serve as a barrier in one location and as a pathway in another depending on the degree of saturation. If saturation is encountered the proposed shallow wells (MCO-6.8, MCO-7.2, MCO-13A, MCO-13B, and TSCO-6A) will be completed within the Cerro Toledo interval, and the two proposed Bandelier Tuff wells (MCOBT-4.4 and MCOBT-8.5) will be completed in the Guaje Pumice Bed. These two wells are designed to determine whether tritium and other contaminants have reached the Guaje Pumice Bed.*

Drilling of the two Bandelier Tuff wells is scheduled for the spring of 1999 (Table 7.3.4-6). Budgeted costs for the wells are also included in the table. Sampling is scheduled for June 1999 and November 1999.

TABLE 7.3.4-6

BANDELIER TUFF WELLS DRILLED IN MORTANDAD CANYON

Activity	Duration (days)	Early Start	Early Finish	Budgeted Cost (dollars)
Write contracts and mobilize groundwater	*22*	*3/10/99*	*4/01/99*	*26169.40*
Drill/log intermediate well no. 1	*14*	*4/02/99*	*4/16/99*	*178041.40*
Waste management	*37*	*4/02/99*	*5/09/99*	*5905.00*
Sample intermediate wells	*24*	*6/01/99*	*6/25/99*	*2361.04*
Analyze water samples	*72*	*6/30/99*	*9/10/99*	*71266.10*
Drill/log intermediate well no. 2	*13*	*7/05/99*	*7/18/99*	*178041.40*
Assess data and write report	*27*	*9/18/99*	*10/15/99*	*32824.00*

Sampling and analysis of the possible intermediate perched zone within the Bandelier Tuff (Guaje Pumice Bed) will focus on chloride, nitrate, tritium, and other solutes in the TA-50 RLWTF discharge to characterize geochemical and hydrologic properties of the stratum and to assess its potential to be a source of recharge to the regional aquifer. Investigations will be conducted in Mortandad Canyon to clarify the distribution of tritium and other solutes in the Bandelier Tuff including

- *the hydraulic properties of the vadose zones in the Otowi Member and Guaje Pumice Bed,*
- *the degree of contamination,*
- *geochemical and hydraulic properties of the Otowi Member and Guaje Pumice Bed and mechanisms that may cause perching and movement of groundwater, and*
- *the potential for recharge to the regional aquifer.*

Investigations will involve drilling, coring, and the installation of two wells (MCOBT-4.4 and MCOBT-8.5) to characterize and assess tritium contamination within the Guaje Pumice Bed (see Section 3.5.3 in Chapter 3 of this work plan). Results of these studies will be used to plan the installation of three regional aquifer wells (R-13, R-14, and R-15) discussed in the Hydrogeologic Workplan (LANL 1996, 55430) and in Section 7.3.4.1.5.

Proposed Bandelier Tuff Wells and Hydrologic and Geochemical Investigations

This section describes the rationale for the proposed hydrologic and geochemical investigations of Bandelier Tuff wells to determine the vertical extent of contamination in the Bandelier Tuff beneath Mortandad Canyon. Questions to be addressed for the Bandelier Tuff system include assessing tritium contamination within the Otowi Member. The issues, importance, and proposed technical approach are discussed below.

The investigation includes installing two Bandelier Tuff wells, which are listed in Table 7.3.3-2. The approximate well locations are shown in Figure 7.3.3-2. The well locations are based on a review of existing hydrologic and geologic data and are intended to determine whether the Guaje Pumice Bed is saturated and contaminated with chloride, nitrate, tritium, and other solutes in the TA-50 RLWTF discharge.

If saturated zones are encountered, borehole water will be sampled during drilling, and groundwater will be sampled after completing and developing each well and again approximately six months later to account for seasonal variations.

Pore water from core samples will be analyzed for the parameters listed in Table 7.3.4-7. Groundwater samples will be analyzed for the parameters listed in Table 7.3.4-8. The analytical suites may be altered if further characterization objectives are identified on the basis of the first analysis. Methods for analysis of water samples are described in Section 7.3.4.3.1; methods for analysis of borehole core samples are described in Section 7.3.4.3.2.

Issue Number 1

To what depth(s) have tritium and other contaminants migrated vertically below the canyon floor west of TW-8 in Mortandad Canyon?

Importance

Chloride, nitrate, ^{90}Sr, and tritium have been detected above background levels in the regional aquifer at TW-8. In addition, Stoker et al. (1991, 7530) confirmed the presence of tritium (tritiated water) (activities up to 20 nCi/L) in the boreholes for moisture access tubes MCM-5.1 and MCM-5.9A. The tritium has migrated to at least 200 ft (61 m) beneath the canyon floor. The purpose of a new borehole is to determine the vertical extent of contamination including whether it occurs below middle Mortandad Canyon and to characterize the hydrogeologic properties of the core samples to further quantify movement of wetting fronts through the Bandelier Tuff.

The conceptual model of contaminant transport beneath middle Mortandad Canyon, presented in Chapter 4 of this work plan, infers movement of contaminated water downward through the Tshirege Member and laterally within the Cerro Toledo interval. A combination of unsaturated and saturated flow may occur within the Otowi Member, which may enhance saturation within the Guaje Pumice Bed. If saturation is found in the Guaje Pumice Bed, the potential for contaminant transport to the regional aquifer may be increased. Data collected from this borehole/characterization well will help determine if the contamination present in TW-8 is due to transport through the Bandelier Tuff and/or leakage along the annulus of TW-8.

TABLE 7.3.4-7

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*	*Nitrite*	
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*		
Dissolved Organic Carbon (fractionation analysis)			
Total Suspended Solids			
Total Dissolved Solids			
Neutral Species (SiO_2)			
Hardness			
Cyanide			
Stable Isotopes			
Deuterium/hydrogen			
$^{18}O/^{16}O$			
Radionuclides			
^{241}Am	$^{239,240}Pu$	^{235}U	*Gamma spectroscopy*
^{137}Cs	^{90}Sr	^{236}U	*Gross-alpha, -beta, and -gamma*
^{238}Pu	^{234}U	^{238}U	*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 7.3.4-8

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*	*Nitrite*
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 Compounds		
VOCs		
SVOCs		
Dissolved Organic Carbon (fractionation analysis)		
Total Suspended Solids		
Total Dissolved Solids		
Neutral Species (SiO_2)		
Hardness		
Cyanide		
Stable and Radiogenic Isotopes		
^{14}C, ^{13}C		
^{36}Cl		
Deuterium/hydrogen		
$^{18}O/^{16}O$		

Radionuclides			
^{241}Am	$^{239,240}Pu$	^{235}U	*Gamma spectroscopy*
^{137}Cs	^{90}Sr	^{236}U	*Gross-alpha, -beta, and -gamma*
^{238}Pu	^{234}U	^{238}U	*Tritium (low-detection-limit)*

Filtered (<0.45 μm) and unfiltered water samples will be collected.

The results of drilling, sampling, and analysis of core samples from the Bandelier Tuff characterization boreholes will help finalize the locations of the regional aquifer wells.

Approach

One borehole will be drilled west of TW-8. The borehole will be drilled into the Guaje Pumice Bed at a projected depth of 480 to 510 ft (146 to 155 m) and into the Puye Formation to approximately 530 ft (162 m) (see Figure 7.3.4-1). Core will be collected continuously. If saturation is encountered within the Guaje Pumice Bed, a well (MCOBT-4.4) will be installed and completed as described in Section 7.3.4.2.2. The well is designed to delineate tritium and other contaminants found in the Tshirege Member, Cerro Toledo interval, Otowi Member, and possibly the Guaje Pumice Bed. A 10-ft (3.0-m) (or greater) screen will be placed across the saturated zone within the Guaje Pumice Bed. A surface casing will be set and cemented in the alluvium to prevent alluvial groundwater from moving down the well/borehole annulus. Groundwater samples will be collected and analyzed for the parameters listed in Table 7.3.4-8. Borehole core samples will be analyzed for the parameters listed in Table 7.3.4-5.

Issue Number 2

To what depth(s) have tritium and other contaminants migrated within the Otowi Member and possibly to the Guaje Pumice Bed east of borehole MCC-8.2 in Mortandad Canyon?

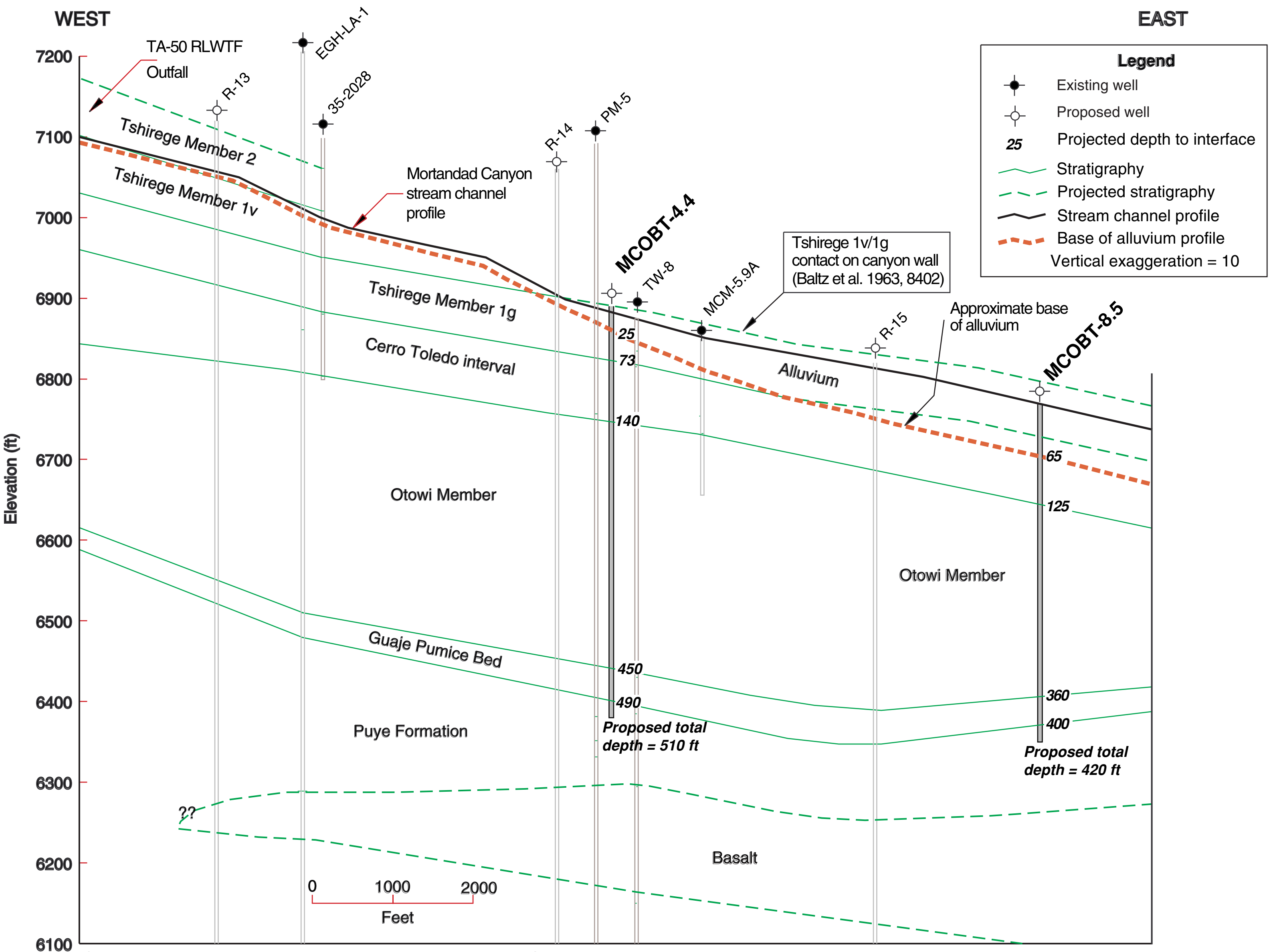
Importance

Alluvial groundwater provides a source of recharge to the Cerro Toledo interval and the Bandelier Tuff beneath lower Mortandad Canyon. Data collected from borehole MCC-8.2 show the presence of americium, tritium, and uranium at varying depths (see Section 3.5 in Chapter 3 of this work plan) (Stoker et al. 1991, 7530); tritium is found to depths of at least 184 ft (56 m). However, the activity of tritium had not reached background level in the deepest penetration. This issue involves both the amount of alluvial groundwater available for infiltration and the stratigraphy and hydraulic properties of the underlying bedrock.

Approach

One borehole will be drilled east of MCC-8.2. Core will be collected through the Guaje Pumice Bed, and a well will be installed (MCOBT-8.5). This well is designed to delineate tritium and other contaminants found in the Otowi Member and possibly the Guaje Pumice Bed. A surface casing will be set in the alluvium to prevent alluvial groundwater migration down the well/borehole annulus. If groundwater is encountered below this zone, the well will be installed with a 10-ft (3.0-m) (or greater) screen placed at the water table. The borehole will be drilled into the Guaje Pumice Bed at a projected depth of 360 to 400 ft (110 to 122 m) and into the Puye Formation to approximately 420 ft (128 m) (see Figure 7.3.4-1). The well will be installed and completed as described in Section 7.3.4.2.2. If saturation is encountered in the Guaje Pumice Bed, MCOBT-8.5 will be completed within the Guaje Pumice Bed.

If a saturated zone is encountered, groundwater samples will be collected and analyzed for the parameters listed in Table 7.3.4-8. Borehole core samples will be collected continuously in other units, such as at the contact between the Cerro Toledo interval and the Otowi Member, at the discretion of the technical team. Core samples will be analyzed for the parameters listed in Table 7.3.4-5.



Source: Broxton and Reneau 1995, 49726; Purtymun 1995, 45344; Stoker et al. 1991, 7530

Figure 7.3.4-1. Projected stratigraphic sections for proposed Bandelier Tuff wells.

7.3.4.1.4 Bandelier Tuff Borehole Characterization

The boreholes for wells MCOBT-4.4 and MCOBT-8.5 will be characterized as described below.

- *Lithologic Log*

  A lithologic log will be prepared from cores, cuttings, and drilling performance data. All cores will be archived for possible future mineralogical, chemical, or hydraulic analyses. Each core or cutting interval will be photographically documented with lithologic observations, geological logs, and other analyses according to depth.

- *Geophysical Logging*

  Geophysical logs will be run in the boreholes, and compact neutron moisture logs may be run in shallower portions of the boreholes. Natural gamma, neutron moisture, and density logs may be run if the drilling method and borehole stability permit. Other geophysical logs, as discussed in Section 4.1.1.6 of the Hydrogeologic Workplan (LANL 1996, 55430), may be considered if, in the opinion of the technical team, they will satisfy a technical need.

- *Core Collection*

  The Bandelier Tuff boreholes will be continuously cored to enable detailed geologic logging. The objectives of continuous coring are to add to the stratigraphic database of the region and to enable the evaluation of the mechanism of perching, sources of recharge, stratigraphic correlation, and hydraulic properties of the zone if a perched zone is encountered. The boreholes will be drilled to a depth sufficient to penetrate the base of the Guaje Pumice Bed (30 ft [9.1 m]) and into the underlying Puye Formation to determine the potential for downward movement of groundwater. The boreholes will be completed as wells if a perched zone is encountered within the Guaje Pumice Bed.

- *Borehole Water Collection*

  Borehole water will be collected during drilling activities from the Guaje Pumice Bed using a clean noncontaminated bailer. Field-measured parameters including pH, temperature, specific conductance, turbidity, and alkalinity will be recorded at the time of sampling. Key indicator contaminants for Bandelier Tuff boreholes in Mortandad Canyon include chloride, fluoride, nitrate, ^{241}*Am,* ^{137}*Cs,* ^{238}*Pu,* ^{239,240}*Pu,* ^{90}*Sr, and tritium. Filtered water samples will be filtered through a 0.45-µm membrane, transferred to clean bottles, and acidified (metals and radionuclides) with nitric acid to pH <2 or nonacidified (anions) before chemical analyses. Unfiltered water samples will be collected and analyzed for tritium and stable isotopes (hydrogen and oxygen). Additional unfiltered samples may be collected and analyzed for organic compounds, metals, and radionuclides if a sufficient volume of borehole water can be extracted. Unfiltered samples will be acidified with nitric acid (pH <2) before chemical analyses for metals and radionuclides. If there is a shortage of water, major anions (bromide, chloride, fluoride, and nitrate) will be analyzed first; then tritium, metals, and other radionuclides will be analyzed.*

7.3.4.1.5 Hydrogeological Characterization of the Regional Aquifer

This section describes the proposed hydrogeologic and geochemical characterization of the regional aquifer within Mortandad Canyon and southward near water supply well PM-5. The ultimate goal of this *characterization effort is to enhance the Laboratory's groundwater monitoring program by identifying the locations of water-bearing zones, determining hydrologic characteristics of those zones, and determining the most appropriate chemical constituents to be monitored. The characterization of Mortandad Canyon will be coordinated with the Hydrogeologic Workplan (LANL 1996, 55430).*

For the purpose of the Mortandad Canyon investigation, the focus of the regional aquifer characterization is to evaluate the potential for downward movement of potentially contaminated groundwater and to determine whether the regional aquifer contains Laboratory-derived contaminants. The characterization effort will involve a reevaluation of information from existing wells (PM-5 and TW-8) that are completed in the regional aquifer near Mortandad Canyon, selective resampling and analysis of those wells, and installation of three new wells (R-13, R-14, and R-15) in accordance with the Hydrogeologic Workplan (LANL 1996, 55430). The activities are listed below in order of priority.

- *Installing regional aquifer well R-15, with continuous core collection in the borehole, to determine hydrologic and geochemical properties of potential intermediate perched zones and the upper portion of the regional aquifer beneath lower Mortandad Canyon near the sediment traps.*
- *Installing regional aquifer well R-13 near MCO-3, as discussed in the Hydrogeologic Workplan (LANL 1996, 55430), after the data from well R-15 have been obtained and assessed. Well R-13 is needed to add detail to the stratigraphy of the area of the canyon system and to determine hydraulic and geochemical properties of potential intermediate perched zones and the upper portion of the regional aquifer beneath upper Mortandad Canyon near well MCO-3.*
- *Installing regional aquifer well R-14 to determine the long-term integrity, in terms of potential contamination, of supply well PM-5 located 0.35 mi (0.56 km) south of Mortandad Canyon.*
- *Resampling of TW-8 and analysis for low-detection-limit tritium, chlorate, organic compounds, dissolved organic carbon, major and minor ions, trace elements, stable isotopes, field-measured parameters, ^{241}Am, ^{14}C, ^{137}Cs, ^{238}Pu, ^{239,240}Pu, ^{90}Sr, ^{234}U, ^{235}U, and ^{238}U. This sampling and analysis is designed to determine if previously reported contaminants (Cl, NO_3, and tritium) are still present in the regional aquifer.*

Proposed Regional Aquifer Wells and Hydrogeologic and Geochemical Investigations

The wells discussed in this section are listed in Table 7.3.3-3 and shown in Figure 7.3.3-2. Methods for analysis of water samples are described in Section 7.3.4.3.1; methods for analysis of borehole core samples are described in Section 7.3.4.3.2. The regional aquifer wells will be located such that alluvial groundwater will not be penetrated, therefore eliminating the potential contamination of the regional aquifer.

Well R-15 will be located east of the sediment traps. The purpose of this well is to investigate the regional aquifer and intermediate perched zones where one interpretation of existing water-balance data (Koenig and McLin circa 1993, 56029) suggests that rates of infiltration from the alluvium are high. In addition, Stoker et al. (1991, 7530) report elevated tritium in borehole MCC-8.2 within the Otowi Member. Sampling of the borehole for well R-15 and the developed well will provide contaminant distribution data for ER Project investigations in Mortandad Canyon. The borehole will be continuously cored.

Well R-13 will be located near alluvial well MCO-3 where the alluvial sediments are relatively thin and form a shallow contact with the Bandelier Tuff. Well MCO-3 contains elevated concentrations of ^{241}Am, ^{137}Cs, NO_3,

^{238}Pu, ^{239,240}Pu, ^{90}Sr, tritium, and other constituents (as discussed in Section 3.7 in Chapter 3 of this work plan). The purpose of this well is to provide water quality, geochemical, and water level data for potential perched groundwater zones and for the regional aquifer within Mortandad Canyon (termed Aggregate 7 in the Hydrogeologic Workplan [LANL 1996, 55430]). Well R-13 will be completed in the Puye Formation, and the data obtained from the installation will supplement the stratigraphic, hydrologic, and geochemical data obtained from the installation of wells R-14 and R-15.

Well R-14 will be located at the eastern end of Ten Site Mesa at TA-35 and installed by personnel from the ER Project and ESH-18 with Defense Program funding. The purpose of well R-14 is to provide early detection of any contaminants at the top of the regional aquifer that may be moving toward water supply well PM-5. However, its location will also provide additional information about the nature and extent of intermediate perched zones.

The three proposed new regional aquifer wells, together with other activities, will address specific issues relevant to the regional aquifer. These issues, their importance, and the proposed technical approach to addressing them are detailed below.

Issue Number 1

Does alluvial and potential intermediate-depth groundwater provide a source of recharge to the regional aquifer near the sediment traps? What is the stratigraphy near the sediment traps?

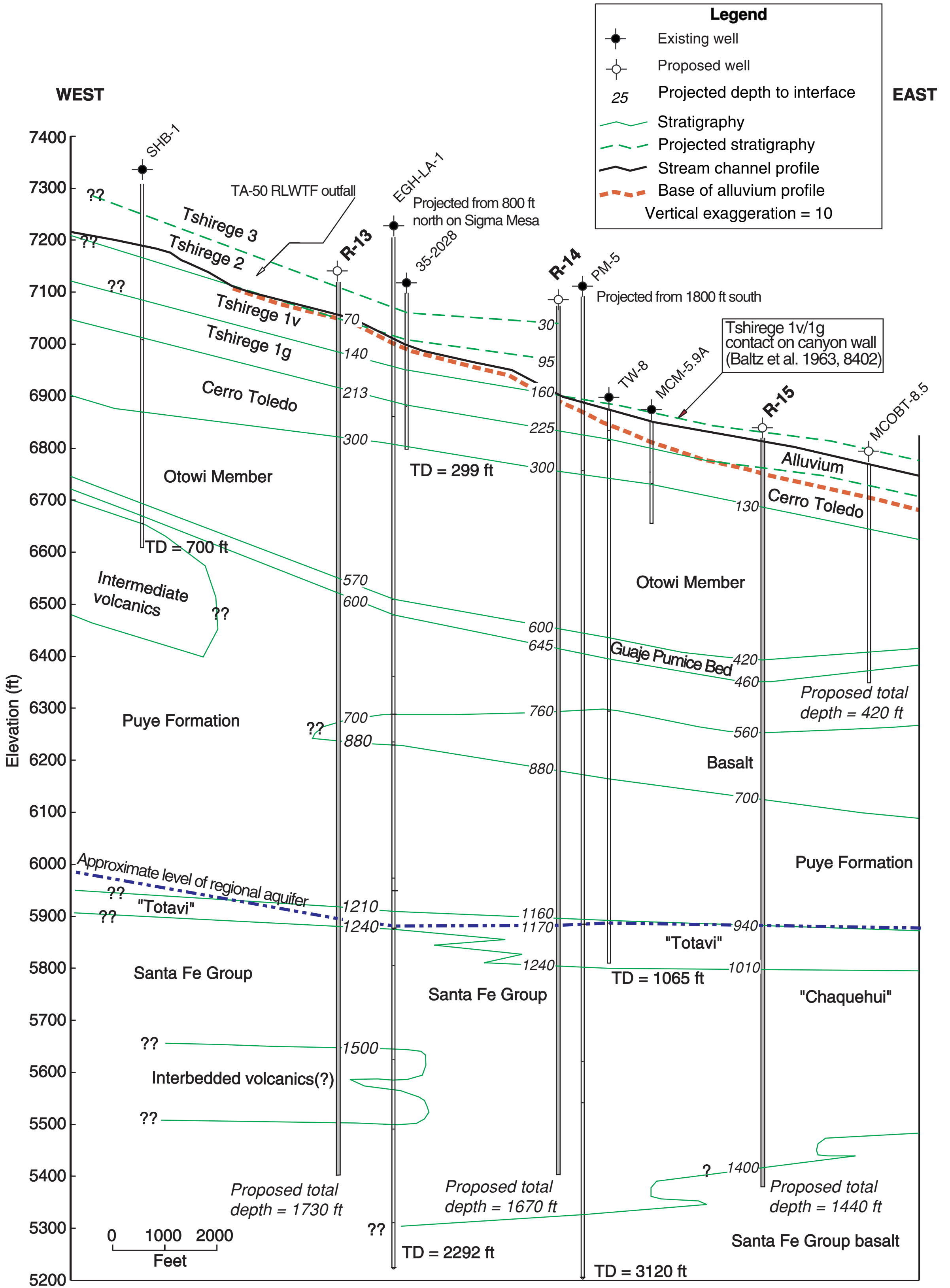
Importance

Laboratory surveillance data collected in Mortandad Canyon show elevated concentrations of ^{241}Am, ^{137}Cs, NO_3, ^{238}Pu, ^{239,240}Pu, ^{90}Sr, tritium, U, ^{234}U, ^{235}U, and ^{238}U in ephemeral surface water. Infiltration of tritium beneath the canyon floor farther east to depths of at least 200 ft (61 m) has been documented by Stoker et al. (1991, 7530) (see Section 3.5.3 in Chapter 3 of this work plan).

Approach

Well R-15 will be located in Mortandad Canyon (near the south side of the canyon). The well is designed to provide characterization water quality, geochemical, and water level data for potential intermediate perched zones (Bandelier Tuff, basalts, and Puye Formation) and the regional aquifer east of the sediment traps. The projected stratigraphy at the location of well R-15 is illustrated in Figure 7.3.4-2. The borehole for well R-15 will be drilled with continuous coring (Type 3 well) into the upper 100 ft (30.5 m) of the regional aquifer (Santa Fe Group) and then backfilled to approximately 40 ft (12.2 m). The well will be completed in the Totavi Lentil, tentatively with a 60-ft (18.3-m) screen placed within the upper 55 ft (16.8 m) of saturation with the regional aquifer. Data from well R-15 will provide stratigraphic, hydrologic, and geochemical information for well R-13 and well R-14. The exact location will be determined based on hydrogeological and geochemical information obtained during this investigation. The installation is proposed as a Type 3 well to be completed in fiscal year (FY) 2000 (LANL 1996, 55430). Borehole advancement and well construction procedures are described in Section 4.1.1.3 of the Hydrogeologic Workplan (LANL 1996, 55430).

Groundwater and/or pore water samples collected from the Bandelier Tuff, basalts, Puye Formation, and Santa Fe Group will be processed using careful sampling and/or filtration/centrugation techniques. Groundwater samples will be analyzed for the parameters listed in Table 7.3.4-8. Given adequate volumes of pore water, those samples will be analyzed for the parameters listed in Table 7.3.4-7. Borehole core samples will be analyzed for the parameters listed in Table 7.3.4-5.



Source: Broxton and Reneau 1995, 49726; Purtymun 1995, 45344; Stoker et al. 1991, 7530

Figure 7.3.4-2. Projected stratigraphic sections for proposed regional aquifer wells.

Issue Number 2

Does contaminated surface water and alluvial and potential intermediate-depth groundwater near MCO-3 provide a source of recharge to the Bandelier Tuff and other intermediate perched zones and to the regional aquifer in middle Mortandad Canyon?

Importance

Well R-13 will be located in Mortandad Canyon (near well MCO-3 and on the south side of the canyon) downstream from active and inactive outfalls at TA-48, -50, and -55. The well is proposed to be installed during FY2001. It is designed to provide water quality, geochemical, and hydrologic data for potential intermediate perched zones and for the regional aquifer near MCO-3. The projected stratigraphy of well R-13 is illustrated in Figure 7.3.4-2. Laboratory surveillance data collected in Mortandad Canyon show elevated concentrations of ^{241}*Am,* ^{137}*Cs,* NO_3*,* ^{238}*Pu,* ^{239,240}*Pu,* ^{90}*Sr, tritium, and uranium in surface water and in alluvial groundwater. Some of the contaminants in alluvial groundwater exceed MCLs in MCO-3 (for example, 22.7 mg/L of* NO_3*-N, MCL = 10 mg/L; 18.5 pCi/L of* ^{90}*Sr, MCL = 8 pCi/L) (Environmental Protection Group 1993, 23249). Contaminant distributions in alluvial groundwater and the observed mobility of* NO_3*,* ^{90}*Sr, and tritium in the unsaturated zone beneath the canyon floor east of MCO-3 strongly support the need to install this additional regional aquifer well. In addition, Purtymun (1967, 8987) suggested that 80% of the annual input to the alluvial groundwater infiltrates into the Bandelier Tuff in the middle canyon near well MCO-3. There is a need to better define the infiltration mechanisms and to quantify the potential transport of contaminants into the Bandelier Tuff and underlying strata.*

The conceptual model of the water loss in middle Mortandad Canyon (as discussed in Chapter 4 of this work plan) includes potential infiltration of alluvial groundwater to perched zones within the Bandelier Tuff, including the Tsankawi Pumice Bed, Cerro Toledo interval, and Guaje Pumice Bed. Infiltration in the upper canyon may occur through units 2, 1g, and 1v of the Tshirege Member of the Bandelier Tuff. A relatively thick section of Cerro Toledo interval that may accumulate water and contaminants may be present beneath Tshirege Qbt 1v unit. The Cerro Toledo interval may merge with the alluvium to form a single hydrogeologic unit in lower Mortandad Canyon.

Infiltration may also occur beneath the Cerro Toledo interval. Groundwater may move downgradient within the Cerro Toledo interval and/or may infiltrate to deeper zones of saturation, such as the Guaje Pumice Bed.

Approach

Well R-13 is proposed to be installed during FY2001 (LANL 1996, 55430) in middle Mortandad Canyon near well MCO-3 to examine existing and potential movement of contaminants to the Guaje Pumice Bed and underlying strata. This Type 2 well will be used to constrain recharge pathways to the regional aquifer to help refine the location of well R-14. In Type 2 wells, approximately 10% of the borehole is cored (rather than continuous core) with emphasis on intermediate perched zones and geologic contacts. The borehole for R-13 will be drilled on the Qbt 2 bench south of the stream channel to avoid saturation within the alluvium. Core will be collected to characterize the subsurface bedrock units, measure moisture content, determine hydraulic properties, and locate possible zones of saturation within the Guaje Pumice Bed and underlying strata. Well R-13 will be completed within the upper 100 ft (30.5 m) of the regional aquifer and may consist of a 60-ft (18.3-m) screen; the top of the screen will be placed 5 ft (1.5 m) above the water table. The well will be installed and completed as described in Section 7.3.4.2.3.

If saturation is encountered within the Guaje Pumice Bed, a separate well will be completed with a screened interval across zones of saturation in the Guaje Pumice Bed at a depth of approximately 570 to 600 ft (174 to 183 m) (see Figure 7.3.4-3). The well will be installed and completed as described in Section 7.3.4.2.2.

Groundwater and/or pore water samples collected from the Bandelier Tuff, basalts, Puye Formation, and Santa Fe Group in well R-13 will be processed using careful sampling and/or filtration/centrugation techniques. Groundwater samples will be analyzed for the parameters listed in Table 7.3.4-8. Given adequate volumes of pore water, those samples will be analyzed for the parameters listed in Table 7.3.4-7.

Borehole core samples will be collected at the base of the Guaje Pumice Bed and the top of the basalts/Puye Formation and, possibly, in other intervals such as the contact between the Cerro Toledo interval and the Otowi Member. Additional borehole core samples will be collected deeper in the borehole when saturation and perching layers are encountered in the Puye Formation. Borehole core samples will be analyzed for the parameters listed in Table 7.3.4-5.

Issue Number 3

What is the long-term integrity, in terms of potential contamination, of supply well PM-5 located 0.35 mi (0.56 km) south of Mortandad Canyon?

Importance

Previous Laboratory investigations and surveillance data show that surface water and alluvial groundwater in Mortandad Canyon contain ^{241}*Am,* NO_3*,* ^{239,240}*Pu,* ^{90}*Sr, and tritium discharged from the TA-50 RLWTF. Elevated activities of tritium occur in core samples collected 200 ft (61 m) below the canyon floor (Stoker et al. 1991, 7530). Sampling and analysis of TW-8 confirmed the presence of* ^{241}*Am (0.034 pCi/L),* NO_3 *(-N) (5.1 mg/L),* ^{239,240}*Pu (0.188 pCi/L),* ^{90}*Sr (2.1 pCi/L), and tritium (89 pCi/L) in the regional aquifer beneath Mortandad Canyon (Environmental Protection Group 1996, 54769).*

Approach

Well R-14 will be installed with Defense Program funding as part of their contribution to the Hydrogeologic Workplan (LANL 1996, 55430). The description of this well is included in this work plan because it supplements and contributes to the hydrogeologic and geochemical characterization of Mortandad Canyon. Well R-14 will be located on the mesa south of Mortandad Canyon upgradient of water supply well PM-5. The well is part of a southeasterly traverse of reference wells for the Laboratory that includes R-6 (Los Alamos Canyon) and R-16 (east side of White Rock) and a north-south traverse that includes R-1 (Rendija Canyon) and R-28 (Water Canyon) as discussed in the Hydrogeologic Workplan (LANL 1996, 55430). The projected stratigraphy at the location of well R-14 is illustrated in Figure 7.3.4-2.

Well R-14 is designed to provide hydrologic information about the radius of influence of pumping from PM-5, and it will be used to detect the migration of contaminants from Mortandad Canyon toward the water supply well. The installation is proposed as a Type 2 well to be completed during FY2001 (LANL 1996, 55430). Borehole advancement and well construction procedures for Type 2 wells are described in Section 4.1.1.2 of the Hydrogeologic Workplan (LANL 1996, 55430). The borehole may be advanced up to 500 ft (152 m) into the regional aquifer. This sampling and analysis plan will be reevaluated after completion of well R-15 and well R-13 for optimizing the information obtained from this borehole and well.

The cores will be subjected to chemical analyses and physical testing, and the borehole will be subjected to a variety of geophysical tests.

Groundwater and/or pore water samples will be collected from the Bandelier Tuff, basalts, Puye Formation, and Santa Fe Group sediments. Samples will be processed using careful sampling and/or filtration/centrugation techniques. Groundwater samples will be analyzed for the parameters listed in Table 7.3.4-8. Given adequate volumes of pore water, those samples will be analyzed for the parameters listed in Table 7.3.4-7. Borehole core samples will be analyzed for the parameters listed in Table 7.3.4-5.

Issue Number 4

What is the composition and geochemistry of the regional aquifer at the water table in well TW-8 in Mortandad Canyon?

Importance

Groundwater that infiltrates beneath the alluvium may form an intermediate perched zone in the Guaje Pumice Bed. No intermediate perched water was reported during the drilling for TW-8 in 1960 (before the TA-50 RLWTF discharge began [1963]), but the borehole was drilled by cable tool, and saturated zones of limited thickness could have been missed. Water-balance studies conducted by Purtymun (1967, 8987) after the TA-50 RLWTF began operation suggested that infiltration from the alluvium may be greatest in the upper canyon upgradient of TW-8. Recharge pathways to the regional aquifer may include flow through the porous rock matrix and fracture flow or leakage along the well annulus. TW-8 is completed in the Puye Formation, and recent sampling and analysis showed the presence of ^{241}*Am (0.034 pCi/L),* NO_3*-N (5.1 mg/L),* ^{239,240}*Pu (0.188 pCi/L),* ^{90}*Sr (2.1 pCi/L), and tritium (89 pCi/L) (Environmental Protection Group 1996, 54769). Pumping tests suggest that the extent of contamination is limited to the immediate vicinity of the well or the water volume immediately inside the well. Near TW-8, the recharge mechanism responsible for the appearance of tritium and other contaminants in the regional aquifer needs to be better defined so that the potential for future contamination can be evaluated.*

Approach

Existing water quality data collected at TW-8 will be reevaluated. After data reevaluation, groundwater samples will be collected in time series (one sample every 4 hours for 48 hours) to evaluate the effects of TW-8 pumping on groundwater chemistry and the distribution of contaminants. Samples will be analyzed for the parameters listed in Table 7.3.4-8.

At installation in 1960, the screen in TW-8 is located at 953 to 1065 ft (290 to 325 m) below ground surface (Purtymun 1995, 45344), and the pump was set at a depth greater than 50 ft (15 m) below the water table of 968 ft (295 m). The depth to water measured in December 1993 was 993 ft (303 m). When the well was refitted in 1993 a submersible pump was installed at an unknown depth below the water table. Dilution of contaminants in infiltrating water may occur during pumping of TW-8 since the pump is not set at the water table. Before collecting additional groundwater samples, the pump will be repositioned within 20 ft (6.1 m) below the water table.

7.3.4.2 Core and Water Sampling Methods

All samples will be collected using the applicable ER Project SOPs (Table 7.3.4-9) (LANL 1991, 21556) 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 7.3.4-9

REQUIREMENTS FOR GROUNDWATER AND BOREHOLE CORE SAMPLING METHODS

Activity	LANL-ER-SOP No.
Surface water sampling	*06.13*
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*

7.3.4.2.1 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 of the Hydrogeologic Workplan (LANL 1996, 55430). The only exception to those specifications is that continuous core samples will be collected throughout the borehole. The boreholes will be drilled through the Cerro Toledo interval to investigate the possible connections between alluvial groundwater and potential groundwater in the Cerro Toledo interval.

7.3.4.2.2 Bandelier Tuff Borehole Advancement and Well Installation

If saturation is encountered within the Guaje Pumice Bed, two Type 5 wells are proposed to be completed in the Bandelier Tuff intermediate perched zones. Borehole advancement and well installation specifications that will be followed in this investigation are discussed in Section 4.1.1.5 of the Hydrogeologic Workplan (LANL 1996, 55430). The only exception to these specifications is that each borehole will be drilled to depths typically less than 500 ft (152 m). Core will be collected along the total depth of the borehole.

Before drilling, the information available on depth and strata expected to be encountered in drilling to the target formation will be reviewed to determine which method of borehole advancement is appropriate for each segment of the borehole.

Well completion will depend on the hydrogeologic conditions encountered at the target horizon, which is expected to be the Guaje Pumice Bed. If a perched zone is encountered, the well will be completed with a

10-ft (3.0-m) or greater length of stainless steel screen and stainless steel casing across the perched zone. From the perched zone to the surface, an alternate casing (such as standard steel or polyvinyl chloride) may be used to minimize cost. A permanent groundwater pump suitable for sample collection may be installed.

7.3.4.2.3 Regional Aquifer Borehole Advancement and Well Installation

Borehole advancement and well installation procedures that will be followed in this investigation are discussed in the Hydrogeologic Workplan (LANL 1996, 55430) (Section 4.1.1.2 for Type 2 wells [R-13 and R-14] and Section 4.1.1.3 for Type 3 wells [R-15]).

7.3.4.2.4 General Geophysical Procedures

Geophysical logging will be conducted on the boreholes for the two Bandelier Tuff wells and the three 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 be determined on a well-by-well basis.

Each borehole for the regional aquifer wells will 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 1000 ft (305 m). Because of the unconsolidated nature of the subsurface strata and use of air-rotary drilling, these boreholes will be cased before wireline logging. Cased-hole logging will be performed from surface to a total nominal depth of 1000 ft (305 m).

Procedures for open-hole and cased-hole geophysical logging are discussed in Section 4.1.6 of the Hydrogeologic Workplan (LANL 1996, 55430).

7.3.4.2.5 General Sampling Guidelines

The procedures described in this section follow those in 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 Bandelier Tuff well and the three regional aquifer wells.

- *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 will be conducted in the Bandelier Tuff at 10-ft (3.0-m) intervals in selected boreholes after the hollow-stem auger and/or Odex/Stratex casing have been removed.*

- *On the continuously cored borehole (R-15), retrieved core samples will be analyzed for tritium and moisture content at 10-ft (3.0-m) intervals. Samples will not be analyzed for moisture content in the Puye Formation, basalts, or Tschicoma Formation 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: three intermediate perched zones (Bandelier Tuff, basalt, and Puye Formation) and the regional aquifer. If possible, moisture profiling will be conducted on four core sample intervals per water-bearing zone. Groundwater samples (and possibly core pore water samples) will be collected from each water-bearing zone and analyzed for the parameters listed in Table 7.3.4-8 (or Table 7.3.4-7 for core pore water samples). Laboratory analyses for these different analytes will be performed on both filtered and unfiltered samples.*

- *Hydraulic properties analyses will be conducted on core samples in each borehole based on stratigraphy, mineralogy, and geochemistry.*

- *Ten samples of cuttings or core will be collected from each borehole drilled into the Bandelier Tuff and the regional aquifer for petrographic, x-ray fluorescence, and x-ray diffraction analyses.*

- *Up to five samples will be collected from the R-15 borehole for K-Ar or $^{39}Ar/^{40}Ar$ isotopic dating of basalts or of tuff deposits in the Puye Formation.*

- *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). In addition, four samples per borehole will be analyzed for VOCs and SVOCs.*

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 Odex/Stratex temporary casing string may be retracted slightly, as necessary, to ensure representative sampling. The borehole will be bailed to promote entry of fresh groundwater, and the borehole will be rested for up to 24 hours before sampling. Samples will be collected for both filtered and unfiltered sample analyses, and sample material will be retained for an appropriate period of time to enable reanalysis, if needed.*

- *As the wells are completed, the temporary Odex/Stradex casing will be retracted, and the annulus grouted, specific intermediate perched zones may be resampled, as needed.*

- *After the wells are completed and developed, groundwater samples will be collected from each screened interval or Westbay-type port and analyzed for the presence of selected RCRA Appendix VIII and IX constituents and radionuclides.*

7.3.4.3 Analytical Methods

This section describes the methods for analyzing groundwater samples for organic chemicals, inorganic chemicals, and radionuclides and the methods for analyzing borehole core samples for inorganic *chemicals and 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.*

7.3.4.3.1 Analysis of Groundwater Samples

Groundwater samples collected according to the strategy outlined in Section 7.3.4.1 will initially undergo full-suite analyses for organic chemicals, inorganic chemicals, and radionuclides at ER Project-approved fixed-site laboratories. The analytical suites for analysis of organic chemicals, inorganic chemicals, and radionuclides are listed in Table 7.3.4-4, Table 7.3.4-5, Table 7.3.4-7, and Table 7.3.4-8. All analyses for organic chemicals will be performed in accordance with EPA SW-846 protocols (EPA 1986, 31733). The detailed analyte lists, EQLs, MDAs, 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, Bandelier Tuff, and regional aquifer well and at each surface water sampling location will undergo analysis for the full suite of organic chemicals, 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 and groundwater. The target analytes, conservative EDLs, and analytical methods for inorganic chemicals are listed in Table 7.3.4-10. 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). 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 1986, 31732), 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, MDAs, and analytical methods for radionuclides are listed in Table 7.3.4-11. In addition to measurements of gross-alpha, -beta, and -gamma radioactivity, the radionuclide analytes include ^{241}Am, ^{238}Pu, ^{239,240}Pu, ^{90}Sr, tritium, ^{234}U, ^{235}U, ^{236}U, and ^{238}U. The analyses for low-detection-limit tritium and ^{236}U 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 ^{232}Th, ^{235}U, and ^{238}U 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

TABLE 7.3.4-10

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*
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 1986, 31732) or equivalent

TABLE 7.3.4-11

MINIMUM DETECTABLE ACTIVITY AND ANALYTICAL METHODS FOR RADIONUCLIDES IN GROUNDWATER SAMPLES[a]

Analyte	Half-Life (yr)	Detected Emission	MDA (pCi/L)	Analytical Method
^{241}Am	432.2	α	0.05	α-Spectrometry
^{238}Pu	87.7	α	0.05	α-Spectrometry
^{239,240}Pu[b]	2.411×10^4	α	0.05	α-Spectrometry
^{90}Sr	28.7	β	1.0	GPC
Tritium	12.3	β	250	LSC
Tritium (low level)	12.3	β	1	Electrolytic enrichment/GPC
^{234}U	2.46×10^5	α	0.1	α-Spectrometry[c]
^{235}U	7.04×10^8	α	0.1	α-Spectrometry[c]
^{236}U[d]	2.342×10^7	α	0.1	TIMS
^{238}U	4.47×10^9	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 ^{239}Pu and ^{240}Pu isotopes cannot be distinguished by alpha spectrometry. The half-life of ^{239}Pu is given.
c. Radionuclide may also be analyzed by ICPMS.
d. Water sampling for ^{236}U 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 MDA for ^{137}Cs is 15 pCi/L; the MDAs for other analytes will vary.

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 ^{40}K 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 ^{40}K gamma emission peak provides a qualitative indicator of the accuracy and precision of the gamma spectroscopy measurement, but ^{40}K is not considered to be a potential contaminant. The required QC procedures and acceptance criteria for the radiochemical analyses (except low-level tritium and ^{236}U) 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.

Groundwater samples will also be analyzed for the additional parameters listed in Table 7.3.4-12. To better understand the nature of recharge to an aquifer, analysis for ^{14}C, ^{36}Cl, and stable isotope ratios deuterium/hydrogen and ^{18}O/^{16}O will be performed to estimate the age of water and to help identify specific sources of recharge. Analyses for ^{13}C 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 7.3.4-13 will be made at the time of sample collection.

TABLE 7.3.4-12

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*
Chlorine-36	*MS*
Organic Compounds	
VOCs	*SW-8260*[c]
SVOCs	*SW-8270*
Other Analytes	
Total organic carbon	*SW-415.1*[d]
Dissolved organic carbon (humic substances)	*USGS/WRI 79-4*
Hardness (as $CaCO_3$)	*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 1986, 31733)

d. EPA 1983, 56406

TABLE 7.3.4-13

FIELD MEASUREMENTS FOR GROUNDWATER SAMPLES

Measurement	Precision[a]	Method
Alkalinity	*±1 mg/L $CaCO_3$*	*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. LANL 1991, 21556

7.3.4.3.2 Analysis of Borehole Core Samples

Borehole core samples collected according to the criteria outlined in Section 7.3.3.1.4 will undergo analysis at ER Project-approved laboratories for the inorganic chemicals and radionuclides listed in Table 7.2.6-3 and Table 7.2.6-4. 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 7.3.4-14. Measurements for inorganic chemicals include analyses for 26 trace metals, major anions (bromide, chloride, fluoride, and sulfate), and total cyanide. All analyses for inorganic chemicals will be performed according to EPA SW-846 protocols

(EPA 1986, 31732) 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 1986, 31733]) 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.

TABLE 7.3.4-14

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*
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 Inorganic Chemicals			
Total cyanide	*0.05*	*Colorimetry*	*SW-9012A*

a. EPA SW-846 Method (EPA 1986, 31732)

b. Anion analyses will be performed on the leachate formed from a deionized water slurry of the homogenized core sample.

Borehole core samples will also be analyzed for the properties identified in Table 7.3.4-15. 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.

TABLE 7.3.4-15

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*
Moisture content	*ASTM D 2216-92*
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 (LANL 1991, 21556).*

7.3.4.4 Hydrologic and Geochemical Modeling

Hydrologic and geochemical modeling will be performed as part of data synthesis and evaluation activities. A central 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 actinides, fission products, metals, nitrates, and other solutes in Mortandad Canyon. Tools for this purpose include computer models, such as MINTEQA2 (Allison et al. 1991, 49930) and others discussed in Section 5.3.1 of the core document (LANL 1997, 55622).

Hydrologic modeling may be useful first to describe and verify water-balance estimates. Models could also include MODFLOW (being applied by New Mexico state personnel), a revised lumped-parameter model (for example, Koenig and McLin circa 1993, 56029), and others. Movement in the alluvium may be modeled using MODFLOW; unsaturated flow may be modeled using UNSATII, FEHM, or TRACR3D. The regional aquifer will probably require development of a completely new model (Frenzel 1995, 56028).

Hydrologic and geochemical modeling will be applied at all stages of this investigation. In the project design phase, modeling can 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 can 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 will 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, they will be used continually to refine the hydrogeologic and geochemical components of the conceptual model. For example, new data collected in Mortandad Canyon will be compared with groundwater flow maps, water chemistry, 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 Mortandad 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.

Key steps in refining the Mortandad Canyon conceptual model are as follows.

1. *Integrate available data for Mortandad Canyon geology, hydrology, and water quality/geochemistry.*
    - *Incorporate hydrologic, stratigraphic, geophysical, and chemical data for Mortandad Canyon into a centralized database (FIMAD)*
    - *Develop a three-dimensional representation of stratigraphy and geology for Mortandad 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 Mortandad 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 shortcomings with respect to placement of wells for characterization*
3. *Refine the conceptual model and upgrade the groundwater monitoring network for Mortandad 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*

7.4 Air-Particulate Sampling and Analysis Plan

This section describes the strategy for collecting suspended air particulates by siting air-particulate sampling stations in reaches of Mortandad Canyon. This section also discusses the type of air-particulate sampling equipment required to collect monthly samples in remote locations and the subsequent analysis of the annual composited samples.

7.4.1 Objective

The objective of air-particulate sampling in Mortandad Canyon is to provide information on the annual total suspended particulate matter load, the inhalable and respirable particulate matter fractions (10 and 2.5 µm in diameter) (PM10 and PM2.5), and the types and concentrations of contaminants bound to these fractions. This information is necessary for evaluating risk from dust inhalation to individuals who use the canyon in the scenarios evaluated for Mortandad Canyon.

Although substantial environmental surveillance data are available from the Laboratory's Airnet monitoring stations, these stations provide data for regulatory compliance and address total airborne emissions at the Laboratory boundary, at occupied areas near the Laboratory, and at active operations areas. Although isotopic analyses of composites of filters from these stations are available for some radionuclides, full-suite analyses are not performed for radionuclides and inorganic chemicals. PM10 data have been collected at some locations, but they have been analyzed only for quantity of suspended particulates in that size fraction and not for specific associated contaminants.

The stations near Mortandad Canyon are all located on mesa tops, locations that are inadequate to address risks to users within the canyon. Resuspension of contaminants will be a function of activities in the canyon including human, vehicular, and animal traffic, activity, and patterns. No Airnet stations currently monitor canyon dust resuspension. At best, EPA Particle Total Exposure Assessment Methodology reports have concluded that air monitoring data, even when obtained near human activity, underestimate concentrations of airborne particulates to which individuals are actually exposed. This discrepancy is caused by human activity producing localized higher particulate concentrations than the surrounding air.

To be useful for risk assessment, air monitoring data must be collected according to the following criteria.

- *Data collected in the breathing zone of humans (5 to 7 ft [~2m] above ground surface)*
- *Monitoring locations within the exposure area to ensure that resuspension resulting from local wind patterns is being measured*
- *Determination of specific radionuclide and other contaminant profiles*
- *Measurement of PM10 (inhalable) and PM2.5 (respirable) fractions*

This last point is a measure of deposition efficiency of contaminants by this exposure route. Toxicity is linked to the ability of the contaminant to be taken into the body and to penetrate deep into the lungs or other target tissues, which is a function of particle size. The smaller particles (2.5-µm fraction) have the *highest probability of penetrating deep into the lungs. Particles larger than 10 μm are unlikely to enter even the upper airways. Contaminant concentrations obtained only on total suspended particulates are not interpretable for risk purposes because the percentage of the total that is likely to reach the target organ cannot be determined.*

Likewise, if the specific contaminants present on the particles are not known, the target tissue and potential dose cannot be determined. For example, if only gross-gamma is measured, the counts may reflect primarily ^{40}K*, known to be naturally occurring at significant concentrations (25 to 40 pCi/g) on the Pajarito Plateau but not of concern for adverse health effects through inhalation. For particulates that contain relatively insoluble contaminants, such as americium and plutonium, penetration deep into the lungs results in long residence times and, therefore, significant radiation doses to lung tissue. For particles that deposit in the upper airways and trachea (>2.5 μm and <10 μm) the possibility of dissolution of contaminants and/or local or systemic penetration before clearance can still result in considerable toxicity. Therefore, the objectives of air-particulate data collection are to determine the correlation of particle size and contaminant concentration so that conclusions can be drawn with respect to toxicity and deposition patterns.*

7.4.2 Data Quality Objectives for Air-Particulate Sampling and Analysis

The results of the radiochemical analyses will be used in present-day risk assessment for evaluating risk from inhalation of dust resuspended from the canyon floors during human activity related to risk exposure scenarios.

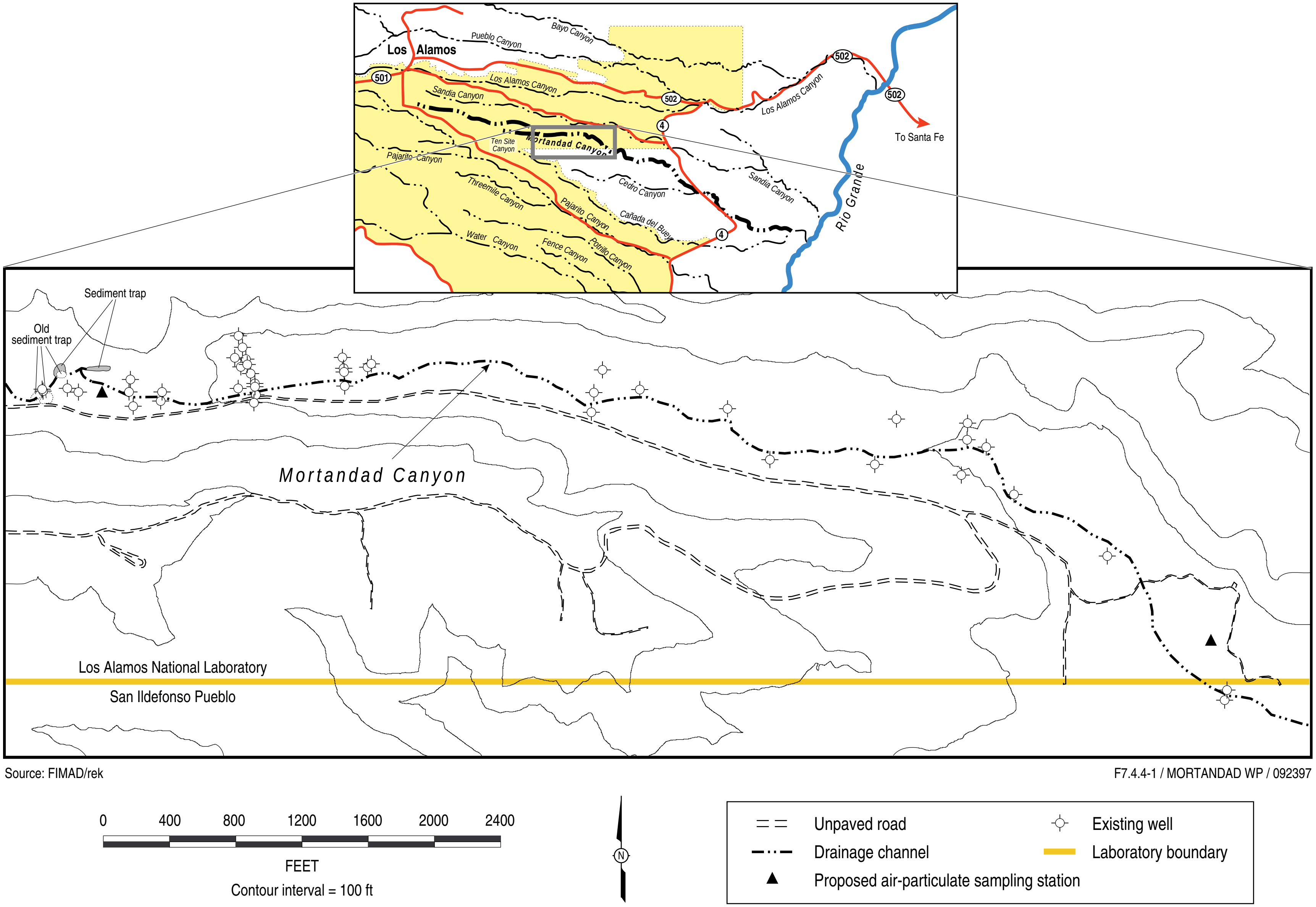
7.4.3 Sampling Design

Because concentrations of radionuclides in air filters are expected to be low, a pilot study is currently investigating the utility of microanalytical techniques such as μ-proton induced x-ray emission (μ-PIXE) to correlate particular inorganic and radionuclide contaminants with specific particle sizes. Pilot data on a sediment sample have indicated that the observed concentration of plutonium is consistent with the standard analytical laboratory data on a larger sample volume and allowed localization of plutonium in that sample to a particle of <3 μm. However, isotopic information on plutonium and other radionuclides cannot be determined with this technique. Generally toxicity does not depend on the specific isotope (mass number) but rather on the radionuclide (atomic number); therefore, loss of this information should not have a major impact on data use in risk assessment. In addition, it is likely that the isotopic ratios in sediments for which data are available are approximately those in the airborne particulates because the dust is derived from the sediments.

The approach to air-particulate sampling in Mortandad Canyon is to assess the relationship between actual airborne particulate concentrations of contaminants and the particle-size distribution of contaminants on sediments. This relationship will allow the development of a canyon-specific resuspension model that is validated through air-particulate monitoring data. Mortandad Canyon is an appropriate place to establish and validate such a model because it will continue to be a discharge point for the Laboratory beyond the scheduled completion of the ER Project, it is heavily used by the public, and the inventory and number of contaminants is high relative to other canyons.

7.4.4 Sampling Locations

Two air-particulate sampling stations are proposed for Mortandad Canyon as shown in Figure 7.4.4-1. One station will be located near the sediment traps; the other station will be located at the boundary between the Laboratory and San Ildefonso Pueblo.



Source: FIMAD/rek

F7.4.4-1 / MORTANDAD WP / 092397

Figure 7.4.4-1. Proposed air-particulate sampling stations in Mortandad Canyon.

Samples will be collected in reaches that are identified for sediment sampling to examine the relationships between sediments and suspended particulates. Air sampler inlets will be sited to ensure that operational specifications are met with respect to clearance above, below, and around the inlet port and that samplers will be operated at a flow rate to ensure that manufacturer's specifications for maintaining laminar flow conditions are met. Stations generally require a minimum of 7 ft (2.1 m) in all directions from the inlet to be free of obstruction because obstructions in the intake path or operation above or below recommended flow rates can result in turbulence that disrupts the flow pattern.

7.4.5 Sampling Methods Requirements

Power requirements, potential for particulate contamination from diesel exhaust, and limitations of filters make the use of high-volume samplers impracticable in Mortandad Canyon. Therefore, low-flow monitors are anticipated to be the most useful and are proposed. Flow rates will be maintained near human breathing rates of 2 to 5 liters per minute. Each monitoring station will be equipped with PM10 impactor cartridges. Contaminants on the PM2.5 fraction will be determined by the filter analyses.

Samples will be collected continuously for a two-month period, although systems will be monitored at least weekly. Pumps are equipped with a sample time monitor to assess equipment performance. Flow controllers on the pumps will ensure that the systems are operated within manufacturer's specifications for the impactor to ensure laminar flow at the inlet ports. Initial samples will be collected during the spring to coincide with the windiest period of the year. Units will be tested before that time to ensure that the run times are sufficient to load the filters with enough material for analysis. Individual filters will be analyzed to determine the correlation of contaminants with particle size fractions, and filters will be retained for bulk analysis of composite samples for a one-year period. Depending on the results of the initial analysis, sampling durations may be altered.

7.4.6 Analytical Methods Requirements

The ideal analytical technique for this approach would have low detection limits, have multielement sensitivity, require small sample volumes, and provide information on particle sizes. Initial data from µ-PIXE analysis in the pilot project suggest that this method is a promising tool in these studies. The quantitation limits are in the fg/particle range, and the analysis can be phased to begin with bulk analysis of the filter with a broad beam width (10 µm) to determine the approximate location of a particle of interest. The beam can be progressively narrowed to isolate the particle and determine its size and composition. Because the technique is nondestructive, samples can be retained for future composite analysis. Therefore, if quantitation is not possible on the individual filter samples, qualitative information on particle size distribution can still be used to improve estimates of toxicity in combination with the laboratory analyses of the larger volume pooled samples. The anticipated costs for these combined techniques are calculated to be less than collecting unfractionated samples, separating fractions by cascade impactors, and analyzing each fraction. Filters will be analyzed for cesium, mercury, plutonium, strontium, uranium, and any other contaminants identified in the reach sediment samples as being of concern for risk.

Composite air-particulate samples will be analyzed for radionuclides including ^{241}*Am,* ^{137}*Cs,* ^{90}*Sr, isotopes of plutonium and uranium, mercury, and any other constituents identified through sediment analyses as potentially important for risk concerns. The analytical methods are discussed in Section 7.2.6.3. Particulate samples will undergo complete digestion before being analyzed for alpha and beta emitters. Alpha emitters will be analyzed by radiochemical separation and alpha spectrometry; beta emitters will be analyzed by gas proportional counter; gamma emitters will be analyzed by gamma spectroscopy. Because alpha and gamma emitters are analyzed by a nondestructive technique, alpha spectrometry and gamma spectroscopy will be performed first.*

These analytical approaches will allow a quantitation through standard analytical procedures on the composite filters. In addition, the µ-PIXE analysis, if applied to this investigation, will allow investigators to qualitatively determine the proportion of the contaminants suspended in air that are bound to noninhalable, inhalable, or respirable fractions. By combining these methods, variables known to be determinants of toxicity for inhaled materials can be addressed in the risk assessment, and a more precise estimate of potential toxicity from this route of exposure can be provided to the public and regulators. Because this route of exposure has been frequently raised as a major public concern, this level of analysis is essential during this investigation.

7.5 Biological Sampling and Analysis Plan

This section presents the sampling and analysis plan for investigating the Mortandad Canyon ecosystem. The biological investigation includes assessment of the risks from Laboratory-derived contaminants to ecosystem receptors, which may be directly or indirectly exposed, and human receptors, who may be exposed by consuming native plants or wildlife living in the canyon.

As discussed in the core document (LANL 1997, 55622), the approach for evaluating ecological risks is currently being negotiated between NMED, DOE, the 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 Mortandad Canyon will be developed to be consistent with that approach.

The iterative approach described in the core document will be followed to evaluate the contribution of biota as a transfer pathway for contaminants from sediment and groundwater to receptor species including humans. For both ecological risk assessment and evaluation of human health risks that result from the distribution and transport of contaminants via biota, it will be necessary to develop transfer coefficients for contaminants from sediments and water to biota. Use of specific plant and animal species and tissues by American Indians is being defined through ongoing surveys. For those species identified as important for the American Indian exposure scenarios, existing site-specific data will be used as the primary basis to develop distributions for contaminant uptake. Additional data from peer-reviewed literature will be incorporated as appropriate to bound transfer coefficients. Sediment and groundwater analytical data will be evaluated using these distributions to derive plant and animal tissue concentrations. If sensitivity analyses on risk evaluations indicate that the risk models are sensitive to remaining uncertainties in these transfer coefficients, additional data will be obtained to address those uncertainties. Specific species, tissues, and analytical techniques will be determined to ensure detection limits sufficient to reduce model uncertainties.

Although some data are available on concentrations of some radionuclides in the tissues of plants and animals found in the Mortandad Canyon system (as discussed in Section 3.9.4 in Chapter 3 of this work plan) the data are incomplete with respect to human health and ecological risk assessment requirements. Data collected in the studies described in this section will target data gaps. Specifically, data will be collected on (1) species and tissues identified as important in American Indian land use scenarios; (2) contaminants identified in sediments, surface water, and groundwater not previously evaluated (for example, mercury and selected radionuclides); and (3) sensitive ecosystems such as wetlands that have not been previously evaluated.

Transfer coefficients for biota-soil and biota-water can vary widely (as discussed in Section 3.9.4 in Chapter 3 of this work plan) depending on the characteristics of the soil, the species, and the growing conditions.

- *Composition of the soil, organic matter, texture, mineralogy, and water (pH, dissolved constituents, and trace metals)*

- *Climatic conditions (light, precipitation, precipitation frequency, and rain splash)*
- *Mixture of contaminants (competition for uptake by competing ligands)*

Exposure also depends on species and intended use, which varies among ingestion, dermal contact, inhalation (of combustion products), and consumption of specific tissues. These parameters will be examined using existing data to improve interpretation, reduce discrepancies and uncertainties to the extent possible, and focus needs for new data on the discrepancies and uncertainties in those parameters that are most sensitive to the risk assessment outcome.

7.5.1 Objective

The objective of the biological investigation in the Mortandad Canyon system is to assess the risk from Laboratory-derived contaminants to human and ecosystem receptors. The objective will be achieved by examining the three components of the Mortandad Canyon ecosystem summarized below.

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

The first two objectives described above will be addressed by the Laboratory-wide ecological risk investigations. The third objective will be addressed as part of this investigation, and the data will support human health risk for the American Indian use scenarios. These data will also be used as a source for future site-wide ecological risk investigations. The appropriate level of detail for ecological risk assessments has not yet been determined.

7.5.2 Data Quality Objectives for Biological Sampling and Analysis

This section briefly describes the data quality objectives process (EPA 1994, 50288) as completed for the investigation of biological system contributors to human health and ecological risk.

1. *State the problem.*

   Contaminants in the Mortandad Canyon system may result in direct and indirect exposure to ecological receptors and humans who use garden produce, native plants, or native wildlife that live in the system.

2. *Identify the decision(s).*

   The data for this investigation are being collected to provide site-specific values for a variety of parameters used in models for human health and ecological risk. Risk estimates will form the basis *for decisions regarding future sampling and analysis, corrective actions, and negotiations with stakeholders.*

3. *Identify inputs to decision(s).*

   From radiation survey

   - *Gross-alpha, -beta, and -gamma readings at selected locations*
   - *Field gamma spectroscopy at selected locations*

   From sediment and water analyses

   - *Contaminant concentrations and distributions as the basis for identifying locations for sampling biota*

   From American Indian stakeholders

   - *Preferred locations for collecting native plant species*
   - *Likely period and location of livestock grazing in the canyon system*
   - *Identification of biota of importance*

   From this study

   - *Concentrations of COPCs in biota of importance*

4. *Define the study boundaries.*

   - *Spatial*

     Plant samples will be collected from locations that span the range of contaminant concentrations found in sediment samples. In addition, samples will be collected at locations identified as important biota sources by stakeholders.

   - *Temporal*

     - *Field Investigations*

       Biota samples will be collected during the same field season as sediment samples to ensure that seasonal effects on contaminant concentrations do not compromise the source data. If additional biota samples are required to reduce uncertainties, soil samples will be collected at the same time.

     - *Interpretive Study*

       Interpretation and assessment of existing and new data are expected to require approximately one year after the data have been collected.

5. Develop a decision rule.

The data will be acceptable unless errors in the sampling process or analytical procedures are identified during data validation. Site-specific values from this and previous investigations will be given preferential weighting for risk assessment inputs. Data from peer-reviewed literature will be incorporated, as necessary, if applicable to reduce model uncertainties.

6. Specify limits or uncertainty.

Based on reported uptake of plutonium by vegetation in Los Alamos Canyon, Pueblo Canyon, and Mortandad Canyon (White and Hakonson 1979, 11995; White et al. 1981, 11994) a standard deviation of 100 to 200% is to be expected in the native plant data. If the concentrations and distributions of data collected in the first field season on parameters that contribute significantly to risk are highly variable, additional data may be collected to reduce uncertainty in the key parameters (such as those for which reducing uncertainty could clarify or alter a remediation decision).

7.5.3 Technical Approach

Tentatively, to evaluate ecological risks, an assessment endpoint evaluation strategy will be used as described in Section 6.5.3 in Chapter 6 of the work plan for Los Alamos Canyon and Pueblo Canyon (LANL 1995, 50290). An assessment endpoint consists of two parts: the potential receptor of the contaminant and a criterion for unacceptable risk to the receptor. The measurement endpoint is the parameter that will be used to determine the risk due to contamination. The proposed assessment endpoints, including the potential receptors and corresponding measurement endpoints, are listed in Table 7.5.3-1 for each of the three components described in Section 7.5.1. The following sections describe the approach to evaluating each component of the ecosystem assessment.

7.5.3.1 Assessment of Ecosystem Receptors

Sample collection and analysis to evaluate exposure to ecological risk receptors will not be proposed until the assessment endpoints and their exposure units have been agreed upon. Negotiations are underway between the Laboratory, DOE, EPA, NMED, and the Accord Pueblos to define the assessment endpoints, exposure units, exposure models, and risk models. In addition, Laboratory personnel have worked with the Accord Pueblos to help define appropriate risk scenarios for the American Indian population near Mortandad Canyon. When an agreement has been reached, a preliminary assessment using available data will be conducted to assess uncertainties and identify sensitive parameters in the models. The sampling and analysis plan will focus on collecting data for the most sensitive and uncertain parameters identified for the ecological risk assessment.

Biological sampling to support ecological risk assessment is not appropriate at this time. Although the exposure units for ecological receptors may closely resemble the Mortandad Canyon boundaries described in Chapter 3 of this work plan, additional areas need to be considered when designing sampling and analysis plans. For example, it is unlikely that Mortandad Canyon contains discrete wildlife populations that would define a single exposure unit. Therefore, the appropriate criteria for risk assessment of biological communities may require examining areas that extend beyond Mortandad Canyon. In some cases, evaluating the entire Pajarito Plateau canyon system may be necessary to support appropriate ecosystem risk assessments.

TABLE 7.5.3-1

PROPOSED BIOLOGICAL ASSESSMENT ENDPOINTS

Receptor	Measurement Endpoints	Rationale for Selection
Ecosystem Receptors: Threatened and Endangered Species		
Jemez Mountains salamander	*Chemical uptake or measured adverse effects on related salamander species*	*Indicator of impacts to moist, mixed-conifer habitats; sensitive to remediation-caused disturbances; effects of contaminants on amphibians are poorly understood*
Peregrine falcon	*Biomarker response in Cooper's hawks and/or juvenile falcons, measured reproductive success rates, chemical concentrations in prey species*	*Species with a history of contaminant-induced population impacts; sensitive to remediation-caused disturbances; substantial population data are available for Cooper's hawks*
Mexican spotted owl	*Concentration in cast pellets and/or prey, biomarker response in juvenile owls*	*Species potentially affected by COPCs in small mammals; sensitive to remediation-caused disturbances*
Meadow jumping mouse	*Biomarker response in this or a surrogate species, measurement of population characteristics*	*Species is an indicator of COPC effects in small mammals; sensitive to remediation-caused disturbance effects*
Spotted bat	*Biomarker response in this or a surrogate species of bats*	*Species is sensitive to remediation-caused disturbances; effects of contaminants on bats are poorly understood*
Ecosystem Receptors: Communities		
Aquatic community	*Benthic invertebrate community structure, chemical water quality criteria, frog embryo teratogenesis assay*	*A sensitive community that integrates and may expose many species to many sources of contaminants; community measures may detect changes in species interactions that are not detectable with single-species approaches; makes use of available data*
Soil community	*Biomarker response in soil organisms (microbes and/or earthworms in field or laboratory bioassays), decomposition rates*	*Effects on these organisms indicate ecosystem-level effects on soil productivity; soil communities are key processors of energy and nutrients in ecosystems; soil organisms are part of ecological exposure pathways*
Plant community	*Community diversity indices, concentrations in plant tissues*	*Community indices may detect ecosystem effects not detectable from single-species approaches and also make use of available data; contaminant concentrations in plants are needed for exposure assessments (ecotoxicological and human)*
Animal community	*Bird community diversity indices, concentrations in animal tissues, biomarker responses of small mammals (pocket gophers) and western bluebirds*	*Bird community measures are relatively inexpensive and may detect changes in species interactions that are not detected with a single-species approach; pocket gophers and bluebirds have relatively high sediment ingestion rates, represent pathways to other ecological receptors, and they are easily sampled; their population dynamics are easily studied; makes use of available data*
Regulated Environment		
Wetlands	*Benthic invertebrate community structure, chemical water quality criteria, frog embryo teratogenesis assay*	*A sensitive habitat (many species use wetlands for part of their life cycle) that integrates many sources of contaminants and may expose many species to them; evaluation is integral with aquatic community evaluation*
Garden produce	*Concentrations of COPCs in washed and unwashed produce*	*Part of human exposure pathway; required for human health risk assessment*
Elk/deer population	*Concentrations in tissues*	*Part of human exposure pathway and part of animal community ecological risk assessment*

TABLE 7.5.3-1 (continued)

PROPOSED BIOLOGICAL ASSESSMENT ENDPOINTS

Receptor	Measurement Endpoints	Rationale for Selection
Biological System Contributors to Human Health Risk		
Small game populations	*Concentrations in tissues, biomarker responses, population characteristics*	*Part of human exposure pathway and part of animal community ecological risk assessment*
Avian population	*Concentrations in tissues, biomarker responses, population characteristics*	*Potential human consumption and other use of tissues or eggs*
Native plants	*Concentrations in tissues, biomarker responses, population characteristics*	*Consumption for dietary or medicinal purposes; inhalation of combustion products during medicinal or ceremonial uses, food preparation, or heating*

The investigations of sediment, groundwater, and air particulates that are proposed in the preceding sections of this chapter will provide important data for the ecological risk assessment. For example, hydrogeologic and geomorphic units are natural sources of environmental heterogeneity within exposure units, and they may form natural boundaries between some exposure units. Therefore, mapping and characterizing heterogeneous units will provide essential data to ecological exposure assessments.

7.5.3.2 Wetlands Investigation

Wetlands are associated with outfalls in Effluent Canyon and Mortandad Canyon. The Laboratory Environmental Assessments and Resource Evaluations group (ESH-20) is preparing an inventory of wetlands as part of an ongoing survey of the canyons of the Pajarito Plateau. Until the wetlands inventory is completed, discrete sampling during the initial stages of the investigation will be limited.

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

7.5.3.3 Biological System Contributors to Human Health Risk

Exposure routes for assessing human health risk include the ingestion of fish, wildlife, native plants, and domesticated plants (see Section 4.2 in Chapter 4 of this work plan). American Indian populations also gather wild edible plants and other plants used for ceremonial purposes. Sampling in Mortandad Canyon is proposed to determine whether native plants and domestic livestock are significant pathways for human exposure.

The Indian Pueblo representatives will be consulted to define significant species routinely gathered in the canyons. From these, three species will be selected for sampling from each of the piñon-juniper and ponderosa pine plant communities in the Mortandad Canyon system. Because of the ceremonial significance of some of these species, sampling will be conducted by Accord Pueblo representatives and exact sampling locations may not be disclosed. Two samples of each species will be collected from each reach in the plant communities in which they occur. Therefore, the maximum number of native plant samples will be six times the number of reaches. The plants will be analyzed for the limited suite of COPCs.

Two samples of livestock forage will be collected from each reach that has been sampled during the sediment investigation and is considered suitable for grazing. The suitability of a reach for livestock grazing will be determined by consulting with stakeholders. Sampling will occur during periods identified by American Indian stakeholders as likely grazing periods. The livestock forage samples will be analyzed for the limited suite of COPCs.

Cores of mature pines suitable for firewood will be analyzed for radionuclides. Autoradiography will be used to determine whether contaminants are localized in specific growth rings such that significant human health risks may result from inhalation of combustion products. Bulk analysis might underestimate actual exposure to localized high contaminant concentrations.

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Appendix A

Maps

Figure A-1. Major contaminant sources for the Mortandad Canyon watershed.

FIMAD Plot ID: 105666 (September 19, 1997)

Available from the Facility for Information Management, Analysis, and Display (665-2807)

Figure A-2. Mortandad Canyon watershed showing locations of boreholes, wells, and sediment samples.

FIMAD Plot ID: 105665 (September 19, 1997)

Available from the Facility for Information Management, Analysis, and Display (665-2807)

Figure A-3. Stream channel profile and cross sections of Mortandad Canyon system showing important wells and well construction information.

FIMAD ID: G105889 (September 25, 1997)

Available from the Facility for Information Management, Analysis, and Display (665-2807)

Figure A-4. East-west cross section of Mortandad Canyon showing important wells and conceptual water/contaminant flow paths.

FIMAD ID: G105890 (September 25, 1997)

Available from the Facility for Information Management, Analysis, and Display (665-2807)

Appendix B

List and Status of PRSs

TABLE B-1

PRSs IN THE MORTANDAD CANYON WATERSHED

PRS No.	Description	HSWA	OU	FU	NFA Status	NFA Criterion
00-001	*Sediment traps*	*Yes*	*1049*	*4*		
00-005	*Former garden plot*	*Yes*	*1071*	*1*	*Final AA approval of permit modification 12/10/96*	*5*
03-001(h)	*Satellite storage area*	*No*	*1114*	*1*	*Proposed in permit modification 9/96*	*3*
03-001(j)	*Satellite storage area*	*No*	*1114*	*1*	*Proposed in permit modification 9/96*	*3*
03-001(y)	*Satellite storage area*	*No*	*1114*	*1*	*Proposed in permit modification 9/96*	*3*
03-003(e)	*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(i)	*Storage area (transformer)*	*No*	*1114*	*1*	*Proposed in work plan or RFI report that received an NOD or disapproval letter from AA*	*4*
03-004(a)	*Container storage*	*No*	*1114*	*1*	*Proposed in permit modification 9/96*	*3*
03-004(b)	*Container storage*	*No*	*1114*	*1*	*Proposed in permit modification 9/96*	*3*
03-004(c)	*Storage area*	*No*	*1114*	*1*		
03-004(d)	*Storage area*	*No*	*1114*	*1*		
03-004(e)	*Storage area*	*No*	*1114*	*1*	*Proposed in permit modification 9/96*	*3*
03-004(f)	*Storage area*	*No*	*1114*	*1*	*Proposed in permit modification 9/96*	*3*
03-007	*Firing site*	*No*	*1114*	*1*		
03-009(c)	*Surface disposal*	*Yes*	*1114*	*1*	*Proposed in permit modification 3/95*	*3*
03-009(e)	*Surface disposal*	*Yes*	*1114*	*1*	*Final AA approval of permit modification 12/10/96*	*1*
03-009(h)	*Surface disposal*	*Yes*	*1114*	*1*	*Final AA approval of permit modification 12/10/96*	*1*
03-010(b)	*Operational release*	*No*	*1114*	*1*	*Final DOE approval of permit modification*	*2*
03-012(a)	*One-time spill*	*Yes*	*1114*	*1*	*Final AA approval of permit modification 12/10/96*	*5*
03-014(w)	*Wastewater treatment facility*	*No*	*1114*	*1*	*Proposed in report/work plan*	*5*
03-014(x)	*Wastewater treatment facility*	*No*	*1114*	*1*	*Proposed in report/work plan*	*5*
03-025(a)	*Tank and/or associated equipment*	*Yes*	*1114*	*1*	*Proposed in permit modification 9/96*	*1*
03-026(a)	*Sump*	*No*	*1114*	*1*	*AA concurrence for deferral*	
03-026(c)	*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*
03-030	*Surface impoundment*	*No*	*1114*	*1*	*Proposed in permit modification 9/96*	*1*
03-031	*Tank and/or associated equipment*	*Yes*	*1114*	*1*	*Proposed in permit modification 9/96*	*3*
03-034(a)	*Tank and/or associated equipment Radioactive liquid waste tanks*	*Yes*	*1114*	*1*		
03-034(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*

TABLE B-1 (continued)

PRSs IN THE MORTANDAD CANYON WATERSHED

PRS No.	Description	HSWA	OU	FU	NFA Status	NFA Criterion
03-041	*Underground tank*	*No*	*1114*	*1*	*Proposed in work plan or RFI report that received an NOD or disapproval letter from AA*	*3*
03-045(h)	*Outfall (industrial or sanitary wastewater treatment)*	*Yes*	*1114*	*1*	*Proposed in permit modification 9/96*	*2*
03-048	*Satellite storage area*	*No*	*1114*	*1*	*Proposed in permit modification 9/96*	*3*
03-049(a)	*Outfall*	*Yes*	*1114*	*1*		
03-049(b)	*Operational release*	*Yes*	*1114*	*1*		
03-049(d)	*Outfall*	*Yes*	*1114*	*1*	*Proposed in permit modification 9/96*	*2*
03-049(e)	*Outfall*	*Yes*	*1114*	*1*	*Proposed in permit modification 9/96*	*1*
03-050(a)	*Exhaust emissions from off-gas scrubber of HEPA filter system*	*Yes*	*1114*	*1*	*Proposed in permit modification 9/96*	*5*
03-050(b)	*Exhaust emissions from off-gas scrubber of HEPA filter system*	*No*	*1114*	*1*	*Proposed in permit modification 9/96*	*5*
03-054(e)	*Outfall*	*Yes*	*1114*	*1*		
03-056(e)	*Satellite storage area*	*No*	*1114*	*1*	*Proposed in permit modification 9/96*	*1*
03-058	*Container storage*	*No*	*1114*	*1*	*Proposed in permit modification 9/96*	*3*
04-001	*Firing site*	*Yes*	*1129*	*4*		
04-002	*Surface disposal*	*Yes*	*1129*	*4*		
04-003(b)	*Outfall*	*Yes*	*1129*	*4*		
05-001(a)	*Firing site*	*Yes*	*1129*	*4*		
05-001(b)	*Firing site*	*Yes*	*1129*	*4*		
05-001(c)	*Firing site*	*No*	*1129*	*4*		
05-002	*Canyon-side disposal*	*Yes*	*1129*	*4*		
05-003	*Calibration chamber*	*Yes*	*1129*	*4*		
05-004	*Septic system*	*Yes*	*1129*	*4*		
05-005(a)	*French drain*	*Yes*	*1129*	*4*		
05-005(b)	*Outfall*	*Yes*	*1129*	*4*		
05-006(a)	*Former building location*	*No*	*1129*	*4*	*Final DOE approval of permit modification*	*5*
05-006(b)	*Soil contamination beneath buildings*	*Yes*	*1129*	*4*		
05-006(c)	*Soil contamination beneath buildings*	*Yes*	*1129*	*4*		
05-006(d)	*Former building location*	*No*	*1129*	*4*	*Final DOE approval of permit modification*	*3*
05-006(e)	*Soil contamination beneath buildings*	*Yes*	*1129*	*4*		
05-006(f)	*Former building location*	*No*	*1129*	*4*	*Final DOE approval of permit modification*	*3*

TABLE B-1 (continued)

PRSs IN THE MORTANDAD CANYON WATERSHED

PRS No.	Description	HSWA	OU	FU	NFA Status	NFA Criterion
05-006(g)	*Former building location*	*No*	*1129*	*4*	*Final DOE approval of permit modification*	*3*
05-006(h)	*Soil contamination beneath buildings*	*Yes*	*1129*	*4*		
35-001	*Material disposal area (MDA W)*	*No*	*1129*	*4*	*Final DOE approval of permit modification*	*3*
35-002	*Material disposal area (MDA X)*	*Yes*	*1129*	*4*	*Proposed in permit modification 3/95*	*5*
35-003(a)	*Wastewater treatment facility underground storage tank*	*Yes*	*1129*	*4*		
35-003(b)	*Wastewater treatment facility underground storage tank*	*Yes*	*1129*	*4*		
35-003(c)	*Wastewater treatment facility underground storage tank*	*Yes*	*1129*	*4*		
35-003(d)	*Wastewater treatment facility former tanks*	*Yes*	*1129*	*4*		
35-003(e)	*Wastewater treatment facility former tank*	*Yes*	*1129*	*4*		
35-003(f)	*Wastewater treatment facility former tank*	*Yes*	*1129*	*4*		
35-003(g)	*Wastewater treatment facility former tank*	*Yes*	*1129*	*4*		
35-003(h)	*Wastewater treatment facility former tank*	*Yes*	*1129*	*4*	*Reviewed for RCRA NFA; radiological/other component must be addressed*	*5*
35-003(i)	*Former oil storage tank*	*Yes*	*1129*	*4*	*Final AA approval of permit modification 12/10/96*	*2*
35-003(j)	*Former oil storage tank*	*Yes*	*1129*	*4*	*Reviewed for RCRA NFA; radiological/other component must be addressed*	*5*
35-003(k)	*Former oil storage tank*	*Yes*	*1129*	*4*	*Reviewed for RCRA NFA; radiological/other component must be addressed*	*5*
35-003(l)	*Wastewater treatment facility former pump pit*	*Yes*	*1129*	*4*		
35-003(m)	*Wastewater treatment facility former sludge tank*	*Yes*	*1129*	*4*		
35-003(n)	*Wastewater treatment facility former phase separator pit*	*Yes*	*1129*	*4*		
35-003(o)	*Wastewater treatment facility former manhole*	*Yes*	*1129*	*4*		
35-003(p)	*Wastewater treatment facility former air filter building*	*Yes*	*1129*	*4*	*Proposed in permit modification 3/95*	*5*
35-003(q)	*Wastewater treatment facility former pipe trench*	*Yes*	*1129*	*4*		

TABLE B-1 (continued)

PRSs IN THE MORTANDAD CANYON WATERSHED

PRS No.	Description	HSWA	OU	FU	NFA Status	NFA Criterion
35-003(r)	*Wastewater treatment facility outfall and Pratt Canyon*	*No*	*1129*	*4*		
35-004(a)	*Storage areas*	*Yes*	*1129*	*4*	*Reviewed for RCRA NFA; radiological/other component must be addressed*	*5*
35-004(b)	*Storage areas*	*Yes*	*1129*	*4*	*Proposed in report/work plan*	*5*
35-004(c)	*Storage areas*	*No*	*1129*	*4*	*Final DOE approval of permit modification*	*3*
35-004(d)	*Container storage area*	*No*	*1129*	*4*	*Final DOE approval of permit modification*	*3*
35-004(e)	*Container storage area*	*Yes*	*1129*	*4*	*Proposed in permit modification 3/95*	*3*
35-004(f)	*Container storage area*	*No*	*1129*	*4*	*Final DOE approval of permit modification*	*3*
35-004(g)	*Container storage area*	*Yes*	*1129*	*4*	*Reviewed for RCRA NFA; radiological/other component must be addressed*	*5*
35-004(h)	*Container storage area*	*Yes*	*1129*	*4*	*Reviewed for RCRA NFA; radiological/other component must be addressed*	*5*
35-004(i)	*Container storage area*	*No*	*1129*	*4*	*Final DOE approval of permit modification*	*3*
35-004(j)	*Container storage area*	*No*	*1129*	*4*	*Final DOE approval of permit modification*	*1*
35-004(k)	*Container storage area*	*No*	*1129*	*4*	*Final DOE approval of permit modification*	*3*
35-004(l)	*Container storage area*	*No*	*1129*	*4*	*Final DOE approval of permit modification*	*3*
35-004(m)	*Container storage area*	*No*	*1129*	*4*	*Reviewed for RCRA NFA; radiological/other component must be addressed*	*5*
35-004(n)	*Container storage area*	*No*	*1129*	*4*	*Final DOE approval of permit modification*	*3*
35-004(o)	*Container storage area*	*No*	*1129*	*4*	*Final DOE approval of permit modification*	*3*
35-005(a)	*Surface impoundment*	*No*	*1129*	*4*	*Final DOE approval of permit modification*	*5*
35-005(b)	*Surface impoundment*	*No*	*1129*	*4*	*Final DOE approval of permit modification*	*5*
35-006	*Surface impoundment*	*Yes*	*1129*	*4*	*Proposed in permit modification 3/95*	*5*
35-007	*Waste oil treatment*	*No*	*1129*	*4*	*Final DOE approval of permit modification*	*3*
35-008	*Surface disposal and landfill*	*Yes*	*1129*	*4*		

TABLE B-1 (continued)

PRSs IN THE MORTANDAD CANYON WATERSHED

PRS No.	Description	HSWA	OU	FU	NFA Status	NFA Criterion
35-009(a)	*Septic system*	*Yes*	*1129*	*4*	*Proposed in cleanup report for RCRA NFA; radiological/other component must be addressed*	*5*
35-009(b)	*Septic system*	*Yes*	*1129*	*4*	*Proposed in cleanup report for RCRA NFA; radiological/other component must be addressed*	*5*
35-009(c)	*Septic system*	*Yes*	*1129*	*4*	*Proposed in cleanup report for RCRA NFA; radiological/other component must be addressed*	*5*
35-009(d)	*Septic system*	*Yes*	*1129*	*4*	*Proposed in cleanup report for RCRA NFA; radiological/other component must be addressed*	*5*
35-009(e)	*Septic system*	*Yes*	*1129*	*4*	*Reviewed for RCRA NFA; radiological/other component must be addressed*	*5*
35-010(a)	*Sanitary lagoon and sand filters*	*Yes*	*1129*	*4*		
35-010(b)	*Sanitary lagoon and sand filters*	*Yes*	*1129*	*4*		
35-010(c)	*Sanitary lagoon and sand filters*	*Yes*	*1129*	*4*		
35-010(d)	*Sanitary lagoon and sand filters*	*Yes*	*1129*	*4*		
35-010(e)	*Discharge headwall*	*No*	*1129*	*4*		
35-011(a)	*Underground storage tank*	*Yes*	*1129*	*4*	*Proposed in permit modification 3/95*	*3*
35-011(b)	*Underground storage tank*	*No*	*1129*	*4*	*Final DOE approval of permit modification*	*4*
35-011(c)	*Underground storage tank*	*No*	*1129*	*4*	*Final DOE approval of permit modification*	*3*
35-011(d)	*Underground storage tank*	*No*	*1129*	*4*	*Final DOE approval of permit modification*	*5*
35-012(a)	*Underground storage tank*	*No*	*1129*	*4*	*Final DOE approval of permit modification*	*5*
35-012(b)	*Underground storage tank (inactive)*	*No*	*1129*	*4*	*Final DOE approval of permit modification*	*2*
35-013(a)	*Sump*	*Yes*	*1129*	*4*	*Proposed in permit modification 3/95*	*3*
35-013(b)	*Sump*	*Yes*	*1129*	*4*	*Proposed in permit modification 3/95*	*3*
35-013(c)	*Sump*	*Yes*	*1129*	*4*	*Proposed in permit modification 3/95*	*3*
35-013(d)	*Sump*	*Yes*	*1129*	*4*	*Proposed in permit modification 3/95*	*3*
35-014(a)	*Operational release*	*Yes*	*1129*	*4*	*Reviewed for RCRA NFA; radiological/other component must be addressed*	*1*
35-014(b)	*Leaking drum*	*Yes*	*1129*	*4*	*Reviewed for RCRA NFA; radiological/other component must be addressed*	*5*
35-014(c)	*Operational release*	*No*	*1129*	*4*	*Final DOE approval of permit modification*	*2*

TABLE B-1 (continued)

PRSs IN THE MORTANDAD CANYON WATERSHED

PRS No.	Description	HSWA	OU	FU	NFA Status	NFA Criterion
35-014(d)	Operational release	No	1129	4	Reviewed for RCRA NFA; radiological/other component must be addressed	5
35-014(e)	Oil spill	Yes	1129	4		
35-014(e_2)	Oil spill	No	1129	4	Proposed in report/work plan	4
35-014(e_3)	Operational release	No	1129	4	Proposed in report/work plan, reviewed by AA	3
35-014(f)	Soil contamination	No	1129	4	Cleanup report submitted	5
35-014(g)	Soil contamination	Yes	1129	4	Reviewed for RCRA NFA; radiological/other component must be addressed	5
35-014(g_2)	Soil contamination	No	1129	4	Reviewed for RCRA NFA; radiological/other component must be addressed	5
35-014(g_3)	Soil contamination	No	1129	4		
35-015(a)	Soil contamination	Yes	1129	4		
35-015(b)	Waste oil treatment	Yes	1129	4	Proposed in report/work plan	5
35-016(a)	Drains and outfalls	Yes	1129	4	Proposed in RFI report	
35-016(b)	Outfall	No	1129	4	Proposed in RFI report	
35-016(c)	Outfall	Yes	1129	4	Proposed in RFI report	
35-016(d)	Outfall	Yes	1129	4	Proposed in RFI report	
35-016(e)	Outfall	No	1129	4	Reviewed for RCRA NFA; radiological/other component must be addressed	5
35-016(f)	Storm drain	No	1129	4	Reviewed for RCRA NFA; radiological/other component must be addressed	5
35-016(g)	Outfall	No	1129	4		
35-016(h)	Storm drain	No	1129	4		
35-016(i)	Drains and outfalls	Yes	1129	4	Reviewed for RCRA NFA; radiological/other component must be addressed	4
35-016(j)	Storm drain	No	1129	4	Proposed in RFI report	
35-016(k)	Drains and outfalls	Yes	1129	4		
35-016(l)	Storm drain	No	1129	4		
35-016(m)	Drains and outfalls	Yes	1129	4	Proposed in RFI report	
35-016(n)	Storm drain	No	1129	4	Proposed in RFI report	
35-016(o)	Drains and outfalls	Yes	1129	4	Proposed in RFI report	
35-016(p)	Outfall	Yes	1129	4	Proposed in RFI report	
35-016(q)	Drains and outfalls	Yes	1129	4	Proposed in RFI report	
35-017	Soil contamination from reactor	No	1129	4	Final DOE approval of permit modification	5

TABLE B-1 (continued)

PRSs IN THE MORTANDAD CANYON WATERSHED

PRS No.	Description	HSWA	OU	FU	NFA Status	NFA Criterion
35-018(a)	Transformer	No	1129	4	Cleanup report submitted	5
35-018(b)	Former transformer site	No	1129	4	Final DOE approval of permit modification	3
42-001(a)	Former incinerator complex	Yes	1129	4	Proposed in report/work plan	5
42-001(b)	Former incinerator complex	Yes	1129	4	Proposed in report/work plan	5
42-001(c)	Former incinerator complex	Yes	1129	4	Proposed in report/work plan	5
42-002(a)	Former decontamination facility	No	1129	4	Proposed in report/work plan	5
42-002(b)	Former decontamination facility driveway	Yes	1129	4	Proposed in report/work plan	5
42-003	Former septic system	Yes	1129	4	Proposed in report/work plan	5
42-004	Canyon disposal	No	1129	4	Final DOE approval of permit modification	5
48-001	Air exhaust system	No	1129	4	Proposed in report/work plan	5
48-002(a)	Container storage area	Yes	1129	4	EC report submitted	5
48-002(b)	Container storage area	Yes	1129	4	EC report submitted	5
48-002(c)	Container storage area	No	1129	4	Final DOE approval of permit modification	3
48-002(d)	Container storage	No	1129	4	Final DOE approval of permit modification	3
48-002(e)	Container storage	No	1129	4	Proposed in report/work plan	5
48-003	Septic system	Yes	1129	4	Reviewed for RCRA NFA; radiological/other component must be addressed	
48-004(a)	Sumps and tanks	Yes	1129	4	Proposed in permit modification 3/95	3
48-004(b)	Sumps and tanks	Yes	1129	4	Proposed in permit modification 3/95	3
48-004(c)	Sumps and tanks	Yes	1129	4	Proposed in permit modification 3/95	3
48-004(d)	Sumps and tanks	No	1129	4	Final DOE approval of permit modification	2
48-005	Waste lines	Yes	1129	4	Reviewed for RCRA NFA; radiological/other component must be addressed	
48-006	Septic system	No	1129	4	Final DOE approval of permit modification	2
48-007(a)	Drains and outfalls	Yes	1129	4	Reviewed for RCRA NFA; radiological/other component must be addressed	
48-007(b)	Drains and outfalls	Yes	1129	4	Reviewed for RCRA NFA; radiological/other component must be addressed	
48-007(c)	Drains and outfalls	Yes	1129	4	Reviewed for RCRA NFA; radiological/other component must be addressed	

TABLE B-1 (continued)

PRSs IN THE MORTANDAD CANYON WATERSHED

PRS No.	Description	HSWA	OU	FU	NFA Status	NFA Criterion
48-007(d)	*Drains and outfalls*	*Yes*	*1129*	*4*	*Reviewed for RCRA NFA; radiological/other component must be addressed*	
48-007(e)	*Outfall*	*No*	*1129*	*4*	*Final DOE approval of permit modification*	*2*
48-007(f)	*Drains and outfalls*	*Yes*	*1129*	*4*	*Reviewed for RCRA NFA; radiological/other component must be addressed*	
48-008	*Transformer leak*	*No*	*1129*	*4*	*Final DOE approval of permit modification*	*3*
48-009	*Soil contamination*	*No*	*1129*	*4*	*Final DOE approval of permit modification*	*2*
48-010	*Surface impoundment*	*Yes*	*1129*	*4*	*Reviewed for RCRA NFA; radiological/other component must be addressed*	
48-011	*Disposal shaft*	*No*	*1129*	*4*		
50-001(a)	*Waste treatment facility*	*Yes*	*1147*	*5*		
50-001(b)	*Waste lines and manholes*	*No*	*1147*	*5*		
50-002(a)	*Underground tanks*	*Yes*	*1147*	*5*		
50-002(b)	*Underground tank*	*Yes*	*1147*	*5*		
50-002(c)	*Underground tank*	*Yes*	*1147*	*5*		
50-002(d)	*Underground tank*	*No*	*1147*	*5*		
50-003(a)	*Storage area*	*No*	*1147*	*5*		
50-003(b)	*Storage area*	*No*	*1147*	*5*	*Final DOE approval of permit modification*	*3*
50-003(c)	*Storage area*	*No*	*1147*	*5*	*Final DOE approval of permit modification*	*4*
50-003(d)	*Storage area*	*No*	*1147*	*5*	*Final DOE approval of permit modification*	*4*
50-003(e)	*Storage area*	*No*	*1147*	*5*	*Final DOE approval of permit modification*	*1*
50-004(a)	*Waste lines*	*Yes*	*1147*	*5*	*Proposed in report/work plan*	*5*
50-004(b)	*Underground tanks*	*Yes*	*1147*	*5*		
50-004(c)	*Waste lines*	*Yes*	*1147*	*5*	*Proposed in report/work plan*	*5*
50-005	*Waste treatment facility*	*No*	*1147*	*5*	*Final DOE approval of permit modification*	*3*
50-006(a)	*Operational release*	*Yes*	*1147*	*5*	*RFI/IA in progress*	
50-006(b)	*Operational release*	*No*	*1147*	*5*	*Final DOE approval of permit modification*	*5*
50-006(c)	*Operational release*	*Yes*	*1147*	*5*	*Proposed in report/work plan*	*5*
50-006(d)	*Effluent discharge*	*Yes*	*1147*	*5*		

TABLE B-1 (continued)

PRSs IN THE MORTANDAD CANYON WATERSHED

PRS No.	Description	HSWA	OU	FU	NFA Status	NFA Criterion
50-006(e)	Aboveground tank	No	1147	5	Final DOE approval of permit modification	5
50-007	Incinerator	No	1147	5	Proposed in report/work plan	5
50-008	Reduction site	No	1147	5	Proposed in report/work plan	5
50-009	Material disposal area (MDA C)	Yes	1147	5		
50-010	Decontamination facility	No	1147	5		
50-011(a)	Septic system	Yes	1147	5	Proposed in report/work plan	5
50-011(b)	Septic system	No	1147	5		
52-002(a)	Septic system	Yes	1129	4		
52-003(a)	Waste treatment facility	No	1129	4		
52-003(b)	Industrial waste line	No	1129	4	Final DOE approval of permit modification	5
55-001	Cement plant	No	1129	4	Final DOE approval of permit modification	3
55-002(a)	Radiological waste storage area	No	1129	4	Final DOE approval of permit modification	3
55-002(b)	Radiological waste storage area	No	1129	4	Final DOE approval of permit modification	3
55-002(c)	Container storage area	No	1129	4	Final DOE approval of permit modification	3
55-003	Containment area	No	1129	4	Final DOE approval of permit modification	3
55-004	Evaporator	No	1129	4	Final DOE approval of permit modification	3
55-005	Filtration unit	No	1129	4	Final DOE approval of permit modification	3
55-006	Glass breaker	No	1129	4	Final DOE approval of permit modification	3
55-007	Thermal combustion unit	No	1129	4	Final DOE approval of permit modification	3
55-008	Sumps and tanks	Yes	1129	4	Proposed in permit modification 3/95	3
55-009	Sumps and tanks	Yes	1129	4	Proposed in permit modification 3/95	2
55-010	Solvent spills	No	1129	4	Final DOE approval of permit modification	1
55-011(a)	Storm drain	No	1129	4	Final DOE approval of permit modification	4
55-011(b)	Storm drain	No	1129	4	Final DOE approval of permit modification	4
55-011(c)	Storm drain	No	1129	4	Final DOE approval of permit modification	4
55-011(d)	Storm drain	No	1129	4	Final DOE approval of permit modification	4

TABLE B-1 (continued)

PRSs IN THE MORTANDAD CANYON WATERSHED

PRS No.	Description	HSWA	OU	FU	NFA Status	NFA Criterion
55-011(e)	Storm drain	No	1129	4	Final DOE approval of permit modification	4
55-012	Container storage area	No	1129	4	Final DOE approval of permit modification	3
55-013(a)	Storage area	No	1129	4	Final DOE approval of permit modification	3
55-013(b)	Storage area	No	1129	4	Final DOE approval of permit modification	3
60-001(d)	Storage area pesticide shed	No	1114	1	Final DOE approval of permit modification	3
60-002	Storage area	Yes	1114	1	Proposed in permit modification 3/95	2
60-004(a)	Storage area	No	1114	1	Final DOE approval of permit modification	1
60-004(b)	Storage area	No	1114	1	Proposed in report/work plan	5
60-004(c)	Storage area	No	1114	1	Proposed in report/work plan	5
60-004(e)	Storage area	No	1114	1	Proposed in report/work plan	5
60-005(a)	Surface impoundment (formerly 3-029[a])	Yes	1114	1	Proposed in report/work plan	5
60-006(b)	Septic system	No	1114	1	Final DOE approval of permit modification	2
63-001(a)	Septic system	Yes	1129	4		
63-001(b)	Septic system	Yes	1129	4		
63-002	Container storage area	No	1129	4	Final DOE approval of permit modification	3
C-35-001	Former UST site	No	1129	4	Final DOE approval of permit modification	3
C-35-002	Former UST site	No	1129	4	Final DOE approval of permit modification	3
C-35-003	Former UST site	No	1129	4	Final DOE approval of permit modification	3
C-35-004	Operational release	No	1129	4	Final DOE approval of permit modification	4
C-35-005	Operational release	No	1129	4	Final DOE approval of permit modification	4
C-35-006	Operational release	No	1129	4	Final DOE approval of permit modification	4
C-35-007	Soil contamination	No	1129	4		
C-35-008	Leaking transformer	No	1129	4	Final DOE approval of permit modification	3
C-60-002	Underground tank	No	1114	1	Proposed in permit modification 9/96	4

Appendix C

Analytical Results for PRS No. 50-006(d) Sediment Samples

TABLE C-1

ACTIVITIES OF RADIONUCLIDES IN SEDIMENTS BELOW THE TA-50 RLWTF OUTFALL AT PRS No. 50-006(d)[a]

Part 1

Location ID	Depth (ft)	Am-241 (pCi/g)	Ba-133 (pCi/g)	Co-57 (pCi/g)	Co-60 (pCi/g)	Cs-137 (pCi/g)	Eu-152 (pCi/g)	Tritium (pCi/g)	H_2O (Wt %)	K-40 (pCi/g)
Background Screening Value[b]		0.139		<0.1	<0.14	1.28	<0.6	0.068		36.8
50-6000	0.5	7.22	NA[c]	NA	BDL[d]	3.48	NA	4.544	11.5	34.55
50-6001	0.5	14.33	NA	NA	1.82	5.71	NA	60.145	17	35.23
50-6002	0.5	BDL	NA	NA	0.93	5.44	NA	4.861	16.9	33.33
50-6002	2.5	71.003	NA	NA	BDL	67.27	NA	29.027	31.7	37.79
50-6002	4	18.57	NA	NA	0.9817	187.49	NA	55.165	39.7	28.67
50-6003	0.5	BDL	NA	NA	BDL	2.96	NA	0.131	1.6	34.52
50-6004	0.5	BDL	NA	NA	BDL	BDL	NA	0.249	1.6	32.03
50-6005	0.5	BDL	NA	NA	0.56	0.44	NA	0.091	3.5	28.53
50-6005	4	BDL	NA	NA	BDL	BDL	NA	0.150	8.9	32.95
50-6006	0.5	16.53	NA	NA	1.47	19.13	NA	0.841	2.6	30
50-6007	0.5	9.24	NA	NA	2.66	13.25	NA	98.216	18	37.01
50-6007	2.5	18.03	NA	NA	5.22	29.37	BDL	105.024	19.8	40.84

Part 2

Location ID	Depth (ft)	Na-22 (pCi/g)	Pu-238 (pCi/g)	Pu-239 (pCi/g)	Ra-226 (pCi/g)	Sr-90 (pCi/g)	Th-232 (pCi/g)	U-234 (pCi/g)	U-235 (pCi/g)	U-238 (pCi/g)
Background Screening Value		<0.1	0.006	0.197	2.03	1.0	2.33	2.39	0.16	2.29
50-6000	0.5	NA	1.96	4.803	1.72	0.54	2.08	1.324	0.12	1.212
50-6001	0.5	NA	4.414	11.681	2.43	0.33	BDL	1.151	0.054	1.088
50-6002	0.5	NA	1.913	3.971	BDL	1.83	BDL	1.142	0.056	1.011
50-6002	2.5	NA	12.421	47.816	BDL	18.3	BDL	1.503	0.063	1.488
50-6002	4	NA	13.804	20.667	2.1	8.43	4.13	3.056	0.118	1.908
50-6003	0.5	NA	0.078	0.444	3.12	0.51	BDL	5.022	0.315	6.068
50-6004	0.5	NA	0.011	0.033	BDL	0.59	BDL	1.099	0.056	1.396
50-6005	0.5	NA	0.006	0.011	2.45	0.37	1.86	0.945	0.101	0.843
50-6005	4	NA	0.009	0.066	2.6504	-0.1	BDL	1.423	0.07	1.578
50-6006	0.5	NA	3.084	13.231	2.75	1.05	BDL	1.33	0.121	1.534
50-6007	0.5	NA	2.855	11.014	2.49	0.43	2.46	1.09	0.049	0.998
50-6007	2.5	NA	6.666	19.235	1.91	1.09	1.97	1.009	0.065	1.013

a. Preliminary unpublished results from Field Unit 5

b. Background data from McDonald et al. 1997, 04-0328; values may include 95% UTLs and maximum observed values

c. NA = not analyzed

d. BDL = below detection limit

TABLE C-1 (continued)

ACTIVITIES OF RADIONUCLIDES IN SEDIMENTS BELOW THE TA-50 RLWTF OUTFALL AT PRS No. 50-006(d)[a]

Part 1

Location ID	Depth (ft)	Am-241 (pCi/g)	Ba-133 (pCi/g)	Co-57 (pCi/g)	Co-60 (pCi/g)	Cs-137 (pCi/g)	Eu-152 (pCi/g)	Tritium (pCi/g)	H_2O (Wt %)	K-40 (pCi/g)
Background Screening Value[b]		*0.139*		*<0.1*	*<0.14*	*1.28*	*<0.6*	*0.068*		*36.8*
50-6008	*0.5*	*BDL[c]*	*NA[d]*	*NA*	*BDL*	*3.56*	*NA*	*0.614*	*9.7*	*42.27*
50-6008	*2.5*	*BDL*	*NA*	*NA*	*BDL*	*0.63*	*NA*	*0.196*	*5*	*40.13*
50-6008	*4*	*BDL*	*NA*	*NA*	*BDL*	*BDL*	*NA*	*19.662*	*27*	*32.34*
50-6009	*0.5*	*BDL*	*NA*	*NA*	*BDL*	*4.76*	*NA*	*0.568*	*20*	*32.2*
50-6009	*4*	*BDL*	*NA*	*NA*	*BDL*	*0.69*	*NA*	*0.139*	*9.3*	*32.6*
50-6010	*0.5*	*8.37*	*NA*	*NA*	*2.7*	*77.9*	*NA*	*2.309*	*6.1*	*21.5*
50-6011	*0.5*	*BDL*	*NA*	*NA*	*BDL*	*11.7*	*NA*	*0.655*	*9.3*	*35.8*
50-6012	*0.5*	*BDL*	*NA*	*NA*	*0.93*	*6.71*	*NA*	*0.274*	*1*	*34.8*
50-6012	*2.5*	*BDL*	*NA*	*NA*	*0.76*	*18.6*	*NA*	*0.406*	*3.1*	*33.4*
50-6013	*0.5*	*24.2*	*NA*	*NA*	*2.24*	*42.9*	*NA*	*10.154*	*7.8*	*25.6*
50-6014	*0.5*	*BDL*	*NA*	*NA*	*BDL*	*BDL*	*NA*	*0.052*	*4.7*	*35.9*
50-6014	*2.5*	*BDL*	*NA*	*NA*	*BDL*	*BDL*	*NA*	*0.069*	*5.4*	*35.4*

Part 2

Location ID	Depth (ft)	Na-22 (pCi/g)	Pu-238 (pCi/g)	Pu-239 (pCi/g)	Ra-226 (pCi/g)	Sr-90 (pCi/g)	Th-232 (pCi/g)	U-234 (pCi/g)	U-235 (pCi/g)	U-238 (pCi/g)
Background Screening Value		*<0.1*	*0.006*	*0.197*	*2.03*	*1.0*	*2.33*	*2.39*	*0.16*	*2.29*
50-6008	*0.5*	*NA*	*0.597*	*0.802*	*2.25*	*1.38*	*BDL*	*3.556*	*0.133*	*4.189*
50-6008	*2.5*	*NA*	*0.125*	*0.23*	*1.89*	*0.05*	*2.36*	*1.354*	*0.068*	*1.455*
50-6008	*4*	*NA*	*0.354*	*0.308*	*4.08*	*2.48*	*2.91*	*1.842*	*0.079*	*1.478*
50-6009	*0.5*	*NA*	*0.24*	*0.927*	*2.98*	*0.97*	*3.89*	*5.608*	*0.258*	*7.125*
50-6009	*4*	*NA*	*0.026*	*0.018*	*2.14*	*0.02*	*2.23*	*1.14*	*0.083*	*1.127*
50-6010	*0.5*	*NA*	*4.093*	*10.43*	*3.24*	*1.49*	*2.53*	*0.76*	*0.003*	*0.938*
50-6011	*0.5*	*NA*	*0.865*	*1.519*	*3.11*	*1.44*	*2.59*	*3.918*	*0.201*	*5.086*
50-6012	*0.5*	*NA*	*0.668*	*1.375*	*1.83*	*0.05*	*BDL*	*0.996*	*0.068*	*0.942*
50-6012	*2.5*	*NA*	*0.382*	*0.904*	*3.15*	*1.13*	*2.55*	*0.813*	*0.047*	*0.822*
50-6013	*0.5*	*NA*	*3.669*	*19.732*	*BDL*	*1.17*	*BDL*	*1.284*	*0.065*	*1.277*
50-6014	*0.5*	*NA*	*0.003*	*0.025*	*BDL*	*-0.06*	*2.84*	*0.859*	*0.053*	*0.91*
50-6014	*2.5*	*NA*	*0.014*	*0.011*	*2.41*	*0.25*	*3.16*	*1.182*	*0.102*	*1.335*

a. *Preliminary unpublished results from Field Unit 5*

b. *Background data from McDonald et al. 1997, 04-0328; values may include 95% UTLs and maximum observed values*

c. *BDL = below detection limit*

d. *NA = not analyzed*

TABLE C-1 (continued)

ACTIVITIES OF RADIONUCLIDES IN SEDIMENTS BELOW THE TA-50 RLWTF OUTFALL AT PRS No. 50-006(d)[a]

Part 1

Location ID	Depth (ft)	Am-241 (pCi/g)	Ba-133 (pCi/g)	Co-57 (pCi/g)	Co-60 (pCi/g)	Cs-137 (pCi/g)	Eu-152 (pCi/g)	Tritium (pCi/g)	H_2O (Wt %)	K-40 (pCi/g)
Background Screening Value[b]		*0.139*		*<0.1*	*<0.14*	*1.28*	*<0.6*	*0.068*		*36.8*
50-6015	*0.5*	*BDL*[c]	*NA*[d]	*NA*	*BDL*	*7.58*	*NA*	*1.121*	*9.2*	*29.8*
50-6015	*4*	*BDL*	*NA*	*NA*	*BDL*	*3.43*	*NA*	*0.323*	*5.2*	*34.4*
50-6016	*0.5*	*6.64*	*NA*	*NA*	*1.98*	*28.3*	*NA*	*10.781*	*14.2*	*27.8*
50-6016	*2.5*	*BDL*	*NA*	*NA*	*3.01*	*32.3*	*NA*	*15.420*	*19.8*	*29.5*
50-6017	*0.5*	*BDL*	*NA*	*NA*	*BDL*	*2.89*	*NA*	*0.686*	*9.2*	*23.8*
50-6017	*4*	*BDL*	*NA*	*NA*	*BDL*	*BDL*	*NA*	*1.326*	*8.8*	*39.3*
50-6018	*0.5*	*19.081*	*NA*	*NA*	*3.2158*	*31.563*	*NA*	*30.363*	*17.5*	*28.386*
50-6018	*2.5*	*18.257*	*NA*	*NA*	*2.0415*	*34.082*	*NA*	*31.587*	*27.1*	*32.125*
50-6018	*4*	*10.531*	*NA*	*NA*	*BDL*	*37.286*	*NA*	*31.932*	*24.9*	*27.774*
50-6019	*0.5*	*BDL*	*NA*	*NA*	*BDL*	*1.054*	*NA*	*0.226*	*5.5*	*23.247*
50-6019	*2.5*	*BDL*	*NA*	*NA*	*BDL*	*1.0177*	*NA*	*6.769*	*17*	*23.25*
50-6019	*4*	*BDL*	*NA*	*NA*	*BDL*	*BDL*	*NA*	*11.888*	*15.8*	*22.219*

Part 2

Location ID	Depth (ft)	Na-22 (pCi/g)	Pu-238 (pCi/g)	Pu-239 (pCi/g)	Ra-226 (pCi/g)	Sr-90 (pCi/g)	Th-232 (pCi/g)	U-234 (pCi/g)	U-235 (pCi/g)	U-238 (pCi/g)
Background Screening Value		*<0.1*	*0.006*	*0.197*	*2.03*	*1.0*	*2.33*	*2.39*	*0.16*	*2.29*
50-6015	*0.5*	*NA*	*0.439*	*1.252*	*2.24*	*5.14*	*3.21*	*5.48*	*0.243*	*6.785*
50-6015	*4*	*NA*	*0.236*	*0.166*	*2.92*	*0.14*	*3.05*	*1.762*	*0.114*	*1.819*
50-6016	*0.5*	*NA*	*2.727*	*5.106*	*BDL*	*1.03*	*2.03*	*1.009*	*0.07*	*0.878*
50-6016	*2.5*	*NA*	*2.401*	*3.947*	*1.83*	*2.33*	*1.88*	*1.206*	*0.162*	*1.136*
50-6017	*0.5*	*NA*	*0.05*	*0.311*	*1.61*	*1.48*	*3.22*	*3.79*	*0.205*	*4.48*
50-6017	*4*	*NA*	*0.005*	*0.024*	*2.5*	*1.27*	*3.23*	*1.509*	*0.094*	*1.732*
50-6018	*0.5*	*NA*	*4.186*	*16.134*	*1.2785*	*1.71*	*1.8589*	*0.976*	*0.049*	*0.995*
50-6018	*2.5*	*NA*	*2.793*	*15.596*	*2.1026*	*1.87*	*BDL*	*1.395*	*3.5836*	*1.263*
50-6018	*4*	*NA*	*3.096*	*7.339*	*BDL*	*3.1*	*BDL*	*1.114*	*0.026*	*0.923*
50-6019	*0.5*	*NA*	*0.03*	*0.155*	*4.6146*	*0.89*	*3.0139*	*1.889*	*0.133*	*2.136*
50-6019	*2.5*	*NA*	*0.185*	*0.512*	*2.7219*	*0.77*	*BDL*	*1.326*	*0.087*	*1.332*
50-6019	*4*	*NA*	*0.031*	*0.064*	*2.0447*	*0.26*	*3.103*	*1.625*	*0.143*	*1.633*

a. *Preliminary unpublished results from Field Unit 5*
b. *Background data from McDonald et al. 1997, 04-0328; values may include 95% UTLs and maximum observed values*
c. *BDL = below detection limit*
d. *NA = not analyzed*

TABLE C-1 (continued)

ACTIVITIES OF RADIONUCLIDES IN SEDIMENTS BELOW THE TA-50 RLWTF OUTFALL AT PRS No. 50-006(d)[a]

Part 1

Location ID	Depth (ft)	Am-241 (pCi/g)	Ba-133 (pCi/g)	Co-57 (pCi/g)	Co-60 (pCi/g)	Cs-137 (pCi/g)	Eu-152 (pCi/g)	Tritium (pCi/g)	H_2O (Wt %)	K-40 (pCi/g)
Background Screening Value[b]		*0.139*		*<0.1*	*<0.14*	*1.28*	*<0.6*	*0.068*		*36.8*
50-6020	*0.5*	*BDL*[c]	*NA*[d]	*NA*	*BDL*	*1.1584*	*NA*	*0.383*	*10*	*34.417*
50-6020	*2.5*	*BDL*	*NA*	*NA*	*BDL*	*0.7022*	*NA*	*0.426*	*7.9*	*36.394*
50-6020	*4*	*BDL*	*NA*	*NA*	*BDL*	*BDL*	*NA*	*0.891*	*7.7*	*29.136*
50-6021	*0.5*	*18.221*	*NA*	*NA*	*2.4397*	*67.685*	*NA*	*0.609*	*4.6*	*34.858*
50-6021	*2.5*	*BDL*	*NA*	*NA*	*BDL*	*203.02*	*NA*	*0.452*	*10.6*	*30.693*
50-6021	*4*	*BDL*	*NA*	*NA*	*BDL*	*113.99*	*NA*	*0.716*	*12.8*	*34.463*
50-6022	*0.5*	*BDL*	*NA*	*NA*	*1.1791*	*14.258*	*NA*	*3.632*	*17.1*	*23.74*
50-6022	*2.5*	*9.4383*	*NA*	*NA*	*0.7825*	*62.148*	*NA*	*7.154*	*22.6*	*31.364*
50-6022	*4*	*9.3875*	*NA*	*NA*	*BDL*	*373.1099*	*NA*	*5.832*	*23.4*	*34.107*
50-6023	*0.5*	*BDL*	*NA*	*NA*	*1.1045*	*50.146*	*NA*	*0.642*	*19.1*	*33.584*
50-6023	*2.5*	*BDL*	*NA*	*NA*	*BDL*	*7.6197*	*NA*	*2.009*	*18.2*	*27.422*
50-6023	*4*	*BDL*	*NA*	*NA*	*0.8782*	*50.176*	*NA*	*2.065*	*13.8*	*38.281*

Part 2

Location ID	Depth (ft)	Na-22 (pCi/g)	Pu-238 (pCi/g)	Pu-239 (pCi/g)	Ra-226 (pCi/g)	Sr-90 (pCi/g)	Th-232 (pCi/g)	U-234 (pCi/g)	U-235 (pCi/g)	U-238 (pCi/g)
Background Screening Value		*<0.1*	*0.006*	*0.197*	*2.03*	*1.0*	*2.33*	*2.39*	*0.16*	*2.29*
50-6020	*0.5*	*NA*	*0.013*	*0.154*	*2.7656*	*1.37*	*BDL*	*2.991*	*0.198*	*3.254*
50-6020	*2.5*	*NA*	*0.008*	*0.157*	*BDL*	*0.12*	*2.4306*	*1.74*	*0.096*	*1.89*
50-6020	*4*	*NA*	*0.006*	*0.025*	*2.3598*	*0.34*	*BDL*	*1.734*	*0.098*	*1.685*
50-6021	*0.5*	*NA*	*5.909*	*17.555*	*BDL*	*3.01*	*2.5312*	*1.154*	*0.078*	*1.206*
50-6021	*2.5*	*NA*	*8.522*	*4.294*	*BDL*	*4.44*	*3.0901*	*1.261*	*0.05*	*1.218*
50-6021	*4*	*NA*	*9.513*	*6.075*	*1.4437*	*3.95*	*2.2594*	*1.609*	*0.052*	*1.667*
50-6022	*0.5*	*NA*	*1.107*	*2.965*	*2.5576*	*0.93*	*BDL*	*0.805*	*0.045*	*1.061*
50-6022	*2.5*	*NA*	*2.508*	*13.376*	*3.0103*	*2.62*	*BDL*	*1.128*	*0.095*	*0.949*
50-6022	*4*	*NA*	*11.358*	*10.59*	*BDL*	*4.03*	*2.1694*	*1.277*	*0.098*	*1.358*
50-6023	*0.5*	*NA*	*7.372*	*4.889*	*BDL*	*2.75*	*3.0552*	*1.434*	*0.042*	*1.571*
50-6023	*2.5*	*NA*	*0.809*	*0.351*	*2.4789*	*3.63*	*2.5498*	*2.103*	*0.06*	*2.149*
50-6023	*4*	*NA*	*0.189*	*0.824*	*BDL*	*4.82*	*BDL*	*1.183*	*0.104*	*1.163*

a. Preliminary unpublished results from Field Unit 5

b. Background data from McDonald et al. 1997, 04-0328; values may include 95% UTLs and maximum observed values

c. BDL = below detection limit

d. NA = not analyzed

TABLE C-1 (continued)

ACTIVITIES OF RADIONUCLIDES IN SEDIMENTS BELOW THE TA-50 RLWTF OUTFALL AT PRS No. 50-006(d)[a]

Part 1

Location ID	Depth (ft)	Am-241 (pCi/g)	Ba-133 (pCi/g)	Co-57 (pCi/g)	Co-60 (pCi/g)	Cs-137 (pCi/g)	Eu-152 (pCi/g)	Tritium (pCi/g)	H_2O (Wt %)	K-40 (pCi/g)
Background Screening Value[b]		*0.139*		*<0.1*	*<0.14*	*1.28*	*<0.6*	*0.068*		*36.8*
50-6024	*0.5*	*6.1279*	*NA*[c]	*NA*	*BDL*[d]	*6.0491*	*NA*	*0.555*	*15.7*	*29.349*
50-6024	*2.5*	*14.979*	*NA*	*NA*	*BDL*	*20.945*	*NA*	*1.593*	*15.2*	*31.464*
50-6025	*0.5*	*7.6766*	*NA*	*NA*	*2.39*	*43.533*	*NA*	*4.521*	*24.8*	*28.283*
50-6026	*0.5*	*9.014*	*NA*	*NA*	*1.1217*	*32.945*	*NA*	*3.276*	*21.5*	*36.055*
50-6026	*2.5*	*41.76*	*0.45*	*2.3*	*0.94*	*69.87*	*1.9*	*11.403*	*20.04*	*25.98*
50-6026	*4*	*21.28*	*BDL*	*BDL*	*0.64*	*129.1*	*0.6*	*5.507*	*23.73*	*27.68*
Minimum		*6.1279*	*0.45*	*2.3*	*0.56*	*0.44*	*0.6*	*0.052*	*1*	*21.5*
Maximum		*71.003*	*0.45*	*2.3*	*5.22*	*373.11*	*1.9*	*105.024*	*39.7*	*47.8*
x Background		*510.81*				*291.5*		*1544*		*1.3*
Geometric Mean		*13.95*	*0.45*	*2.30*	*1.53*	*13.39*	*1.07*	*1.94*	*10.75*	*31.71*

Part 2

Location ID	Depth (ft)	Na-22 (pCi/g)	Pu-238 (pCi/g)	Pu-239 (pCi/g)	Ra-226 (pCi/g)	Sr-90 (pCi/g)	Th-232 (pCi/g)	U-234 (pCi/g)	U-235 (pCi/g)	U-238 (pCi/g)
Background Screening Value		*<0.1*	*0.006*	*0.197*	*2.03*	*1.0*	*2.33*	*2.39*	*0.16*	*2.29*
50-6024	*0.5*	*NA*	*1.295*	*5.702*	*2.2506*	*0.54*	*2.6221*	*2.028*	*0.115*	*2.165*
50-6024	*2.5*	*NA*	*4.235*	*10.71*	*3.2494*	*0.37*	*BDL*	*1.623*	*0.088*	*1.388*
50-6025	*0.5*	*NA*	*3.556*	*7.881*	*3.2628*	*1.48*	*3.164*	*1.211*	*0.042*	*1.195*
50-6026	*0.5*	*NA*	*4.18*	*13.214*	*3.2994*	*1.48*	*4.3764*	*2.539*	*0.128*	*2.349*
50-6026	*2.5*	*0.56*	*10.63*	*28.96*	*BDL*	*1.4*	*0.99*	*1.106*	*0.031*	*0.776*
50-6026	*4*	*0.23*	*10.06*	*9.556*	*BDL*	*1.2*	*0.94*	*1.099*	*0.041*	*0.372*
Minimum		*0.23*	*0.003*	*0.011*	*1.61*	*-0.1*	*0.94*	*0.76*	*0.003*	*0.372*
Maximum		*0.56*	*13.804*	*47.816*	*4.6146*	*18.3*	*4.3764*	*5.608*	*3.5836*	*6.785*
x Background			*2300.7*	*243*	*2.3*	*18.3*	*1.9*	*2.3*	*22.4*	*2.96*
Geometric Mean		*0.36*	*0.53*	*1.33*	*2.40*	*1.91*	*2.52*	*1.56*	*0.09*	*1.64*

a. Preliminary unpublished results from Field Unit 5

b. Background data from McDonald et al. 1997, 04-0328; values may include 95% UTLs and maximum observed values

c. NA = not analyzed

d. BDL = below detection limit

TABLE C-2

CONCENTRATIONS OF METALS IN SEDIMENTS BELOW THE TA-50 RLWTF OUTFALL AT PRS No. 50-006(d)[a]

Part 1

Location ID	Depth (ft)	Ag	As	Ba	Be	Cd	Cr	Hg
Background Screening Value[b]		*0.28*	*3.98*	*127*	*1.31*	*0.18*	*10.5*	*0.03*
50-6000	*0.5*	*BDL*[c]	*1.28*	*36*	*0.44*	*BDL*	*4.7*	*BDL*
50-6001	*0.5*	*BDL*	*1.147*	*28*	*0.52*	*BDL*	*4.1*	*BDL*
50-6002	*0.5*	*BDL*	*1.56*	*48*	*0.44*	*BDL*	*15*	*BDL*
50-6002	*2.5*	*BDL*	*4.18*	*73*	*0.61*	*BDL*	*6.5*	*BDL*
50-6002	*4*	*BDL*	*3.01*	*59*	*0.55*	*BDL*	*22*	*0.2*
50-6003	*0.5*	*BDL*	*1.87*	*65*	*0.76*	*BDL*	*2.8*	*BDL*
50-6004	*0.5*	*BDL*	*2*	*41*	*0.5*	*BDL*	*2.7*	*BDL*
50-6005	*0.5*	*BDL*	*1.33*	*33*	*0.29*	*BDL*	*2*	*BDL*
50-6005	*4*	*8*	*2.03*	*38*	*0.5*	*BDL*	*3.2*	*BDL*
50-6006	*0.5*	*BDL*	*1.77*	*53*	*0.58*	*BDL*	*8*	*0.2*
50-6007	*0.5*	*BDL*	*0.7*	*14*	*0.26*	*BDL*	*56*	*0.1*
50-6007	*2.5*	*BDL*	*1.87*	*25*	*0.46*	*BDL*	*4.3*	*0.1*
50-6008	*0.5*	*BDL*	*2.79*	*86*	*0.64*	*BDL*	*4.3*	*BDL*

Part 2

Location ID	Depth (ft)	K	Ni	Pb	Sb	Se	Tl
Background Screening Value		*2690*	*9.38*	*19.7*	*5*	*<0.2*	*3.2*
50-6000	*0.5*	*NA*[d]	*3*	*6*	*0.1*	*BDL*	*BDL*
50-6001	*0.5*	*NA*	*2*	*10*	*0.1*	*BDL*	*BDL*
50-6002	*0.5*	*NA*	*9*	*8*	*0.15*	*BDL*	*0.18*
50-6002	*2.5*	*NA*	*5*	*11*	*BDL*	*0.41*	*0.2*
50-6002	*4*	*NA*	*5.2*	*11*	*BDL*	*BDL*	*0.15*
50-6003	*0.5*	*NA*	*2.8*	*21*	*BDL*	*BDL*	*BDL*
50-6004	*0.5*	*NA*	*BDL*	*10*	*BDL*	*BDL*	*0.1*
50-6005	*0.5*	*NA*	*BDL*	*BDL*	*0.1*	*BDL*	*BDL*
50-6005	*4*	*NA*	*2*	*6*	*0.1*	*BDL*	*BDL*
50-6006	*0.5*	*NA*	*5*	*13*	*0.13*	*BDL*	*BDL*
50-6007	*0.5*	*NA*	*30*	*6*	*0.12*	*BDL*	*BDL*
50-6007	*2.5*	*NA*	*3*	*10*	*BDL*	*BDL*	*BDL*
50-6008	*0.5*	*1000*	*5*	*14*	*BDL*	*0.34*	*0.13*

[a] *Preliminary unpublished results from Field Unit 5 in mg/kg*

[b] *McDonald et al. 1997, 04-0328*

[c] *BDL = below detection limit*

[d] *NA = not analyzed*

TABLE C-2 (continued)

CONCENTRATIONS OF METALS IN SEDIMENTS BELOW THE TA-50 RLWTF OUTFALL AT PRS No. 50-006(d)[a]

Part 1

Location ID	**Depth (ft)**	**Ag**	**As**	**Ba**	**Be**	**Cd**	**Cr**	**Hg**
Background Screening Value[b]		*0.28*	*3.98*	*127*	*1.31*	*0.18*	*10.5*	*0.03*
50-6008	*2.5*	*BDL*[c]	*1*	*28*	*0.49*	*BDL*	*2.2*	*BDL*
50-6008	*4*	*BDL*	*1.65*	*20*	*0.57*	*BDL*	*5.9*	*BDL*
50-6009	*0.5*	*BDL*	*5.18*	*130*	*0.82*	*BDL*	*5.6*	*0.2*
50-6009	*4*	*BDL*	*1.91*	*22*	*0.35*	*BDL*	*1.8*	*BDL*
50-6010	*0.5*	*BDL*	*0.83*	*13*	*0.22*	*BDL*	*4.7*	*0.1*
50-6011	*0.5*	*BDL*	*3.96*	*84*	*0.69*	*BDL*	*4.1*	*BDL*
50-6012	*0.5*	*BDL*	*1.8*	*23*	*0.36*	*BDL*	*4.1*	*BDL*
50-6012	*2.5*	*BDL*	*0.93*	*10*	*0.18*	*BDL*	*1.2*	*BDL*
50-6013	*0.5*	*BDL*	*1.16*	*26*	*0.36*	*BDL*	*5.4*	*BDL*
50-6014	*0.5*	*BDL*	*1.39*	*24*	*0.25*	*BDL*	*1.8*	*BDL*
50-6014	*2.5*	*BDL*	*1.29*	*25*	*0.47*	*BDL*	*2.3*	*BDL*
50-6015	*0.5*	*BDL*	*2.46*	*110*	*0.83*	*BDL*	*4.5*	*0.2*
50-6015	*4*	*BDL*	*2.09*	*44*	*0.61*	*BDL*	*5.6*	*BDL*

Part 2

Location ID	**Depth (ft)**	**K**	**Ni**	**Pb**	**Sb**	**Se**	**Tl**
Background Screening Value		*2690*	*9.38*	*19.7*	*5*	*<0.2*	*3.2*
50-6008	*2.5*	*NA*[d]	*2*	*5*	*0.1*	*BDL*	*BDL*
50-6008	*4*	*580*	*4*	*16*	*0.11*	*0.34*	*BDL*
50-6009	*0.5*	*NA*	*7*	*36*	*BDL*	*0.39*	*0.09*
50-6009	*4*	*NA*	*2*	*BDL*	*BDL*	*BDL*	*0.04*
50-6010	*0.5*	*NA*	*4*	*7*	*BDL*	*BDL*	*0.08*
50-6011	*0.5*	*NA*	*4.5*	*24*	*BDL*	*BDL*	*0.13*
50-6012	*0.5*	*NA*	*3.5*	*6.7*	*BDL*	*BDL*	*0.04*
50-6012	*2.5*	*NA*	*BDL*	*4*	*BDL*	*BDL*	*0.06*
50-6013	*0.5*	*NA*	*5*	*5*	*BDL*	*BDL*	*0.04*
50-6014	*0.5*	*NA*	*3.4*	*6*	*BDL*	*BDL*	*0.03*
50-6014	*2.5*	*NA*	*BDL*	*11*	*BDL*	*BDL*	*0.03*
50-6015	*0.5*	*NA*	*5*	*70*	*BDL*	*BDL*	*0.07*
50-6015	*4*	*NA*	*4.6*	*11*	*BDL*	*BDL*	*0.11*

[a] *Preliminary unpublished results from Field Unit 5 in mg/kg*

[b] *McDonald et al. 1997, 04-0328*

[c] *BDL = below detection limit*

[d] *NA = not analyzed*

TABLE C-2 (continued)

CONCENTRATIONS OF METALS IN SEDIMENTS BELOW THE TA-50 RLWTF OUTFALL AT PRS No. 50-006(d)[a]

Part 1

Location ID	Depth (ft)	Ag	As	Ba	Be	Cd	Cr	Hg
Background Screening Value[b]		0.28	3.98	127	1.31	0.18	10.5	0.03
50-6016	0.5	1	0.83	20	0.61	BDL[c]	6.8	BDL
50-6016	2.5	BDL	0.52	12	0.25	BDL	16	BDL
50-6017	0.5	BDL	2.73	67	0.65	BDL	2.4	BDL
50-6017	4	BDL	1.01	22	0.61	BDL	2.3	BDL
50-6018	0.5	BDL	1.4	16	0.5	BDL	3.1	BDL
50-6018	2.5	BDL	0.9	16	0.54	BDL	1.4	BDL
50-6018	4	BDL	0.9	19	0.33	BDL	3	BDL
50-6019	0.5	BDL	1.1	110	0.51	BDL	2.9	BDL
50-6019	2.5	BDL	1	62	0.59	BDL	4.9	BDL
50-6019	4	BDL	1.3	27	0.77	BDL	3.1	BDL
50-6020	0.5	BDL	2.6	160	0.69	BDL	3.7	BDL
50-6020	2.5	BDL	1.2	65	0.66	BDL	2.5	BDL
50-6020	4	BDL	1	34	0.53	BDL	1.8	BDL

Part 2

Location ID	Depth (ft)	K	Ni	Pb	Sb	Se	Tl
Background Screening Value		2690	9.38	19.7	5	<0.2	3.2
50-6016	0.5	NA[d]	7	11	BDL	BDL	0.07
50-6016	2.5	NA	8	3	BDL	BDL	0.08
50-6017	0.5	NA	3.1	24	BDL	BDL	0.07
50-6017	4	NA	2	10	BDL	BDL	BDL
50-6018	0.5	NA	4.3	4	0.09	0.3	0.15
50-6018	2.5	NA	2	4	BDL	BDL	0.06
50-6018	4	NA	48	6	BDL	BDL	BDL
50-6019	0.5	NA	3	7	BDL	BDL	0.06
50-6019	2.5	NA	4	5	BDL	BDL	0.05
50-6019	4	NA	3.3	7	BDL	0.3	0.07
50-6020	0.5	NA	5.6	25	BDL	BDL	0.05
50-6020	2.5	NA	4.6	12	BDL	BDL	0.05
50-6020	4	NA	3	13	BDL	BDL	0.05

a. Preliminary unpublished results from Field Unit 5 in mg/kg

b. McDonald et al. 1997, 04-0328

c. BDL = below detection limit

d. NA = not analyzed

TABLE C-2 (continued)

CONCENTRATIONS OF METALS IN SEDIMENTS BELOW THE TA-50 RLWTF OUTFALL AT PRS No. 50-006(d)[a]

Part 1

Location ID	Depth (ft)	Ag	As	Ba	Be	Cd	Cr	Hg
Background Screening Value[b]		*0.28*	*3.98*	*127*	*1.31*	*0.18*	*10.5*	*0.03*
50-6021	*0.5*	*BDL*[c]	*1.1*	*27*	*0.49*	*BDL*	*6*	*BDL*
50-6021	*2.5*	*BDL*	*1.7*	*36*	*0.56*	*BDL*	*4.7*	*0.1*
50-6021	*4*	*BDL*	*1.2*	*32*	*0.46*	*BDL*	*3.9*	*BDL*
50-6022	*0.5*	*BDL*	*0.8*	*11*	*0.22*	*BDL*	*1.7*	*BDL*
50-6022	*2.5*	*BDL*	*1*	*8.4*	*0.1*	*BDL*	*1.2*	*BDL*
50-6022	*4*	*BDL*	*1.1*	*20*	*0.29*	*BDL*	*3.1*	*0.1*
50-6023	*0.5*	*BDL*	*1.8*	*62*	*0.6*	*BDL*	*7.7*	*BDL*
50-6023	*2.5*	*BDL*	*1*	*35*	*0.51*	*BDL*	*3*	*BDL*
50-6023	*4*	*BDL*	*1.1*	*37*	*0.43*	*BDL*	*5.8*	*BDL*
50-6024	*0.5*	*BDL*	*2.9*	*71*	*0.71*	*BDL*	*4.2*	*BDL*
50-6024	*2.5*	*BDL*	*2.1*	*39*	*0.57*	*BDL*	*4.9*	*BDL*
50-6025	*0.5*	*BDL*	*1.3*	*17*	*0.29*	*BDL*	*3.1*	*BDL*
50-6026	*0.5*	*BDL*	*4.82*	*89*	*0.81*	*BDL*	*10*	*0.1*

Part 2

Location ID	Depth (ft)	K	Ni	Pb	Sb	Se	Tl
Background Screening Value		*2690*	*9.38*	*19.7*	*5*	*<0.2*	*3.2*
50-6021	*0.5*	*NA*[d]	*6*	*4*	*BDL*	*BDL*	*0.08*
50-6021	*2.5*	*NA*	*3.2*	*5*	*BDL*	*BDL*	*0.34*
50-6021	*4*	*NA*	*3.6*	*4*	*BDL*	*BDL*	*0.18*
50-6022	*0.5*	*NA*	*2*	*BDL*	*BDL*	*BDL*	*BDL*
50-6022	*2.5*	*NA*	*BDL*	*4*	*BDL*	*BDL*	*0.05*
50-6022	*4*	*NA*	*3*	*5*	*BDL*	*BDL*	*0.13*
50-6023	*0.5*	*NA*	*4*	*11*	*BDL*	*BDL*	*0.1*
50-6023	*2.5*	*NA*	*3*	*3*	*BDL*	*BDL*	*BDL*
50-6023	*4*	*NA*	*3*	*8.3*	*BDL*	*BDL*	*0.09*
50-6024	*0.5*	*NA*	*5*	*15*	*BDL*	*BDL*	*0.09*
50-6024	*2.5*	*NA*	*4*	*7*	*BDL*	*BDL*	*0.1*
50-6025	*0.5*	*NA*	*4*	*4*	*BDL*	*BDL*	*0.04*
50-6026	*0.5*	*NA*	*5*	*15*	*BDL*	*0.39*	*0.2*

a. *Preliminary unpublished results from Field Unit 5 in mg/kg*
b. *McDonald et al. 1997, 04-0328*
c. *BDL = below detection limit*
d. *NA = not analyzed*

TABLE C-2 (continued)

CONCENTRATIONS OF METALS IN SEDIMENTS BELOW THE TA-50 RLWTF OUTFALL AT PRS No. 50-006(d)[a]

Part 1

Location ID	Depth (ft)	Ag	As	Ba	Be	Cd	Cr	Hg
Background Screening Value[b]		0.28	3.98	127	1.31	0.18	10.5	0.03
50-6026	2.5	1.6	0.9	71	2	BDL[c]	5.1	0.1
50-6026	4	1.5	0.8	54	1.5	BDL	7.2	0.2
	Minimum	1	0.52	8.4	0.1	BDL	1.2	0.1
	Maximum	8	5.18	160	2	BDL	56	0.2
	x Background	28.6	1.30	1.26	1.53	0.00	5.33	6.67
	Geometric Mean	2.09	1.47	35.10	0.49	BDL	4.11	0.13

Part 2

Location ID	Depth (ft)	K	Ni	Pb	Sb	Se	Tl
Background Screening Value		2690	9.38	19.7	5	<0.2	3.2
50-6026	2.5	NA[d]	10	6	BDL	BDL	BDL
50-6026	4	NA	5.1	5.7	BDL	BDL	BDL
	Minimum	580	2	3	0.09	0.3	0.03
	Maximum	1000	48	70	0.15	0.41	0.34
	x Background	0.37	5.12	3.55	0.03	2.05	0.11
	Geometric Mean	761.58	4.25	8.45	0.11	0.35	0.08

a. Preliminary unpublished results from Field Unit 5 in mg/kg
b. McDonald et al. 1997, 04-0328
c. BDL = below detection limit
d. NA = not analyzed

TABLE C-3

CONCENTRATIONS OF DETECTABLE ORGANIC COMPOUNDS IN SEDIMENTS BELOW THE TA-50 RLWTF OUTFALL AT PRS No. 50-006(d)*

Location ID	Depth (ft)	Sample ID	Analyte	Result	Uncertainty	Analytical Method
50-6000	0.5	AAA2492	Trichlorofluoromethane	0.019	0.0057	GC/MS
50-6002	2.5	AAA2750	Isopropyltoluene[4-]	0.017	0.0051	GC/MS
50-6002	4	AAA2752	Acetone	0.027	0.0081	GC/MS
50-6004	0.5	AAA2496	Isopropyltoluene[4-]	0.044	0.0132	GC/MS
50-6005	4	AAA2753	Aroclor-1260	0.11	0.022	GC/ECD
50-6005	4	AAA2753	Aroclors (mixed)	0.11	0.022	GC/ECD
50-6006	0.5	AAA2498	Trimethylbenzene[1,3,5-]	0.0082	0.00246	GC/MS
50-6006	0.5	AAA2498	Aroclor-1260	0.021	0.0042	GC/ECD
50-6006	0.5	AAA2498	Aroclors (mixed)	0.021	0.0042	GC/ECD
50-6006	0.5	AAA2498	Trimethylbenzene[1,2,4-]	0.026	0.0078	GC/MS
50-6011	0.5	AAA2503	Aroclors (mixed)	0.053	0.0106	GC/ECD
50-6011	0.5	AAA2742	Aroclor-1260	0.05	0.01	GC/ECD
50-6011	0.5	AAA2742	Aroclors (mixed)	0.05	0.01	GC/ECD
50-6011	0.5	AAA2503	Aroclor-1260	0.053	0.0106	GC/ECD
50-6017	0.5	AAA2509	Aroclor-1260	0.02	0.004	GC/ECD
50-6017	0.5	AAA2509	Aroclors (mixed)	0.02	0.004	GC/ECD
50-6023	4	AAA2734	Trichlorofluoromethane	0.022	0.0066	GC/MS
50-6026	2.5	AAA2730	Bis(2-ethylhexyl)phthalate	0.39	0.117	GC/MS
50-6026	2.5	AAA2730	Di-n-butylphthalate	0.45	0.135	GC/MS
50-6026	4	AAA2737	Bis(2-ethylhexyl)phthalate	0.36	0.108	GC/MS

*Preliminary unpublished results from Field Unit 5 in mg/kg

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Appendix D

Data for Wells, Boreholes, and Moisture Access Tubes in Mortandad Canyon

TABLE D-1

SUMMARY AND STATUS OF MORTANDAD CANYON WELLS, BOREHOLES, AND MOISTURE ACCESS TUBES

ID	Date Completed	Total Depth (ft)	Depth Completed (ft)	General Location	Current Status	Well Comment
35-2028	*11/7/94*	*299*	*0*	*Pratt Canyon*	*Plugged core hole*	*PRS No. 35-003(r) RFI sample hole*
EGH-LA-1	*7/31/79*	*2292*	*0*	*Sigma Mesa*	*Plugged and abandoned*	*Geothermal test on Sigma Mesa*
MCC-8.2	*4/1/89*	*184*	*0*	*Lower Mortandad Canyon*	*Plugged and abandoned*	*Deep core hole, plugged and abandoned*
MCM- 12B	*6/1/71*	*79*	*79*	*Lower Mortandad Canyon*	*Active*	*Moisture access tube*
MCM-10	*10/1/60*	*67*	*67*	*Lower Mortandad Canyon*	*Inactive*	*Moisture access tube, not found in 1991*
MCM-10-1	*8/1/91*	*119*	*119*	*Lower Mortandad Canyon*	*Active*	*Seismic reflection test completed as moisture access tube*
MCM-10-2	*8/1/91*	*43*	*43*	*Lower Mortandad Canyon*	*Active*	*Seismic reflection test completed as moisture access tube*
MCM-10-3A	*8/1/91*	*33*	*33*	*Lower Mortandad Canyon*	*Active*	*Seismic reflection test completed as moisture access tube*
MCM-10-3B	*8/1/91*	*43*	*43*	*Lower Mortandad Canyon*	*Active*	*Seismic reflection test completed as moisture access tube*
MCM-12A	*6/1/71*	*98*	*98*	*Lower Mortandad Canyon*	*Active*	*Moisture access tube*
MCM-1A	*11/1/60*	*12*	*12*	*Upper Mortandad Canyon*	*Abandoned*	*Moisture access tube, not found 1996*
MCM-1B	*11/1/60*	*11*	*11*	*Upper Mortandad Canyon*	*Abandoned*	*Moisture access tube, not found 1996*
MCM-2.2	*11/1/61*	*90*	*87*	*Upper Mortandad Canyon*	*Active*	*Moisture access tube, angle hole*
MCM-2.8	*11/1/61*	*60*	*58*	*Upper Mortandad Canyon*	*Active*	*Moisture access tube, angle hole*
MCM-2A	*11/1/60*	*11*	*11*	*Upper Mortandad Canyon*	*Active*	*Moisture access tube*
MCM-2B	*11/1/60*	*1*	*1*	*Upper Mortandad Canyon*	*Active*	*Moisture access tube*
MCM-3A	*11/1/60*	*13*	*13*	*Upper Mortandad Canyon*	*Active*	*Moisture access tube*
MCM-3B	*11/1/60*	*10*	*10*	*Upper Mortandad Canyon*	*Active*	*Moisture access tube*

TABLE D-1 (continued)

SUMMARY AND STATUS OF MORTANDAD CANYON WELLS, BOREHOLES, AND MOISTURE ACCESS TUBES

ID	Date Completed	Total Depth (ft)	Depth Completed (ft)	General Location	Current Status	Well Comment
MCM-4.5	*11/1/61*	*48*	*48*	*Middle Mortandad Canyon*	*Active*	*Moisture access tube into bedrock*
MCM-4.8	*11/1/61*	*33*	*33*	*Middle Mortandad Canyon*	*Inactive*	*Moisture access tube, not found 1996*
MCM-4A	*11/1/60*	*9*	*9*	*Middle Mortandad Canyon*	*Inactive*	*Moisture access tube, not found 1996*
MCM-4B	*11/1/60*	*24*	*24*	*Middle Mortandad Canyon*	*Inactive*	*Moisture access tube*
MCM-5.1	*9/1/90*	*112*	*112*	*Middle Mortandad Canyon*	*Active*	*Moisture access tube*
MCM-5.9	*7/1/90*	*44*	*0*	*Middle Mortandad Canyon*	*Abandoned*	*Plugged and abandoned*
MCM-5.9A	*7/1/90*	*194*	*194*	*Middle Mortandad Canyon*	*Active*	*Moisture access tube*
MCM-5A	*10/1/60*	*25*	*25*	*Middle Mortandad Canyon*	*Active*	*Moisture access tube*
MCM-5B	*10/1/60*	*30*	*30*	*Middle Mortandad Canyon*	*Inactive*	*Moisture access tube, not found 1996*
MCM-5C	*10/1/60*	*37*	*37*	*Middle Mortandad Canyon*	*Active*	*Moisture access hole*
MCM-6.5	*11/1/61*	*95*	*95*	*Middle Mortandad Canyon*	*Active*	*Moisture access tube into bedrock*
MCM-6.5A	*8/1/89*	*23*	*23*	*Middle Mortandad Canyon*	*Active*	*Moisture access tube*
MCM-6A	*10/1/60*	*18*	*18*	*Middle Mortandad Canyon*	*Active*	*Moisture access tube*
MCM-6B	*10/1/60*	*52*	*52*	*Middle Mortandad Canyon*	*Inactive*	*Moisture access tube, not found 1996*
MCM-6C	*10/1/60*	*57*	*57*	*Middle Mortandad Canyon*	*Inactive*	*Moisture access tube, not found 1996*
MCM-6D	*10/1/60*	*35*	*35*	*Middle Mortandad Canyon*	*Inactive*	*Moisture access tube, not found 1996*
MCM-6E	*10/1/60*	*21*	*21*	*Middle Mortandad Canyon*	*Active*	*Moisture access tube*
MCM-7.5	*11/1/61*	*94*	*94*	*Lower Mortandad Canyon*	*Active*	*Moisture access tube into bedrock*
MCM-8A	*10/1/60*	*20*	*20*	*Lower Mortandad Canyon*	*Inactive*	*Moisture access tube, not found 1996*
MCM-8B	*10/1/60*	*30*	*30*	*Lower Mortandad Canyon*	*Active*	*Moisture access tube*
MCM-8C	*10/1/60*	*66*	*66*	*Lower Mortandad Canyon*	*Active*	*Moisture access tube*

TABLE D-1 (continued)

SUMMARY AND STATUS OF MORTANDAD CANYON WELLS, BOREHOLES, AND MOISTURE ACCESS TUBES

ID	Date Completed	Total Depth (ft)	Depth Completed (ft)	General Location	Current Status	Well Comment
MCM-8D	*10/1/60*	*86*	*86*	*Lower Mortandad Canyon*	*Active*	*Moisture access tube*
MCM-8E	*10/1/60*	*53*	*53*	*Lower Mortandad Canyon*	*Active*	*Moisture access tube*
MCM-8F	*10/1/60*	*23*	*23*	*Lower Mortandad Canyon*	*Active*	*Moisture access tube*
MCO-1	*11/1/60*	*8*	*8*	*Effluent Canyon*	*Abandoned*	*Observation well, not found in 1991*
MCO-11	*11/1/61*	*23*	*20*	*Lower Mortandad Canyon*	*Inactive*	*Observation well, not found in 1991*
MCO-12	*6/1/71*	*112*	*108*	*Lower Mortandad Canyon*	*Active*	*Observation well*
MCO-12 Old	*11/1/61*	*64*	*60*	*Lower Mortandad Canyon*	*Abandoned*	*Casing pulled, hole plugged (relocated N ~12 ft); see MCM-12A*
MCO-12B	*6/1/71*	*112*	*108*	*Lower Mortandad Canyon*	*Active*	*Observation well*
MCO-13	*7/1/70*	*112*	*107*	*Lower Mortandad Canyon*	*Active*	*Observation well*
MCO-2	*11/1/60*	*10*	*9*	*Effluent Canyon*	*Active*	*Observation well*
MCO-3	*3/1/67*	*18*	*12*	*Upper Mortandad Canyon*	*Active*	*Originally installed 11/60; reinstalled 3/67*
MCO-4	*10/1/63*	*24*	*19*	*Middle Mortandad Canyon*	*Active*	*Observation well*
MCO-4.9	*7/1/73*	*43*	*30*	*Middle Mortandad Canyon*	*Active*	*Observation well*
MCO-4A	*11/1/89*	*24*	*19.4*	*Middle Mortandad Canyon*	*Active*	*RCRA observation well*
MCO-4B	*11/1/89*	*34*	*33.9*	*Middle Mortandad Canyon*	*Active*	*Observation well*
MCO-5	*10/1/60*	*47*	*46*	*Middle Mortandad Canyon*	*Active*	*Observation well*
MCO-5.1A	*6/1/95*	*24.9*	*Unknown*	*Middle Mortandad Canyon*	*Inactive*	*Not previously reported*
MCO-6	*3/1/74*	*47*	*47*	*Middle Mortandad Canyon*	*Active*	*Original installed 10/60; plugged and abandoned, relocated*
MCO-6 Old	*10/1/60*	*82*	*71*	*Middle Mortandad Canyon*	*Abandoned*	*Plugged and abandoned in 1974; see MCO-6*
MCO-6.5A	*11/1/61*	*47*	*45*	*Middle Mortandad Canyon*	*Active*	*Observation well*

TABLE D-1 (continued)

SUMMARY AND STATUS OF MORTANDAD CANYON WELLS, BOREHOLES, AND MOISTURE ACCESS TUBES

ID	Date Completed	Total Depth (ft)	Depth Completed (ft)	General Location	Current Status	Well Comment
MCO-6.5B	*11/1/61*	*42*	*42*	*Middle Mortandad Canyon*	*Active*	*Observation well*
MCO-6A	*11/1/89*	*33*	*32.7*	*Middle Mortandad Canyon*	*Active*	*RCRA observation well*
MCO-6B	*8/1/90*	*48*	*47.1*	*Middle Mortandad Canyon*	*Active*	*Observation well*
MCO-7	*10/1/60*	*77*	*69*	*Lower Mortandad Canyon*	*Active*	*Observation well*
MCO-7.1	*1/1/75*	*50*	*50*	*Lower Mortandad Canyon*	*Inactive*	*Not previously reported*
MCO-7.1A	*1/1/75*	*60*	*60*	*Lower Mortandad Canyon*	*Inactive*	*Observation well*
MCO-7.5A	*11/1/61*	*63*	*60*	*Lower Mortandad Canyon*	*Abandoned*	*Well damaged (relocated)*
MCO-7.5B	*4/1/74*	*62*	*60*	*Lower Mortandad Canyon*	*Active*	*Observation well*
MCO-7A	*11/1/89*	*47*	*44.8*	*Lower Mortandad Canyon*	*Active*	*Observation well*
MCO-8	*10/1/60*	*92*	*84*	*Lower Mortandad Canyon*	*Inactive*	*Observation well, obstruction in well*
MCO-8.2	*11/1/61*	*72*	*70*	*Lower Mortandad Canyon*	*Active*	*Observation well*
MCO-8A	*11/1/61*	*52*	*50*	*Lower Mortandad Canyon*	*Active*	*Observation well*
MCO-9	*11/1/60*	*57*	*55*	*Lower Mortandad Canyon*	*Active*	*Observation well*
MCO-9.5	*11/1/61*	*57*	*46*	*Lower Mortandad Canyon*	*Active*	*Observation well*
MCWB-4	*12/6/94*	*15*	*15*	*Middle Mortandad Canyon*	*Active*	*Water-balance well*
MCWB-5	*12/6/94*	*33*	*33*	*Middle Mortandad Canyon*	*Active*	*Water-balance well*
MCWB-5.5A	*12/22/94*	*37.5*	*37.5*	*Middle Mortandad Canyon*	*Active*	*Water-balance well*
MCWB-5.5B	*12/22/94*	*37.5*	*37.5*	*Middle Mortandad Canyon*	*Active*	*Water-balance well*
MCWB-6.2A	*12/7/94*	*45.5*	*45.5*	*Middle Mortandad Canyon*	*Active*	*Water-balance well*
MCWB-6.2B	*12/7/94*	*32.5*	*32.5*	*Middle Mortandad Canyon*	*Active*	*Water-balance well*
MCWB-6.2C	*12/22/94*	*42.5*	*42.5*	*Middle Mortandad Canyon*	*Active*	*Water-balance well*

TABLE D-1 (continued)

SUMMARY AND STATUS OF MORTANDAD CANYON WELLS, BOREHOLES, AND MOISTURE ACCESS TUBES

ID	Date Completed	Total Depth (ft)	Depth Completed (ft)	General Location	Current Status	Well Comment
MCWB-6.5C	12/8/94	47.5	47.5	Middle Mortandad Canyon	Active	Water-balance well
MCWB-6.5D	12/8/94	42.5	42.5	Middle Mortandad Canyon	Active	Water-balance well
MCWB-6.5E	12/21/94	50	50	Middle Mortandad Canyon	Active	Water-balance well
MCWB-6.6	12/20/94	47.5	47.5	Lower Mortandad Canyon	Active	Water-balance well
MCWB-7.2	12/12/94	67.5	67.5	Lower Mortandad Canyon	Active	Water-balance well
MCWB-7.4A	12/13/94	70	70	Lower Mortandad Canyon	Active	Water-balance well
MCWB-7.4B	12/13/94	70	70	Lower Mortandad Canyon	Active	Water-balance well
MCWB-7.7A	12/19/94	67.5	67.5	Lower Mortandad Canyon	Active	Water-balance well
MCWB-7.7B	12/19/94	70	70	Lower Mortandad Canyon	Active	Water-balance well
MCWB-7A	12/9/94	52	52	Lower Mortandad Canyon	Active	Water-balance well
MCWB-7B	12/9/94	47.5	47.5	Lower Mortandad Canyon	Active	Water-balance well
MCWB-8.1A	12/14/94	75	75	Lower Mortandad Canyon	Active	Water-balance well
MCWB-8.1B	12/19/94	72.5	72.5	Lower Mortandad Canyon	Active	Water-balance well
MCWB-8.1C	12/14/94	80	80	Lower Mortandad Canyon	Active	Water-balance well
MCWB-9A	12/15/94	75	75	Lower Mortandad Canyon	Active	Water-balance well
MCWB-9B	12/15/94	80	80	Lower Mortandad Canyon	Active	Water-balance well
MT-1	11/1/88	69	69	Lower Mortandad Canyon	Active	Observation well
MT-2	11/1/88	64	64	Lower Mortandad Canyon	Active	Observation well
MT-3	11/1/88	74	74	Lower Mortandad Canyon	Active	Observation well
MT-4	11/1/88	74	74	Lower Mortandad Canyon	Active	Observation well
SHB-1	12/15/91	700	700	West of TA-55	3-in. tubing with water	Seismic hazards borehole

TABLE D-1 (continued)

SUMMARY AND STATUS OF MORTANDAD CANYON WELLS, BOREHOLES, AND MOISTURE ACCESS TUBES

SIMO	*9/1/90*	*104*	*104*	*Lower Mortandad Canyon*	*Active*	*Observation well, on San Ildefonso Pueblo*
SIMO-1	*9/1/92*	*163*	*163*	*Lower Mortandad Canyon*	*Active*	*Observation well, San Ildefonso and BIA well*
TSCM-1	*11/1/61*	*22*	*22*	*Lower Ten Site Canyon*	*Active*	*Moisture access tube*
TSCO-1	*11/1/61*	*37*	*35*	*Lower Ten Site Canyon*	*Inactive*	*Observation well, not found 1991*
TSWB-6	*12/21/94*	*40*	*40*	*Lower Ten Site Canyon*	*Active*	*Water-balance well*
TW-8	*12/1/60*	*1065*	*1065*	*Middle Mortandad Canyon*	*Active*	*Regional aquifer test well*

TABLE D-2

COORDINATES FOR MORTANDAD CANYON WELLS, BOREHOLES, AND MOISTURE ACCESS TUBES

ID	Coordinates		Elevation (ft MSL)	LSD MP[a]	Coordinate Source	Coordinate Confidence	Coordinate Comment
	Easting	Northing					
35-2028	1,629,013.26	1,769,223.50	7,102.89		1995 survey	Good	
EGH-LA-1	1,628,830.00	1,770,620.00	7,215.00		FIMAD map pick	Moderate	
MCC-8.2	1,636,727.09	1,768,664.51	6,781.26	Cement	1996 survey	Good	At cement slab
MCM-10	1,638,880.73	1,768,393.05	6,730.58	Ground	1996 survey	Good	
MCM-10-1	1,639,133.18	1,768,085.36	6,729.70	Ground	1996 survey	Good	
MCM-10-2	1,639,769.97	1,768,056.30	6,709.34	Ground	1996 survey	Good	
MCM-10-3A	1,640,612.49	1,767,868.80	6,695.95	Ground	1996 survey	Good	
MCM-10-3B	1,640,606.16	1,767,873.15	6,696.04	Ground	1996 survey	Good	
MCM-12A	1,640,291.18	1,767,991.25	6,704.49	Ground	1996 survey	Good	
MCM-12B	1,640,328.77	1,768,305.42	6,701.62		1996 survey	Good	
MCM-1A	1,625,444.00	1,770,152.10	7,156.00		b	Moderate	Unable to locate 1996
MCM-1B	1,625,444.00	1,770,172.10	7,155.00		b	Moderate	Unable to locate 1996
MCM-2.2	1,626,188.11	1,770,113.52	7,125.44	Ground	1996 survey	Good	Measured from south side
MCM-2.8	1,626,671.29	1,770,269.84	7,097.64	Ground	1996 survey	Good	Measured from south side
MCM-2A	1,625,917.97	1,770,114.04	7,140.63	Ground	1996 survey	Good	
MCM-2B	1,625,927.60	1,770,156.66	7,136.25	Ground	1996 survey	Good	
MCM-3A	1,627,357.73	1,770,205.78	7,055.53	Ground	1996 survey	Good	
MCM-3B	1,627,367.02	1,770,241.41	7,052.42	Ground	1996 survey	Good	
MCM-4.5	1,631,890.10	1,769,695.91	6,888.55	Ground	1996 survey	Good	
MCM-4.8	1,632,244.00	1,769,562.10	6,887.00		b (old 4.5)	Questionable	Unable to locate 1996
MCM-4A	1,631,214.00	1,769,700.20	6,901.00		FIMAD map pick	Questionable	Unable to locate 1996
MCM-4B	1,631,214.00	1,769,789.20	6,900.00		b	Questionable	Unable to locate 1996
MCM-5.1	1,632,873.41	1,769,480.75	6,870.87	Brass cap	Old survey	Good	Checked in 1996 survey
MCM-5.9	1,633,603.00	1,769,030.80	6,852.00	b		Moderate	Unable to locate 1996
MCM-5.9A	1,633,603.26	1,769,028.17	6,851.83	Brass cap	1996 survey		
MCM-5A	1,632,427.92	1,769,506.84	6,880.84	Brass cap	1996 survey	Good	
MCM-5B	1,632,443.00	1,769,521.10	6,879.00		b	Moderate	Unable to locate 1996
MCM-5C	1,632,485.49	1,769,553.61	6,877.31	Ground	1996 survey	Good	
MCM-6.5	1,634,034.59	1,768,745.86	6,839.64	Ground	1996 survey	Good	
MCM-6.5A	1,634,010.44	1,768,556.74	6,838.74	Brass cap	1996 survey	Good	
MCM-6A	1,633,549.63	1,768,962.43	6,851.79	Brass cap	1996 survey	Good	
MCM-6B	1,633,626.00	1,769,001.50	6,851.00		b	Moderate	Unable to locate 1996
MCM-6C	1,633,618.00	1,769,007.80	6,851.00		b	Moderate	Unable to locate 1996
MCM-6D	1,633,644.00	1,769,012.10	6,850.00		b	Moderate	Unable to locate 1996
MCM-6E	1,633,694.43	1,769,066.55	6,850.17	Ground	1996 survey	Good	
MCM-7.5	1,635,463.03	1,768,496.21	6,809.26	Ground	1996 survey	Good	

a. LSD MP = land surface datum measuring point

b. Purtymun 1995, 45344

TABLE D-2 (continued)

COORDINATES FOR MORTANDAD CANYON WELLS, BOREHOLES, AND MOISTURE ACCESS TUBES

ID	Coordinates		Elevation (ft MSL)	LSD MP[a]	Coordinate Source	Coordinate Confidence	Coordinate Comment
	Easting	Northing					
MCM-8A	1,636,020.80	1,768,429.40	6,807.00		b	Moderate	Unable to locate 1996
MCM-8B	1,636,031.10	1,768,479.54	6,797.25	Ground	1996 survey	Good	
MCM-8C	1,635,996.84	1,768,606.85	6,798.46	Ground	1996 survey	Good	
MCM-8D	1,635,969.03	1,768,692.13	6,795.80	Brass cap	1996 survey	Good	
MCM-8E	1,635,948.92	1,768,764.61	6,796.25	Ground	1996 survey	Good	
MCM-8F	1,635,923.65	1,768,834.59	6,799.19	Ground	1996 survey	Good	
MCO-1	1,625,444.00	1,770,162.10	7,153.00		b	Moderate	Unable to locate 1996
MCO-11	1,639,897.00	1,768,331.00	6,720.00		FIMAD map pick	Questionable	Unable to locate 1996
MCO-12	1,640,326.32	1,768,206.21	6,697.15	Ground	1996 survey	Good	
MCO-12 Old	1,640,444.00	1,768,162.10	6,700.00		b	Questionable	
MCO-13	1,641,174.29	1,767,501.88	6,674.48	Ground	1996 survey	Good	
MCO-2	1,625,919.28	1,770,135.14	7,136.60	Ground	1996 survey	Good	
MCO-3	1,627,362.77	1,770,234.95	7,052.60	Ground	1996 survey	Good	
MCO-4	1,631,215.12	1,769,786.45	6,897.54	Ground	1996 survey	Good	
MCO-4.9	1,632,371.65	1,769,606.00	6,879.95	Brass cap	1996 survey	Good	
MCO-4A	1,632,028.12	1,769,698.19	6,886.58	Brass cap	1996 survey	Good	
MCO-4B	1,632,036.18	1,769,694.61	6,886.75	Brass cap	1996 survey	Good	
MCO-5	1,632,466.32	1,769,537.46	6,875.66	Ground	1996 survey	Good	
MCO-5.1A	1,632,858.37	1,769,504.46	6,869.65	Ground	1996 survey	Good	Not previously reported
MCO-6	1,633,633.54	1,769,011.79	6,849.48	Ground	1996 survey	Good	
MCO-6 Old	1,633,635.30	1,769,012.10	6,849.00		b	Moderate	Unable to locate 1996
MCO-6.5A	1,633,847.90	1,768,595.40	6,842.19	Brass cap	1996 survey	Good	
MCO-6.5B	1,633,962.36	1,768,688.11	6,838.84	Ground	1996 survey	Good	
MCO-6A	1,633,633.22	1,768,960.78	6,849.72	Brass cap	1996 survey	Good	
MCO-6B	1,633,629.57	1,768,981.74	6,850.29	Brass cap	1996 survey	Good	
MCO-7	1,634,516.11	1,768,507.85	6,827.31	Brass cap	1996 survey	Good	
MCO-7.1	1,634,737.43	1,768,511.81	6,823.04		1996 survey	Good	Not previously reported
MCO-7.1A	1,634,745.00	1,768,500.00	6,824.30	Top of casing	Interpolation	Estimated	Location estimate
MCO-7.5A	1,635,457.25	1,768,440.60	6,808.88	Brass cap	1996 survey	Good	
MCO-7.5B	1,635,453.22	1,768,439.56	6,808.88	Ground	1996 survey	Good	
MCO-7A	1,634,501.09	1,768,508.00	6,827.58	Brass cap	1996 survey	Good	
MCO-8	1,636,021.00	1,768,529.00	6,796.70	Brass cap	1996 survey	Good	
MCO-8.2	1,636,704.41	1,768,645.96	6,781.60	Brass cap	1996 survey	Good	
MCO-8A	1,635,937.41	1,768,647.61	6,797.47	Ground	1996 survey	Good	
MCO-9	1,638,056.24	1,768,370.63	6,749.67	Brass cap	1996 survey	Good	
MCO-9.5	1,638,348.52	1,768,505.85	6,743.27	Ground	1996 survey	Good	
MCWB-4	1,631,740.60	1,769,745.70	6,893.40	Brass cap	1995 survey	Good	

a. LSD MP = land surface datum measuring point

b. Purtymun 1995, 45344

TABLE D-2 (continued)

COORDINATES FOR MORTANDAD CANYON WELLS, BOREHOLES, AND MOISTURE ACCESS TUBES

ID	Coordinates		Elevation (ft MSL)	LSD MP[a]	Coordinate Source	Coordinate Confidence	Coordinate Comment
	Easting	Northing					
MCWB-5	1,632,578.30	1,769,484.60	6,876.20	Brass cap	1995 survey	Good	
MCWB-5.5A	1,633,455.50	1,769,177.00	6,858.40	Brass cap	1995 survey	Good	
MCWB-5.5B	1,633,420.50	1,769,125.80	6,856.90	Brass cap	1995 survey	Good	
MCWB-6.2A	1,633,754.50	1,768,968.20	6,848.30	Brass cap	1995 survey	Good	
MCWB-6.2B	1,633,685.10	1,768,897.80	6,848.00	Brass cap	1995 survey	Good	
MCWB-6.2C	1,633,682.30	1,768,893.50	6,848.00	Brass cap	1995 survey	Good	
MCWB-6.5C	1,633,993.30	1,768,759.40	6,841.00	Brass cap	1995 survey	Good	
MCWB-6.5D	1,633,878.10	1,768,536.20	6,843.20	Brass cap	1995 survey	Good	
MCWB-6.5E	1,633,833.40	1,768,583.80	6,843.80	Brass cap	1995 survey	Good	
MCWB-6.6	1,634,021.00	1,768,565.70	6,839.40	Brass cap	1995 survey	Good	
MCWB-7.2	1,634,957.00	1,768,491.90	6,818.90	Brass cap	1995 survey	Good	
MCWB-7.4A	1,635,270.30	1,768,569.50	6,812.40	Brass cap	1995 survey	Good	
MCWB-7.4B	1,635,287.70	1,768,407.80	6,813.10	Brass cap	1995 survey	Good	
MCWB-7.7A	1,635,902.30	1,768,700.70	6,798.30	Brass cap	1995 survey	Good	
MCWB-7.7B	1,635,921.80	1,768,517.30	6,799.00	Brass cap	1995 survey	Good	
MCWB-7A	1,634,356.60	1,768,551.00	6,831.20	Brass cap	1995 survey	Good	
MCWB-7B	1,634,350.20	1,768,469.70	6,832.50	Brass cap	1995 survey	Good	
MCWB-8.1A	1,636,552.40	1,768,704.10	6,786.00	Brass cap	1995 survey	Good	
MCWB-8.1B	1,636,560.00	1,768,618.30	6,783.80	Brass cap	1995 survey	Good	
MCWB-8.1C	1,636,565.70	1,768,531.70	6,785.60	Brass cap	1995 survey	Good	
MCWB-9A	1,638,123.00	1,768,627.70	6,752.10	Brass cap	1995 survey	Good	
MCWB-9B	1,638,069.00	1,768,491.00	6,753.60	Brass cap	1995 survey	Good	
MCWW-1	1,634,890.44	1,768,518.17	6,819.50	Ground	1996 survey	Good	Not previously reported
MT-1	1,635,262.86	1,768,493.96	6,811.63	Ground	1996 survey	Good	
MT-2	1,636,019.79	1,768,544.59	6,796.20	Ground	1996 survey	Good	
MT-3	1,635,980.95	1,768,657.83	6,796.65	Ground	1996 survey	Good	
MT-4	1,636,557.31	1,768,634.21	6,783.59	Ground	1996 survey	Good	
PM-3	1,642,590.00	1,769,530.00	6,610.00		FIMAD map pick	Moderate	New pick from wellhouse
PM-5	1,632,110.00	1,767,790.00	7,095.00		FIMAD map pick	Moderate	New pick from wellhouse
SHB-1	1,624,052.20	1,769,848.70	7,314.60		1994 survey	Good	
SIMO	1,641,883.42	1,766,633.76	6,650.90	Ground	1996 survey	Good	
SIMO-1	1,641,897.26	1,766,694.55	6,650.02	Ground	1996 survey	Good	
TSCM-1	1,633,142.99	1,768,502.62	6,857.83	Ground	1996 survey	Good	
TSCO-1	1,633,344.00	1,768,462.00	6,857.00		b	Questionable	Unable to locate 1991, 1996
TSWB-6	1,633,383.10	1,768,490.80	6,853.20	Brass cap	1995 survey	Good	
TW-8	1,632,573.95	1,769,504.85	6,875.46	Top of casing	1996 survey	Good	Survey top of casing 2 ft above ground level

a. LSD MP = land surface datum measuring point

b. Purtymun 1995, 45344

TABLE D-3

CONSTRUCTION INFORMATION FOR MORTANDAD CANYON WELLS, BOREHOLES, AND MOISTURE ACCESS TUBES

Part 1

ID	Tubing Type	Tubing Diameter (in.)	Surface Casing Type	Surface Casing Diameter (in.)	Depth to Top of Screen (ft)	Depth to Bottom of Screen (ft)	Perforation Size (in.)
35-2028	*None*		*None*	*0*			
EGH-LA-1							
MCC-8.2	*None*		*None*				
MCM-10	*Plastic*	*2*	*None*				
MCM-10-1	*PVC*	*2*	*None*				
MCM-10-2	*Plastic*	*2*	*Steel*	*6*			
MCM-10-3A	*PVC*	*2*	*None*				
MCM-10-3B	*PVC*	*2*	*None*				
MCM-12A	*Plastic*	*2*	*None*				
MCM-12B	*Plastic*	*2*	*None*				
MCM-1A	*Plastic*	*2*	*None*				
MCM-1B	*Plastic*	*2*	*None*				
MCM-2.2	*PVC*	*2*	*None*				
MCM-2.8	*PVC*	*2*	*None*				
MCM-2A	*Plastic*	*2*	*None*				
MCM-2B	*Plastic*	*2*	*None*				
MCM-3A	*Plastic*	*2*	*None*				
MCM-3B	*Plastic*	*2*	*None*				
MCM-4.5	*Plastic*	*2*	*Steel*	*4*			

Part 2

ID	Annulus Pack	Sump Length (ft)	Casing Comment	Screen Comment
35-2028			*No casing*	*Plugged and abandoned*
EGH-LA-1				*Plugged and abandoned*
MCC-8.2	*Cement*		*Augers parted, hole abandoned*	*Plugged and abandoned*
MCM-10	*Cuttings*		*Can cap*	*No screen interval*
MCM-10-1	*Cuttings*		*7-in. high 11/5/96*	*No screen interval*
MCM-10-2	*Cuttings*			*No screen interval*
MCM-10-3A	*Cuttings*		*No cap*	*No screen interval*
MCM-10-3B	*Sand 0.010–0.020*		*No cap*	*No screen interval*
MCM-12A	*Cuttings*		*Can cap*	*No screen interval*
MCM-12B	*Cuttings*			*No screen interval*
MCM-1A	*Cuttings*		*Unable to locate 1991*	*No screen interval*
MCM-1B	*Cuttings*		*Unable to locate 1991*	*No screen interval*
MCM-2.2	*Cuttings*		*45° hole, tubing broken*	*No screen interval*
MCM-2.8	*Cuttings*		*30° hole, tubing broken*	*No screen interval*
MCM-2A	*Cuttings*			*No screen interval*
MCM-2B	*Cuttings*		*Cracked at base*	*No screen interval*
MCM-3A	*Cuttings*			*No screen interval*
MCM-3B	*Cuttings*			*No screen interval*
MCM-4.5	*Cuttings*		*Double-cased*	*No screen interval*

TABLE D-3 (continued)

CONSTRUCTION INFORMATION FOR MORTANDAD CANYON WELLS, BOREHOLES, AND MOISTURE ACCESS TUBES

Part 1

ID	Tubing Type	Tubing Diameter (in.)	Surface Casing Type	Surface Casing Diameter (in.)	Depth to Top of Screen (ft)	Depth to Bottom of Screen (ft)	Perforation Size (in.)
MCM-4.8	*Plastic*	*2*	*Steel*	*4*			
MCM-4A	*Plastic*	*2*	*None*	*0*			
MCM-4B	*Plastic*	*2*	*Steel*	*4*			
MCM-5.1	*Plastic*	*2*	*Steel*	*10*			
MCM-5.9	*Plastic*	*2*	*None*				
MCM-5.9A	*PVC*	*2*	*Steel*	*8*			
MCM-5A	*Plastic*	*2*	*Steel*	*6*			
MCM-5B	*Plastic*	*2*	*None*				
MCM-5C	*Plastic*	*2*	*None*				
MCM-6.5	*Plastic*	*2*	*Steel*	*4*			
MCM-6.5A	*Aluminum*	*2*	*Aluminum*	*6*			
MCM-6A	*Plastic*	*2*	*Steel*	*6*			
MCM-6B	*Plastic*	*2*					
MCM-6C	*Plastic*	*2*					
MCM-6D	*Plastic*	*2*					
MCM-6E	*Plastic*	*2*					
MCM-7.5	*Plastic*	*2*	*Steel*	*4*			
MCM-8A	*Plastic*	*2*	*None*				

Part 2

ID	Annulus Pack	Sump Length (ft)	Casing Comment	Screen Comment
MCM-4.8	*Cuttings*			*No screen interval*
MCM-4A	*Cuttings*		*Unable to locate*	*No screen interval*
MCM-4B	*Cuttings*		*Unable to locate*	*No screen interval*
MCM-5.1	*Sand/bentonite*			*No screen interval*
MCM-5.9			*Hole abandoned*	*Plugged and abandoned*
MCM-5.9A	*Sand/bentonite*			*No screen interval*
MCM-5A	*Cuttings*			*No screen interval*
MCM-5B	*Cuttings*			*No screen interval*
MCM-5C	*Cuttings*			*No screen interval*
MCM-6.5	*Cuttings*		*Double-cased bedrock moisture tube*	*No screen interval*
MCM-6.5A	*Sand?*			*No screen interval*
MCM-6A	*Cuttings*			*No screen interval*
MCM-6B	*Cuttings*		*Unable to locate 1996*	*No screen interval*
MCM-6C	*Cuttings*		*Unable to locate 1996*	*No screen interval*
MCM-6D	*Cuttings*		*Unable to locate 1996*	*No screen interval*
MCM-6E	*Cuttings*			*No screen interval*
MCM-7.5	*Cuttings*		*Double-cased bedrock moisture tube*	*No screen interval*
MCM-8A	*Cuttings*		*Unable to locate 1996*	*No screen interval*

TABLE D-3 (continued)

CONSTRUCTION INFORMATION FOR MORTANDAD CANYON WELLS, BOREHOLES, AND MOISTURE ACCESS TUBES

Part 1

ID	Tubing Type	Tubing Diameter (in.)	Surface Casing Type	Surface Casing Diameter (in.)	Depth to Top of Screen (ft)	Depth to Bottom of Screen (ft)	Perforation Size (in.)
MCM-8B	*Plastic*	*2*	*Steel*				
MCM-8C	*Plastic*	*2*	*None*				
MCM-8D	*Plastic*	*2*	*None*				
MCM-8E	*Plastic*	*2*	*None*				
MCM-8F	*Plastic*	*2*	*None*				
MCO-1	*Plastic*	*3*		*3*	*1*	*8*	
MCO-11	*Plastic*	*2*			*10*	*20*	*0.25*
MCO-12	*Plastic*	*2*	*None*		*88*	*108*	*0.25*
MCO-12 Old				*0*	*40*	*60*	*0.25*
MCO-13	*PVC*	*2*	*None*		*87*	*107*	*0.25*
MCO-2	*Plastic*	*2*	*None*		*2*	*7*	*0.25*
MCO-3	*PVC*	*3*	*Steel*	*8*	*2*	*12*	*0.25*
MCO-4	*Plastic*	*3*	*Steel*	*8*	*4*	*19*	*0.25*
MCO-4.9	*PVC*	*4*	*Steel*	*8*	*10*	*30*	*0.25*
MCO-4A	*PVC*	*2*	*Steel*	*8*	*9.4*	*19.4*	*0.01*
MCO-4B	*PVC*	*2*	*Steel*	*8*	*8.9*	*28.9*	*0.01*
MCO-5	*PVC*	*4*	*Steel*	*8*	*21*	*46*	*0.25*
MCO-5.1A	*PVC*	*2*	*None*	*0*			*0.25*
MCO-6	*PVC*	*4*	*Steel*	*10*	*27*	*47*	*0.25*

Part 2

ID	Annulus Pack	Sump Length (ft)	Casing Comment	Screen Comment
MCM-8B	*Cuttings*			*No screen interval*
MCM-8C	*Cuttings*			*No screen interval*
MCM-8D	*Cuttings*			*No screen interval*
MCM-8E	*Cuttings*			*No screen interval*
MCM-8F	*Cuttings*			*No screen interval*
MCO-1	*Cuttings*	*0*	*1 ft of surface casing*	*Open hole below 1 ft*
MCO-11	*Cuttings*	*0*	*Unable to locate 1991, 1996*	
MCO-12	*Cuttings*	*0*	*Can cap*	
MCO-12 Old	*Cuttings*	*0*		*Hole abandoned, replaced*
MCO-13	*Cuttings*	*0*	*Galvanized threaded cap*	
MCO-2	*Cuttings*	*0*		
MCO-3	*Cuttings*	*0*		
MCO-4	*Cuttings*	*0*	*Tubing 8 in. above casing top*	
MCO-4.9	*Cuttings*	*0*		
MCO-4A	*Sand 0.010–0.020*	*0*		
MCO-4B	*Sand 0.010–0.020*	*5*		*5-ft sump below perforations*
MCO-5	*Cuttings*	*0*		
MCO-5.1A			*Screw cap*	*Screen interval unknown*
MCO-6	*Gravel pack*	*0*		

TABLE D-3 (continued)

CONSTRUCTION INFORMATION FOR MORTANDAD CANYON WELLS, BOREHOLES, AND MOISTURE ACCESS TUBES

Part 1

ID	Tubing Type	Tubing Diameter (in.)	Surface Casing Type	Surface Casing Diameter (in.)	Depth to Top of Screen (ft)	Depth to Bottom of Screen (ft)	Perforation Size (in.)
MCO-6 Old				*0*	*36*	*71*	*0.25*
MCO-6.5A	*Plastic*	*2*	*Steel*	*6*	*25*	*45*	*0.25*
MCO-6.5B	*Steel*	*4*			*22*	*42*	*0.25*
MCO-6A	*PVC*	*2*	*Steel*	*8*	*22.7*	*32.7*	*0.25*
MCO-6B	*PVC*	*2*	*Steel*	*8*	*22*	*42*	*0.25*
MCO-7	*Plastic*	*3*	*Steel*	*8*	*39*	*69*	*0.25*
MCO-7.1	*Plastic*	*2*	*None*	*0*			
MCO-7.1A	*PVC*	*4*	*None*	*0*			
MCO-7.5A	*PVC*	*3*	*Steel*	*8*	*40*	*60*	*0.25*
MCO-7.5B	*PVC*	*4*		*8*	*35*	*60*	*0.25*
MCO-7A	*PVC*	*3*	*Steel*	*8*	*34.8*	*44.8*	*0.25*
MCO-8	*Plastic*	*3*	*Steel*	*8*	*64*	*84*	*0.25*
MCO-8.2	*Plastic*	*2*	*Steel*	*6*	*60*	*70*	*0.25*
MCO-8A	*Plastic*	*2*	*None*		*40*	*50*	*0.25*
MCO-9	*PVC*	*3*			*45*	*55*	*0.25*
MCO-9.5	*Plastic*	*2*			*26*	*46*	*0.25*
MCWB-4	*PVC*	*3*	*Steel*	*8*	*10*	*15*	*0.02*
MCWB-5	*PVC*	*3*	*Steel*	*8*	*17*	*27*	*0.02*

Part 2

ID	Annulus Pack	Sump Length (ft)	Casing Comment	Screen Comment
MCO-6 Old	*Cuttings*	*0*		*Hole abandoned, replaced*
MCO-6.5A	*Cuttings*	*0*		
MCO-6.5B	*Cuttings*	*0*	*20 ft 4 in. plastic, 22 ft 4 in. steel casing*	*Perforations are in the plastic pipe*
MCO-6A	*Sand 0.010–0.020*	*0*		
MCO-6B	*Sand 0.010–0.020*	*5*		*5-ft sump below perforations*
MCO-7	*Cuttings*	*0*		
MCO-7.1				*Construction unknown*
MCO-7.1A			*Old gauge box on well*	*Construction unknown*
MCO-7.5A	*Cuttings*	*0*	*PVC casing broken 1 in. below ground surface*	*Hole abandoned, replaced*
MCO-7.5B	*Gravel pack*	*0*		
MCO-7A	*Sand 0.010–0.020*	*0*		
MCO-8	*Cuttings*	*0*		*Obstruction in tubing*
MCO-8.2	*Cuttings*	*0*		
MCO-8A	*Cuttings*	*0*		
MCO-9	*Cuttings*	*0*		
MCO-9.5	*Cuttings*	*0*		
MCWB-4	*Sand 0.0787–0.0331*	*0*	*Metal box on top of casing*	*No sump*
MCWB-5	*Sand 0.0787–0.0331*	*5*		*5-ft sump below perforations*

TABLE D-3 (continued)

CONSTRUCTION INFORMATION FOR MORTANDAD CANYON WELLS, BOREHOLES, AND MOISTURE ACCESS TUBES

Part 1

ID	Tubing Type	Tubing Diameter (in.)	Surface Casing Type	Surface Casing Diameter (in.)	Depth to Top of Screen (ft)	Depth to Bottom of Screen (ft)	Perforation Size (in.)
MCWB-5.5A	*PVC*	*3*	*Steel*	*8*	*22.5*	*32.5*	*0.02*
MCWB-5.5B	*PVC*	*3*	*Steel*	*8*	*22.5*	*32.5*	*0.02*
MCWB-6.2A	*PVC*	*3*	*Steel*	*8*	*30.5*	*40.5*	*0.02*
MCWB-6.2B	*PVC*	*3*	*Steel*	*8*	*27.5*	*37.5*	*0.02*
MCWB-6.2C	*PVC*	*3*	*Steel*	*8*	*25*	*30*	*0.02*
MCWB-6.5C	*PVC*	*3*	*Steel*	*8*	*32.5*	*42.5*	*0.02*
MCWB-6.5D	*PVC*	*3*	*Steel*	*8*	*32.5*	*42.5*	*0.02*
MCWB-6.5E	*PVC*	*3*	*Steel*	*8*	*35*	*45*	*0.02*
MCWB-6.6	*PVC*	*3*	*Steel*	*8*	*32.5*	*42.5*	*0.02*
MCWB-7.2	*PVC*	*3*	*Steel*	*8*	*42.5*	*62.5*	*0.02*
MCWB-7.4A	*PVC*	*3*	*Steel*	*8*	*45*	*65*	*0.02*
MCWB-7.4B	*PVC*	*3*	*Steel*	*8*	*45*	*65*	*0.02*
MCWB-7.7A	*PVC*	*3*	*Steel*	*8*	*52.5*	*62.5*	*0.02*
MCWB-7.7B	*PVC*	*3*	*Steel*	*8*	*55*	*65*	*0.02*
MCWB-7A	*PVC*	*3*	*Steel*	*8*	*37*	*47*	*0.02*
MCWB-7B	*PVC*	*3*	*Steel*	*8*	*32.5*	*42.5*	*0.02*
MCWB-8.1A	*PVC*	*3*	*Steel*	*8*	*50*	*70*	*0.02*
MCWB-8.1B	*PVC*	*3*	*Steel*	*8*	*47.5*	*67.5*	*0.02*
MCWB-8.1C	*PVC*	*3*	*Steel*	*8*	*55*	*75*	*0.02*

Part 2

ID	Annulus Pack	Sump Length (ft)	Casing Comment	Screen Comment
MCWB-5.5A	*Sand 0.0787–0.0331*	*5*		*5-ft sump below perforations*
MCWB-5.5B	*Sand 0.0787–0.0331*	*5*		*5-ft sump below perforations*
MCWB-6.2A	*Sand 0.0787–0.0331*	*5*		*5-ft sump below perforations*
MCWB-6.2B	*Sand 0.0787–0.0331*	*5*		*5-ft sump below perforations*
MCWB-6.2C	*Sand 0.0787–0.0331*	*2.5*		*2.5-ft sump below perforations*
MCWB-6.5C	*Sand 0.0787–0.0331*	*0*		*No sump*
MCWB-6.5D	*Sand 0.0787–0.0331*	*5*		*5-ft sump below perforations*
MCWB-6.5E	*Sand 0.0787–0.0331*	*5*		*5-ft sump below perforations*
MCWB-6.6	*Sand 0.0787–0.0331*	*5*		*5-ft sump below perforations*
MCWB-7.2	*Sand 0.0787–0.0331*	*5*		*5-ft sump below perforations*
MCWB-7.4A	*Sand 0.0787–0.0331*	*5*		*5-ft sump below perforations*
MCWB-7.4B	*Sand 0.0787–0.0331*	*5*		*5-ft sump below perforations*
MCWB-7.7A	*Sand 0.0787–0.0331*	*5*		*5-ft sump below perforations*
MCWB-7.7B	*Sand 0.0787–0.0331*	*5*		*5-ft sump below perforations*
MCWB-7A	*Sand 0.0787–0.0331*	*5*		*5-ft sump below perforations*
MCWB-7B	*Sand 0.0787–0.0331*	*5*		*5-ft sump below perforations*
MCWB-8.1A	*Sand 0.0787–0.0331*	*5*		*5-ft sump below perforations*
MCWB-8.1B	*Sand 0.0787–0.0331*	*5*		*5-ft sump below perforations*
MCWB-8.1C	*Sand 0.0787–0.0331*	*5*		*5-ft sump below perforations*

TABLE D-3 (continued)

CONSTRUCTION INFORMATION FOR MORTANDAD CANYON WELLS, BOREHOLES, AND MOISTURE ACCESS TUBES

Part 1

ID	Tubing Type	Tubing Diameter (in.)	Surface Casing Type	Surface Casing Diameter (in.)	Depth to Top of Screen (ft)	Depth to Bottom of Screen (ft)	Perforation Size (in.)
MCWB-9A	*PVC*	*3*	*Steel*	*8*	*50*	*70*	*0.02*
MCWB-9B	*PVC*	*3*	*Steel*	*8*	*55*	*75*	*0.02*
MCWW-1	*PVC*	*3*	*None*	*0*			
MT-1	*PVC*	*2*	*Steel*	*8*	*39*	*59*	*0.01*
MT-2	*PVC*	*2*	*Steel*	*8*	*44*	*54*	*0.01*
MT-3	*PVC*	*2*	*Steel*	*8*	*44*	*64*	*0.01*
MT-4	*PVC*	*2*	*Steel*	*8*	*54*	*64*	*0.01*
SHB-1	*PVC*	*3*	*Steel*	*8*			
SIMO	*PVC*	*2*	*Steel*	*4*	*50*	*90*	*0.01*
SIMO-1			*Steel*	*8*			
TSCM-1	*Plastic*	*2*		*0*			
TSCO-1	*Plastic*	*2*			*15*	*35*	*0.25*
TSWB-6	*PVC*	*3*	*Steel*	*8*	*25*	*35*	*0.02*
TW-8	*Steel*	*8*	*Steel*	*14*	*953*	*1065*	

Part 2

ID	Annulus Pack	Sump Length (ft)	Casing Comment	Screen Comment
MCWB-9A	*Sand 0.0787–0.0331*	*5*		*5-ft sump below perforations*
MCWB-9B	*Sand 0.0787–0.0331*	*5*		*5-ft sump below perforations*
MCWW-1			*Casing broken at surface*	*Construction unknown*
MT-1	*Sand pack*	*10*		
MT-2	*Sand pack*	*10*		*Sump slotted??*
MT-3	*Sand pack*	*10*		
MT-4	*Sand pack*	*10*		
SHB-1			*3-in. tubing left filled with water*	*Not completed*
SIMO	*Sand and cuttings*	*14*	*Casing broken*	*Screened 50–60 and 80–90 ft*
SIMO-1			*Casing locked*	*Hole screen intervals unknown*
TSCM-1	*Cuttings*			*No screen interval*
TSCO-1	*Cuttings*	*0*	*Unable to locate 1991, 1996*	
TSWB-6	*Sand 0.0787–0.0331*	*5*		*5-ft sump below perforations*
TW-8		*0*	*0–44 ft: 20 in., 0–64 ft: 14 in.*	*Lower 112 ft slotted*

TABLE D-4

STRATIGRAPHIC INFORMATION FOR MORTANDAD CANYON AND NEARBY BOREHOLES

					Purtymun 1995 Data		Revised Model		
ID	**Depth Drilled (ft)**	**Depth Completed (ft)**	**Depth 1991 (ft)**	**Formation**	**Start Depth (ft)**	**End Depth (ft)**	**Start Depth (ft)**	**End Depth (ft)**	**Stratigraphic Pick Comment**
SHB-1	*700*			*Tshirege*	*0*	*306*			
SHB-1	*700*			*Cerro Toledo?*	*306*	*445*			
SHB-1	*700*			*Otowi*	*445*	*631*			
SHB-1	*700*			*Sedimentary interval*	*631*	*644*			
SHB-1	*700*			*Basalt*	*644*	*700*			
EHG-LA-1	*2292*			*Tshirege*	*0*	*345*			
EHG-LA-1	*2292*			*Otowi*	*345*	*695*			
EHG-LA-1	*2292*			*Guaje*	*695*	*725*			
EHG-LA-1	*2292*			*Puye-Fanglomerate*	*725*	*910*			
EHG-LA-1	*2292*			*Puye-Basalt 2*	*910*	*1050*			
EHG-LA-1	*2292*			*Puye-Fanglomerate*	*1050*	*1305*			
EHG-LA-1	*2292*			*Puye-Totavi*	*1305*	*1330*			
EHG-LA-1	*2292*			*SF Group-Chaquehui*	*1330*	*1895*			
EHG-LA-1	*2292*			*SF Group-Volcanics*	*1895*	*2292*			
MCM-1A	*12*	*12*		*Bandelier Tuff*	*0*	*12*			
MCM-1B	*11*	*11*		*Bandelier Tuff*	*0*	*11*			
MCO-1	*8*	*8*		*Alluvium*	*0*	*1*			
MCO-1	*8*	*8*		*Tuff*	*1*	*8*			
MCM-2A	*11*	*11*		*Tuff*	*0*	*11*			
MCM-2B	*1*	*1*		*Tuff*	*0*	*1*			
MCO-2	*10*	*9*	*7.5*	*Alluvium*	*0*	*1*			
MCO-2	*10*	*9*	*7.5*	*Tuff*	*1*	*10*			
MCM-2.2	*90*	*87*	*87*	*Tshirege*	*0*	*64*			
MCM-2.8	*60*	*58*	*58*	*Tshirege*	*0*	*52*			
MCM-3A	*13*	*13*		*Alluvium*	*0*	*10*			
MCM-3A	*13*	*13*		*Tuff*	*10*	*13*			
MCO-3	*18*	*12*	*10.1*	*Alluvium*	*0*	*7*			
MCO-3	*18*	*12*	*10.1*	*Tuff*	*7*	*18*			
MCM-3B	*10*	*10*		*Alluvium*	*0*	*10*			
35-2028	*299*	*0*		*Alluvium*			*0*	*4.5*	
35-2028	*299*	*0*		*Tshirege 3*			*4.5*	*25*	
35-2028	*299*	*0*		*Tshirege 2*			*25*	*90*	

TABLE D-4 (continued)

STRATIGRAPHIC INFORMATION FOR MORTANDAD CANYON AND NEARBY BOREHOLES

ID	Depth Drilled (ft)	Depth Completed (ft)	Depth 1991 (ft)	Formation	Purtymun 1995 Data Start Depth (ft)	Purtymun 1995 Data End Depth (ft)	Revised Model Start Depth (ft)	Revised Model End Depth (ft)	Stratigraphic Pick Comment
35-2028	*299*	*0*		*Tshirege1v*			*90*	*149*	
35-2028	*299*	*0*		*Tshirege1g*			*149*	*217*	
35-2028	*299*	*0*		*Tsankawi*			*217*	*220*	
35-2028	*299*	*0*		*Cerro Toledo*			*220*	*297*	
35-2028	*299*	*0*		*Otowi*			*297*	*299*	
MCM-4B	*24*	*24*		*Alluvium*	*0*	*18*			
MCM-4B	*24*	*24*		*Tuff*	*18*	*24*			
MCO-4	*24*	*19*	*16.3*	*Alluvium*	*0*	*18*			
MCO-4	*24*	*19*	*16.3*	*Tuff*	*18*	*24*			
MCM-4.8	*33*	*33*		*Alluvium*	*0*	*30*			
MCM-4.8	*33*	*33*		*Tuff*	*30*	*33*			
MCO-4A	*24*	*19.4*		*Alluvium*	*0*	*16*			
MCO-4A	*24*	*19.4*		*Tuff*	*16*	*24*			
MCM-4A	*9*	*9*		*Alluvium*	*0*	*9*			
MCO-4B	*34*	*33.9*		*Alluvium*	*0*	*28*			
MCO-4B	*34*	*33.9*		*Tuff*	*28*	*34*			
MCM-4.5	*48*	*48*	*35*	*Alluvium*	*0*	*26*			
MCM-4.5	*48*	*48*	*35*	*Tuff*	*26*	*48*			
MCO-4.9	*43*	*30*	*23.4*	*Alluvium*			*0*	*27*	
MCO-4.9	*43*	*30*	*23.4*	*Tuff*			*27*	*43*	
MCM-5A	*25*	*25*		*Alluvium*	*0*	*22*			
MCM-5A	*25*	*25*		*Tuff*	*22*	*25*			
MCM-5B	*30*	*30*		*Alluvium*	*0*	*25*			
MCM-5B	*30*	*30*		*Tuff*	*25*	*30*			
MCO-5	*47*	*46*	*44.9*	*Alluvium*	*0*	*35*			
MCO-5	*47*	*46*	*44.9*	*Tuff*	*35*	*47*			
MCM-5C	*37*	*37*		*Alluvium*	*0*	*30*			
MCM-5C	*37*	*37*		*Tuff*	*30*	*37*			
TW-8	*1065*			*Alluvium*	*0*	*40*			
TW-8	*1065*			*Tshirege*	*40*	*60*			
TW-8	*1065*			*Tsankawi/ Cerro Toledo*			*60*	*130*	*Projected from stratigraphic correlations*
TW-8	*1065*			*Otowi*	*60*	*445*	*130*	*445*	
TW-8	*1065*			*Guaje*	*445*	*490*			

TABLE D-4 (continued)

STRATIGRAPHIC INFORMATION FOR MORTANDAD CANYON AND NEARBY BOREHOLES

					Purtymun 1995 Data		Revised Model		
ID	**Depth Drilled (ft)**	**Depth Completed (ft)**	**Depth 1991 (ft)**	**Formation**	**Start Depth (ft)**	**End Depth (ft)**	**Start Depth (ft)**	**End Depth (ft)**	**Stratigraphic Pick Comment**
TW-8	*1065*			*Puye-Fanglomerate*	*490*	*1065*			
TW-8	*1065*			*Basalt Unit 2*	*580*	*725*			
MCM-5.1	*112*	*112*	*112*	*Alluvium*	*0*	*31*			
MCM-5.1	*112*	*112*	*112*	*Tshirege*	*31*	*93*	*31*	*50*	
MCM-5.1	*112*	*112*	*112*	*Tsankawi/ Cerro Toledo*	*93*	*112*	*50*	*112*	*Cerro Toledo revised based on stratigraphic and geochemical correlation*
MCM-5.1A	*50?*	*24.9*		*Alluvium*			*0*	*25*	*Existing well added to database*
PM-5	*3120*	*3110*		*Tshirege*	*0*	*335*			
PM-5	*3120*	*3110*		*Otowi*	*335*	*710*			
PM-5	*3120*	*3110*		*Guaje*	*710*	*740*			
PM-5	*3120*	*3110*		*Basalt Unit 2*	*740*	*1145*			
PM-5	*3120*	*3110*		*Puye-Fanglomerate*	*760*	*1470*			
PM-5	*3120*	*3110*		*Puye-Totavi Lentil*	*1470*	*1550*			
PM-5	*3120*	*3110*		*Puye-Chaquehui*	*1550*	*2780*			
PM-5	*3120*	*3110*		*Basalt Unit 1*	*1765*	*2740*			
PM-5	*3120*	*3110*		*Chamita*	*2780*	*2860*			
PM-5	*3120*	*3110*		*Tesuque*	*2860*	*3120*			
TSCO-1	*37*	*35*	*23.1*	*Alluvium*	*0*	*37*			
TSCM-1	*22*	*22*		*Alluvium*	*0*	*22*			
MCM-6A	*18*	*18*		*Alluvium*	*0*	*10*			
MCM-6A	*18*	*18*		*Tuff*	*10*	*18*			
MCM-5.9	*44*	*0*		*Alluvium*	*0*	*33*			
MCM-5.9	*194*			*Tshirege*	*33*	*44*			
MCM-5.9A	*194*	*194*	*194*	*Alluvium*	*0*	*38*			
MCM-5.9A	*194*	*194*	*194*	*Tshirege*	*38*	*98*	*38*	*48*	*Top of Cerro Toledo revised based on lithologic description*
MCM-5.9A	*194*	*194*	*194*	*Tsankawi/ Cerro Toledo*	*98*	*118*	*48*	*118*	*Photos of core and regional stratigraphic relations*
MCM-5.9A	*194*	*194*	*194*	*Otowi*	*118*	*194*			
MCM-6C	*57*	*57*		*Alluvium*	*0*	*47*			

TABLE D-4 (continued)

STRATIGRAPHIC INFORMATION FOR MORTANDAD CANYON AND NEARBY BOREHOLES

					Purtymun 1995 Data		Revised Model		
ID	**Depth Drilled (ft)**	**Depth Completed (ft)**	**Depth 1991 (ft)**	**Formation**	**Start Depth (ft)**	**End Depth (ft)**	**Start Depth (ft)**	**End Depth (ft)**	**Stratigraphic Pick Comment**
MCM-6C	*57*	*57*		*Tuff*	*47*	*57*			
MCM-6B	*52*	*52*		*Alluvium*	*0*	*37*			
MCM-6B	*52*	*52*		*Tuff*	*37*	*52*			
MCO-6B	*48*	*47.1*		*Alluvium*	*0*	*40*			
MCO-6B	*48*	*47.1*		*Tuff*	*40*	*48*			
MCO-6A	*33*	*32.7*		*Alluvium*	*0*	*24*			
MCO-6A	*33*	*32.7*		*Tuff*	*24*	*33*			
MCO-6 Old	*82*	*71*		*Alluvium*	*0*	*36*			
MCO-6 Old	*82*	*71*		*Tuff*	*36*	*82*			
MCO-6	*47*	*47*	*41.5*	*Alluvium*	*0*	*36*			
MCO-6	*47*	*47*	*41.5*	*Tuff*	*36*	*47*			
MCM-6D	*35*	*35*		*Alluvium*	*0*	*35*			
MCM-6E	*21*	*21*		*Alluvium*	*0*	*12*			
MCM-6E	*21*	*21*		*Tuff*	*12*	*21*			
MCO-6.5A	*47*	*45*	*33.3*	*Alluvium*	*0*	*47*			
MCO-6.5B	*42*	*42*	*36.0*	*Alluvium*	*0*	*42*			
MCM-6.5	*95*	*95*	*95*	*Alluvium*	*0*	*46*	*0*	*46*	
MCM-6.5	*95*	*95*	*95*	*Tuff*	*46*	*95*	*46*	*56?*	
MCM-6.5	*95*	*95*	*95*	*Tsankawi/ Cerro Toledo*			*56?*	*95*	
MCM-6.5A	*23*	*23*		*Alluvium*	*0*	*23*			
MCO-7A	*47*	*44.8*		*Alluvium*	*0*	*37*	*0*	*47*	*Well does not penetrate alluvium*
MCO-7A	*47*	*44.8*		*Tuff*	*37*	*47*			
MCO-7	*77*	*69*	*54.7*	*Alluvium*	*0*	*55*	*0*	*55*	
MCO-7	*77*	*69*	*54.7*	*Tuff*	*55*	*77*			
MCO-7	*77*	*69*	*54.7*	*Cerro Toledo*			*55*	*77*	*Revised based on lithologic description*
MCO-7.1	*?*	*?*							*Existing well added to database, no data on well*
MCWW-1	*?*	*?*							*Existing well added to database, no data on well*
MT-1	*69*	*69*	*68*	*Alluvium*	*0*	*30*	*0*	*69*	*Alluvium revised based on nearby MCWB wells*

TABLE D-4 (continued)

STRATIGRAPHIC INFORMATION FOR MORTANDAD CANYON AND NEARBY BOREHOLES

					Purtymun 1995 Data		Revised Model		
ID	**Depth Drilled (ft)**	**Depth Completed (ft)**	**Depth 1991 (ft)**	**Formation**	**Start Depth (ft)**	**End Depth (ft)**	**Start Depth (ft)**	**End Depth (ft)**	**Stratigraphic Pick Comment**
MT-1	*69*	*69*	*68*	*Tuff*	*30*	*69*			*Probably no Tshirege encountered in MT-1*
MCO-7.5A	*63*	*60*		*Alluvium*	*0*	*60*			
MCO-7.5A	*63*	*60*		*Tuff*	*60*	*63*			
MCO-7.5B	*62*	*60*	*56.0*	*Alluvium*	*0*	*60*	*0*	*60*	
MCO-7.5B	*62*	*60*	*56.0*	*Tuff*	*60*	*63*			
MCO-7.5B	*62*	*60*	*56.0*	*Tsankawi/ Cerro Toledo*			*60*	*63*	*Revised based on lithologic description*
MCM-7.5	*94*	*94*	*94*	*Alluvium*	*0*	*61*	*0*	*61*	
MCM-7.5	*94*	*94*	*94*	*Tuff*	*61*	*94*			
MCM-7.5	*94*	*94*	*94*	*Tsankawi/ Cerro Toledo*			*61*	*94*	*Revised based on lithologic description*
MT-3	*74*	*74*	*73*	*Alluvium*	*0*	*31*	*0*	*70*	*Revised based on lithologic description and for consistency with nearby wells*
MT-3	*74*	*74*	*73*	*Tuff*	*31*	*74*			
MT-3	*74*	*74*	*73*	*Tsankawi/ Cerro Toledo*			*70*	*74*	*Probably Cerro Toledo*
MCO-8	*92*	*84*	*22.7*	*Alluvium*	*0*	*61*	*0*	*61*	
MCO-8	*92*	*84*	*22.7*	*Tuff*	*61*	*92*			
MCO-8	*92*	*84*	*22.7*	*Tsankawi/ Cerro Toledo*			*61*	*92*	*Probably Cerro Toledo*
MCO-8A	*52*	*50*	*48.5*	*Alluvium*	*0*	*52*			
MT-2	*64*	*64*	*64*	*Alluvium*	*0*	*35*	*0*	*64*	*Revised based on lithologic description and for consistency with nearby wells*
MT-2	*64*	*64*	*64*	*Tuff*	*35*	*64*			
MCM-8A	*20*	*20*		*Alluvium*	*0*	*3*			
MCM-8A	*20*	*20*		*Tuff*	*3*	*17*			
MCM-8B	*30*	*30*		*Alluvium*	*0*	*30*			
MCM-8C	*66*	*66*		*Alluvium*	*0*	*57*			
MCM-8C	*66*	*66*		*Tuff*	*57*	*66*			*Maybe Cerro Toledo*
MCM-8D	*86*	*86*		*Alluvium*	*0*	*59*			
MCM-8D	*86*	*86*		*Tuff*	*59*	*86*			*Probably Cerro Toledo*
MCM-8E	*53*	*53*		*Alluvium*	*0*	*32*			
MCM-8E	*53*	*53*		*Tuff*	*32*	*53*			
MCM-8F	*23*	*23*		*Alluvium*	*0*	*4*			
MCM-8F	*23*	*23*		*Tuff*	*4*	*23*			

TABLE D-4 (continued)

STRATIGRAPHIC INFORMATION FOR MORTANDAD CANYON AND NEARBY BOREHOLES

					Purtymun 1995 Data		Revised Model		
ID	**Depth Drilled (ft)**	**Depth Completed (ft)**	**Depth 1991 (ft)**	**Formation**	**Start Depth (ft)**	**End Depth (ft)**	**Start Depth (ft)**	**End Depth (ft)**	**Stratigraphic Pick Comment**
MCO-8.2	*72*	*70*	*60.3*	*Alluvium*	*0*	*72*			
MT-4	*74*	*74*	*74*	*Alluvium*	*0*	*44*	*0*	*65*	*Revised based on lithologic description and for consistency with nearby wells*
MT-4	*74*	*74*	*74*	*Tuff*	*44*	*74*			
MT-4	*74*	*74*	*74*	*Tsankawi/ Cerro Toledo*			*64*	*74*	*Revised based on lithologic description*
MCC-8.2	*184*			*Alluvium*	*0*	*76*	*0*	*59*	*Revised based on lithologic description*
MCC-8.2	*184*			*Tshirege*	*76*	*84*			
MCC-8.2	*184*			*Tsankawi/ Cerro Toledo*	*84*	*104*	*59*	*124*	*Revised based on lithologic description*
MCC-8.2	*184*			*Otowi*	*104*	*184*	*124*	*184*	
MCO-9	*57*	*55*	*54.6*	*Alluvium*	*0*	*57*			
MCO-9.5	*57*	*46*	*40.3*	*Alluvium*	*0*	*57*			
MCM-10-1	*119*	*119*		*Alluvium*	*0*	*4*	*0*	*63*	
MCM-10-1	*119*	*119*		*Tuff*	*4*	*119*			
MCM-10-1	*119*	*119*		*Tsankawi/ Cerro Toledo*			*63*	*119*	*Revised based on lithologic description*
MCM-10-2	*43*	*43*		*Alluvium*	*0*	*43*			
MCM-10	*67*	*67*		*Alluvium*	*0*	*62*			
MCM-10	*67*	*67*		*Tuff*	*62*	*67*			*Probably Cerro Toledo*
MCO-11	*23*	*20*		*Alluvium*	*0*	*23*			
MCM-12A	*98*	*98*		*Alluvium*	*0*	*93*			
MCM-12A	*98*	*98*		*Tuff*	*93*	*98*			*Probably Cerro Toledo*
MCM-12B	*79*	*79*		*Alluvium*	*0*	*79*			
MCO-12 Old	*64*	*60*		*Alluvium*	*0*	*64*			
MCO-12	*112*	*108*	*96.2*	*Alluvium*	*0*	*71*	*0*	*71*	
MCO-12	*112*	*108*	*96.2*	*Tuff*	*71*	*112*			
MCO-12	*112*	*108*	*96.2*	*Tsankawi/ Cerro Toledo*			*71*	*112*	*Revised based on lithologic description*
MCM-10-3B	*43*	*43*		*Alluvium*	*0*	*43*			
MCM-10-3A	*33*	*33*		*Alluvium*	*0*	*33*			
MCO-13	*112*	*107*	*106.2*	*Alluvium*	*0*	*65*	*0*	*65*	
MCO-13	*112*	*107*	*106.2*	*Tuff*	*65*	*112*			
MCO-13	*112*	*107*	*106.2*	*Tsankawi/ Cerro Toledo*			*65*	*112*	*From description, Cerro Toledo 65–96 ft*
SIMO	*104*	*104*		*Alluvium*	*0*	*11*	*0*	*51*	

TABLE D-4 (continued)

STRATIGRAPHIC INFORMATION FOR MORTANDAD CANYON AND NEARBY BOREHOLES

ID	Depth Drilled (ft)	Depth Completed (ft)	Depth 1991 (ft)	Formation	Purtymun 1995 Data Start Depth (ft)	Purtymun 1995 Data End Depth (ft)	Revised Model Start Depth (ft)	Revised Model End Depth (ft)	Stratigraphic Pick Comment
SIMO	*104*	*104*		*Tshirege*	*11*	*47*			*Tshirege not present*
SIMO	*104*	*104*		*Tsankawi*	*47*	*64*	*51*	*104*	*Revised based on lithologic description*
SIMO	*104*	*104*		*Otowi*	*64*	*104*			*Revised based on lithologic description*
SIMO-1	*163*	*163*		*Alluvium*			*0*	*53*	
SIMO-1	*163*	*163*		*Tshirege*	*0*	*53*			
SIMO-1	*163*	*163*		*Tsankawi/ Cerro Toledo*			*53*	*118*	
SIMO-1	*163*	*163*		*Otowi*	*53*	*163*	*118*	*163*	
PM-3	*2552*			*Alluvium*	*0*	*30*			
PM-3	*2552*			*Otowi*	*30*	*170*			
PM-3	*2552*			*Guaje*	*170*	*190*			
PM-3	*2552*			*Puye-Fanglomerate*	*190*	*745*			
PM-3	*2552*			*Basalt Unit 2*	*215*	*540*			
PM-3	*2552*			*Puye-Totavi Lentil*	*745*	*805*			
PM-3	*2552*			*Puye-Chaquehui*	*805*	*2060*			
PM-3	*2552*			*Basalt Unit 1*	*1105*	*1540*			
PM-3	*2552*			*Tesuque*	*2060*	*2552*			
MCWB-4	*15.0*	*15.0*		*Alluvium*	*0*	*8.8*			
MCWB-4	*15.0*	*15.0*		*Tuff*	*8.8*	*15.0*			
MCWB-5	*33.0*	*33.0*		*Alluvium*	*0*	*29.0*			
MCWB-5	*33.0*	*33.0*		*Tuff*	*29*	*33.0*			
MCWB-5.5A	*37.5*	*37.5*		*Alluvium*	*0*	*35.1*			
MCWB-5.5A	*37.5*	*37.5*		*Tuff*	*35.1*	*37.5*			
MCWB-5.5B	*37.5*	*37.5*		*Alluvium*	*0*	*37.0*			
MCWB-5.5B	*37.5*	*37.5*		*Tuff*	*37*	*37.5*			
MCWB-6.2A	*45.5*	*45.5*		*Alluvium*	*0*	*41.3*			
MCWB-6.2A	*45.5*	*45.5*		*Tuff*	*41.3*	*45.5*			
MCWB-6.2B	*32.5*	*32.5*		*Alluvium*	*0*	*32.5*			
MCWB-6.2C	*42.5*	*42.5*		*Alluvium*	*0*	*40.2*			
MCWB-6.2C	*42.5*	*42.5*		*Tuff*	*40.2*	*42.5*			
MCWB-6.5C	*47.5*	*47.5*		*Alluvium*	*0*	*46.5*			
MCWB-6.5C	*47.5*	*47.5*		*Tuff*	*46.5*	*47.5*			

TABLE D-4 (continued)

STRATIGRAPHIC INFORMATION FOR MORTANDAD CANYON AND NEARBY BOREHOLES

					Purtymun 1995 Data		Revised Model		
ID	**Depth Drilled (ft)**	**Depth Completed (ft)**	**Depth 1991 (ft)**	**Formation**	**Start Depth (ft)**	**End Depth (ft)**	**Start Depth (ft)**	**End Depth (ft)**	**Stratigraphic Pick Comment**
MCWB-6.5D	*42.5*	*42.5*		*Alluvium*	*0*	*42.5*			
MCWB-6.5E	*50.0*	*50.0*		*Alluvium*	*0*	*47.5*			
MCWB-6.5E	*50.0*	*50.0*		*Tuff*	*47.5*	*50.0*			
MCWB-6.6	*47.5*	*47.5*		*Alluvium*	*0*	*41.8*			
MCWB-6.6	*47.5*	*47.5*		*Tuff*	*41.8*	*47.5*			
MCWB-7.2	*67.5*	*67.5*		*Alluvium*	*0*	*65.5*			
MCWB-7.2	*67.5*	*67.5*		*Tuff*	*65.5*	*67.5*			
MCWB-7.4A	*70.0*	*70.0*		*Alluvium*	*0*	*69.3*			
MCWB-7.4A	*70.0*	*70.0*		*Tuff*	*69.3*	*70.0*			
MCWB-7.4B	*70.0*	*70.0*		*Alluvium*	*0*	*66.0*			
MCWB-7.4B	*70.0*	*70.0*		*Tuff*	*66.0*	*70.0*			
MCWB-7.7A	*67.5*	*67.5*		*Alluvium*	*0*	*67.0*			
MCWB-7.7A	*67.5*	*67.5*		*Tuff*	*67.0*	*67.5*			
MCWB-7.7B	*70.0*	*70.0*		*Alluvium*	*0*	*69.0*			
MCWB-7.7B	*70.0*	*70.0*		*Tuff*	*69.0*	*70.0*			
MCWB-7A	*52.0*	*52.0*		*Alluvium*	*0*	*47.0*			
MCWB-7A	*52.0*	*52.0*		*Tuff*	*47.0*	*52.0*			
MCWB-7B	*47.5*	*47.5*		*Alluvium*	*0*	*44.0*			
MCWB-7B	*47.5*	*47.5*		*Tuff*	*44.0*	*47.5*			
MCWB-8.1A	*75.0*	*75.0*		*Alluvium*	*0*	*69.5*			
MCWB-8.1A	*75.0*	*75.0*		*Tuff*	*69.5*	*75.0*			*Probably Cerro Toledo*
MCWB-8.1A	*72.5*	*72.5*		*Alluvium*	*0*	*69.3*			
MCWB-8.1B	*72.5*	*72.5*		*Tuff*	*69.3*	*72.5*			*Probably Cerro Toledo*
MCWB-8.1C	*80.0*	*80.0*		*Alluvium*	*0*	*62.5*			
MCWB-8.1C	*80.0*	*80.0*		*Tuff*	*62.5*	*80.0*			*Probably Cerro Toledo*
MCWB-9A	*75.0*	*75.0*		*Alluvium*	*0*	*70.0*			
MCWB-9A	*75.0*	*75.0*		*Tuff*	*70.0*	*75.0*			*Probably Cerro Toledo*
MCWB-9B	*80.0*	*80.0*		*Alluvium*	*0*	*68.3*			
MCWB-9B	*80.0*	*80.0*		*Tuff*	*68.3*	*80.0*			*Probably Cerro Toledo*
TSWB-6	*40.0*	*40.0*		*Alluvium*	*0*	*31.3*			
TSWB-6	*40.0*	*40.0*		*Tuff*	*31.3*	*40.0*			

Source: Purtymun 1995, 45344

TABLE D-5

RECENT WATER LEVEL MEASUREMENTS IN MORTANDAD CANYON ALLUVIAL OBSERVATION WELLS

Part 1

ID	Well Elevation (ft)	Depth Completed (ft)	Measured Well Depth (ft)	Measurement Date	SWL[a] (ft)	Measuring Point
MCM-2A	*7140.63*	*11*	*5.8*	*11/20/96*	*1.22*	*GL[b]*
MCM-2A	*7140.63*	*11*	*5.18*	*11/20/96*	*.6*	*GL*
MCO-2	*7136.6*	*9*	*9.33*	*11/20/96*	*6.77*	*GL*
MCO-2	*7136.6*	*9*		*11/20/96*	*4.38*	*GL*
MCM-2B	*7136.25*	*1*	*2.02*	*11/20/96*	*2.02*	*GL*
MCM-2B	*7136.25*	*1*	*0.68*	*11/20/96*	*.68*	*GL*
MCM-2.2	*7125.44*	*87*	*86.5*	*11/20/96*	*86.33*	*GL*
MCM-2.8	*7097.64*	*58*	*59.85*	*11/20/96*	*Trace*	*GL*
MCM-3A	*7055.53*	*13*	*13.48*	*11/20/96*	*Dry*	*GL*
MCO-3	*7052.6*	*12*	*8.21*	*11/20/96*	*3.34*	*GL*
MCM-3B	*7052.42*	*10*	*7.84*	*11/20/96*	*3.91*	*GL*
MCO-4	*6897.54*	*19*	*14.01*	*11/13/96*	*5.61*	*GL*
MCO-4	*6897.54*	*19*		*11/18/96*		*GL*
MCWB-4	*6893.4*	*15*		*1/9/95*	*Trace*	*GL*
MCWB-4	*6893.4*	*15*		*9/18/95*	*Trace*	*GL*
MCWB-4	*6893.4*	*15*		*11/13/96*	*13.81*	*GL*
MCM-4.5	*6888.55*	*48*	*25.1*	*11/13/96*	*24.5*	*GL*

Part 2

ID	Tubing Height AGL[c] (ft)	SWL Source	SWL Confidence	Water Level Comment
MCM-2A	*0.62*	*NMED OB[d]*	*?*	*Not formation water?*
MCM-2A	*0.62*	*NMED OB*	*?*	*Not formation water?*
MCO-2	*2.39*	*NMED OB*	*Good*	*Open tubing*
MCO-2	*2.39*	*NMED OB*	*Good*	
MCM-2B	*1.34*	*NMED OB*	*?*	*Trace of water in tubing, casing broken*
MCM-2B	*1.34*	*NMED OB*	*Good*	*Tubing cracked at base*
MCM-2.2	*2.2*	*NMED OB*	*Good*	*Angle hole*
MCM-2.8	*4.54*	*NMED OB*	*Good*	*Angle hole*
MCM-3A	*2.02*	*NMED OB*		
MCO-3	*1.93*	*NMED OB*	*Good*	*Well partially washed out, tilted*
MCM-3B	*1.81*	*NMED OB*	*Good*	
MCO-4	*1.02*	*NMED OB*	*Good*	*Well partially washed out*
MCO-4	*1.02*	*NMED OB*		*Well locked*
MCWB-4	*2*	*McLin 1997*	*Good*	
MCWB-4	*2*	*McLin 1997*	*Good*	
MCWB-4	*2*	*McLin 1997*	*Good*	
MCM-4.5	*1.7*	*NMED OB*	*Good*	

a. SWL = static water level below measuring point
b. GL = ground level
c. AGL = above ground level
d. NMED OB = New Mexico Environment Department Oversight Bureau
e. MP = measuring point (top of tubing)

TABLE D-5 (continued)

RECENT WATER LEVEL MEASUREMENTS IN MORTANDAD CANYON ALLUVIAL OBSERVATION WELLS

Part 1

ID	Well Elevation (ft)	Depth Completed (ft)	Measured Well Depth (ft)	Measurement Date	SWL[a] (ft)	Measuring Point
MCO-4A	6886.58	19.4	19.15	11/13/96	14.33	GL[b]
MCO-4B	6886.75	33.9		3/31/95	20.65	MP[e]
MCO-4B	6886.75	33.9		6/27/95	19.7	MP
MCO-4B	6886.75	33.9	35.2	8/9/95	20.3	MP
MCO-4B	6886.75	33.9		12/20/95	27.85	MP
MCO-4B	6886.75	33.9		3/5/96	27.25	MP
MCO-4B	6886.75	33.9		11/13/96	14.71	GL
MCO-4.9	6879.95	30	22.62	11/13/96	17.4	GL
MCM-5A	6880.84	25	25.4	11/13/96	25.35	GL
MCO-5	6875.66	46		8/1/95	26.5	MP
MCO-5	6875.66	46		8/8/96	27.12	MP
MCO-5	6875.66	46	45.35	11/13/96	14.75	GL
MCM-5C	6877.31	37	39.88	11/13/96	3.3	GL
MCWB-5	6876.2	33		1/9/95	18.46	GL
MCWB-5	6876.2	33		9/18/95	18.87	GL
MCWB-5	6876.2	33		11/13/96	20.79	GL
MCO-5.1A	6869.65		22.15	11/13/96	22.7	GL

Part 2

ID	Tubing Height AGL[c] (ft)	SWL Source	SWL Confidence	Water Level Comment
MCO-4A	1.75	NMED OB[d]	Good	
MCO-4B	1.75	ESH-18	Good	
MCO-4B	1.75	ESH-18	Good	
MCO-4B	1.75	ESH-18	Good	
MCO-4B	1.75	ESH-18	Good	
MCO-4B	1.75	ESH-18	Good	
MCO-4B	1.75	NMED OB	Good	29 ft to top of bladder pump
MCO-4.9	1.25	NMED OB	Good	
MCM-5A		NMED OB	?	
MCO-5	1.95	ESH-18	Good	
MCO-5	1.95	ESH-18	Good	
MCO-5	1.95	NMED OB	Good	
MCM-5C		NMED OB	Bad	
MCWB-5	1.92	McLin 1997	Good	
MCWB-5	1.92	McLin 1997	Good	
MCWB-5	1.92	McLin 1997	Good	
MCO-5.1A	2.75	NMED OB	Good	

a. SWL = static water level below measuring point
b. GL = ground level
c. AGL = above ground level
d. NMED OB = New Mexico Environment Department Oversight Bureau
e. MP = measuring point (top of tubing)

TABLE D-5 (continued)

RECENT WATER LEVEL MEASUREMENTS IN MORTANDAD CANYON ALLUVIAL OBSERVATION WELLS

Part 1

ID	Well Elevation (ft)	Depth Completed (ft)	Measured Well Depth (ft)	Measurement Date	SWL[a] (ft)	Measuring Point
MCM-5.1	*6870.87*	*112*	*111.49*	*11/13/96*	*Dry*	*GL[b]*
TSCM-1	*6857.83*	*22*	*23.19*	*11/13/96*	*2.87*	*GL*
TSWB-6	*6853.2*	*40*		*1/9/95*	*Dry*	*GL*
TSWB-6	*6853.2*	*40*		*9/18/95*	*Dry*	*GL*
TSWB-6	*6853.2*	*40*		*11/13/96*	*Dry*	*GL*
MCWB-5.5B	*6856.9*	*37.5*		*1/9/95*	*28.9*	*GL*
MCWB-5.5B	*6856.9*	*37.5*		*9/18/95*	*31.39*	*GL*
MCWB-5.5B	*6856.9*	*37.5*		*11/13/96*	*31.8*	*GL*
MCWB-5.5A	*6858.4*	*37.5*		*1/9/95*	*28.78*	*GL*
MCWB-5.5A	*6858.4*	*37.5*		*9/18/95*	*31.18*	*GL*
MCWB-5.5A	*6858.4*	*37.5*		*11/13/96*	*31.64*	*GL*
MCM-6A	*6851.79*	*18*	*16.7*	*11/13/96*	*Dry*	*GL*
MCM-5.9A	*6851.83*	*194*		*11/13/96*		*GL*
MCO-6B	*6850.29*	*47.1*		*3/31/95*	*38.35*	*MP[e]*
MCO-6B	*6850.29*	*47.1*		*8/9/95*	*Dry*	*MP*
MCO-6B	*6850.29*	*47.1*	*45.5*	*11/13/96*	*34.7*	*GL*
MCO-6A	*6849.72*	*32.7*		*6/27/95*	*48.5*	*MP*

Part 2

ID	Tubing Height AGL[c] (ft)	SWL Source	SWL Confidence	Water Level Comment
MCM-5.1	*0.22*	*NMED OB[d]*	*Good*	
TSCM-1	*0.97*	*NMED OB*	*?*	
TSWB-6	*1.92*	*McLin 1997*	*Good*	
TSWB-6	*1.92*	*McLin 1997*	*Good*	
TSWB-6	*1.92*	*McLin 1997*	*Good*	
MCWB-5.5B	*2.17*	*McLin 1997*	*Good*	
MCWB-5.5B	*2.17*	*McLin 1997*	*Good*	
MCWB-5.5B	*2.17*	*McLin 1997*	*Good*	
MCWB-5.5A	*2*	*McLin 1997*	*Good*	
MCWB-5.5A	*2*	*McLin 1997*	*Good*	
MCWB-5.5A	*2*	*McLin 1997*	*Good*	
MCM-6A		*NMED OB*	*Good*	
MCM-5.9A	*0.94*	*NMED OB*	*Good*	*Tubing damaged*
MCO-6B	*1.6*	*ESH-18*	*Good*	
MCO-6B	*1.6*	*ESH-18*	*Good*	
MCO-6B	*1.6*	*NMED OB*	*Good*	
MCO-6A	*2.8*	*ESH-18*	*Good*	

a. SWL = static water level below measuring point
b. GL = ground level
c. AGL = above ground level
d. NMED OB = New Mexico Environment Department Oversight Bureau
e. MP = measuring point (top of tubing)

TABLE D-5 (continued)

RECENT WATER LEVEL MEASUREMENTS IN MORTANDAD CANYON ALLUVIAL OBSERVATION WELLS

Part 1

ID	Well Elevation (ft)	Depth Completed (ft)	Measured Well Depth (ft)	Measurement Date	SWL[a] (ft)	Measuring Point
MCO-6A	*6849.72*	*32.7*		*12/20/95*	*40*	*MP[e]*
MCO-6A	*6849.72*	*32.7*	*31.17*	*11/13/96*	*30.96*	*GL[b]*
MCO-6	*6849.48*	*47*		*3/31/95*	*37.7*	*MP*
MCO-6	*6849.48*	*47*		*6/27/95*	*38.1*	*MP*
MCO-6	*6849.48*	*47*		*8/9/95*	*37*	*MP*
MCO-6	*6849.48*	*47*		*8/6/96*	*41.75*	*MP*
MCO-6	*6849.48*	*47*	*41.4*	*11/13/96*	*33.6*	*GL*
MCWB-6.2C	*6848*	*42.5*		*1/9/95*	*Dry*	*GL*
MCWB-6.2C	*6848*	*42.5*		*9/18/95*	*Dry*	*GL*
MCWB-6.2C	*6848*	*42.5*		*11/13/96*	*Dry*	*GL*
MCWB-6.2B	*6848*	*32.5*		*1/9/95*	*Dry*	*GL*
MCWB-6.2B	*6848*	*32.5*		*9/18/95*	*Dry*	*GL*
MCWB-6.2B	*6848*	*32.5*		*11/13/96*	*Dry*	*GL*
MCM-6E	*6850.17*	*21*	*22.56*	*11/13/96*	*Dry*	*GL*
MCWB-6.2A	*6848.3*	*45.5*		*1/9/95*	*34.12*	*GL*
MCWB-6.2A	*6848.3*	*45.5*		*9/18/95*	*38.18*	*GL*
MCWB-6.2A	*6848.3*	*45.5*		*11/13/96*	*38.09*	*GL*

Part 2

ID	Tubing Height AGL[c] (ft)	SWL Source	SWL Confidence	Water Level Comment
MCO-6A	*2.8*	*ESH-18*	*Good*	
MCO-6A	*2.8*	*NMED OB[d]*	*Good*	
MCO-6	*2.34*	*ESH-18*	*Good*	
MCO-6	*2.34*	*ESH-18*	*Good*	
MCO-6	*2.34*	*ESH-18*	*Good*	
MCO-6	*2.34*	*ESH-18*	*Good*	
MCO-6	*2.34*	*NMED OB*	*Good*	
MCWB-6.2C	*2*	*McLin 1997*	*Good*	
MCWB-6.2C	*2*	*McLin 1997*	*Good*	
MCWB-6.2C	*2*	*McLin 1997*	*Good*	
MCWB-6.2B	*2*	*McLin 1997*	*Good*	
MCWB-6.2B	*2*	*McLin 1997*	*Good*	
MCWB-6.2B	*2*	*McLin 1997*	*Good*	
MCM-6E	*0.5*	*NMED OB*	*Good*	
MCWB-6.2A	*2.08*	*McLin 1997*	*Good*	
MCWB-6.2A	*2.08*	*McLin 1997*	*Good*	
MCWB-6.2A	*2.08*	*McLin 1997*	*Good*	

a. SWL = static water level below measuring point
b. GL = ground level
c. AGL = above ground level
d. NMED OB = New Mexico Environment Department Oversight Bureau
e. MP = measuring point (top of tubing)

TABLE D-5 (continued)

RECENT WATER LEVEL MEASUREMENTS IN MORTANDAD CANYON ALLUVIAL OBSERVATION WELLS

Part 1

ID	Well Elevation (ft)	Depth Completed (ft)	Measured Well Depth (ft)	Measurement Date	SWL[a] (ft)	Measuring Point
MCWB-6.5E	*6843.8*	*50*		*1/9/95*	*38.89*	*GL*[b]
MCWB-6.5E	*6843.8*	*50*		*9/18/95*	*41.12*	*GL*
MCWB-6.5E	*6843.8*	*50*		*11/13/96*	*42.96*	*GL*
MCWB-6.5E	*6843.8*	*50*	*52.35*	*3/18/97*	*42.5*	*MP*[e]
MCO-6.5A	*6842.19*	*45*	*32.8*	*11/13/96*	*Dry*	*GL*
MCWB-6.5D	*6843.2*	*42.5*		*1/9/95*	*Dry*	*GL*
MCWB-6.5D	*6843.2*	*42.5*		*9/18/95*	*Dry*	*GL*
MCWB-6.5D	*6843.2*	*42.5*		*11/13/96*	*Dry*	*GL*
MCWB-6.5D	*6843.2*	*42.5*	*44.55*	*3/18/97*	*42.65*	*MP*
MCO-6.5B	*6838.84*	*42*	*34.31*	*11/13/96*	*Dry*	*GL*
MCWB-6.5C	*6841*	*47.5*		*1/9/95*	*36.21*	*GL*
MCWB-6.5C	*6841*	*47.5*		*9/18/95*	*40.66*	*GL*
MCWB-6.5C	*6841*	*47.5*		*11/13/96*	*42.56*	*GL*
MCWB-6.5C	*6841*	*47.5*		*1/2/97*	*42.43*	*GL*
MCWB-6.5C	*6841*	*47.5*	*48.4*	*3/18/97*	*42.83*	*MP*
MCM-6.5A	*6838.74*	*23*	*22.6*	*11/13/96*	*21*	*GL*
MCWB-6.6	*6839.4*	*47.5*		*1/9/95*	*Dry*	*GL*

Part 2

ID	Tubing Height AGL[c] (ft)	SWL Source	SWL Confidence	Water Level Comment
MCWB-6.5E	*2*	*McLin 1997*	*Good*	
MCWB-6.5E	*2*	*McLin 1997*	*Good*	
MCWB-6.5E	*2*	*McLin 1997*	*Good*	
MCWB-6.5E	*2*	*NMED OB*[d]	*Good*	
MCO-6.5A	*2.15*	*NMED OB*	*Good*	
MCWB-6.5D	*2.17*	*McLin 1997*	*Good*	
MCWB-6.5D	*2.17*	*McLin 1997*	*Good*	
MCWB-6.5D	*2.17*	*McLin 1997*	*Good*	
MCWB-6.5D	*2.17*	*NMED OB*	*Good*	
MCO-6.5B	*0.7*	*NMED OB*	*Good*	
MCWB-6.5C	*1.92*	*McLin 1997*	*Good*	
MCWB-6.5C	*1.92*	*McLin 1997*	*Good*	
MCWB-6.5C	*1.92*	*McLin 1997*	*Good*	*Water level below screen*
MCWB-6.5C	*1.92*	*NMED OB*	*Good*	
MCWB-6.5C	*1.92*	*NMED OB*	*Good*	
MCM-6.5A		*NMED OB*	*?*	*Not formation water?*
MCWB-6.6	*2*	*McLin 1997*	*Good*	

a. SWL = static water level below measuring point
b. GL = ground level
c. AGL = above ground level
d. NMED OB = New Mexico Environment Department Oversight Bureau
e. MP = measuring point (top of tubing)

TABLE D-5 (continued)

RECENT WATER LEVEL MEASUREMENTS IN MORTANDAD CANYON ALLUVIAL OBSERVATION WELLS

Part 1

ID	Well Elevation (ft)	Depth Completed (ft)	Measured Well Depth (ft)	Measurement Date	SWL[a] (ft)	Measuring Point
MCWB-6.6	6839.4	47.5		9/18/95	Dry	GL[b]
MCWB-6.6	6839.4	47.5		11/13/96	Dry	GL
MCWB-7B	6832.5	47.5		1/9/95	37.15	GL
MCWB-7B	6832.5	47.5		9/18/95	40.50	GL
MCWB-7B	6832.5	47.5		11/13/96	42.01	GL
MCWB-7A	6831.2	52		1/9/95	35.78	GL
MCWB-7A	6831.2	52		9/18/95	39.33	GL
MCWB-7A	6831.2	52		11/13/96	41.89	GL
MCO-7A	6827.58	44.8		3/31/95	39.12	MP[e]
MCO-7A	6827.58	44.8		6/28/95	40.3	MP
MCO-7A	6827.58	44.8		8/10/95	39.5	MP
MCO-7A	6827.58	44.8		8/6/96	43.1	MP
MCO-7A	6827.58	44.8	43.84	11/13/96	39.85	GL
MCO-7	6827.31	69		6/28/95	41.8	MP
MCO-7	6827.31	69		8/10/95	39.1	MP
MCO-7	6827.31	69		12/20/95	41.08	MP
MCO-7	6827.31	69		8/6/96	43.7	MP

Part 2

ID	Tubing Height AGL[c] (ft)	SWL Source	SWL Confidence	Water Level Comment
MCWB-6.6	2	McLin 1997	Good	
MCWB-6.6	2	McLin 1997	Good	
MCWB-7B	1.92	McLin 1997	Good	
MCWB-7B	1.92	McLin 1997	Good	
MCWB-7B	1.92	McLin 1997	Good	
MCWB-7A	2.17	McLin 1997	Good	
MCWB-7A	2.17	McLin 1997	Good	
MCWB-7A	2.17	McLin 1997	Good	
MCO-7A	2	ESH-18	Good	
MCO-7A	2	ESH-18	Good	
MCO-7A	2	ESH-18	Good	
MCO-7A	2	ESH-18	Good	
MCO-7A	2	NMED OB[d]	Good	
MCO-7	1.24	ESH-18	Good	
MCO-7	1.24	ESH-18	Good	
MCO-7	1.24	ESH-18	Good	
MCO-7	1.24	ESH-18	Good	

a. SWL = static water level below measuring point
b. GL = ground level
c. AGL = above ground level
d. NMED OB = New Mexico Environment Department Oversight Bureau
e. MP = measuring point (top of tubing)

TABLE D-5 (continued)

RECENT WATER LEVEL MEASUREMENTS IN MORTANDAD CANYON ALLUVIAL OBSERVATION WELLS

Part 1

ID	Well Elevation (ft)	Depth Completed (ft)	Measured Well Depth (ft)	Measurement Date	SWL[a] (ft)	Measuring Point
MCO-7	6827.31	69	48.3	11/13/96	39.78	GL[b]
MCO-7.1	6823.04	50	48.9	4/4/97	39.2	GL
MCO-7.1A	6824.3	60	59.85	4/4/97	40.39	MP[e]
MCWB-7.2	6818.9	67.5		1/9/95	Dry	GL
MCWB-7.2	6818.9	67.5		9/18/95	Dry	GL
MCWB-7.2	6818.9	67.5		11/13/96	65.89	GL
MT-1	6811.63	69	67.56	11/13/96	58.45	GL
MCWB-7.4A	6812.4	70		1/9/95	40.69	GL
MCWB-7.4A	6812.4	70		9/18/95	44.21	GL
MCWB-7.4A	6812.4	70		11/13/96	65.64	GL
MCWB-7.4B	6813.1	70		1/9/95	46.13	GL
MCWB-7.4B	6813.1	70		9/18/95	48.85	GL
MCWB-7.4B	6813.1	70		11/13/96	54.54	GL
MCO-7.5B	6808.88	60		8/1/95	57.3	MP
MCO-7.5B	6808.88	60		8/6/96	Dry	MP
MCO-7.5B	6808.88	60	54.4	11/13/96	Damp	GL
MCM-7.5	6809.26	94	94.55	11/13/96	93.66	GL

Part 2

ID	Tubing Height AGL[c] (ft)	SWL Source	SWL Confidence	Water Level Comment
MCO-7	1.24	NMED OB[d]	Good	
MCO-7.1	1.3	NMED OB	Good	
MCO-7.1A	5	NMED OB	Good	
MCWB-7.2	1.92	McLin 1997	Good	
MCWB-7.2	1.92	McLin 1997	Good	
MCWB-7.2	1.92	McLin 1997	Good	Water level below screen
MT-1	1.79	NMED OB	Good	
MCWB-7.4A	2.08	McLin 1997	Good	
MCWB-7.4A	2.08	McLin 1997	Good	
MCWB-7.4A	2.08	McLin 1997	Good	Water level below screen
MCWB-7.4B	2.17	McLin 1997	Good	
MCWB-7.4B	2.17	McLin 1997	Good	
MCWB-7.4B	2.17	McLin 1997	Good	
MCO-7.5B	1.28	ESH-18	Good	
MCO-7.5B	1.28	ESH-18	Good	
MCO-7.5B	1.28	NMED OB	Good	Wet sand at bottom
MCM-7.5	1	NMED OB	?	Not formation water?

a. SWL = static water level below measuring point
b. GL = ground level
c. AGL = above ground level
d. NMED OB = New Mexico Environment Department Oversight Bureau
e. MP = measuring point (top of tubing)

TABLE D-5 (continued)

RECENT WATER LEVEL MEASUREMENTS IN MORTANDAD CANYON ALLUVIAL OBSERVATION WELLS

Part 1

ID	Well Elevation (ft)	Depth Completed (ft)	Measured Well Depth (ft)	Measurement Date	SWL[a] (ft)	Measuring Point
MCWB-7.7A	6798.3	67.5		1/9/95	Dry	GL[b]
MCWB-7.7A	6798.3	67.5		9/18/95	Dry	GL
MCWB-7.7A	6798.3	67.5		11/13/96	Dry	GL
MCWB-7.7B	6799	70		1/9/95	56.71	GL
MCWB-7.7B	6799	70		9/18/95	57.93	GL
MCWB-7.7B	6799	70		11/13/96	66.66	GL
MCM-8F	6799.19	23	23.4	11/13/96	7.7	GL
MCM-8F	6799.19	23		2/11/97	7.78	GL
MCO-8A	6797.47	50	49.07	11/13/96	Dry	GL
MCO-8A	6797.47	50	48.29	11/15/96	Dry	GL
MCM-8E	6796.25	53	51.9	11/13/96	Dry	GL
MCM-8D	6795.8	86	85.9	11/13/96	85.85	GL
MT-3	6796.65	74	72.42	11/13/96	64.16	GL
MT-3	6796.65	74		2/11/97	63.59	GL
MCM-8C	6798.46	66	59.03	11/13/96	.69	GL
MT-2	6796.2	64	64.27	11/13/96	63.98	GL
MCO-8	6796.7	84	4	11/13/96	N/A	GL

Part 2

ID	Tubing Height AGL[c] (ft)	SWL Source	SWL Confidence	Water Level Comment
MCWB-7.7A	2.17	McLin 1997	Good	
MCWB-7.7A	2.17	McLin 1997	Good	
MCWB-7.7A	2.17	McLin 1997	Good	
MCWB-7.7B	2.08	McLin 1997	Good	
MCWB-7.7B	2.08	McLin 1997	Good	
MCWB-7.7B	2.08	McLin 1997	Good	Water level below screen
MCM-8F	1.37	NMED OB[d]	?	Not formation water?
MCM-8F	1.37	NMED OB	?	Purged dry, no inflow
MCO-8A	0.61	NMED OB	Good	
MCO-8A	0.61	NMED OB	Good	
MCM-8E		NMED OB	Good	Not formation water
MCM-8D		NMED OB	?	Not formation water
MT-3	1.3	NMED OB	Good	
MT-3	1.3	NMED OB	Good	TDS = 560, NO_3 = 7 mg/L
MCM-8C		NMED OB	?	Not formation water
MT-2	1.6	NMED OB	Good	
MCO-8	0.25	NMED OB	Good	Obstruction 4 ft below top of casing

a. SWL = static water level below measuring point
b. GL = ground level
c. AGL = above ground level
d. NMED OB = New Mexico Environment Department Oversight Bureau
e. MP = measuring point (top of tubing)

TABLE D-5 (continued)

RECENT WATER LEVEL MEASUREMENTS IN MORTANDAD CANYON ALLUVIAL OBSERVATION WELLS

Part 1

ID	Well Elevation (ft)	Depth Completed (ft)	Measured Well Depth (ft)	Measurement Date	SWL[a] (ft)	Measuring Point
MCM-8B	6797.25	30	30.6	11/13/96	20.1	GL[b]
MCM-8B	6797.25	30		2/11/97	21.3	GL
MCWB-8.1A	6786	75		1/9/95	Dry	GL
MCWB-8.1A	6786	75		9/18/95	Dry	GL
MCWB-8.1A	6786	75		11/13/96	Trace	GL
MT-4	6783.59	74	67.84	11/13/96	64.9	GL
MT-4	6783.59	74		2/11/97	64.59	GL
MCWB-8.1B	6783.8	72.5		1/9/95	Dry	GL
MCWB-8.1B	6783.8	72.5		9/18/95	Trace	GL
MCWB-8.1B	6783.8	72.5		11/13/96	Dry	GL
MCWB-8.1C	6785.6	80		1/9/95	Dry	GL
MCWB-8.1C	6785.6	80		9/18/95	Dry	GL
MCO-8.2	6781.6	70	59.2	11/13/96	Dry	GL
MCO-9	6749.67	55	44.6	11/13/96	Dry	GL
MCWB-9B	6753.6	80		1/9/95	Dry	GL
MCWB-9B	6753.6	80		9/18/95	Dry	GL

Part 2

ID	Tubing Height AGL[c] (ft)	SWL Source	SWL Confidence	Water Level Comment
MCM-8B	0.8	NMED OB[d]	?	Not formation water?
MCM-8B	0.8	NMED OB	?	Purged dry, no inflow
MCWB-8.1A	2.17	McLin 1997	Good	
MCWB-8.1A	2.17	McLin 1997	Good	
MCWB-8.1A	2.17	McLin 1997	Good	Water level below screen
MT-4	1.34	NMED OB	Good	
MT-4	1.34	NMED OB	Good	TDS = 471, NO_3 = 23.2 mg/L
MCWB-8.1B	2.17	McLin 1997	Good	
MCWB-8.1B	2.17	McLin 1997	Good	Water level below screen
MCWB-8.1B	2.17	McLin 1997	Good	
MCWB-8.1C	2.08	McLin 1997	Good	
MCWB-8.1C	2.08	McLin 1997	Good	
MCO-8.2	2	NMED OB	Good	
MCO-9	1.44	NMED OB	Good	
MCWB-9B	2.08	McLin 1997	Good	
MCWB-9B	2.08	McLin 1997	Good	

a. SWL = static water level below measuring point
b. GL = ground level
c. AGL = above ground level
d. NMED OB = New Mexico Environment Department Oversight Bureau
e. MP = measuring point (top of tubing)

TABLE D-5 (continued)

RECENT WATER LEVEL MEASUREMENTS IN MORTANDAD CANYON ALLUVIAL OBSERVATION WELLS

Part 1

ID	Well Elevation (ft)	Depth Completed (ft)	Measured Well Depth (ft)	Measurement Date	SWL[a] (ft)	Measuring Point
MCWB-9B	6753.6	80		11/13/96	Dry	GL[b]
MCWB-9A	6752.1	75		1/9/95	Dry	GL
MCWB-9A	6752.1	75		9/18/95	Dry	GL
MCWB-9A	6752.1	75		11/13/96	Dry	GL
MCO-9.5	6743.27	46	39.5	11/18/96	Dry	GL
MCM-10	6730.58	67	65.54	11/18/96	62.07	GL
MCM-10-1	6729.7	119	120.02	11/18/96	Dry	GL
MCM-10-2	6709.34	43	43.57	11/18/96	Dry	GL
MCM-12A	6704.49	98	98.7	11/18/96	Dry	GL
MCO-12	6697.15	108	97.15	11/18/96	Dry	GL
MCO-12	6697.15	108	97.85	11/18/96	Dry	GL
MCM-10-3B	6696.04	43	43.59	11/18/96	42.76	GL
MCM-10-3A	6695.95	33	30.34	11/18/96	29.9	GL
MCO-13	6674.48	107	106.1	11/18/96	105.25	GL
MCO-13	6674.48	107		2/11/97	104.3	GL
SIMO	6650.9	104	102.85	11/18/96	Dry	GL

Part 2

ID	Tubing Height AGL[c] (ft)	SWL Source	SWL Confidence	Water Level Comment
MCWB-9B	2.08	McLin 1997	Good	
MCWB-9A	2.17	McLin 1997	Good	
MCWB-9A	2.17	McLin 1997	Good	
MCWB-9A	2.17	McLin 1997	Good	
MCO-9.5	2	NMED OB[d]	Good	
MCM-10	1.4	NMED OB	?	Not formation water
MCM-10-1	1	NMED OB	Good	
MCM-10-2	1	NMED OB	Good	
MCM-12A	0.7	NMED OB	Good	
MCO-12	0.7	NMED OB	Good	
MCO-12	0.7	NMED OB	Good	
MCM-10-3B	1	NMED OB	?	Not formation water
MCM-10-3A	1	NMED OB	?	Not formation water
MCO-13	0.67	NMED OB	Good	
MCO-13	0.67	NMED OB	Good	TDS = 544, NO_3 = 19.2 mg/L
SIMO		NMED OB	Good	

a. SWL = static water level below measuring point
b. GL = ground level
c. AGL = above ground level
d. NMED OB = New Mexico Environment Department Oversight Bureau
e. MP = measuring point (top of tubing)

Source: McLin et al. 1997, 04-0327; NMED unpublished data; ESH-18 unpublished data

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Appendix E

List of Contributors

Name and Affiliation	Education and Expertise	Function
Wesley L. Bradford (Los Alamos Technical Associates, Inc.)	*Ph.D. Earth Sciences 31 years experience in conducting field investigations in hydrology, hydrogeology, and geochemistry and managing RI/FS environmental contamination assessments and RCRA corrective actions*	*Technical coordinator*
David Broxton (EES-1)	*M.S. Geology 20 years experience conducting field investigations in geology, geologic disposal of high-level nuclear waste, and project management*	*Canyons technical team leader Technical lead for geology*
Karen Burkheimer (Los Alamos Technical Associates, Inc.)	*A.S. Business Management 8 years experience in records management; 3 years experience in document control and archival retrieval*	*Archival research and document production*
Leslie Dale (Science Applications International Corporation)	*M.S. Geology 5 years experience in site characterization and remediation, waste management, and regulatory compliance*	*Field technical support*
Michael Dale (NMED DOE OB)	*M.S. Geology with emphasis on hydrogeology 5 years experience*	*Provided oversight input for hydrologic processes*
Dave Dander (ESH-18)	*B.S. Geology Master's candidate in hydrology 5 years experience*	*Provided gaging station data*
Alison Dorries (TSA-11)	*Ph.D. Chemistry/M.P.H. Public Health 9 years experience in toxicology, pulmonary health research, regulation development, and human health risk assessment*	*Technical team leader for the Laboratory Environmental Restoration Decision Support Council*
Christy Fläming (Los Alamos Technical Associates, Inc.)	*24 years experience in graphics, illustration, printing, and document production*	*Artist/designer Graphics team leader Word processing*
Teralene Foxx (ESH-20)	*M.S. Biology 18 years field ecology and waste site characterization experience; adjunct professor, University of New Mexico; author of books and publications on plant and fire ecology*	*NEPA biological evaluation*
Bruce Gallaher (ESH-18)	*M.S. Hydrology 15 years experience in waste management and contaminant hydrology*	*Principal investigator for hydrology*
Chris Hanlon-Meyer (NMED DOE OB)	*B.S. Soils/Environmental Sciences 5 years experience in environmental science investigations*	*Provided oversight input for hydrologic processes*
Bill Hardesty (ERM/Golder)	*B.S. Chemistry 11 years experience designing and implementing field analytical methods at EPA superfund sites*	*Performed quality checks on FIMAD data*

Name and Affiliation	Education and Expertise	Function
Janet Jacobson (Science Applications International Corporation)	*B.A. Chemistry/M.S. Environmental Science/ J.D. Law 12 years experience in water quality, environmental science, and regulatory review and support*	*Regulatory review*
Marcia Jones (FIMAD)	*6 years experience in the geographical information system specializing in cartography*	*Produced large maps*
Richard Kelley (Los Alamos Technical Associates, Inc.)	*B.S. Geology 17 years experience in geologic and petroleum geologic exploration including 7 years of environmental and hydrological specialization*	*GIS mapping consultant*
Richard Koch (Science Applications International Corporation)	*M.S. Geology 22 years experience in conducting field investigations and integrating and analyzing geologic, hydrologic, geophysical, and geochemical data*	*Technical support for geology, hydrogeology, and geochemistry*
Beverly Larson (ESH-20)	*M.A. Anthropology/Ph.D. Candidate in Anthropology 17 years field experience, including 6 years as a Laboratory archaeologist; adjunct professor, University of New Mexico*	*NEPA cultural evaluation*
Johnnye Lewis (Environmental Health Associates, Inc.)	*Ph.D. Pharmacology/Toxicology, DABT 20 years experience in environmental health with focus on development of interdisciplinary models to assess community-specific health risks; Associate Scientist, Center for Population Health, University of New Mexico*	*Technical team leader for the canyons decision support team*
Patrick Longmire (CST-7)	*Ph.D. Aqueous Geochemistry 19 years experience in field hydrogeochemistry, soil chemistry regulatory oversight (NMEID), the UMTRA project, and RCRA/CERCLA remediation (Roy F. Weston)*	*Technical lead for aqueous geochemistry*
Max Maes (ESH-18)		*Provided water level data*
Pamela Maestas (Los Alamos Technical Associates, Inc.)	*B.A. Human Resources Management 1 year experience as an electronic publications specialist; 2 years experience in word processing, data entry, and various software*	*Electronic publications specialist*
David Mahan (Los Alamos Technical Associates, Inc.)	*2 years experience in graphics and technical illustration*	*Artist*
Steve McLin (ESH-18)	*Ph.D. Hydrology*	*Technical support*
Mary Ann Mullen (ESH-20)	*M.S. Statistics 2 years experience with the Laboratory Environmental Restoration Project; expertise in statistical ecology and environmental sciences*	*Statistician*

Name and Affiliation	Education and Expertise	Function
Orrin Myers (EES-15)	*Ph.D. Wildlife Biology 10 years experience conducting field investigations on effects of environmental contaminants on wetland and terrestrial wildlife populations, including 4 years in ecological risk assessment*	*Technical lead for ecological risk assessment*
Jack Nyhan (EES-15)	*Ph.D. Soil Science/Radioecology/Systems Ecology 31 years experience conducting field and modeling studies for DOE, USPA, NRC, EPA, and DOD*	*Provided sediment data*
Maureen Oakes (CIC-1)	*B.S. Biology 6 years experience writing and editing technical documents, including environment, safety, and health and environmental restoration documentation*	*Technical writer/editor*
Allyn Pratt (EES-13)	*B.S. Environmental Science/M.B.A. 19 years experience in natural resource management, project management, and environmental management*	*Field Unit 4 project leader*
William Purtymun (Los Alamos Technical Associates, Inc.)	*B.S. Geology 14 years experience with the United States Geological Survey; 26 years experience in monitoring of water supplies and waste disposal*	*Technical support*
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*
Randy Ryti (Neptune and Co., Inc.)	*Ph.D. Biology 16 years experience in environmental science problems, including 4 years supporting the Environmental Restoration Project in the areas of statistical analysis and decision support*	*Lead statistician*
Celina Salazar (EES-13)		*Data entry*
David Shaull (ESH-18)	*33 years experience in all phases of hydrologic data collection and analysis*	*Provided gaging station data*
Catherine Smith (Los Alamos Technical Associates, Inc.)	*Ph.D. Analytical Chemistry 10 years experience in analytical chemistry with emphasis on environmental characterization; expertise in quality assurance for analytical services and analytical data quality evaluation*	*Technical consultant*
Everett Springer (EES-15)	*Ph.D. Watershed Management 16 years experience in surface and subsurface hydrologic characterization studies and modeling*	*Technical support*

Name and Affiliation	Education and Expertise	Function
Darril Stafford (Science Applications International Corporation)	*5 years experience in site characterization and remediation, field unit health and safety officer, and radiological control technician*	*Field technical support*
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*