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EXECUTIVE SUMMARY

This Hydrogeologic Workplan (Workplan) describes activities proposed to be performed by Los Alamos National Laboratory (Laboratory) to characterize the hydrogeologic setting beneath the Laboratory, and to enhance the Laboratory's groundwater monitoring program. The need for characterization of the hydrogeologic setting beyond that already established by studies conducted by and for the Laboratory over the last 50 years, and the possible need to enhance the groundwater monitoring program at the Laboratory, is driven by requirements, with which the Department of Energy (DOE) and the Laboratory are committed to comply, and the Laboratory's own commitment to groundwater protection.

A major driver for preparation of this Workplan was the New Mexico Environmental Department's (NMED's) letter dated August 17, 1995 which expressed concerns over groundwater contamination and protection at the Laboratory. The letter reiterated concerns expressed in prior correspondence from NMED that characterization of basic geology, hydrogeology, and pathways for contaminant transport had not been adequately addressed at the Laboratory to date. The letter listed four issues and questions summarized below that were deemed by NMED to be unresolved.

- Individual zones of saturation beneath the Laboratory have not been adequately delineated, and the "hydraulic interconnection" between these is not understood.
- The recharge area(s) for the regional aquifer and intermediate perched zones have not been identified, and the effect of fracture-fault zones on recharge is unknown.
- The ground-water flow direction(s) of the regional aquifer and intermediate perched zones, as influenced by pumping of production wells are unknown.
- Aquifer characteristics cannot be determined without additional monitoring wells installed within specific intervals of the various aquifers beneath the facility. Location of wells designed for aquifer testing cannot be addressed adequately without delineation of individual zones of saturation beneath the Laboratory.

A second major driver for preparation of this Workplan was NMED's letter of May 30, 1995 which denied the Laboratory's requests for waivers of groundwater monitoring requirements at several regulated units. The letter noted as justification for the denials that the Laboratory had provided inadequate and incomplete information pertaining to the unsaturated and saturated conditions across the Pajarito Plateau and that basic geology, hydrogeology, and pathways for contaminant transport had not been adequately addressed to date.

The objectives of the activities described in this Workplan are to address the four specific issues raised by NMED in the letter dated August 17, 1995, and to provide answers to the following three questions:

Is characterization of the hydrogeologic system beneath Los Alamos National Laboratory adequate to determine where uppermost subsurface water, alluvial groundwater, intermediate perched zone groundwater, or regional aquifer groundwater exists and whether concentrations of contaminants in alluvial groundwater, intermediate perched zone groundwater or regional aquifer groundwater exceed regulatory limits or risk levels?;

Is the characterization information sufficient either to establish detection monitoring programs pursuant to 40 CFR 264.91-100 for regulated units or to demonstrate that groundwater monitoring requirements could be waived, or to provide appropriate groundwater monitoring as part of corrective actions pursuant to 40 CFR 264.101 for Solid Waste Management Units that have been determined to have had a release that is a threat to human health or the environment?; and

Is the characterization information sufficient to satisfy the conditions of the Hazardous and Solid Waste Amendments (HSWA) portion of the Laboratory's Resource Conservation and Recovery Act (RCRA) operating permit?

The Environmental Protection Agency's Data Quality Objectives (DQO) Process was applied to the development of this Workplan in order to identify the data needs that must be fulfilled to answer these questions and address the four issues raised by NMED. By using the DQO Process, the Laboratory has assured that the type, quantity, and quality of hydrogeologic data used in decision-making will be appropriate to meet the primary objective to characterize the hydrogeologic setting at the Laboratory. As the Workplan is implemented, the DQO Process will continue to be applied in an iterative fashion as new data become available to ensure that the right data necessary to make decisions is being collected. This iterative application of the DQO Process will form the basis for annual renegotiation of the scope and schedule of the Workplan with NMED.

The centerpiece of the Workplan is the installation of additional wells that will provide extensive new hydrogeologic information. However, additional activities described in this Workplan will integrate and utilize all existing Laboratory (and other agency) reports, data, and modeling related to hydrogeologic characterization beneath the Laboratory. Section 3 of this Workplan, describes the proposed activities that will integrate this information as a foundation for future activities.

The Workplan scope represents an integration of all Laboratory projects and activities that contribute to the characterization of the hydrogeologic setting beneath the Laboratory, the results of which will ensure appropriate groundwater monitoring and enhanced groundwater protection. The scope of this document relies heavily on the performance of activities by the Laboratory's Environmental Restoration (ER) Project and by the Nuclear Weapons Technology (NWT) Program's Monitoring Well Installation Project. Both projects will provide significant characterization, assessment, and groundwater monitoring data that will be used to meet the objectives of this Workplan.

The expected outcomes of the activities described in this Workplan are:

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

If it is determined, as a result of this characterization effort, that enhanced groundwater monitoring is necessary, an inter-disciplinary Laboratory group will develop a proposed amendment to the Groundwater Monitoring Plan that will be reviewed and endorsed by the Technical Review Committee (TRC) prior to submittal to the appropriate regulatory agency(ies).

HYDROGEOLOGIC WORKPLAN
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ACRONYMS

CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulation
COC	Chain-of-Custody
CY	Calendar Year
DOE	U.S. Department of Energy
DOE-OB	DOE-Oversight Bureau
DP	Defense Programs
DQO	Data Quality Objective
ACL	Alternative Concentration Limit
EM	Environmental Management
EPA	Environmental Protection Agency
ER	Environmental Restoration
ESH	Environment, Safety and Health
ET	Evapotranspiration
FIMAD	Facility for Information Management, Analysis, and Display
FUSRAP	Formally Utilized MED/AEC Sites Remedial Action Program
FY	Fiscal Year
GIS	Geographic Information System
GIT	Groundwater Integration Team
GWPMPP	Groundwater Protection Management Program Plan
HE	High Explosive
I.D.	Inner Diameter
LA	Los Alamos
LAAO	Los Alamos Area Office
LANL	Los Alamos National Laboratory
LANSCE	Los Alamos Neutron Science Center
Ma	Millions of years before the present
MED/AEC	Manhattan Engineering District/Atomic Energy Commission
MCL	Maximum Contaminant Level
MDA	Material Disposal Area
MWIP	Monitoring Well Installation Project
NEPA	National Environmental Policy Act
NGVD	National Geodetic Vertical Datum
NMAC	New Mexico Annotated Code
NMED	New Mexico Environment Department
NMWQCC	New Mexico Water Quality Control Commission

NPDES	National Pollutant Discharge Elimination System
NTU	Nephelometric Turbidity Units
NWT	Nuclear Weapons Technology
OB/OD	Open Burning/Open Detonation
O.D.	Outer Diameter
OU	Operational Unit
PID	Photoionization Detector
PRS	Potential Contaminant Source
PVC	Polyvinylchloride
QA	Quality Assurance
QAPjP	Quality Assurance Project Plan
RCRA	Resource Conservation and Recovery Act
RFI	RCRA Facility Investigation.
RLWTF	Radioactive Liquid Waste Treatment Facility
SAP	Sampling and Analysis Plan
SARA	Superfund Amendments and Reauthorization
SOP	Standard Operating Procedure
STP	Sewage Treatment Plant
SWMU	Solid Waste Management
TA	Technical Area
TIVC	Total Ionizable Volatile Compounds
TRC	Technical Review Committee
TRU	Transuranic
USGS	United States Geologic Survey
VOC	Volatile Organic Compound

1.0 INTRODUCTION

This Hydrogeologic Workplan (Workplan) describes activities proposed to be performed by Los Alamos National Laboratory (Laboratory) to characterize the hydrogeologic setting beneath the Laboratory and to enhance the Laboratory's groundwater monitoring program. The need for characterization of the hydrogeologic setting beyond that already established by studies conducted by and for the Laboratory over the last 40 years, and the possible need for an enhanced groundwater monitoring program at the Laboratory, are driven by requirements, with which the Department of Energy (DOE) and the Laboratory are committed to comply, and the Laboratory's own commitment to groundwater protection. These requirements and commitments are described in detail in this section.

This introduction includes a narrative on the issues and rationale (including regulatory drivers) responsible for preparation of the Workplan; discusses the Laboratory's groundwater protection strategy; describes the decision-making process utilized to determine activities described in this Workplan; and provides an explanation of terminology used in the Workplan. A comprehensive table of hydrogeologic activities, including resource requirements and schedule of performance follows the introduction.

This Workplan provides a foundation for the reader by describing, in Section 2, a basic hydrogeologic background and a preliminary conceptual model for the hydrogeologic setting beneath the Laboratory. The Workplan builds on this foundation by describing, in Section 3, the planned activities with regard to information management and modeling and, in Section 4, hydrogeologic characterization, relating in each case their purpose and the rationale for implementation. In order to avoid excessive repetition, general sampling and analysis plans, well construction details, geophysical tests, and other interpretive activities are described separately in Section 4.1.

The descriptions of the activities are summarized in Section 4 by "aggregates", each representing a collection of Technical Areas (TAs), watershed(s), potential contaminant sources, and adjacent geographical areas within or surrounding the 43 mi^2 Laboratory (see the Map, Appendix 6 and Section 1.5). The boundaries for the aggregates were drawn to serve the purpose of focusing discussions and attention on specific areas of the Laboratory that collectively contain numerous sources of potential contamination. The aggregate boundaries should not be viewed as fixed in any geographical sense; hydrogeologic characterization activities relevant to a particular aggregate are proposed within as well as outside the aggregate boundaries.

While it is DOE's and the University of California's (UC) intention to ensure a comprehensive, well-integrated approach to addressing all applicable regulatory programs, implementation of this Workplan is driven by DOE's and UC's attempt to comply with the hazardous waste regulations. Specifically, the plan provides a characterization program that responds to groundwater monitoring waiver issues delineated by the New Mexico Environment Department (NMED) [May 30 and August 17, 1995 letters] and requirements set forth in the Hazardous and Solid Waste Amendments (HSWA) portion of the Laboratory's Resource Conservation and Recovery Act (RCRA) operating permit.

1.1 Workplan Objectives and Scope

As discussed in detail in Sections 1.5.2 and 1.5.3, this Workplan responds to technical and regulatory issues raised by NMED in their correspondence dated May 30 and August 17, 1995. Specifically, the objectives of the activities described in this Workplan are to address the four specific issues raised by NMED in the letter dated August 17, 1995 (see Appendix 2), and to provide answers to the following questions:

1. Is characterization of the hydrogeologic system beneath Los Alamos National Laboratory adequate to determine where uppermost subsurface water, alluvial groundwater, intermediate perched zone groundwater, or regional aquifer groundwater exists and whether concentrations of

contaminants in alluvial groundwater, intermediate perched zone groundwater or regional aquifer groundwater exceed regulatory limits or risk levels?;

2. Is the characterization information sufficient either to establish detection monitoring programs pursuant to 40 CFR 264.91-100 for regulated units or to demonstrate that groundwater monitoring requirements could be waived, or to provide appropriate groundwater monitoring as part of corrective actions pursuant to 40 CFR 264.101 for Solid Waste Management Units that have been determined to have had a release that is a threat to human health or the environment?; and
3. Is the characterization information sufficient to satisfy the conditions of the Hazardous and Solid Waste Amendments (HSWA) portion of the Laboratory's Resource Conservation and Recovery Act (RCRA) operating permit?

This has been achieved, in part, by incorporating the four issues into the Environmental Protection Agency's (EPA) Data Quality Objectives (DQO) Process (EPA 1987) used to plan these activities via specific decisions and questions (see Section 1.5 for details). In addition, those issues were emphasized in the scoring criteria for the scheduling of well construction by assigning the highest points related to those factors that addressed the four issues. Specifically, higher points were assigned to those wells the construction of which would: (1) reduce the hydrologic setting uncertainties; (2) reduce stratigraphic and structural uncertainties; (3) detect contamination of the water supply system; and (4) assess the nature and extent of potential contamination in groundwater.

Additional activities described in this Workplan are intended to integrate and utilize all existing Laboratory (and other agency) reports, data, and modeling related to hydrogeologic characterization beneath the Laboratory. The Laboratory recognizes the value of historical information, and Section 3 of this Workplan describes the proposed activities that will integrate this information as a foundation for future activities. An additional benefit of the characterization will be realized in that the information obtained will assist in making future water supply development decisions.

The Workplan scope represents an integration of all Laboratory projects and activities that contribute to the characterization of the hydrogeologic setting beneath the Laboratory, the results of which will ensure appropriate groundwater monitoring and enhanced groundwater protection. The scope of this document relies heavily on the implementation of the Monitoring Well Installation Project, the construction management of which has been delegated by the Laboratory to the Environmental Restoration (ER) Project. The ER Project is responsible for providing the Laboratory with a comprehensive groundwater characterization and monitoring network that enables groundwater protection and regulatory compliance. The ER Project will provide significant characterization, assessment, and monitoring data that will be used to meet the objectives of this Workplan.

Other Laboratory projects and activities will significantly contribute to the characterization of the Laboratory's hydrogeologic setting. For example, a Performance Assessment pursuant to DOE Order 5820.2A Radioactive Waste Management, is currently being conducted at TA-54, Area G. The information and data produced will complement the objectives of this Workplan. Likewise, numerous geologic, geochemical, and hydrologic studies are being performed (or planned) by Laboratory organizations that will result in products and deliverables relevant to the objectives of this Workplan. These projects and activities are further addressed in Section 3 of this Workplan, and included in the schedule of Workplan activities.

1.2 Communication

The implementation of this Workplan is intended to remain flexible, such that the scope and schedule of activities can be based on annual re-evaluation of the conceptual site model and reiteration of the DQOs. A critical factor in maintaining flexibility in the Workplan is communication with the regulatory decision-makers. Although decisions about Workplan activities will be on an annual basis, DOE and the Laboratory are committed to keeping NMED consistently informed as described in this section.

An annual meeting will be held in March to perform a review and reassessment of DQOs and to negotiate the Workplan scope and schedule for the next year's well installation and other activities. Although the installation schedules contained in this Workplan (see Figure 1-1) are intended to be comprehensive and to indicate a prospective long-term order of activity performance, it is technically prudent to perform activities using a year-by-year iterative process of data collection, review and re-assessment. By doing so, full advantage will be taken of all new information and data prior to locating and installing subsequent wells. This approach will ensure that characterization activities and well installation are optimized; the need for installation of subsequent wells (alluvial, intermediate perched zone, or regional aquifer wells) will always depend on data and information gained from the previously installed wells and on interpretation of data from those wells.

An annual report, the "Groundwater Annual Status Summary Report", will be prepared to summarize the activities over the previous fiscal year and to make recommendations for the current fiscal year's activities. The report will include data generated by any program at the Laboratory (Environmental Restoration, Environmental Surveillance, Waste Management, etc) that may further enhance the conceptual model. The annual report will be submitted to NMED by January 15th to allow sufficient review and response time prior to the March meeting. Both the annual report and the annual meeting minutes describing modifications to the Hydrogeologic Workplan scope or schedule will be distributed based on a formal distribution list to be developed and maintained by the Laboratory.

In addition to the annual meeting, there will be regularly scheduled quarterly meetings to present progress on active workplan tasks and to discuss the available data. Changes in the conceptual model will be made by consensus. Quarterly meetings are anticipated to occur in June, September, and December. The discussions will be informal and will focus on progress and data collected in the previous quarter. The minutes from these meetings will also be distributed based on the formal distribution list.

Between scheduled meetings, communication with NMED will be in a form appropriate for informational content and regulatory requirements. Updates on drilling progress may be provided through phone calls, e-mail, or fax. Notifications or documentation of agreements will be through typical correspondence procedures. Deliverables required under permit or other regulatory framework will be submitted formally within the stipulated time frame. For example, under the HSWA module of the RCRA Operating Permit, a well report will be submitted within 30 days of well completion.

1.3 Workplan Approach and Implementation

In general, the activities described in this Workplan follow an iterative approach to characterizing the hydrogeologic setting beneath the Laboratory. As discussed in Section 3, the foundation for the iterative approach will be the utilization of a database to store and manipulate existing and newly-collected hydrogeologic data, and the use of modeling techniques to enhance the conceptual model of the hydrogeologic setting. New data and information will allow refinement of the conceptual model, and will facilitate an iterative reassessment of DQOs for the activities described in this Workplan.

In this regard, this Workplan proposes to implement numerous activities including the construction of wells (see the Master Schedule of Workplan Activities, Figure 1-1 and the Resources Table, Table 1-1). The proposed wells serve as the centerpiece of this Workplan because they will provide extensive hydrogeologic information which, coupled with existing hydrogeologic information, will largely fulfill the Workplan objective of hydrogeologic characterization and monitoring. By using the DQO Process to determine the prospective number, location, and construction details of these monitoring wells, the Laboratory has assured that the type, quantity, and quality of hydrogeologic data obtained from these wells will be appropriate for the intended applications.

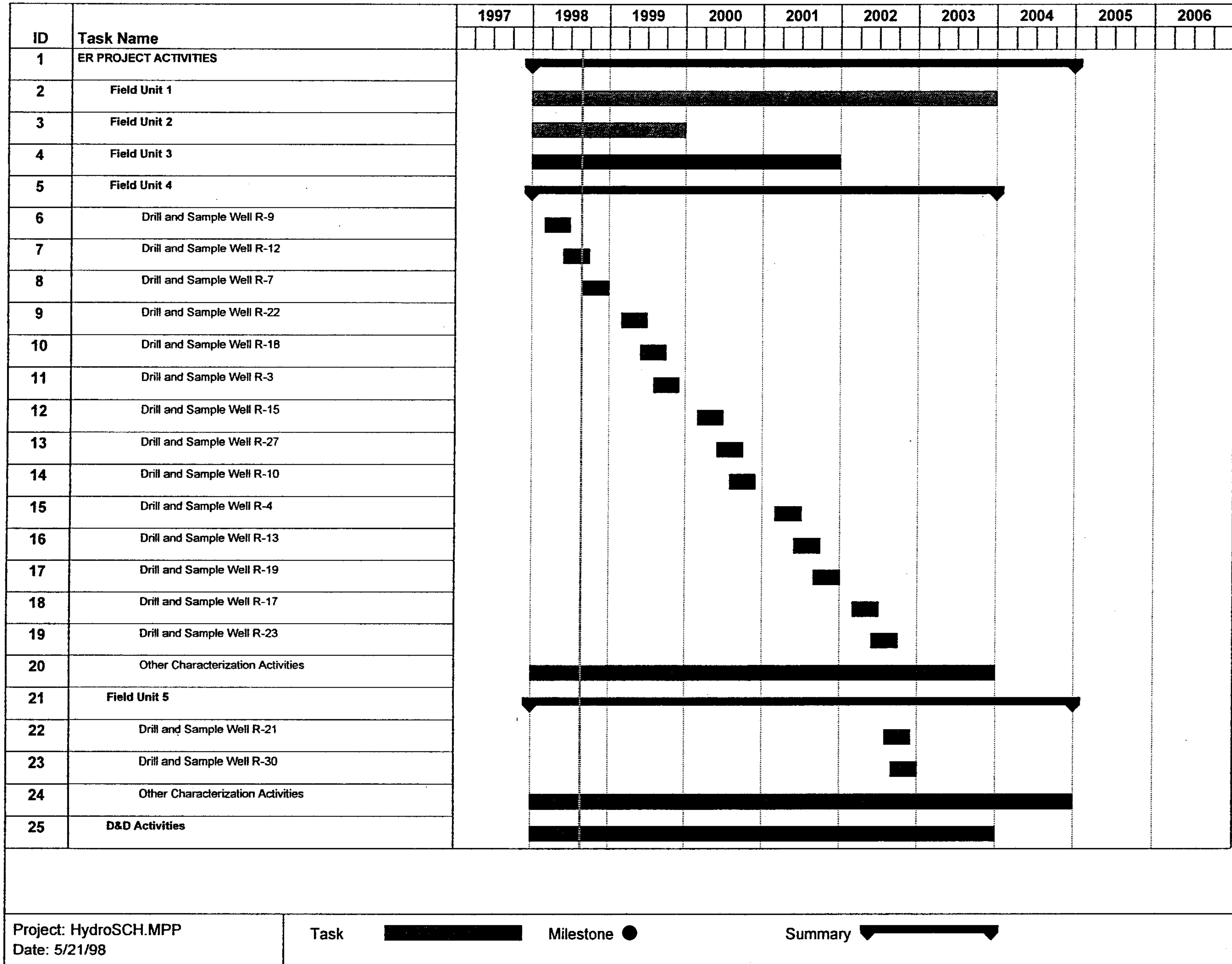
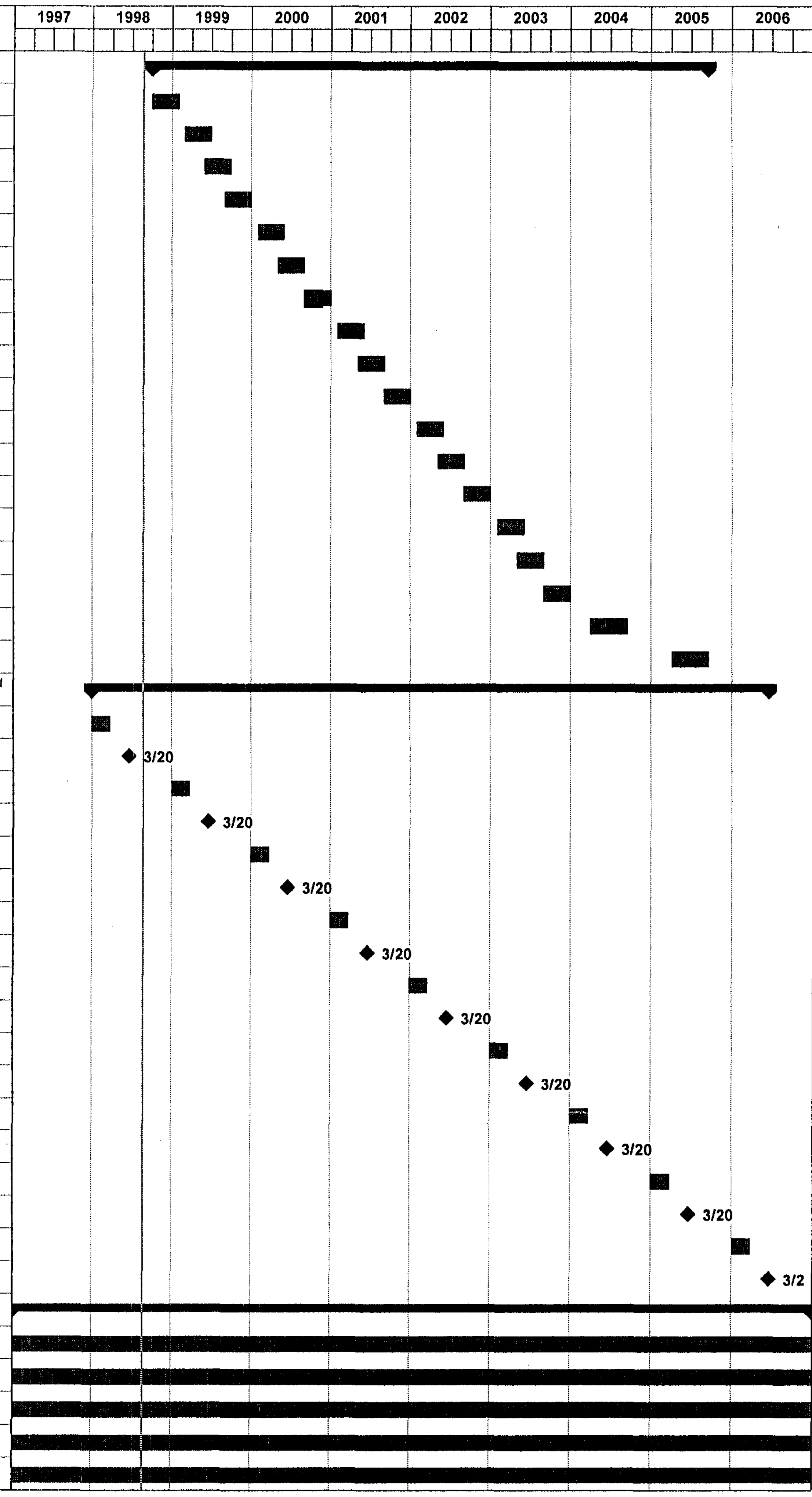


Figure 1-1. Master schedule of Workplan activities by fiscal year.

ID	Task Name
26	NWT PROGRAM ACTIVITIES
27	Drill and Sample Well R-25
28	Drill and Sample Well R-5
29	Drill and Sample Well R-31
30	Drill and Sample Well R-28
31	Drill and Sample Well R-32
32	Drill and Sample Well R-2
33	Drill and Sample Well R-1
34	Drill and Sample Well R-8
35	Drill and Sample Well R-20
36	Drill and Sample Well R-14
37	Drill and Sample Well R-6
38	Drill and Sample Well R-11
39	Drill and Sample Well R-24
40	Drill and Sample Well R-26
41	Drill and Sample Well R-29
42	Drill and Sample Well R-16
43	Drill and Sample Well R-28d
44	Drill and Sample Well R-1d
45	MANAGEMENT ACTIVITIES AND INFORMATION INTERPRETATION
46	Annual Groundwater Status Summary Report Preparation-FY98
47	Annual NMED Negotiation Meeting--March 1998
48	Annual Groundwater Status Summary Report Preparation-FY99
49	Annual NMED Negotiation Meeting--March 1999
50	Annual Groundwater Status Summary Report Preparation-FY00
51	Annual NMED Negotiation Meeting--March 2000
52	Annual Groundwater Status Summary Report Preparation-FY01
53	Annual NMED Negotiation Meeting--March 2001
54	Annual Groundwater Status Summary Report Preparation-FY02
55	Annual NMED Negotiation Meeting--March 2002
56	Annual Groundwater Status Summary Report Preparation-FY03
57	Annual NMED Negotiation Meeting--March 2003
58	Annual Groundwater Status Summary Report Preparation-FY04
59	Annual NMED Negotiation Meeting--March 2004
60	Annual Groundwater Status Summary Report Preparation-FY05
61	Annual NMED Negotiation Meeting--March 2005
62	Annual Groundwater Status Summary Report Preparation-FY06
63	Annual NMED Negotiation Meeting--March 2006
64	ADDITIONAL ACTIVITIES--see Table 1-1 for subtasks
65	Maintain Central Database
66	Maintain Core Facility
67	Develop Geologic Model
68	Develop Hydrologic Model
69	Develop Geochemical Model



Project: HydroSCH.MPP
Date: 5/21/98

Task ■ Milestone ◆ Summary

Figure 1-1. Master schedule of Workplan activities by fiscal year.

Table 1-1. Resources

ID	Task Name	Estimated Funding Requirement[1]	Estimate Detail
1	ER PROJECT ACTIVITES		
2	Field Unit 1	$82,629,000	ER Characterization activities for OUs 1071, 1078, 1079, 1106, 1114, 1136
3	Field Unit 2	$10,852,000	ER Characterization activities for OUs 1085, 1086, 1093, 1100, 1130, 1132
4	Field Unit 3	$25,829,000	ER Characterization activities for OUs 1082, 1122, 1140
5	Field Unit 4	$62,242,000	ER Characterization activities for OUs 1049, 1098, 1129
6	Drill and Sample Well R-9	$640,870	Construction and completion only
7	Drill and Sample Well R-12	$824,102	Construction and completion only
8	Drill and Sample Well R-7	$878,591	Construction and completion only
9	Drill and Sample Well R-22	$839,707	Construction and completion only
10	Drill and Sample Well R-18	$900.232	Construction and completion only
11	Drill and Sample Well R-3	$726,880	Construction and completion only
12	Drill and Sample Well R-15	$804,172	Construction and completion only
13	Drill and Sample Well R-27	$760,299	Construction and completion only
14	Drill and Sample Well R-10	$801,908	Construction and completion only
15	Drill and Sample Well R-4	$679,465	Construction and completion only
16	Drill and Sample Well R-13	$888,222	Construction and completion only
17	Drill and Sample Well R-19	$803,061	Construction and completion only
18	Drill and Sample Well R-17	$870,740	Construction and completion only
19	Drill and Sample Well R-23	$698,940	Construction and completion only
20	Other Characterization Activities	57,518,658	
21	Field Unit 5	$81,356,000	Characterization activities for OUs 1111, 1144, 1147, 1148, 1154, 1157
22	Drill and Sample Well R-21	$785,519	Construction and completion only
23	Drill and Sample Well R-30	$868,959	Construction and completion only
24	Other Characterization Activities		
25	D&D Activities	$59,572,000	Decontamination and Decommission for OUs 1082, 1106, 1122, 1129
26	NWT PROGRAM ACTIVITIES		
27	Drill and Sample Well R-25	$1,052,152	Well completion cost, oversight crew, analytical costs, access improvements, and miscellaneous equipment
28	Drill and Sample Well R-5	$769,142	Well completion cost, oversight crew, analytical costs, access improvements, and miscellaneous equipment
29	Drill and Sample Well R-31	$697,575	Well completion cost, oversight crew, analytical costs, access improvements, and miscellaneous equipment
30	Drill and Sample Well R-28	$929,079	Well completion cost, oversight crew, analytical costs, access improvements, and miscellaneous equipment
31	Drill and Sample Well R-32	$828,228	Well completion cost, oversight crew, analytical costs, access improvements, and miscellaneous equipment
32	Drill and Sample Well R-2	$884,799	Well completion cost, oversight crew, analytical costs, access improvements, and miscellaneous equipment
33	Drill and Sample Well R-1	$1,019,834	Well completion cost, oversight crew, analytical costs, access improvements, and miscellaneous equipment
34	Drill and Sample Well R-8	$846,665	Well completion cost, oversight crew, analytical costs, access improvements, and miscellaneous equipment
35	Drill and Sample Well R-20	$734,197	Well completion cost, oversight crew, analytical costs, access improvements, and miscellaneous equipment
36	Drill and Sample Well R-14	$1,008,281	Well completion cost, oversight crew, analytical costs, access improvements, and miscellaneous equipment

Table 1-1. Resources (continued)

ID	Task Name	Estimated Funding Requirement[1]	Estimate Detail
37	Drill and Sample Well R-6	$880,571	Well completion cost, oversight crew, analytical costs, access improvements, and miscellaneous equipment
38	Drill and Sample Well R-11	$682,347	Well completion cost, oversight crew, analytical costs, access improvements, and miscellaneous equipment
39	Drill and Sample Well R-24	$764,104	Well completion cost, oversight crew, analytical costs, access improvements, and miscellaneous equipment
40	Drill and Sample Well R-26	$704,089	Well completion cost, oversight crew, analytical costs, access improvements, and miscellaneous equipment
41	Drill and Sample Well R-29	$586,922	Well completion cost, oversight crew, analytical costs, access improvements, and miscellaneous equipment
42	Drill and Sample Well R-16	$759,808	Well completion cost, oversight crew, analytical costs, access improvements, and miscellaneous equipment
43	Drill and Sample Well R-28d	$2,561,875	Well completion cost, oversight crew, analytical costs, access improvements, and miscellaneous equipment
44	Drill and Sample Well R-1d	$2,332,800	Well completion cost, oversight crew, analytical costs, access improvements, and miscellaneous equipment
45	MANAGEMENT ACTIVITIES AND INFORMATION INTERPRETATION		
----	Annual Groundwater Status Report Preparation		
----	Annual NMED Negotiation Meeting		
64	ADDITIONAL ACTIVITIES		
65	Maintain Central Database		
66	Maintain Core Storage Facility		
67	**Develop Geologic Model**		
----	Compile and publish drilling and completion data from all significant boreholes		
----	Stratigraphic Modeling-Perform comprehensive review of 3-D stratigraphy and develop a 3-D stratigraphy database		
----	Salvage data from stratigraphic and geochemical analysis of available canyon bottom core samples		
68	**Develop Hydrologic Model**		
----	Compile and publish hydraulic characteristics data including Bandelier Tuff moisture retention characteristics, determination of vadose zone fluxes, and estimation of hydraulic parameters		
----	Consolidate historic water quality data and evaluate variations, trends and vertical stratification		
----	Inventory springs on-site and near boundary		
----	Long-term water balance		
----	Groundwater flow model using FEHM code		
69	**Develop Geochemical Model**		
----	Hydrogeochemical and statistical evaluation of solute distributions on natural surface and groundwaters		
----	Geochemical characteristics of key subsurface units		
----	Geochemical Modeling		

[1] Costs are from the 100% CDR well construction estimates (LANL, 1997).

Information provided in later sections of this Workplan details the rationale for the proposed 51 alluvial wells, 32 regional aquifer wells[1], and one intermediate perched zone well identified for installation through application of the DQO process. Each of the 32 regional aquifer wells, in particular, were scored utilizing a set of criteria (Appendix 5) to assess the optimum sequence of installation. As new data become available and are evaluated, the sequence of installation can be revised through consultation with DOE and regulatory agencies as discussed further below.

Three of the regional aquifer wells (see below) are committed to in FY98. All wells proposed to be installed subsequent to the first year are contingent on data obtained from previously-advanced boreholes and on the annual regulatory renegotiation of the Workplan scope and schedule. This annual Laboratory/DOE/NMED review, reassessment, and renegotiation is proposed to occur in March of each calendar year that the Workplan is in force. The first annual renegotiation meeting with the NMED will occur in March, 1998. The Laboratory will be responsible for scheduling this annual meeting. Further details regarding this approach are provided in Section 4.1 of this Workplan.

Between November 1996 and October 1998, three regional aquifer wells listed below are proposed for installation pursuant to this approach.

Well Number	Year	Location
R-9	FY 98	Los Alamos Canyon at eastern boundary of Laboratory
R-12	FY 98	Sandia Canyon at eastern boundary of Laboratory
R-25	FY 98	Cañon de Valle near MDA P

During this timeframe, the ER Project will continue to install alluvial wells and characterize subsurface contamination pursuant to individual RFI workplan commitments.

1.4 Program Integration

The Laboratory has a number of on-going programs and projects that collect data that can be used to refine the conceptual hydrogeologic model including environmental restoration, environmental surveillance, waste management, environmental permitting, and National Environmental Protection Act (NEPA) projects and programs. Implicit in this Hydrogeologic Workplan is the integration of the data collection activities of these projects. This Workplan does not replace plans or specifications associated with individual programs, but establishes a framework that recognizes data necessary for groundwater characterization and identifies programs as sources for those data needs. Data needed for groundwater characterization that is not currently being generated or planned by other programs is detailed in this Workplan. However, all of the data needs listed in the DQO Process outputs (Appendix 4) will be used to make decisions regardless of program or activity.

Two critical steps have been taken by the Laboratory to ensure effective program integration. The first step is the formation of the Groundwater Integration Team (GIT). The GIT consists of earth science specialists from the major programs at the Laboratory that involve groundwater. The GIT will serve an integrating function by coordinating the activities in this Workplan to meet the needs of all programs. The GIT will oversee the Workplan's implementation schedule, and derive a Laboratory-wide agreement on data interpretation and proposed revisions to the conceptual models. The GIT will track deliverables and activities, and serve as the primary group for interpreting site-specific information from a Laboratory-wide context. The GIT is further described in Section 4.1 of this plan.

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[1] Extensive hydrogeologic characterization information will be collected in any intermediate perched zone encountered during advancement of the regional aquifer well boreholes.

The second step is the assignment of the Monitoring Well Installation Project (MWIP) construction management to the ER Project with technical participation and oversight by the Water Quality and Hydrology Group (ESH-18). Thus a single project is responsible for collecting the data, analyzing the data, and providing the data to the decision-makers. The GIT will provide guidance to the ER Project in implementing these activities. This organization will provide added assurance that data is collected in a consistent manner.

This Hydrogeologic Workplan is intended to provide a general description of the groundwater characterization activities for the Laboratory as a whole. As more detailed RCRA Facility Investigation (RFI) Workplans are prepared as a result of ER Project investigations, the activities will be refined for specific aggregates. For example, the canyon-specific workplans that currently exist are based on extensive research and compilation of existing data that was beyond the scope of this Hydrogeologic Workplan. Knowledge gained during the development of the canyon-specific workplans will be used to modify information in the Hydrogeologic Workplan in terms of well locations, types of wells, depths, and sampling and coring intervals. The final well locations will be selected by balancing several concerns including physical access, administrative access, presence of threatened or endangered species, and Laboratory operations. A Field Implementation Plan that includes a drilling plan will be prepared for each regional well that may further modify the drilling and sampling activities described in this Workplan and the canyon-specific workplans. The individual drilling plans will include specifications for drilling, sampling, logging, construction, and well completion.

This hierarchy of increasingly specific documents provides the flexibility to respond to expected conditions on a well-by-well basis. Refinements to the activities described in the Hydrogeologic Workplan via the canyon-specific workplans and the well-specific drilling plans will be discussed at the quarterly and annual meetings. The discussions and agreements made during the annual meetings will be summarized in an annual addendum that will be distributed to the Hydrogeologic Workplan distribution list.

1.5 Background Issues

1.5.1 Groundwater Protection Management Program Plan

On March 6, 1995 the Laboratory issued a draft Groundwater Protection Management Program Plan (GWPMPP) for review and approval by DOE. Subsequently, the GWPMPP was revised and resubmitted to DOE on January 31, 1996. On March 15, 1996 DOE's Albuquerque Operations Office approved the GWPMPP (LANL, 1996a) pursuant to DOE Order 5400.1.

The GWPMPP provides a detailed framework for consolidating and coordinating groundwater protection activities at the Laboratory. The GWPMPP addresses the following issues concerning the groundwater resource at the Laboratory: (1) hydrogeologic characterization; (2) potential contamination; (3) groundwater monitoring network; (4) water supply; (5) information management; (6) quality assurance; and (7) regulatory compliance. To address these issues, hydrogeologists, geologists, and consultants, as well as representatives of NMED and the EPA, have examined the issues and have recommended technical and managerial approaches to address them, as they pertain to Laboratory operations.

Laboratory hydrogeologists do not have, at present, adequate information to characterize the hydrogeology of the region or the potential movement of contaminants from the Laboratory's operational areas (i.e. TAs) to the extent necessary to address the requirements and to fulfill commitments to groundwater protection. The principal source of the inadequacy stems from the fact that the existing network of monitoring wells is insufficient in number and location. The primary solution to this problem, therefore, should be to expand the current groundwater monitoring network. By increasing the number of boreholes and by installing wells at selected locations across the Pajarito Plateau, hydrogeologists will be able to collect sufficient data to provide the characterization required.

The GWPMPP serves as a Laboratory precursor and driver for the development of this Hydrogeologic Workplan. The GWPMPP issue of "hydrogeologic characterization" is addressed by this Workplan. The GWPMPP describes this issue with the following language:

> An ..."issue concerning the regional aquifer is the lack of hydrogeologic data. Not enough wells are completed to the regional aquifer to understand local and regional hydrogeologic properties. The depth and continuity of the regional aquifer is not well understood. Also, information is not available on the vertical stratification of the aquifer materials. Studies of the storage and transmissivity of the aquifer, as well as the physical characteristics of aquifer materials, need to be performed."

In addition to the GWPMPP, the Laboratory has received letters from the NMED which provide further impetus to create this Workplan. Specifically, DOE/Los Alamos Area Office (LAAO) received a letter dated May 30, 1995 from NMED denying the Laboratory's groundwater monitoring waiver requests. A second letter received by DOE/LAAO August 17, 1995 contained NMED comments and concerns regarding groundwater contamination and protection at the Laboratory, and required development of this Workplan. The two NMED letters are described in further detail in the following sections. Copies of these two key letters are provided in Appendix 1 and Appendix 2.

1.5.2 NMED Correspondence: May 30, 1995

NMED's letter of May 30, 1995 responds to correspondence during the late 1980's and early 1990's in which the Laboratory submitted documentation to support requests for waivers of groundwater monitoring requirements under RCRA. In response, NMED opined that the information provided did not fulfill the groundwater monitoring standards at 40 CFR 265. This was the basis for denial of the requests. The letter stated:

> "Los Alamos National Laboratory (LANL) has provided inadequate and incomplete information pertaining to the unsaturated and saturated conditions across the Pajarito Plateau in support of ground-water monitoring waivers for the various RCRA-regulated units (TA-54 Area G & L, TA-16 Surface Impoundment & Area P Landfill, TA-35-125 & 85 Surface Impoundments, and TA-53 Surface Impoundments). Basic geology, hydrogeology, and pathways for contaminant transport have not been adequately addressed to date."

The letter stated further:

> "Because these demonstrations, have not met the technical standards necessary for approval of ground-water monitoring waivers at the sites listed above, ground-water monitoring program plans will be required for LANL to be in compliance with 20 NMAC Subpart VI, 40 CFR 265 Subpart F regulations."

> "Although NMED does not relinquish any of New Mexico's regulatory or statutory authorities, these denials do not require immediate submittal of ground-water monitoring program plans for each closure. Instead, in light of DOE/LANL's budgetary constraints, a comprehensive ground-water monitoring program plan should be developed which addresses both site-specific and site-wide ground-water monitoring objectives. This may be achieved by modifying the existing site-wide Groundwater Protection Management Program Plan, Revision 1.0, March 6, 1995 to include regulatory site-specific considerations. NMED intends to coordinate with DOE/LANL in this site-wide approach."

The revisions to the GWPMPP were submitted as Revision 2.0 in October, 1995 (LANL, 1995c).

1.5.3 NMED Correspondence: August 17, 1995

NMED's letter dated August 17, 1995 expressed concerns over groundwater contamination and protection at the Laboratory as a result of an assessment of the Laboratory's groundwater protection program by the

NMED's DOE Oversight Bureau and Hazardous and Radioactive Material Bureau. The letter reiterated that basic geology, hydrogeology, and pathways for contaminant transport have not been adequately addressed to date, and listed four issues and questions that were deemed by NMED to be unresolved.

> "Individual zones of saturation beneath LANL have not been adequately delineated, and the "hydraulic interconnection" between these is not understood. A facility-wide description of the hydrogeologic characteristics affecting ground-water flow beneath the facility cannot be made without adequate delineation of the perched-intermediate aquifer(s) beneath LANL.
>
> The recharge area(s) for the main and perched-intermediate aquifers have not been identified. It is unknown at this time if any significant quantity of water is recharging the main aquifer through fracture-fault zones which occur on the Pajarito Plateau. Characterization of these site-wide fault zones as potential pathways for aqueous migration is not complete. It is unknown what effect, if any, these zones may have on the direction of ground-water flow and hydraulic gradient of the main and perched-intermediate aquifers.
>
> The ground-water flow direction(s) of the main aquifer and perched-intermediate aquifer(s), as influenced by pumping of production wells are unknown.
>
> Aquifer characteristics cannot be determined without additional monitoring wells installed within specific intervals of the various aquifers beneath the facility. Location of wells designed for aquifer testing cannot be addressed adequately without delineation of individual zones of saturation beneath LANL."

Addressing these four issues was a primary concern in preparing this Workplan. In particular, as prospective hydrogeologic data collection activities were defined, criteria for scheduling well construction were applied that emphasized these issues. These criteria are discussed in detail in Section 4.1 of this Workplan.

The letter further stated that NMED was evaluating work to be conducted to assure compliance with both the hydrogeologic requirements of the HSWA Module of the Laboratory's RCRA operating permit (EPA, 1990) and the requirements for groundwater monitoring of RCRA regulated units (A letter from NMED providing this evaluation was received in August, 1996). The August 17, 1995 letter stated the following determination:

> "...a RCRA site-wide hydrogeologic Workplan should be developed and submitted to NMED and EPA for review and approval. A site-wide hydrogeologic Workplan developed under the driver of RCRA will provide a mechanism to assure a compliance schedule with specific tasks to meet the permit objectives. The Workplan should address both the HSWA hydrogeologic permit requirements and RCRA regulatory ground-water monitoring requirements."

This determination by NMED is the primary driver for preparation of this Workplan.

1.5.4 HSWA Module VIII of the Laboratory's RCRA Operating Permit

HSWA Module VIII of the Laboratory's RCRA operating permit (EPA 1990) establishes conditions for: the management of newly generated hazardous waste treatment and storage units; waste minimization; land disposal restrictions; the scope of work for RCRA Facility Investigations (RFIs); and corrective actions at solid waste management units. The requirements of the Facility Investigation task (Task III of the RFI scope of work) for detailed information regarding the hydrogeology of the Laboratory are extensive as discussed briefly below. Generally, the Facility Investigation task requires that the permittee: collect information to supplement and verify existing information on the environmental setting at the facility; collect analytical data to completely characterize wastes and areas where wastes have been placed; and collect analytical data on groundwater, soils, surface water, sediments, and subsurface gas contamination to characterize contamination.

Specifically, Task III, Section A.1 requires a program to evaluate hydrogeologic conditions and to provide the following information:

- A description of regional and facility specific geologic and hydrogeologic characteristics affecting groundwater flow beneath the facility;
- An analysis of any topographic features that might influence the groundwater flow system;
- An analysis of fractures within the tuff, addressing tectonic trend fractures versus cooling fractures;
- Based on field data, test, and cores, a representative and accurate classification and description of the hydrogeologic units which may be part of the migration pathways at the facility (e.g., the aquifers and any intervening saturated and unsaturated units);
- Based on field studies and cores, structural geology and hydrogeologic cross sections showing the extent (depth, thickness, lateral extent) of hydrogeologic units which may be part of the migration pathways identifying (1) unconsolidated sand and gravel deposits, (2) zones of fracturing or channeling in consolidated or unconsolidated deposits, and (3) zones of high permeability or low permeability that might direct and restrict flow of contaminants;
- Based on data obtained from groundwater monitoring wells and piezometers installed upgradient and downgradient of the potential contaminant source, a representative description of water level or fluid pressure monitoring;
- A description of manmade influences that may affect the hydrogeology of the site; and
- Analysis of available geophysical information and remote sensing information such as infrared photography and Landsat imagery.

Further, Task III, Section A.2 requires a program to characterize soil conditions above the water table in the vicinity of a contaminant release, providing numerous specific measurements of soil physical, hydraulic, and chemical properties, and contaminant concentrations.

Task III, Section C.1 requires a groundwater investigation to characterize any plumes of contamination at the facility. This investigation must include the collection of sufficient data to define:

- A description of the extent of contamination;
- Rate and direction of contaminant movement;
- Concentration profiles of applicable constituents and radiochemical constituents in the plume;
- An evaluation of factors influencing plume migration, and
- An extrapolation of future contaminant movement.

Task III, Section C.2 requires an investigation characterizing the contamination of the soil above the water table in order to provide:

- A description of the extent of contamination;
- A description of contaminant and soil chemical properties within the contaminant source area and plume migration and transformation;
- Specific contaminant concentrations;
- Rate and direction of contaminant movement; and
- Worst case scenarios for future contaminant movement over the life of the contaminant.

1.5.5 Other Requirements

In addition to the HSWA Module VIII requirements, numerous federal and state requirements are relevant to groundwater protection, groundwater monitoring, and hydrogeologic characterization. For example, DOE Order 5400.1 Environmental Protection, and the New Mexico Water Quality Control Commission Regulations (WQCC) both address groundwater characterization, monitoring, and protection. These two examples, as well as other relevant federal and state requirements have been technically considered in the preparation of this Workplan.

The structured groundwater monitoring requirements applied to regulated units under RCRA are prescriptive[2]. The New Mexico Annotated Code, Title 20, Chapter 4, Part 1 (20 NMAC 4.1) Subpart VI, Sections 264.91-100 establish three progressive monitoring programs that, unless a demonstration can be made that no potential for migration of liquid from the regulated unit to the uppermost aquifer exists, may be necessary to implement for detecting and addressing releases to groundwater. To adequately establish a monitoring network under any of these programs, it is necessary to characterize the subsurface (including groundwater) in a comprehensive manner.

It is the DOE and UC's intention to perform characterization activities set forth in this Workplan to ensure that information is gathered sufficient either to demonstrate an adequate groundwater monitoring waiver or to provide for the installation of a detection monitoring network (or both, as appropriate). If it is determined to be necessary, repetitive monitoring described in any of the three progressive monitoring programs will be performed outside the scope of this plan.

1.6 Groundwater Protection Strategy

The Laboratory has developed a Groundwater Protection Strategy (Strategy) [Appendix 3] to provide a basis and direction for groundwater protection, and to serve as a guide for the development of this Workplan. The goal of the Strategy is to describe a dynamic approach to protecting the groundwater resource from unacceptable impacts resulting from past, present, and future Laboratory operations. Fundamental to the Strategy is the utilization and development of four major sources of monitoring and characterization information at the Laboratory.

The first source encompasses all existing hydrogeologic and geochemical information accumulated from past studies and the Laboratory's existing ground and surface water monitoring network. The second is the ER Project's characterization and assessment of Potential Release Sites (PRSs) on a site-specific basis, including investigations of the canyons which will provide information regarding the Laboratory's vadose zone and evaluations of saturated systems associated with PRSs. A third source will be the proposed installation of wells that will be used to characterize and define the Laboratory's basic hydrogeologic setting by providing geologic, geochemical, and hydrologic information (e.g. data from borehole core samples, geophysical logs, aquifer tests, water quality analyses, and information regarding depth to and flow direction of the regional aquifer). The fourth source involves the installation of regional aquifer

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[2] Following examination of relevant regulations, DOE and UC have determined that, depending on the status of the units in question, different groundwater monitoring requirements could apply. Specifically, in New mexico Annotated Code, Title 20, chapter 4, Part 1 (20 NMAC 4.1) Subpart VI, 264.90, a distinction is made between regulated units (those surface impoundments, landfills, land treatment units, and waste piles that have received hazardous waste after July 26, 1982), and other solid waste management units (SWMUs). Regulated units are subject to 264.91 - 100 requiring, in many cases, groundwater monitoring. (However, a Subpart X unit, while it does not meet the definition of a surface impoundmant, landfill, land treatment unit, or waste pile, can also be subject to 264.91 - 100 if it potentially impacts groundwater -- otherwise 264.101 applies). In contrast, no formal monitoring requirements are established in 264.101 for SWMUs that are not regulated units. Although monitoring may be a component of remediation, no automatic monitoring requirements are triggered by 264.101. Instead, actions pursuant to 264.101 are driven by the occurrence of an actual release for which a threat to human health and the environment has been established and corrective action is necessary.

wells and intermediate perched zone wells (if appropriate) downgradient from large geographic areas of the Laboratory which have historically hosted major Laboratory operations and activities, i.e. large aggregates of PRSs, which will provide long-term water quality monitoring.

The Strategy is intended to protect groundwater to sustain uses which the water can support by applying regulatory standards for groundwater quality appropriate to protecting the particular beneficial use. The selected standards establish a baseline for monitoring to determine whether the standards are, or are likely to be, exceeded as a result of Laboratory activities. Groundwater from the regional aquifer serves many beneficial uses (e.g. potable water supply, irrigation, livestock and wildlife watering). In general, the Strategy seeks to place the highest priority on the protection of all groundwater and, in particular, groundwater of the regional aquifer because of its beneficial use as a source of drinking water. The regional aquifer also contributes flow via springs and seeps into New Mexico surface waters, e.g. the Rio Grande, which also has incumbent beneficial uses and water quality standards, as designated by the WQCC. Every effort has been made to integrate the groundwater protection strategy with the Laboratory's surface water protection strategy. Therefore, the Strategy also applies appropriate surface water quality standards to those relevant surface waters influenced by groundwater discharge.

According to the Strategy, RCRA concentration limits, as provided under 40 CFR 264.94 will be established as they apply to groundwater and surface water influenced by groundwater discharge. These concentration limits will be established based on either background levels of a constituent or, if applicable, from the constituent limit appearing in Table 1 of 40 CFR 264.94 (a)(2). Background levels will be determined from various sources e.g. historical data, existing or new wells. If neither of these methods of establishing a constituent limit is appropriate, the Laboratory may propose an Alternative Concentration Limit (ACL) to NMED and, if established by the NMED, the ACL will be applied. In proposing ACLs, the Laboratory intends to use the maximum concentration limits (MCLs) contained in the following regulations and standards, as appropriate, for the specific water use to be protected:

- National Primary Drinking Water Regulations (40 CFR 141);
- National Secondary Drinking Water Regulations (40 CFR 143);
- New Mexico Environmental Improvement Board (NMEIB) Drinking Water Regulations (20 NMAC 7.1);
- WQCC Groundwater Standards (20 NMAC 6.2, Subpart III, 3103);
- WQCC Standards for Interstate and Intrastate Streams (20 NMAC 6.1, Subpart I);
- WQCC Abatement Standards and Requirements (20 NMAC 6.2, Subpart IV, 4103);
- San Ildefonso Pueblo (proposed) Water Quality Standards; and
- Cochiti Pueblo Water Quality Standards.

The intent of the Strategy is to select the most protective standards from various applicable regulatory standards, based on groundwater uses and the degree of interconnection between water-bearing zones, and to apply those standards for monitoring and risk assessment. The strategy describes the application of regulatory standards to three groundwater zones known to be present at the Laboratory -- uppermost subsurface water (including alluvial groundwater); intermediate perched zone groundwater; and regional aquifer groundwater.

The Strategy relies on the RFI process employed by the ER Project as the preferred methodology to assess risks to human health and the environment. The RFI process entails the following steps: (1) collect and evaluate available data; (2) plan and conduct additional investigations; (3) assess risks to human health and the environment; (4) propose a remedy, if necessary; and (5) implement the remedy, if necessary. This process can end at any step that a remedy, if needed, becomes obvious or when there is no need for further action.

The Strategy contains several technical definitions of terminology which should be repeated here as they apply to this Workplan as well. The hydrogeologic zone between the mesa tops and the top of the regional aquifer is a vadose zone, which is defined as "the geological profile extending from the ground surface to the upper surface of the principal water bearing formation. The term groundwater is defined as: interstitial water which occurs in saturated earth material and which is capable of entering a well in sufficient amounts to be utilized as a water supply. The term subsurface water is defined as groundwater and water in the vadose zone that may become groundwater or surface water in the reasonably foreseeable future or may be utilized by vegetation.

The term groundwater is used in this Workplan in accordance with the definition, but use of the term herein does not imply that the groundwater-bearing zone being discussed has sufficient capacity or seasonal persistence to provide a reliable water supply for even a single household.

1.7 Data Quality Objectives Process

In preparing this Workplan, the Laboratory utilized the EPA DQO Process (EPA, 1987), a strategic planning approach used to prepare for a data collection activity. By using the DQO Process, the Laboratory has assured that the type, quantity, and quality of hydrogeologic data used in decision-making will be appropriate to meet the primary objective to characterize the hydrogeologic setting at the Laboratory.

The DQO Process consists of seven (7) steps, as shown in Figure 1-2. The output from each step influences the choices that will be made later in the Process. Even though the DQO Process is illustrated as a linear sequence of steps, in practice it is iterative; the outputs from one step may lead to reconsideration of prior steps.

From January through July, 1996 the Laboratory utilized the DQO Process to develop the activities enumerated in this Workplan. At the onset, the Laboratory developed four basic hydrogeologic scenarios to aid the identification of decisions to be made. The scenarios included: (1) a canyon underlain by a regional aquifer with both intermediate perched zone groundwater and alluvial groundwater above it; (2) a canyon underlain by a regional aquifer; (3) a mesa underlain by a regional aquifer with intermediate perched zone groundwater above it; and (4) a mesa underlain by a regional aquifer. Each of these scenarios was analyzed to develop a set of basic decisions that must be made regarding their hydrogeologic characterization.

Ultimately, the scenarios were reduced to two representing canyons and mesas, with their incumbent underlying hydrogeologic setting.

The following decisions were developed for the two scenarios.

Canyon Scenario

1. Are the alluvial groundwaters and uppermost subsurface waters from various present and legacy sources at contaminant concentrations greater than some regulatory limit or risk level?
2. Is the intermediate perched zone groundwater underlying the alluvial groundwater and uppermost subsurface water at contaminant concentrations greater than some regulatory limit or risk level?
3. Is the regional aquifer, as affected by the canyon systems, impacted by contaminant concentrations greater than some regulatory limit or risk level?
4. What are the pathways for exposure to contaminants from alluvial groundwater and the uppermost subsurface water?

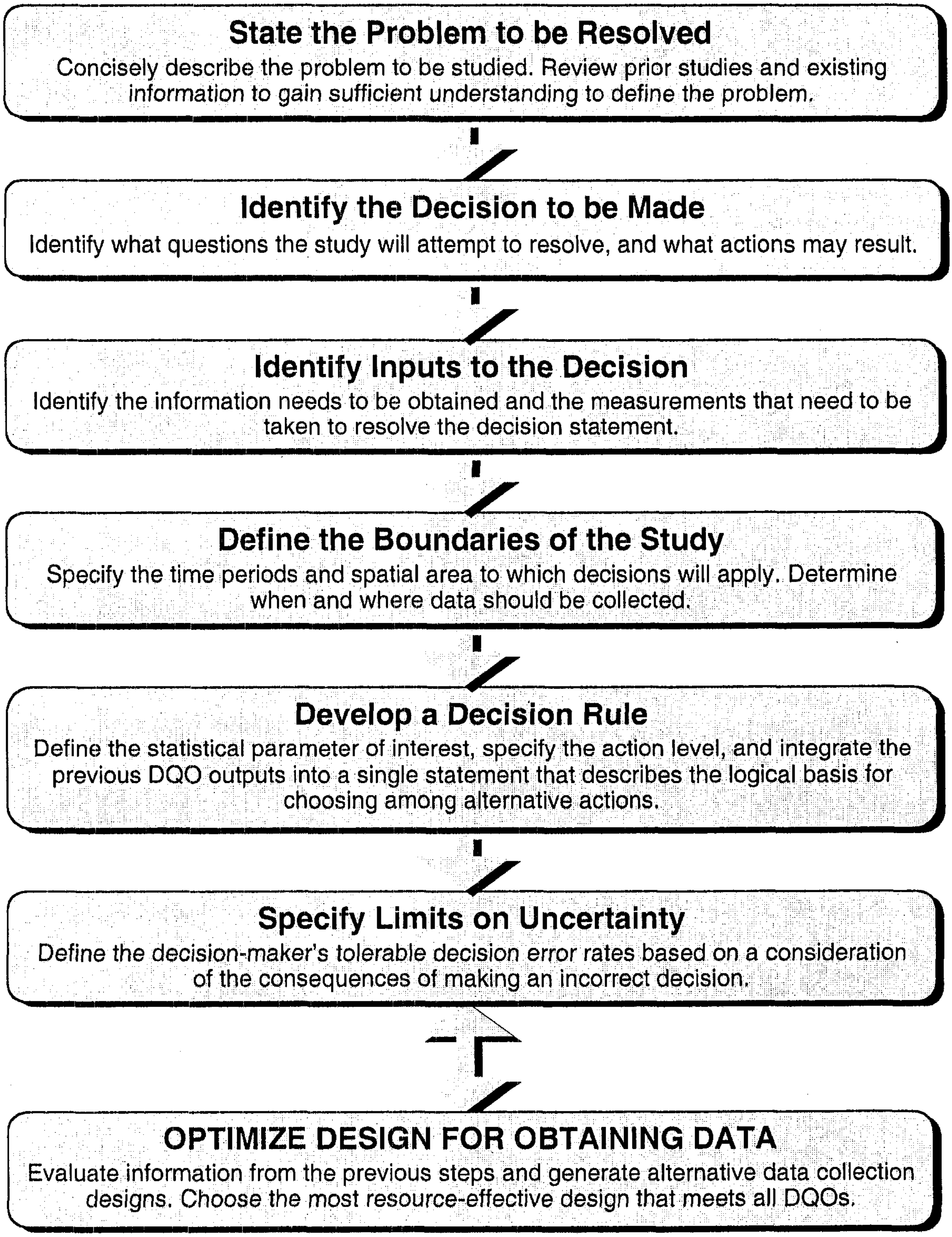


Figure 1-2. Data Quality Objectives Process.

Mesa Scenarios

1. Are the soils/tuff or uppermost subsurface water from various present and legacy sources at contaminant concentrations greater than some regulatory limit or risk level?
2. Is the regional aquifer or an underlying intermediate perched zone, as potentially affected by a present or legacy source, predicted to be impacted by contaminant concentrations greater than some regulatory standard or risk level using a conservative model?
3. What are the pathways for exposure to contaminants from soil/tuff and water in the uppermost subsurface waters?

After assembling the decisions, the Laboratory worked through the DQO Process applying these decisions to the canyons and mesas within the geographical boundary of the Laboratory. Each decision has several subordinate questions that require some data to answer. The decisions cannot be resolved until data sufficient to answer each subordinate question are available. For example, for canyon scenario decision 1: "Are there pathways for exposure to contaminants from alluvial sediments and uppermost subsurface water?" the subordinate questions are:

- "Does significant recharge occur from near surface to underlying groundwater bodies?
- Do we know the hydraulic properties of the alluvium?
- What are the retardation factors of alluvial sediments?
- Do we understand groundwater movement from alluvial water to intermediate perched zones?
- Do we understand groundwater movement from intermediate perched zones to regional aquifer?
- Are fractures and faults important contaminant transport pathways for liquids in canyons?"

Figure 1-3 illustrates the generalized groundwater protection decision flow logic. On the left side of the diagram are a series of decision diamonds that are used to determine whether groundwater currently exceeds standards. On the right side of the diagram are decision diamonds that establish whether pathways exist that may allow contamination to occur in the future. If source terms and pathways exist, then remedial actions are required. The pathways decision shown in Figure 1-3 are incorporated in the DQO process as a decision and subordinate questions that must be answered to resolve the decision in each aggregate. Because the DQO process is iterative, the reader should note that the collection of additional data will cause the process to begin again as that additional data becomes "existing data". Additionally, negative answers to any of the three major decision diamonds on the left side of the diagram lead to the decision diamond regarding the presence of pathways for exposure to contaminants. The complete output from the DQO process is contained in Appendix 4.

The Laboratory was divided into nine study areas: one regional (e.g., site-wide) area and eight specific areas called "aggregates." This division, or categorization, allows the following question (DQO process decision) to be asked of each study area:

> "Based on the cumulative data from Aggregate "X" characterization, and the resulting refined conceptual model, are there indications of impact from Laboratory activities that would impair beneficial use of groundwater, and require further action?"

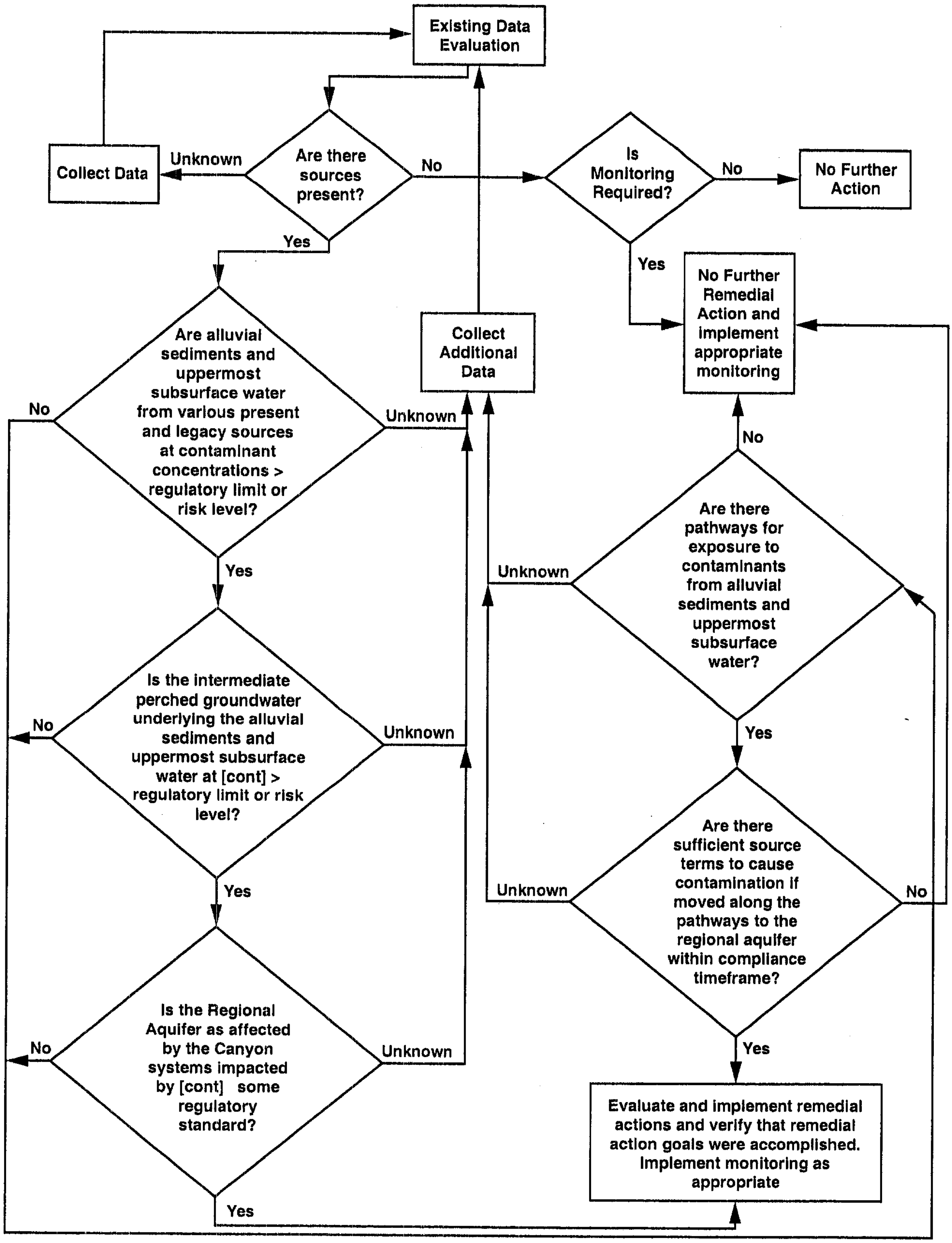


Figure 1-3. Groundwater protection decision flow diagram.

The concept of using aggregates came from the need to use resources efficiently. In general, the aggregate boundaries were drawn to encompass groups of PRSs within canyons and on adjacent mesa tops. The boundaries are proximal to geographic groupings of PRSs or areas of similar operational functions (see individual aggregate descriptions in Section 4). The utility of the aggregate approach is two-fold. First, defining aggregate boundaries facilitates assessing the cumulative impact of multiple sources on the groundwater. This avoids the pitfall of finding no groundwater impacts on a PRS-by-PRS basis, whereas the cumulative impact of the PRSs together may warrant remedial action. Assessing the cumulative impact of a group of PRSs is a more effective use of resources than attempting to assess each PRS individually, and the outcome is the same– the remediation of groundwater contamination and sources of potential groundwater contamination. Second, the aggregate approach prioritizes areas where impacts are most likely to occur, allowing efficient use of resources. To ensure that the potential impacts from PRSs located outside of aggregate boundaries are not overlooked, the entire length of each canyon and mesa have been evaluated using the DQO process. The DQO output can be found in Appendix 4.

The nine aggregates are described by the following nomenclature, distinguishing between canyons and mesas. The aggregates are illustrated on Figure 1-4.

Aggregate 1: Pueblo, Los Alamos, and Sandia Canyons, and Los Alamos and DP Mesas and Mesita de Los Alamos.

Aggregate 2: Cañada del Buey and Pajarito Canyon, and Mesita del Buey.

Aggregate 3: Frijoles Mesa.

Aggregate 4: Ancho and Chaquehui Canyons, and Un-named Mesa Top Containing TAs -33 and -39.

Aggregate 5: Cañon de Valle, Threemile Mesa, and Un-named Mesa Top Containing TA-16.

Aggregate 6: Portrillo, Fence, and Water Canyons, Threemile Mesa and Lower Frijoles Mesa.

Aggregate 7: Mortandad Canyon.

Aggregate 8: Rendija, Guaje, Barrancas, and Bayo Canyons.

Aggregate 9: Regional (e.g., site-wide)

Several of the wells proposed for installation within or around the specific aggregates are also expected to provide site-wide hydrogeologic characterization. These are discussed in detail in Section 4.2.

1.8 Technical Approach

The data needs for both the canyon and mesa scenarios include the number and quality of water-bearing zones. This plan proposes to characterize the hydrogeologic setting by drilling, logging, installing and sampling wells to the regional aquifer without installing separate intermediate depth wells. This approach provides the greatest amount of characterization data. This approach was discussed with NMED representatives at a meeting on August 7, 1996 and consensus with the approach is documented in a letter sent to NMED on September 11, 1996 (addressed to Dr. Ed Kelley, subject: The proposed Los Alamos National Laboratory Groundwater Protection Strategy and Related Data Quality Objectives and Decision Flow Process). The rationale for this approach is as follows:

- The presence of intermediate zone(s) is controlled by geologic structure and the geology across the Lab is extremely variable. Understanding the geologic setting from the surface to the regional aquifer is more important in predicting flow than measurements in individual intermediate zones.

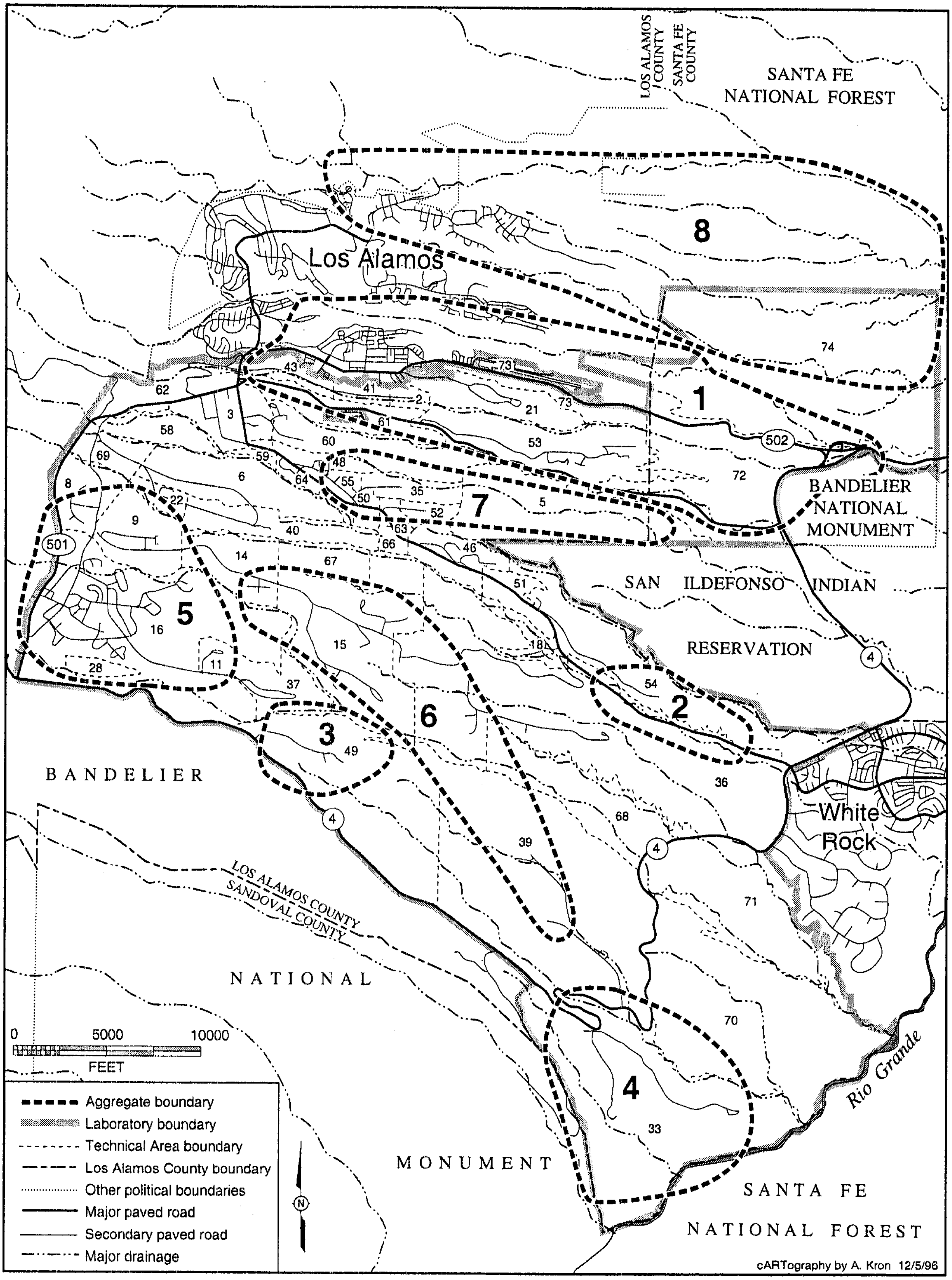


Figure 1-4. Location of aggregates.

- If a well were installed at the first intermediate zone encountered, there would be a gap in the information between the upper intermediate zone and the top of the regional aquifer. Furthermore, wells installed in the first intermediate zone will not provide any information on the underlying, less permeable perching layer. The characteristics of the perching layer must be understood in order to assess the impact to the regional aquifer. The perching layer stratigraphy is as important to evaluating potential pathways as the hydrologic characteristics of the saturated zone itself

- The data collection described in the Hydrogeologic Workplan is intended to characterize the hydrogeologic setting to a sufficient degree that an adequate detection monitoring system can be developed. Wells that may be needed to monitor the intermediate zone(s) will be considered as part of the monitoring system design.

Sampling and testing the intermediate zone within the borehole is expected to provide adequate characterization data to make decisions regarding the need to continue monitoring the intermediate zone. This is supported by data presented at the August 7, 1996 meeting with NMED. The data consists of analytical results from four wells (PO-4, POI-4, LADP-3, and LAOI-1.1) that were sampled from the borehole before the well was installed and on a quarterly basis from completed wells. The major ion chemistry and tritium analyses were in good agreement for all of the wells. Data from a fifth well, LAO-B, was presented to show the variation that can be expected in quarterly sampling from completed wells. Based on these data, adequate characterization of the intermediate zones can be accomplished by sampling within the borehole.

The information gathered during the characterization will be used to design a detection monitoring network that almost certainly will include monitoring wells in the intermediate zone. The installation of wells in intermediate perched zones will be determined in conjunction with the completion of each regional well. When the drilling of a regional well is complete such that the number and depth of intermediate perched zones are known and validated, and water quality analyses are available, the number and depth of intermediate perched zone wells will be determined. The determination process will include concurrence from NMED personnel at Quarterly and Annual Meetings.

2.0 HYDROGEOLOGIC BACKGROUND AND CONCEPTUAL MODEL

This section introduces the general hydrogeologic setting at the Laboratory and the current understanding of how the major components of the hydrogeologic system are integrated (the conceptual model). Some of the components of the current conceptual model are based on interpolation of information between widely spaced boreholes and, for that reason, there is considerable uncertainty in the conceptual model as a whole. Uncertainties in current knowledge through the conceptual model are discussed in greater detail in Section 4 of this Workplan.

2.1 General Hydrogeologic Setting

2.1.1 Geographic Setting

Los Alamos National Laboratory (the Laboratory) and the neighboring residential areas of Los Alamos and White Rock are located predominantly in Los Alamos County, north-central New Mexico, approximately 60 mi north-northeast of Albuquerque and 25 mi northwest of Santa Fe (Figure 2-1). The 43-mi^2 Laboratory site and the communities adjacent to it are situated on the Pajarito Plateau, which consists of a series of finger-like mesas separated by deep canyons containing ephemeral and intermittent streams that run from west to east. Mesa tops range in elevation from approximately 7,800 ft on the flank of the Jemez Mountains to about 6,200 ft at their eastern termination above the Rio Grande valley. The eastern margin of the plateau stands 300 to 900 ft above the Rio Grande (DOE 1979). The Department of Energy (DOE) controls the area within the Laboratory's boundaries and has the option of completely restricting access. The Laboratory is divided into Technical Areas (TAs) each of which has a specific research function or use. A TA map is provided as a transparency in Figure 2-2 so that it can be placed over the existing well maps (Figure 2-8 and Figure 2-9) and proposed well maps (Figure 4-1 and Figure 4-2) provided in the text. Two large-scale well maps showing the locations of proposed regional and alluvial wells are provided in Appendix 6 and include locations and labels for existing wells.

2.1.2 Geologic Setting

The stratigraphy and structure that comprise the Pajarito Plateau are described in this section. Other descriptions of the geologic setting, providing additional details, can be found in the Installation Work Plan for Environmental Restoration (LANL 1995e) and the draft Core Document for Operable Unit 1049, Canyons Investigations (LANL 1996b). A large-scale map of the surface geology at LANL is provided in Appendix 7. The conceptual model, which provides the most current understanding of the subsurface geology, consists of six cross sections given in Section 4 as Figure 4-9 "Pueblo Canyon", Figure 4-12 "upper Los Alamos Canyon", Figure 4-15 "Pajarito and Twomile Canyons", Figure 4-18 "Ancho Canyon", Figure 4-20 "Cañon de Valle and Water Canyon", and Figure 4-23 "Mortandad Canyon".

2.1.2.1 Bedrock Stratigraphy

The Pajarito Plateau lies on the east flank of the Jemez volcanic field and astride the active west margin of the Española basin of the Rio Grande rift (Figure 2-3). The principal bedrock units in this area (Figure 2-4) consist of, in ascending order,

1. the Santa Fe Group (4-21 Ma, Manley 1979),
2. the Puye Formation (1.7-4 Ma, Turbeville et al. 1989 and Spell et al. 1990) and interstratified volcanic rocks including the Tschicoma Formation on the west (2-7 Ma, Gardner and Goff 1984) and basalts of the Cerros del Rio on the east (2-3 Ma, Gardner and Goff 1984),
3. the Otowi Member of the Bandelier Tuff (1.613 ± 0.011 Ma, Izett and Obradovich 1994),
4. epiclastic sediments and tephras of the Cerro Toledo interval, and
5. the Tshirege Member of the Bandelier Tuff (1.223 ± 0.018 Ma, Izett and Obradovich 1994).

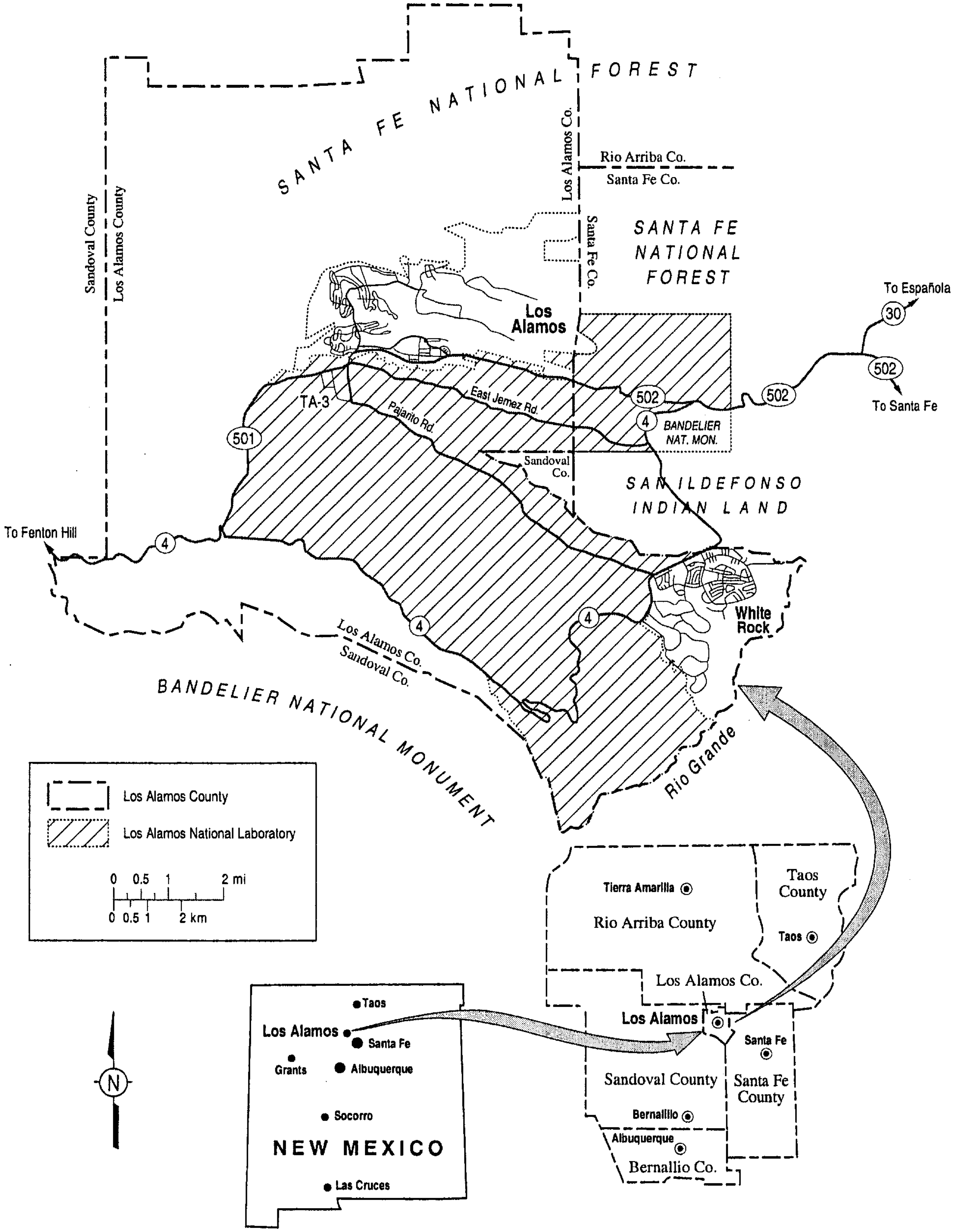


Figure 2-1. Regional location of Los Alamos National Laboratory.

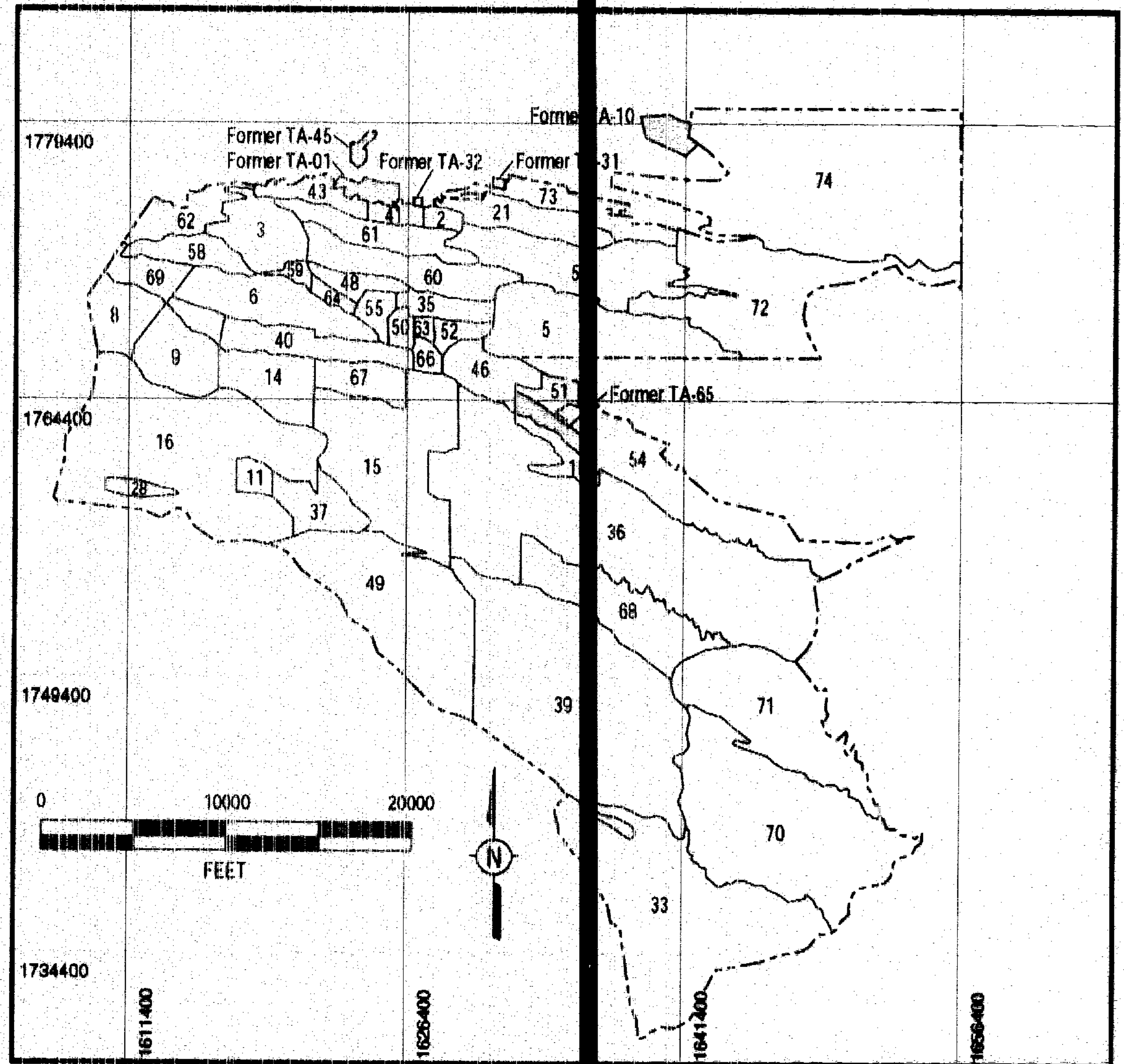


Figure 2-2. Technical areas at the Los Alamos National Laboratory.

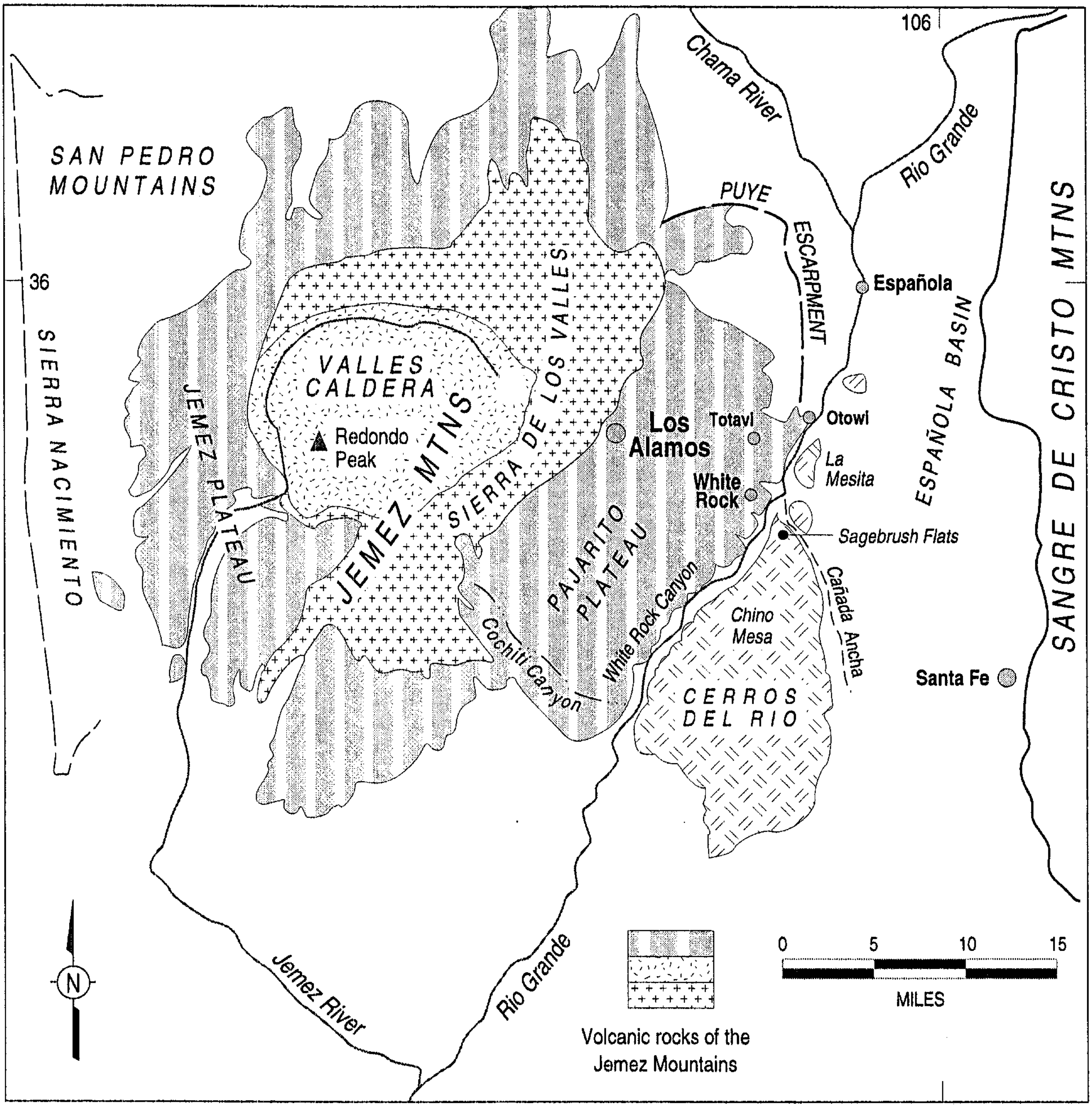


Figure 2-3. Geographic location map showing topographic features near Los Alamos and the Pajarito Plateau.

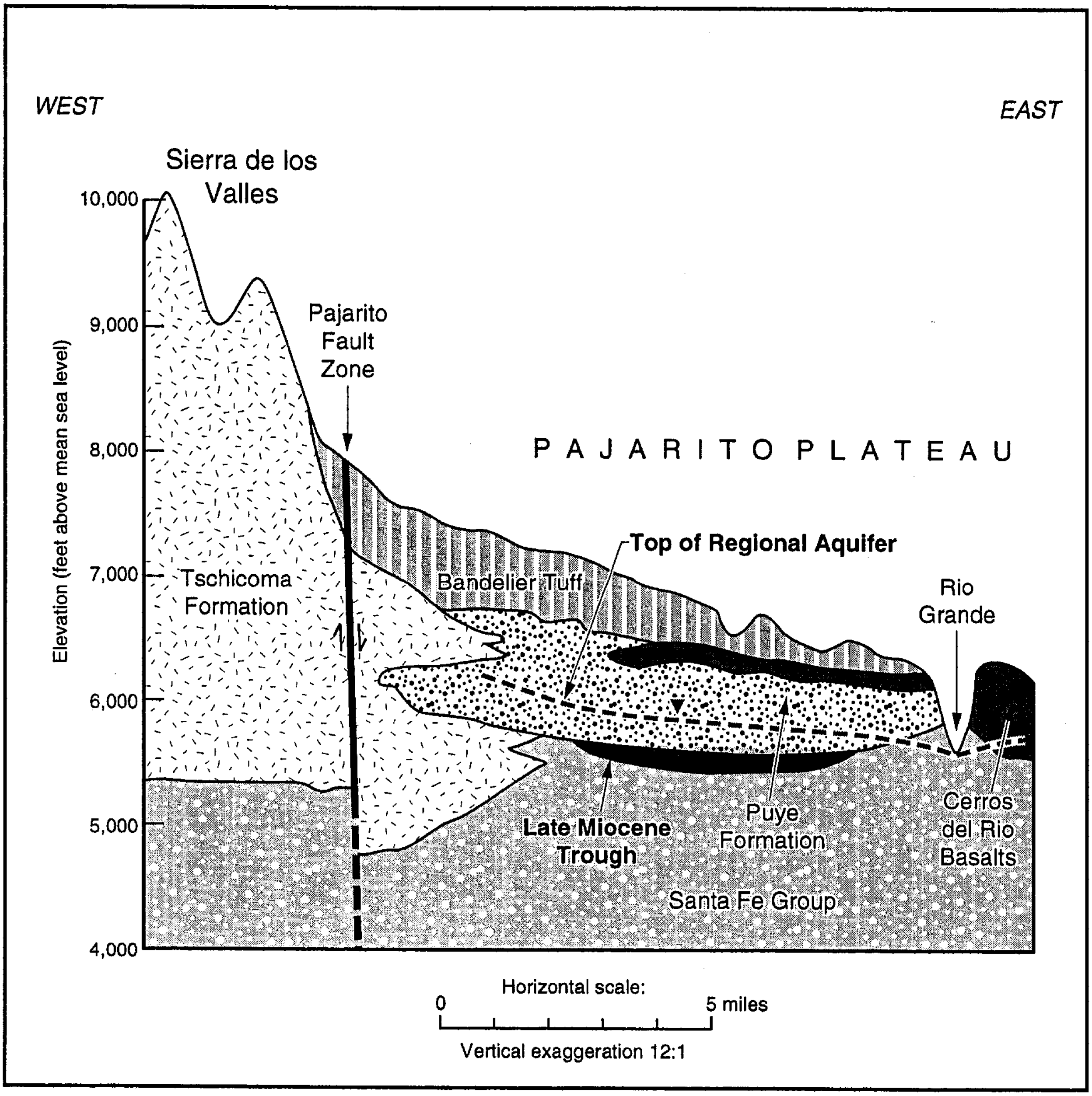


Figure 2-4. Geologic cross section across the Pajarito Plateau.

The distribution of these geologic units is shown on several geologic maps of the area (Griggs 1964; Smith et al. 1970; Kelley 1978; Rogers 1995). A brief description of the principal bedrock units is given below.

Santa Fe Group

The upper Española basin-fill includes several formations of the broadly defined Santa Fe Group. The Santa Fe Group consists of predominately fluvial, slightly consolidated sedimentary rocks that crop out in the lower reaches of Los Alamos Canyon, along White Rock Canyon, and in extensive areas east of the Rio Grande. Galusha and Blick (1971) subdivided the Santa Fe Group into formations and members based on geologic mapping and faunal assemblages of late Tertiary mammals. Manley (1979) refined their stratigraphy based on additional mapping and dates on interbedded volcanic ash layers, lava flows, and dikes. Cavazza (1989) proposed changes in stratigraphic nomenclature based on sedimentary facies pattern. In the vicinity of the Pajarito Plateau, the Santa Fe Group consists of the Tesuque Formation and overlying Chamita Formation.

The Tesuque Formation consists of poorly consolidated buff, red, or gray arkosic sand, silt, clay, pebble beds, and thin white or green ash beds derived primarily from Precambrian basement and Tertiary volcanic sources to the east and northeast of the Española basin. These clastic rocks range in age from about 21 to 7 Ma (Manley 1979; Cavazza 1989). In addition to extensive outcrops east of the Rio Grande, the Tesuque Formation is exposed on the east side of St. Peter's Dome and on the west edge of the Pajarito fault zone (southwest Pajarito Plateau). These exposures are overlain by a 13 Ma rhyolite tuff of the Keres Group, and they are interbedded with a 16.5 Ma basalt (Goff et al. 1990). In the Pojoaque area, tephras interbedded with the Tesuque Formation have ages of 14 to 9 Ma (Manley 1979). To the north in the Chili Quadrangle the Tesuque Formation is cut by dikes and interbedded with basalt flows dated at about 12 to 9 Ma (Dethier and Manley 1985). Cavazza (1989) states that the aggregate thickness of the Tesuque Formation is >2000 m and shows the unit thickening to the west.

The Chamita Formation overlies and interfingers with the Tesuque Formation. Galusha and Blick (1971) show the Chamita Formation dipping westward under the Pajarito Plateau where it is generally covered by volcanic rocks of the Jemez Mountains. Chamita deposits are believed to thicken westward under the Pajarito Plateau (Galusha and Blick 1971). Details of depositional settings and provenance of the Chamita Formation are poorly known due to lack of continuous, well-exposed outcrops. Uplift of the Española basin during the last 5 m.y. has resulted in the erosion of most of the Chamita Formation that probably covered much of the Española basin (Ingersoll et al 1990). Some workers believe the Chamita Formation represents the first evidence of southward drainage of the ancestral Rio Grande through the Española basin (John Hawley 1988, pers. comm. cited in Ingersoll et al. 1990). Galusha and Blick (1971) believe that integration of the ancestral Rio Grande as a through-going drainage post-dated deposition of the Chamita Formation. Paleomagnetic data in the type area limit the Chamita to an age range of 4.5 to 6 Ma (MacFadden 1977), and tephra dates by Manley (1979) support an age of about 5 Ma for at least part of the formation. Chamita deposits are similar in appearance to Tesuque deposits, but the former reportedly contains a larger proportion of volcanic and granitic clasts in its gravel layers (Galusha and Blick 1971) and Paleozoic limestone cobbles in its conglomerate layers (Dethier and Manley 1985). The Chamita Formation contains lithologically distinct quartzitic gravels (Galusha and Blick 1971). Upper layers of Chamita 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 Chamita from Tesuque deposits is often difficult, particularly in borehole investigations.

Griggs (1964) shows many basalt flows and flow breccias interbedded with Santa Fe Group deposits near the east side of the Pajarito Plateau. Basalt flows 12 to 200 ft thick were penetrated within the Santa Fe Group by water supply wells O-1 and O-4 (Purtymun et al. 1990; Stoker et al. 1991). Recent dating of these volcanic units shows that these basalt flows range in age from 9.8 to 11 Ma (WoldeGabriel et al.

1995), suggesting they are intercalated in the Tesuque Formation. The Chamita Formation, if present, is less than 100 m thick in the vicinity of well O-4.

Purtymun (1995) describes a trough of late Miocene coarse-grained sediments at the top of the Santa Fe Group that post-date the Chamita Formation. Purtymun called these deposits the "Chaquehui Formation" and they are important for the development of high-yield, low-drawdown municipal and industrial water supply wells. The late Miocene trough is 3 to 4 miles wide and extends 7 to 8 miles from the northeast to the southwest (Figure 2-5). It is filled with up to 1500 ft 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 anomalously low gravity measurements that Ferguson et al. (1995) interpreted as a sediment-filled graben on the western side of the Española basin of the Rio Grande rift. The nature of the eastern boundary of the "Chaquehui Formation" is unknown. The great difference in stratigraphic sections encountered between wells Otowi-1 and PM-1 suggests that the eastern boundary may be very sharp as if bounded by a fault. On the other hand, in the Guaje Well Field, the "Chaquehui Formation" is not as thick and appears to thin to the east.

Puye Formation

The Puye Formation (Turbeville et al. 1989; Spell et al. 1990) is a fanglomerate deposit consisting of poorly sorted boulders, cobbles, and coarse sands made up of dacitic to latitic debris eroded from the contemporaneous Tschicoma Formation. In the lower reaches of Los Alamos Canyon and along the Rio Grande, the Puye Formation also contains basaltic debris derived from contemporaneous volcanism and erosion of the Cerros del Rio volcanic field. The Puye Formation contains numerous interbedded lapilli tuff beds and laharic deposits. Lacustrine deposits are volumetrically significant in the distal parts of the fan.

The lower part of the Puye Formation includes the Totavi Lentil (Griggs 1964), a deposit of well-rounded cobbles and boulders of Precambrian quartzites and crystalline rocks. The Totavi Lentil probably represents channel deposits of the ancestral Rio Grande, and it may interfinger with the fanglomerate facies of the Puye Formation along White Rock Canyon.

Otowi Member, Bandelier Tuff

The Otowi Member is a poorly consolidated ignimbrite exposed in the lower parts of many of the deeper canyons on the Pajarito Plateau. This tuff commonly crops out in shallow drainages that incise gentle colluvium-covered slopes extending from the base of canyon walls to the canyon floor. The basal part of the Otowi Member includes the Guaje Pumice Bed (Figure 2-6), a thick series of well-stratified pumice-fall and ash-fall deposits that blanketed the pre-existing landscape before the overlying ignimbrites were erupted. In the central part of the Pajarito Plateau, borehole LADP-4 in DP Canyon penetrated 85 m of Otowi Member, including 8.5 m of the basal Guaje Pumice Bed (Broxton et al. 1995b).

The Otowi Member is made up of numerous stacked ash-flow tuffs which lack significant welding, thus boundaries between individual flow units are often difficult to identify and it has a massive, homogenous appearance. The Otowi Member consists of light gray to orange pumice lapilli supported by a white to tan ashy matrix. The matrix is made up of glass shards, broken pumice fragments, phenocrysts, and fragments of nonvesiculated perlite. Shards are glassy and show no evidence of either post-emplacement high-temperature devitrification or of subsequent low-temperature diagenetic alteration. Pumice lapilli typically make up 10 to 30% of the tuff and range from 0.5 cm to 6 cm in diameter. Pumices are larger (up to 20 cm) and more abundant (~40% of the rock) at the top of the unit, which has a distinct a orange coloration due either to the oxidation of iron by escaping vapors as the ash-flow sheet cooled or to incipient weathering of the top of the unit before deposition of overlying units.

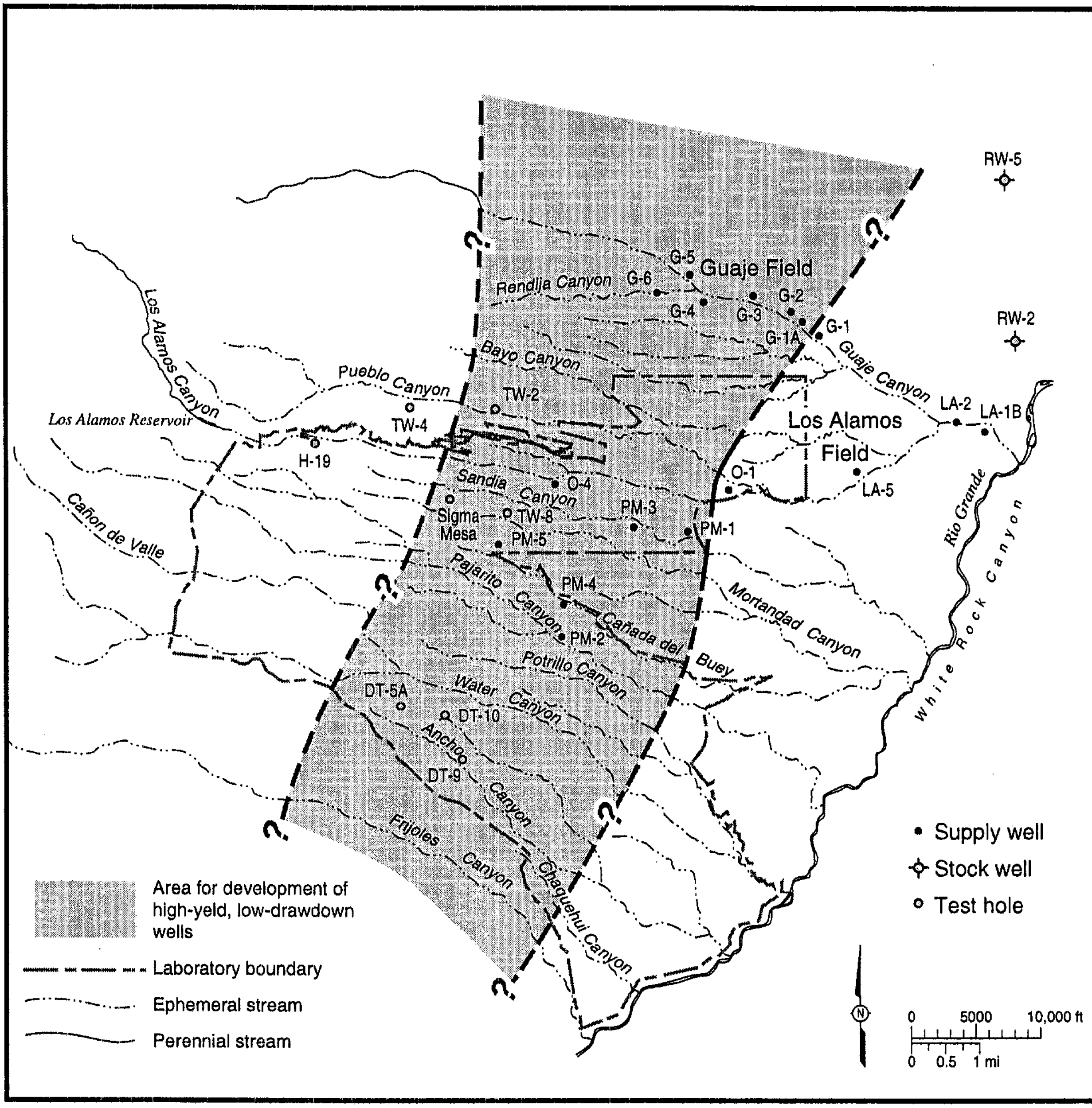


Figure 2-5. Area of inferred Late Miocene trough within upper Santa Fe Group (modified from Purtymun, 1984).

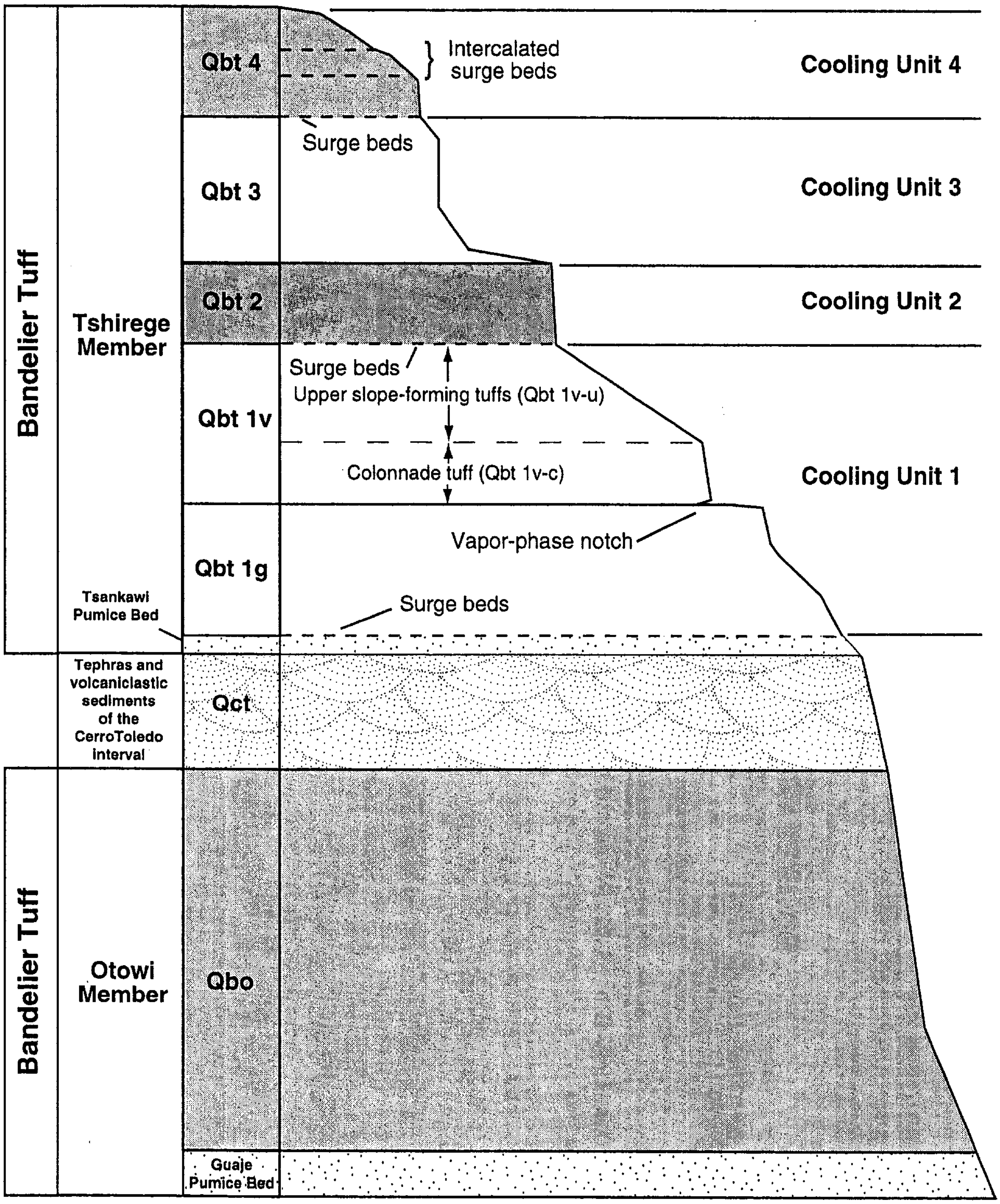


Figure 2-6. Stratigraphic nomenclature for the Bandelier Tuff (from Broxton and Reneau, 1995).

Cerro Toledo Interval

The Cerro Toledo interval is an informal name given to a sequence of epiclastic sediments and tephras of mixed provenance that lie between the two members of the Bandelier Tuff (Broxton and Reneau 1995). This unit contains deposits normally assigned to the Cerro Toledo Rhyolite as described by Smith et al. (1970), and it includes well-stratified tuffaceous sandstones and siltstones and subordinate primary ash-fall and pumice-fall deposits. The Cerro Toledo interval also contains intercalated deposits not normally assigned to the Cerro Toledo Rhyolite. These include poorly-sorted sands, gravels, cobbles, and boulders derived from lava flows of the Tschicoma Formation. The Cerro Toledo interval is approximately 9 ft to 36 ft thick at TA-21 and about 45 ft thick in upper Pueblo Canyon. The Cerro Toledo interval is distributed widely throughout the region, but predicting the presence and thickness of these deposits at any particular location is problematic because of the spatially variable nature of fluvial deposits.

Rhyolitic tuffaceous sediments and tephras are the dominant lithologies found in the Cerro Toledo interval in many outcrops. The tuffaceous sediments are the reworked equivalents of Cerro Toledo Rhyolite tephras erupted from the Cerro Toledo and Rabbit Mountain rhyolite domes located in the Sierra de los Valles. Primary pumice-fall deposits are found in some locations. The pumice falls tend to form the most porous and permeable horizons within the Cerro Toledo interval, and locally they may provide important pathways for moisture transport. Clast-supported gravel, cobble, and boulder deposits made up of porphyritic dacite derived from the Tschicoma Formation are interbedded with the tuffaceous rocks. The coarse dacitic deposits are typically 0.25 to 1.2 m thick and generally occur as overlapping lenticular paleochannels up to a meter deep (Broxton et al. 1995; Goff 1995; Broxton and Reneau 1995).

The proportions of tuffaceous to dacitic detritus making up the Cerro Toledo interval vary from location to location across the Pajarito Plateau. Whereas Cerro Toledo deposits exposed at TA-41 are dominantly tuffaceous in character, rocks at this stratigraphic horizon in lower DP Canyon and in the subsurface at TA-55 (Gardner et al. 1993) predominantly consist of coarse dacitic detritus derived from the Tschicoma Formation and include only subordinate amounts of interbedded tuffaceous detritus.

Tshirege Member, Bandelier Tuff

The Tshirege Member is a multiple-flow ash-flow sheet that forms the prominent cliffs and flat mesa tops of the Pajarito Plateau. The Tshirege Member is a compound cooling unit whose physical properties vary vertically and laterally. Variations in physical properties result from zonal patterns of welding and crystallization determined by emplacement temperature, thickness, gas content, and composition (Smith 1960 a, b). The Tshirege Member varies from about 100 m thick in the west and north central part of the Laboratory to about 200 m thick in the vicinity of TA-49.

The Tshirege Member can be divided into mappable subunits (Figure 2-6) based on a combination of hydrologic properties and lithologic characteristics. There is a certain amount of confusion due to the inconsistent use of subunit names for the Tshirege Member (Baltz et al. 1963; Weir and Purtymun 1962; Crowe et al. 1978; Vaniman and Wohletz 1990; Vaniman and Wohletz 1991; Goff 1995; Broxton et al. 1995a). To avoid such confusion, this Workplan follows the nomenclature of Broxton and Reneau (1995) which was adopted by the Environmental Restoration (ER) Project (LANL 1996b).

The Tsankawi Pumice Bed is the basal pumice fall of the Tshirege Member. This pumice bed is 73 cm to 95 cm thick where exposed. This pumice fall deposit consists of two subunits, each of which has normally graded bedding. The lower subunit is 60 cm to 74 cm thick and contains equant angular to subangular clast-supported pumice lapilli up to 6 cm in diameter. A 2 cm- to 7 cm-thick ash bed overlies the lower pumice bed. The upper pumice bed is 13 cm to 14 cm thick and consists of clast-supported pumice lapilli that grade upwards into a coarse ash bed at the top of the unit. Pumices in the Tsankawi Pumice Bed are rhyolitic in composition and contain ~5 % phenocrysts, consisting of sanidine and quartz.

Qbt 1g is the lowermost unit in the thick ignimbrite deposit of the Tshirege Member. This unit 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 is a porous, nonwelded, poorly sorted, vitric ignimbrite. A thin (10-25 cm) pumice-poor surge deposit is commonly found at the base of this unit.

Qbt 1v forms a combination of cliff-like and sloping outcrops comprised 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 the Pajarito Plateau. The lower part of the unit is a resistant orange-brown colonnade tuff that has distinctive columnar jointing. The colonnade tuff is overlain by a distinctive white band of slope-forming tuffs. The tuffs of Qbt 1v are commonly nonwelded and have an open, porous structure.

Qbt 2 forms a distinctive, medium-brown, vertical cliff that stands out in marked contrast to the slope-forming, lighter-colored tuffs above and below. This unit is the zone of greatest welding in the Tshirege Member with the degree of welding increasing up section through the unit. Vapor phase alteration is extensive in this unit.

Qbt 3 is a nonwelded to partially welded, vapor-phase altered ignimbrite. It consists of a basal, nonwelded tuff that forms a broad gently sloping bench on top of the unit and an upper partially welded tuff which forms the mesa caprock in the central part of the Laboratory.

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 the Pajarito Plateau.

Soils

A large variety of soils have developed on the Pajarito Plateau as the result of interactions of the underlying bedrock, slope, and climate (Nyhan et al. 1978). Table 2-1 lists by abundance soils described by both the LASL-Soil Conservation Service soil survey and the Forest Service soil survey as taken from Nyhan et al. (1978). The mineral components of the soils are in large part derived from the Bandelier Tuff, but dacitic lavas of the Tschicoma Formation, basalts of the Cerros del Rio volcanic field, and sedimentary rocks of the Puye Formation are locally important. Alluvium derived from the Pajarito Plateau and from the east side of the Jemez Mountains contributes to soils in the canyons and also to those on some of the mesa tops. Layers of pumice derived from El Cajete in the Jemez Mountains and windblown sediment derived from other parts of New Mexico are also significant components of many soils on the Pajarito Plateau.

Soils formed on the tops of mesas on the Pajarito Plateau include the Carjo, Frijoles, Hackroy, Nyjack, Pogna, Prieta, Seaby, and Tocal series. These soils typically have loam or sandy loam surface horizons and clay or clay loam subsurface horizons. Some, including the Frijoles, Hackroy, and Seaby soils, contain abundant pumice. Others, including the Prieta soils, contain abundant wind-deposited sediment. Soils on the mesas can vary widely in thickness and are typically thinnest near the edges of the mesas, where bedrock is often exposed. Soils formed from alluvial and colluvial deposits include the Potrillo, Puye, and Totavi series and are generally loose and sandy. The slopes between the mesa tops and canyon bottoms often consist of steep rock outcrops and patches of shallow, undeveloped colluvial soils. South-facing canyon walls are steep and usually have little or no soil material or vegetation; in contrast, the north-facing walls generally have areas of very shallow, dark-colored soils and are more heavily vegetated (Nyhan et al. 1978).

Soil-forming processes extend along fractures in bedrock, and coatings of clay and calcium carbonate on fractures record the transport of water to significant depths in the tuff. For example, at TA-54, Area G, calcium carbonate has been observed as deep as 39 ft and clay coatings as deep as 46 ft below the ground surface (Purtymun et al. 1978). Roots have also been observed at similar depths along fractures in core holes and pits, suggesting that these soil-forming processes continue at depth today.

Table 2-1. LANL Soils

Soil Mapping Unit[1]	% of Area Surveyed[2]	Description
Rock outcrop, steep	9.98	Consists of steep to very steep (30% to 50% grade) mesa breaks and canyon walls and is approximately 90% tuff rock outcrop. The inclusions in this mapping unit are very shallow undeveloped soils on tuff, mesic rock outcrop, and frigid rock outcrop. South-facing canyon walls are steep and have little or no soil material or vegetation. North-facing walls have areas of very shallow dark-colored soils vegetated by ponderosa pine, spruce, and fir.
Rock outcrop-Pelado-Kwage complex	7.51	Deep (Pelado) and moderately deep (Kwage), well-drained soils that weathered from Tschicoma Formation dacites. Contains a higher proportion of rock outcrop than the Kwage-Pelado outcrop complex discussed previously. Found on very steep to extremely steep mountain sideslopes vegetated by Douglas fir-ponderosa pine forest.
Kwage-Pelado-Rock outcrop complex	6.89	Deep, well-drained soils formed on very steep to extremely steep mountain slopes with Tschicoma Formation dacites as parent materials. Vegetation is dominantly Douglas fir-ponderosa pine forest.
Turkey-Cabra-Rock outcrop complex	6	Shallow (Turkey) to deep (Cabra), well-drained soils weathered from Tschicoma Formation dacites and latites. Found on very steep to extremely steep mountain sideslopes vegetated by ponderosa pine forest.
Hackroy series - includes Hackroy-Rock outcrop	5.5	Very shallow to shallow, well-drained soils formed in material weathered from tuff on mesa tops. The rock outcrop portion consists of Hackroy soils and 70% rock outcrop that are so intermingled, they could not be separated at the scale selected for mapping. Native vegetation is mainly piñon pine, one-seed juniper, scattered ponderosa pine, and blue grama.
Quemazon-Arriba-rock outcrop complex	3.97	Shallow (Quemazon) to deep (Arriba), well-drained soils formed in materials weathered from tuff. Found on level to very steep mesa tops vegetated by ponderosa pine forest.
Rock outcrop, very steep	3.84	Consists of slopes with >50% grade on the canyon wall of the Rio Grande Gorge and is approximately 90% rock outcrop. The rocks are mainly basalt, with some tuffs near the mesa tops, and exposures of the Tesuque Formation near the river. Landslides and exfoliation have deposited large accumulations of basalt talus, with boulders as large as 5 to 7 m in diameter. Vegetation is very sparse and is dominantly piñon pine, one-seed juniper, and blue grama.
Pelado series	3.39	Deep, well-drained soils formed in materials weathered from Tschicoma Formation dacites. This mapping unit differs from the Pelado soils found in the Kwage-Pelado-rock outcrop complex in that these soils are found only on less steep mountain slopes. Vegetation is dominantly Douglas fir-ponderosa pine forest.
Rock outcrop, mesic	3.29	Found on moderately sloping to steep mesa tops and edges and consists of approximately 65% tuff rock outcrop. The inclusions in this mapping unit are about 5% very shallow, undeveloped soils on tuff bedrock, 5% Hackroy soils, and 25% narrow escarpments. Native vegetation is blue grama, piñon pine, and one-seed juniper.
Griegos series	3.08	Classified into two mapping units on the basis of slope: 16-40% slope (moderately steep to very steep topography) and 41-80% slope (very steep to extremely steep topography). Both mapping units consist of deep, well-drained soils formed in Tschicoma Formation dacites, latites, and andesites. Vegetation is Engelmann spruce and Douglas fir.
Sanju-Arriba complex	2.94	Deep, well-drained soils weathered in materials derived from pumice (Sanju) or dacites of the Puye Conglomerate (Arriba). Found on moderately steep to very steep mountain sideslopes forested with ponderosa pine.
Totavi series	2.89	Deep, well-drained soils formed in canyons bottoms in the central and eastern portion of the soil survey area. Individual areas are 2 to 60 acres in size and occur as long slender bodies. Vegetated by blue grama, piñon pine, one-seed juniper, and annual grasses and forbs.
Rock outcrop, frigid	2.62	Found on gently sloping to steep (5-30% slope) mesa tops and edges and consists of approximately 65% tuff rock outcrop. Inclusion in this mapping unit are 5% very shallow, undeveloped soils on tuff bedrock,5% Tocal soils, and 25% narrow escarpments. Native vegetation is Kentucky bluegrass, ponderosa pine, spruce, fir and oak.
Carjo series	2.6	Moderately deep, well-drained soils formed in material weathered from tuff. Found on nearly level to moderately sloping mesa tops near the Jemez Mountains. Included with this soil in mapping are areas of Pogna, Tocal, and fine Typic Eutroboralf soils, all of which make up about 10% of this mapping unit. Native vegetation is mainly blue and black grama, and ponderosa pine.
Emod series	1.24	Deep, well-drained soils formed in materials weathered dominantly from dacites, which were water-laid over pumice and ash deposits. Found on moderately steep to very steep upland areas where the native vegetation is piñon-juniper woodland.
Tocal series	2.54	Very shallow to shallow, well-drained soils formed in material weathered from tuff on gently to moderately sloping mesa tops. Individual areas of Tocal soils are 5 to 80 acres in size. Approximately 15% of this mapping unit consists of small amounts of Pogna, Carjo and fine Typic Eutroboralf soils. Vegetated by ponderosa pine, mountain mahogany, and Kentucky bluegrass.

Table 2-1. LANL Soils (continued)

Soil Mapping Unit[1]	% of Area Surveyed[2]	Description
Rock outcrop-Pines-Tentrock complex	2.35	Deep (Pines) and moderately deep (Tentrock), well-drained soils weathered from welded tuff. Approximately 20% of this mapping unit is rock outcrop. Found on very steep to extremely steep mountain sideslopes vegetated by ponderosa pine.
Rabbit-Tsankawi-rock outcrop complex	2.11	Moderately deep (Rabbit) to very shallow (Tsankawi), well drained soils formed from weathered tuff. Found on level to very steep mesa tops where the dominant vegetation is Douglas fir-ponderosa pine forest.
Penistaja series	1.98	Deep, well-drained soils formed in material weathered from alluvial and eolian deposits on basalt. Found on nearly level to gently sloping topography in the White Rock and Pajarito Acres areas. Small areas (<3 acres) of Prieta, Servelleta, and Nyjack soils are included in the Penistaja mapping unit and make up less than 10% of the total area of the unit. Vegetation is mainly blue grama, piñon pine, and one-seed juniper.
Rock outcrop-Colle-Painted Cave complex	1.74	Moderately deep, well-drained soils formed in materials weathered from welded tuff. Found on very steep to extremely steep mountain sideslopes where the native vegetation is dominantly Douglas fir-ponderosa pine forest.
Nyjack series	1.69	Moderately deep, well-drained soils formed in material weathered from tuff on nearly level to gently sloping mesa tops. Individual areas of these soils are 5 to 75 acres in size and include about 20% rock outcrop, as well as Hackroy and Typic Eutroboralf soils in the mapping unit. Vegetation is mainly piñon pine, one-seed juniper, and blue grama.
Arriba-Copar complex	1.43	Deep (Arriba series) to moderately deep (Copar series), well-drained soils formed on level to moderately sloping mesa tops with tuff as the parent material. Native vegetation is ponderosa pine forest.
Pogna series	1.28	Shallow, well-drained soils formed in material weathered from tuff on gently to strongly sloping mesa tops. Approximately 10% of this soil mapping unit consists of rock outcrop, Carjo, fine Typic Eutroboralf, and Tocal soils. Native vegetation is mainly ponderosa pine, mountain mahogany, and Kentucky bluegrass.
Latas series	1.27	Deep, well-drained soils formed in materials weathered from tuff. Found on level to moderately sloping mountain sideslopes where ponderosa pine is the dominant vegetation.
Cabra series	1.26	Classified into two mapping units on the basis of slope: 0-15% slope (level to moderately sloping topography), 16-40% slope (moderately steep to very steep topography). Both units are deep soils formed in materials weathered from Tschicoma Formation dacites and latites. Found on mountain sideslopes with ponderosa pine vegetation.
Potrillo series	1.23	Deep, well-drained soils formed in alluvial and colluvial sediments derived from tuff and pumice. Found on level to gently sloping canyon floors and on inextensive, flat benches along the Rio Grande Gorge. Approximately 10% of this mapping unit on the canyon floors consists of Puye and Totavi soils and some soils that have a more developed subsoil than the Potrillo soils. Where the Potrillo soils are found along the Rio Grande Gorge, small areas of the Totavi soils and soil profiles containing silt or cobble throughout the profile are included in the Potrillo mapping unit. Native vegetation is blue grama, piñon pine, one-seed juniper, and annual grasses and forbs.
Prieta series	1.23	Shallow, well-drained soils formed in eolian sediments and weathered basalt . Individual areas of Prieta soils are 5 to 80 acres in size and include approximately 15% rock outcrop and Servelleta soil. Found on gently to moderately sloping mesa tops. Vegetation is mainly piñon pine, one-seed juniper, blue grama and big sagebrush.
Santa Clara-Armstead complex	1.23	Moderately deep (Santa Clara) to deep (Armstead), well-drained soils weathered from Tschicoma Formation dacites and latites. Found on moderately steep to very steep mountain sideslopes vegetated by Douglas fir-ponderosa pine forests.
Shell-Anesa complex Shell-Anesa-Rock outcrop complex	1.17	Deep, well-drained soils weathered in materials derived from tuff (Shell) or pumice (Anesa). Formed on very steep to extremely steep mountain sideslopes vegetated by Douglas fir-ponderosa pine forest.
Pueblo series	1.14	Deep, well-drained soils formed in materials derived from welded tuffs. Found on moderately steep to very steep mountain sideslopes where the native vegetation is Douglas fir-ponderosa pine forest.
Frijoles series	1.03	Deep, well-drained soils formed in thick pumice beds on nearly level to moderately sloping mesa tops. Included with this soil in mapping are Seaby, Nyjack, and fine Typic Eutroboralf soils; these inclusions make up about 10% of the mapping unit. Native vegetation is mainly piñon pine, one-seed juniper, and blue grama.
Seaby series	1	Shallow to moderately deep, well-drained soils formed in weathered tuff material on gently to moderately sloping mesa tops. Approximately 10% of this mapping unit consists of Nyjack, Frijoles, fine Typic Eutroboralf, and Carjo soils. Vegetated by ponderosa pine, Kentucky bluegrass, and annual grasses and forbs.

[1] Soil mapping units from Nyhan et al. 1978. Mapping units making up less than 1% of the surveyed area are not listed here.
[2] Surveyed land area consists of about 79% of Los Alamos county and includes all of the Los Alamos National Laboratory.

2.1.2.2 Geologic Structure

The Laboratory is on the Pajarito Plateau which lies at the western margin of the Española basin of the Rio Grande rift, a major tectonic feature of the North American continent. The Pajarito fault system forms the western margin of the Española basin and exhibits Holocene movement and historic seismicity (Gardner and House 1987, 0110; Gardner et al. 1990, 0639; Gardner and House 1994). The fault system is made up of over 65 mi of mapped fault traces and connects with regional structures that extend at least as far as Cochiti to the south and Taos to the northeast (Gardner and House 1987).

Within Los Alamos County, the Pajarito fault system consists of three active, or potentially active, fault segments: the Frijoles Canyon, Rendija Canyon, and Guaje Mountain segments.

The Frijoles Canyon fault segment is a zone of faulting over 0.25 mi in width, whose major scarp forms the western boundary of the Laboratory. Near the southwestern corner of the Laboratory, the major scarp of the Frijoles Canyon segment is over 410 ft high in rocks about 1 million years old. Movement on this fault segment is normal-oblique, and the fault's eastern side is relatively down-dropped.

Where exposed north of Los Alamos Canyon, the Rendija Canyon and Guaje Mountain faults are characterized by zones of gouge and breccia, generally 100 to 150 ft wide. Both fault segments produce visible offsets of stratigraphic horizons and are dominantly normal-oblique faults, whose west sides are down-dropped. There are some indications of strike-slip movements on the Guaje Mountain fault segment (Wachs et al. 1988, 0502; Aldrich and Dethier 1990, 0017; Gardner et al. 1990). The youngest movements on the Guaje Mountain segment have been constrained to between roughly 4,000 and 6,000 years ago (Gardner et al. 1990). Displacement on the Guaje Mountain and Rendija Canyon faults apparently decreases south of Los Alamos Canyon, and narrow zones of faulting are replaced by wide (over 300 ft) zones of intense brecciation and fracturing superimposed on the network of cooling joints in the Bandelier Tuff (Vaniman and Wohletz 1990). In contrast to cooling joints, these tectonic fractures cross flow unit and lithologic unit boundaries; thus, tectonic fractures may provide more continuous and more deeply penetrating flow paths for groundwater migration (where saturated flow occurs) than do cooling joints.

Dransfield and Gardner (1985) integrated a variety of data to produce structure contour and paleogeologic maps of the pre-Bandelier Tuff surface beneath the Pajarito Plateau. Their maps suggest that subsurface rock units are cut by a series of down-to-the-west normal faults; the overlying Bandelier Tuff is not obviously displaced by these buried faults. However, where detailed fracture studies have been done on the plateau, they have shown that fracture abundances and apertures increase in the Bandelier Tuff over fault projections which may reflect the tectonic fracturing mentioned above (Vaniman and Wohletz 1990). In addition, small-scale offsets along fractures have been observed in various parts of the Laboratory, including Area G at TA-54 (Rogers 1977), which might suggest additional unmapped fault zones.

2.1.3 Hydrologic Setting

The hydrologic setting of the Pajarito Plateau includes surface water, alluvial groundwater, intermediate perched zone groundwater and the regional aquifer.

2.1.3.1 Surface Water

General Hydrology

The Rio Grande is the master stream in north-central New Mexico. All surface water drainage and groundwater discharge from the plateau ultimately arrive at the Rio Grande. The Rio Grande at Otowi, just east of Los Alamos, has a drainage area of 14,300 mi^2 in southern Colorado and northern New Mexico. The discharge for the period of record has ranged from a minimum of 60 cubic feet per second (cfs) in 1902 to 24,400 cfs in 1920. The river transports about 1 million tons of suspended sediments past Otowi annually (Graf 1993).

Essentially all Rio Grande flow downstream of the Laboratory passes through Cochiti Reservoir, which began filling in 1976. It is designed to provide flood control, sediment retention, recreation, and fishery development. Flood flows are temporarily stored and released at safe rates. The dam is expected to trap at least 90% of the sediments carried by the Rio Grande (Graf 1993).

Figure 2-7 shows the locations of the major surface water drainages in the Los Alamos Area. Included in Figure 2-7 are the ephemeral, intermittent, and perennial reaches of surface waters; the major wastewater effluent-created reaches; and springs. Naturally perennial surface water reaches are located in Ancho, Pajarito, and Chaquehui Canyons. A spring on DOE property within the western Laboratory boundary occurs in Pajarito Canyon, i.e. perennial flow has been noted in Pajarito Canyon associated with Homestead Spring. Springs near the Rio Grande in Ancho, and Chaquehui Canyons are within the eastern Laboratory boundary. Figure 2-7 includes a number of additional springs within the Laboratory boundary, that have been identified during the past few years by the NMED Oversight Bureau. Several of these springs may support perennial flow, however confirmation of their flow characteristics remains to be determined during Workplan studies related to spring discharge measurements, and the ER Canyon studies. When new springs are identified and their nature and yearly flow characteristics evaluated, they will be added to the inventory of springs through the Annual Report, which will also reflect flow frequency information, indicating whether they should be added to the list of perennial reaches of surface water.

Within Laboratory boundaries, perennial reaches in the lower portions of Ancho and Chaquehui canyon are close enough to the Rio Grande that they extend to the Rio Grande without being depleted. In Pajarito Canyon, about 1 mi east of State Road 501, a spring sometimes called Homestead Spring feeds a perennial reach a few hundred yards long, followed by an intermittent reach that flows varying distances, depending on climate conditions.

Essentially all other reaches of canyons within the Laboratory's boundaries are ephemeral; that is, they flow naturally only briefly in response to precipitation or snowmelt in the immediate locality. Some other reaches are intermittent, especially those that flow during part of the year as the result of snowmelt. This snowmelt recharges the alluvial groundwater, and discharge from springs supports intermittent stream flow for a somewhat longer period.

Springs between elevations of 7,900 and 8,900 ft mean sea level on the flanks of the Jemez Mountains supply base flow throughout the year to the upper reaches of Cañon de Valle and in Guaje, Los Alamos, Pajarito, and Water canyons (Purtymun 1975). These springs discharge water perched in the Bandelier Tuff and Tschicoma Formation at rates from 2 to 135 gal./min (Abeele et al. 1981). The volume of flow from the springs is insufficient to maintain surface flow within more than the western third of the canyons before it is depleted by evaporation, transpiration, and infiltration into the underlying alluvium.

The canyons of eleven drainage areas, with a total area of 82 mi^2, pass through the Laboratory's eastern boundary. Runoff from heavy thunderstorms and heavy snowmelt reaches the Rio Grande several times a year in some drainages. Los Alamos, Pajarito, and Water canyons have drainage areas upstream of the east Laboratory boundary that are greater than 10 mi^2. Pueblo Canyon has 8 mi^2, and the rest have less than 5 mi^2. Theoretical maximum flood peaks range from 24 cfs for a 2-yr frequency to 686 cfs for a 50-yr frequency (McLin 1992). The overall flooding risk to community and Laboratory buildings is low because nearly all the structures are located on the mesa tops, from which runoff drains rapidly into the deep canyons.

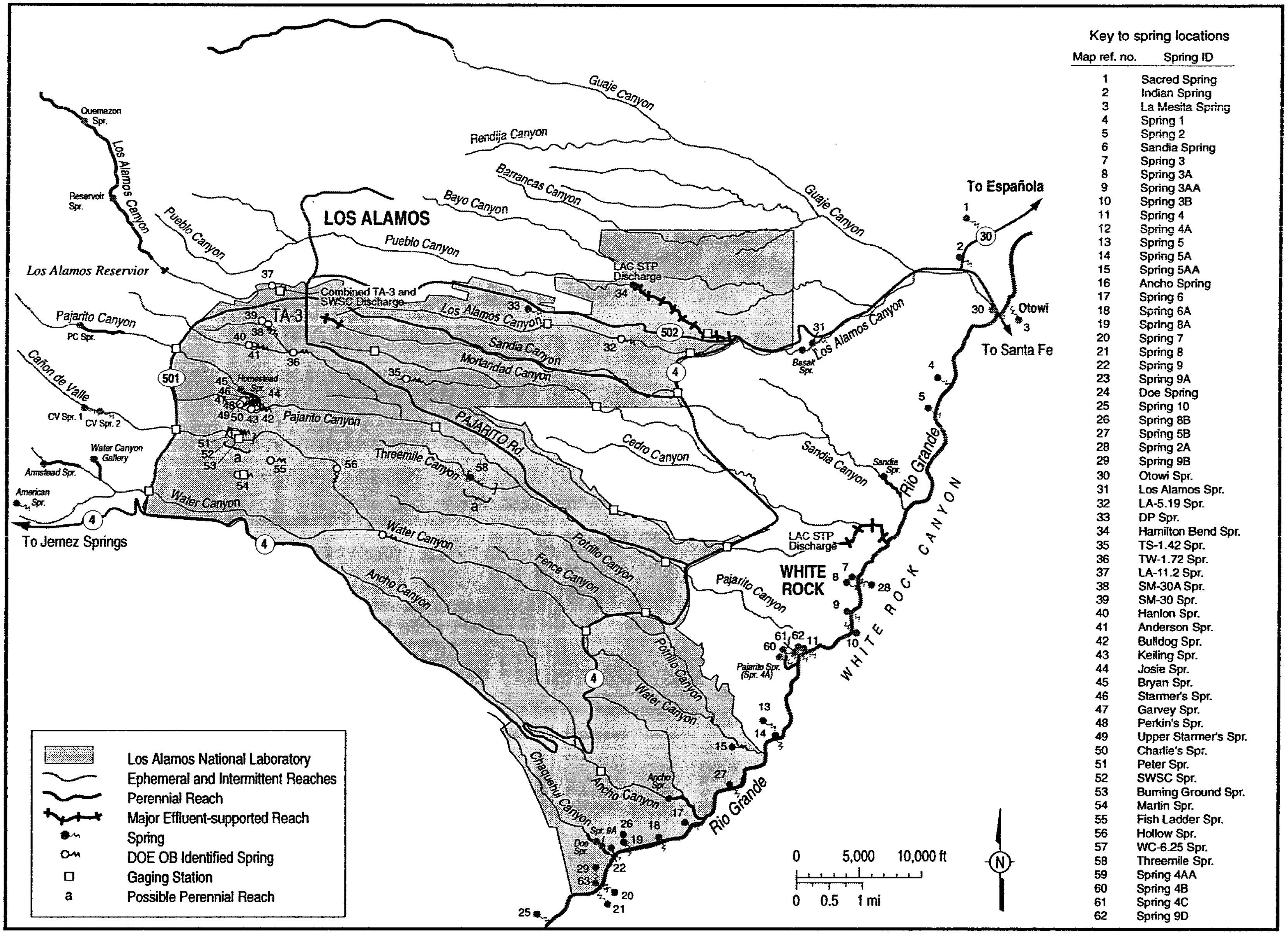


Figure 2-7. Major surface water drainages in the Los Alamos area (from LANL 1995e).

Contaminant Transport by Surface Water

Contaminants enter the surface water drainages by surface runoff, by liquid discharges, and occasionally by air deposition (Becker et al. 1985, 0029; Becker 1986). Runoff-derived contaminants are largely bound to sediments; their rate of downstream travel is governed by the scouring and carrying power of subsequent runoff events (Lane et al. 1985). Given sufficient time, these sediments eventually will be moved across the Laboratory boundary.

Nearly every drainage has received liquid industrial or sanitary effluents discharged from the Laboratory. The effluent discharges determine the flow and water quality characteristics in drainages that contain little natural water. With travel downstream, most of the effluent-derived metals and radionuclides become sediment-bound and remain near the surface of the stream channel; other contaminants, such as nitrate, are lost by evaporation or plant uptake, or move downward into the alluvium. Detailed field investigations in Mortandad Canyon, for example, demonstrate that generally more than 99% of the total inventory of transuranic radionuclides discharged from the treatment plant effluents is associated with sediments in or immediately adjacent to the stream channel (Stoker et al. 1991).

In canyons that have received treated low-level radioactive effluents (Acid-Pueblo, DP-Los Alamos, and Mortandad canyons) concentrations of radionuclides in the alluvium are generally highest near the treated effluent outfall and decrease downstream in the canyon as the sediments and radionuclides are transported and dispersed by other treated industrial effluents, sanitary effluents, and surface runoff.

A study of transport of plutonium by snowmelt runoff (Purtymun et al. 1990) includes the finding that most plutonium moved by runoff in Los Alamos and Pueblo canyons that reached the Rio Grande is transported with sediments—about 57% with suspended sediments and 40% with bed sediments. A total of about 600 μCi of plutonium was carried to the Rio Grande by 5 snowmelt runoff events studied during the years 1975 to 1986.

A regional plutonium analysis for the Rio Grande upstream of Elephant Butte Reservoir (located on the Rio Grande south of Albuquerque) shows that fallout contributes about 90% of the total plutonium moving through the drainage system in any given year. The remaining 10% is from releases at Los Alamos. The contribution to the plutonium budget from Los Alamos is associated with relatively coarse sediment, which often behaves as bedload in the Rio Grande (Graf 1993).

2.1.3.2 Groundwater

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

Numerous wells have been installed over the past several decades at the Laboratory and in the surrounding area to investigate the presence of groundwater in these three zones and to monitor groundwater quality. The locations of existing wells are shown in Figures 2-7 and 2-8.

Alluvial Groundwater

Intermittent and ephemeral streamflows in the canyons of the Pajarito Plateau have deposited alluvium that is as much as 100 ft. thick. The alluvium in canyons that head on the Jemez Mountains is generally composed of sands, gravels, pebbles, cobbles, and boulders derived from the Tschicoma Formation and Bandelier Tuff on the flank of the mountains. The alluvium in canyons that head on the plateau is comparatively more finely grained, consisting of clays, silts, sands, and gravels derived from the Bandelier Tuff. Saturated hydraulic conductivity of the alluvium typically ranges from 10^{-2} cm/s for a sand to 10^{-4} cm/s for a silty sand (Abeele et al. 1981).

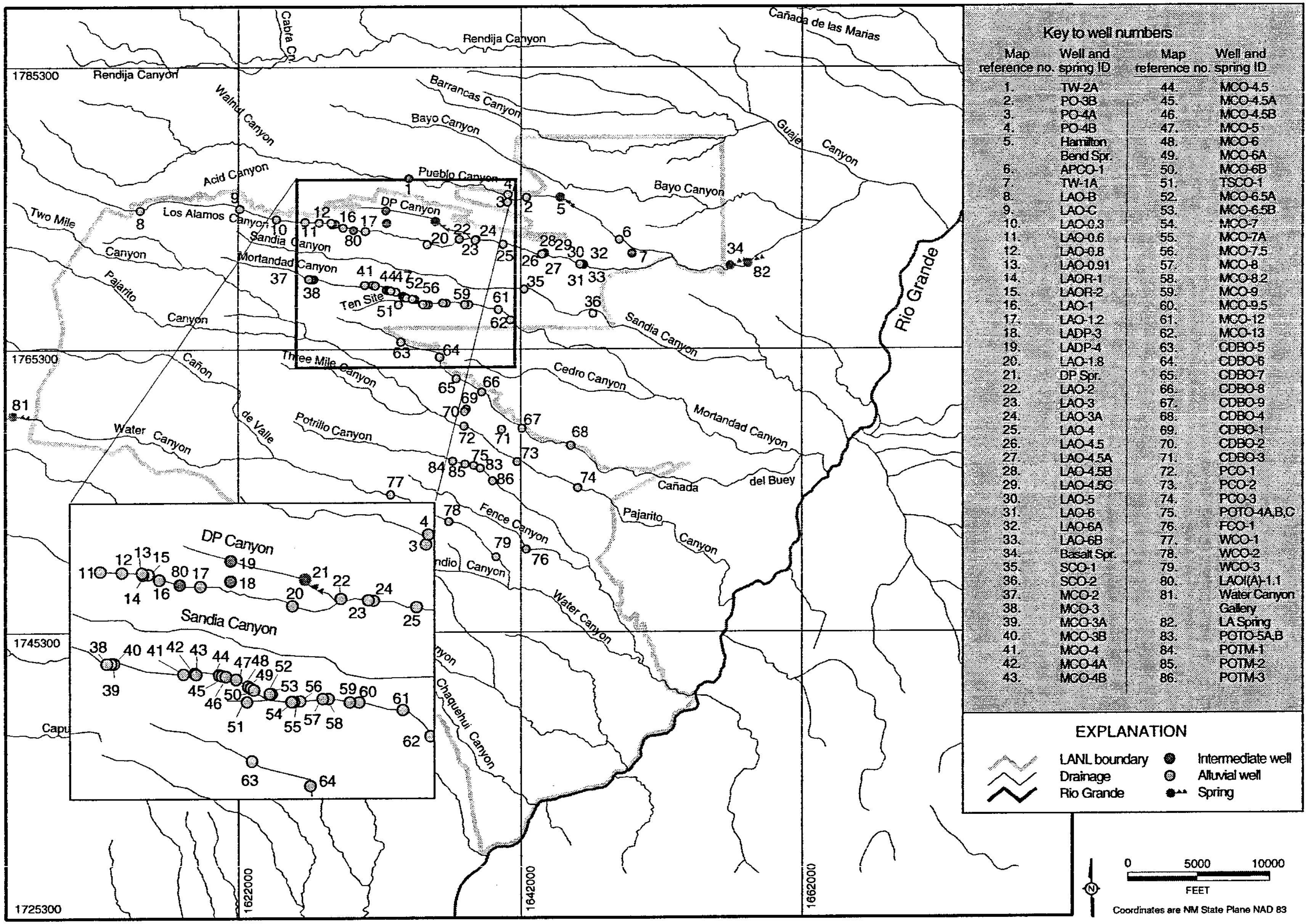


Figure 2-8. Alluvial groundwater and intermediate perched zone wells and springs.

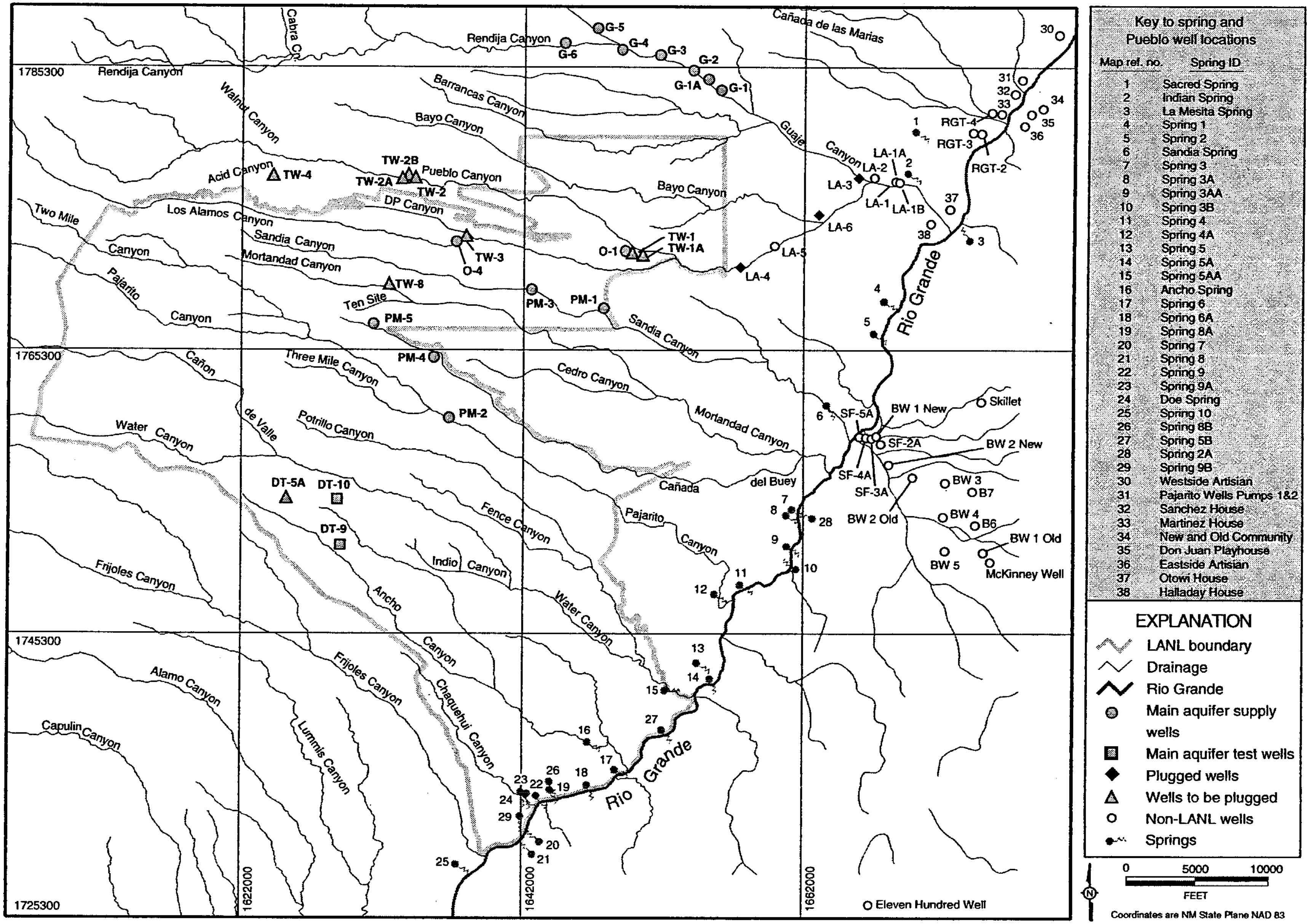


Figure 2-9. Regional aquifer supply and test well locations, and locations of wells to be plugged.

In contrast to the underlying volcanic tuff and sediments, the alluvium is quite permeable. Ephemeral runoff in some canyons infiltrates the alluvium until downward movement is impeded by the less permeable underlying strata which results in a buildup of shallow alluvial groundwater. In addition to the alluvium, in some cases relatively thin zones of shallow groundwater can also be contained in the weathered tuff or some other unit immediately underlying the alluvium. Depletion by evapotranspiration and movement into the underlying rocks limit the horizontal and vertical extent of the alluvial groundwater (Purtymun et al. 1977). The limited saturated thickness and extent of the alluvial groundwater preclude its use as a viable source of municipal and industrial supply to the community and the Laboratory. Lateral flow of the alluvial groundwaters is in an easterly, down-canyon direction. Tracer studies in Mortandad Canyon have shown that the velocity of water ranges from about 60 ft/day in the upper reach to about 7 ft/day in the lower reach of the canyon (Purtymun 1974).

The chemical quality of alluvial groundwaters is variable, depending on the location and history of effluent discharges. In Mortandad Canyon, for example, plutonium concentrations fluctuate in response to variations in treatment plant effluent and storm runoff which dilutes the alluvial groundwater. Tritium concentrations have fluctuated almost in direct response to the average annual concentration of tritium in the effluent from the Laboratory's Radioactive Liquid Waste Treatment Facility (RLWTF) at TA-50, with a lag time of about 1 year (Environmental Protection Group 1992).

Purtymun (1975 1973) reviewed alluvial groundwaters by drainage area. The results of extensive monitoring studies of the alluvial groundwater in Mortandad Canyon are presented by Abrahams et al. (1961), Baltz et al. (1963), Purtymun (1973), Purtymun (1974), Purtymun et al. (1977), Purtymun et al. (1983), and Stoker et al. (1991).

Intermediate Perched Zone Groundwater

Localized bodies of perched groundwater occur beneath several canyons in the eastern portion of the Laboratory, along the eastern flanks of the Jemez Mountains west of the Laboratory, and possibly beneath the mesas and canyons at S Site (TA-16), located in the southwestern part of the Laboratory near the Jemez Mountains. Perched groundwater may exist beneath other canyons in the south and central portions of the Laboratory, which have not yet been investigated by drilling. These perched zones are found in areas where a sufficient water source is present to maintain saturation within the deeper units. Thus perched groundwater beneath canyon bottoms may be maintained by infiltration from the overlying stream, and perched groundwater within the Bandelier Tuff near the Jemez Mountains may be maintained by seepage from streams exiting the mountains. The presence of these perched zones is controlled by the occurrence of a perching layer, whose lower permeability causes water to pond in a more permeable horizon above it. Perching layers are found within the interlayered Cerros del Rio Basalt flows and the sediments of the Puye Formation, for example, where they underlie the more permeable Guaje Pumice Bed in Los Alamos Canyon. The presence of perched groundwater at S Site and on the flanks of the Jemez Mountains is evidently controlled by contrasts in lithologic properties within the Bandelier Tuff, which might exist at boundaries between flow units.

Perched zones occur in the conglomerates and basalts beneath the alluvium in the mid- and lower reaches of Pueblo and Los Alamos canyons and in the lower reach of Sandia Canyon. Depth to perched groundwater ranges from about 90 ft in the midreach of Pueblo Canyon to about 450 ft in lower Sandia Canyon. The vertical and lateral extent of the perched zones, the nature and extent of perching units, and the potential for migration of perched groundwater to the regional aquifer are not yet fully understood. Only the intermediate perched zone in lower Pueblo and Los Alamos canyons has been studied in some detail.

Patterns of chemical quality and groundwater levels indicate that the intermediate perched zone groundwater in Pueblo Canyon is hydrologically connected to the stream in Pueblo Canyon (Abrahams and Purtymun 1966). Water from this perched zone discharges at the base of the basalt at Basalt Spring, which is on the San Ildefonso Pueblo Land, east of the Laboratory in lower Los Alamos Canyon. The rate of movement of the perched groundwater in this vicinity has been estimated at about 60 ft/day or about 6 months from recharge to discharge (Purtymun 1975).

It is unknown whether the intermediate perched zones are hydraulically interconnected. Available data suggest that most of the systems are of limited extent. Testing of the intermediate perched zone in mid-Pueblo Canyon depleted the groundwater after about an hour's pumping at 2 to 3 gal./min (Weir et al. 1963). A perched zone was encountered in mid-Los Alamos Canyon during the drilling of supply well O-4 (Stoker et al. 1992), but it was not reported in an adjacent well (Test Well (TW)-3) located 300 ft to the east. (However, TW-3 was drilled with a cable tool rig in 1947, and the driller may not have noticed the perched groundwater if it was present.)

Measurements of tritium in intermediate perched zone groundwater demonstrate that recharge to those depths has occurred during the last several decades. The levels of tritium in those locations are high enough to be attributed to recharge of surface water contaminated by effluent or other releases from Laboratory operations. These observations have been made at four locations in Pueblo and Los Alamos canyons. For several years, tritium has been observed in TW-2A in Pueblo Canyon at concentrations between 2,000 and 3,000 pCi/L. Starting in 1991, low-detection-limit tritium measurements have consistently revealed tritium at levels of about 150 pCi/L in samples from TW-1A, located in lower Pueblo Canyon near its confluence with Los Alamos Canyon, and in Basalt Spring, located in Los Alamos Canyon just downstream from its confluence with Pueblo Canyon. The measurements at these three locations are consistent with previous understanding, starting with measurements made by the USGS in the 1950s and 1960s (Abrahams et al. 1961): the intermediate perched zone groundwater has long been known to be affected by effluents discharged into Pueblo Canyon.

The most recent observation of tritium in intermediate perched zone groundwater was made in well LADP-3, completed in 1993 by the ER Project in the middle reach of Los Alamos Canyon about 1 mi down gradient of TA-2, the Omega Reactor site (Broxton and Eller 1995). Well LADP-3 encountered perched groundwater at a depth of about 320 to 330 ft, at the contact of the Otowi Tuff and the Puye Formation. Samples of water from that well contained about 6,000 pCi/L of tritium.

Some perched groundwater occurs in volcanics on the flanks of the Jemez Mountains to the west of the Laboratory. This groundwater discharges in several springs (including American and Armstead springs) and provides flow for the gallery in Water Canyon. The gallery contributed to the Los Alamos water supply for 41 years, producing 23 to 96 million gallons annually.

Several springs have been noted in the area of S Site by the ER Project and the NMED DOE Oversight Bureau (unpublished data). Some of these springs are located along interrupted stream reaches in canyons, where groundwater return flow to the dry stream channel occurs, and do not represent springs in the usual sense. In other cases flow issues from canyon walls well above the alluvium. The origin of water supplying these springs is uncertain. In some cases the flow may have its source from nearby outfalls. The ER Project and the NMED DOE Oversight Bureau (unpublished data) have discovered high explosives residuals in samples from some of these springs.

Regional Aquifer

The regional aquifer of the Los Alamos area is the only aquifer capable of large-scale municipal water supply (Purtymun 1984). In 1989, water for the Laboratory, the communities of Los Alamos and White Rock, and Bandelier National Monument was supplied from 11 deep wells in 3 well fields. The wells are located on the Pajarito Plateau and in Los Alamos and Guaje canyons east of the plateau. Municipal and industrial water supply pumpage during 1992 was 1.43 billion gal. Yields from individual wells ranged from about 175 to 1,400 gpm (Stoker et al. 1992). Purtymun (1984) summarized the hydraulic characteristics of the aquifer as determined during aquifer tests and during periods of production of supply wells and test holes.

The surface of the regional aquifer rises westward from the Rio Grande within the Santa Fe Group into the lower part of the Puye Formation beneath the central and western part of the Pajarito Plateau (Figure 2-10). The depths to groundwater below the mesa tops range from about 1,200 ft along the western margin of the plateau to about 600 ft at the eastern margin. The regional aquifer is separated from the alluvial groundwater and intermediate perched zone groundwater by 350 to 620 ft of tuff, basalt, and sediments (Environmental Protection Group 1993). The regional aquifer exhibits artesian conditions in the eastern part along the Rio Grande (Purtymun 1984). Continuously recorded water level measurements collected in test wells since the fall of 1992 indicate that, throughout the plateau, the regional aquifer responds to barometric and earth tide effects in the manner typical of confined aquifers.

The hydraulic gradient of the regional aquifer averages about 60 to 80 ft/mi within the Puye Formation but increases to 80 to 100 ft/mi along the eastern edge of the plateau as the groundwater enters the less permeable sediments of the Santa Fe Group. The rate of movement of groundwater in the upper section of the aquifer varies depending on the materials in the aquifer. Aquifer tests indicate that the rate of movement ranges from 20 ft/yr in the Tesuque Formation to 345 ft/yr in the more permeable Puye Formation (Purtymun 1984). The highest yielding water supply wells are located within the late Miocene trough described by Purtymun (1984).

The exact source of recharge to the regional aquifer is unknown. Groundwater elevation measurements suggest that groundwater flows from the Jemez Mountains towards the Rio Grande to the east and east-southeast where a portion discharges into the river through seeps and springs (Purtymun et al. 1980). Springs fed by the regional aquifer discharge an estimated 4,300 to 5,000 acre-ft of water annually into White Rock Canyon along an 11-mi reach between Otowi Bridge at State Road 502 and the mouth of Rito de Frijoles (Cushman 1965). There is considerable uncertainty regarding recharge along the Jemez Mountains. Infiltration of stream flow occurs along the mountain flanks, but the limited drilling to date generally has not indicated the presence of significant recharge. Major recharge of the regional aquifer from the west is inferred because the piezometric surface slopes downward to the east (Figure 2-10). Cushman (1965) suggested three sources of recharge: infiltration of runoff in canyons; underflow from the Valles Caldera through the Tschicoma Formation; and infiltration on mesas. However, a large quantity of hydrologic, structural, and geochemical data indicate that the caldera may not serve as an appreciable source of recharge to the regional aquifer (Conover et al. 1963; Griggs 1964, Goff 1991). Furthermore, natural recharge through undisturbed Bandelier Tuff on the mesa tops is believed to be insignificant (Purtymun and Kennedy 1971; Kearl et al. 1986), and few or no data exist to support an evaluation of canyon runoff as a recharge source.

The total volume of annual recharge near the Pajarito Plateau is apparently less than the quantify of municipal water production (approximately 5,000 acre-ft/year). This is based on an overall decline in regional aquifer water levels across the plateau since pumping began in the 1950s.

To estimate recharge rates beneath the Pajarito Plateau, Rogers and Gallaher (1995) tabulated Bandelier Tuff core hydraulic properties from several boreholes beneath the Laboratory. Rogers et al. (1996a) evaluated the direction and flux of water through the unsaturated zone using hydraulic properties from seven boreholes which had sufficient data. These seven boreholes represent mesa top and canyon bottom locations, which are two of the distinct hydrologic regimes on the Pajarito Plateau. Most head gradients determined for the boreholes are approximately unity, implying that flow is nearly steady state. An exception to the unit gradient was found for boreholes at MDA G (TA-54), where gradient reversals at depths of about 100 ft suggest that evaporative drying may be taking place. Rogers et al. (1996a) used vertical head gradients and unsaturated hydraulic conductivity estimates (using geometric means) to approximate infiltration rates for liquid water at the seven sites. The flux estimates presume that flow is vertical only; that is, that no lateral flow is occurring along lithologic interfaces. Apparent fluxes beneath mesa top sites range from about 0.06 cm/yr beneath MDA G to 245 cm/yr beneath surface impoundments at TA-53. High precipitation or surface disturbances including disposal ponds lead to higher fluxes beneath some mesas. Hypothesized evaporation resulting from air movement through the mesa apparently creates a barrier to infiltration beneath MDA G at Mesita del Buey.

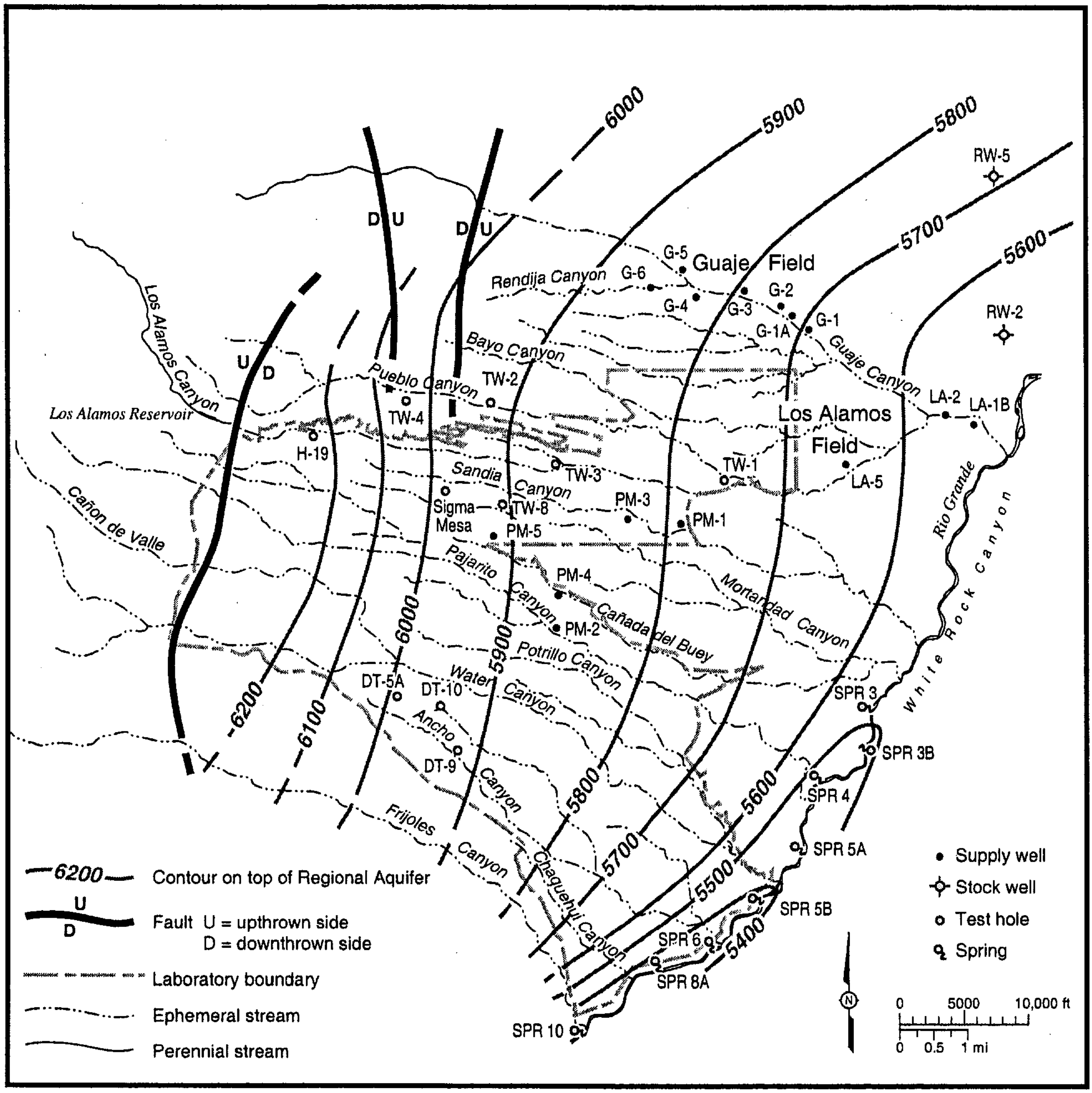


Figure 2-10. Generalized water-level contours on top of the Regional Aquifer (modified from Purtymun, 1984).

Apparent canyon bottom infiltration rates are about 0.4 to 8.3 cm/yr beneath two dry canyons (Cañada del Buey and Potrillo Canyon), and 1 to 10 cm/yr beneath Mortandad Canyon, the only relatively wet canyon represented. Canyon bottom infiltration rates beneath wetter canyons such as Los Alamos Canyon could be much greater, but no data for those sites are currently available.

Data on stable isotope (deuterium and oxygen-18) geochemistry of groundwaters from the regional aquifer and the Valles Caldera indicate that most regional aquifer wells were recharged from elevations lower than the Sierra de los Valles, and do not show the trace elements characteristic of deeper Valles Caldera thermal waters (F. Goff, unpublished Los Alamos National Laboratory memo 1991; Blake et al. 1995). Based on the stable isotope analyses, Blake et al. (1995) conclude that most waters discharging in White Rock Canyon and located under the Pajarito Plateau and San Ildefonso Pueblo have been precipitated locally, or possibly have migrated from the north. An exception to this pattern of recharge elevations is found at former Los Alamos well field wells LA-6 and LA-1B located near the Rio Grande in lower Los Alamos Canyon (Figure 2-9). These are among the deepest of the wells in this area, and recharge elevations determined from stable isotopes suggest that the recharge area for the wells in lower Los Alamos Canyon could be the Sangre de Cristo Mountains (Goff and Sayer 1980; Vuataz and Goff 1986) as suggested by flow paths in Figure 2-11.

In an effort to better understand the nature of recharge to the regional aquifer, additional isotope and age-dating measurements were made. Samples were collected from test wells and water supply wells that penetrate the regional aquifer. Carbon-14 and low-level tritium measurements permit some tentative estimates of the age of the water in the Regional aquifer at various locations. "Age of water" means the time elapsed since the water, as precipitation, entered the ground to form recharge and became isolated from the atmosphere. The precipitation at the time of entry into the ground is assumed to have contained atmospheric equilibrium amounts of both tritium and carbon. Radioactive carbon-14 comes mainly from natural sources. Tritium comes from both natural sources and fallout from nuclear weapons testing in the atmosphere.

The interpretation of ten carbon-14 analyses indicates that the minimum age of water in the regional aquifer ranges from about 1,000 years under the western portion of the Pajarito Plateau, increasing as it moves eastward, to about 30,000 years near the Rio Grande (Rogers et al. 1996b). Importantly, samples collected from the water supply wells integrate water drawn from screened intervals of 600 to 3100 feet and are thus composite water ages. The age values in the range of several thousand years suggest that much of the water has been in the aquifer for long periods. A corollary is that recent recharge is not a volumetrically significant portion of the aquifer water. Because the screened intervals start hundreds of feet below the water table, however, the results may partly mask evidence of recent recharge to the top of the aquifer. It is tempting to conclude that these ages support an easterly flow direction with younger water recharged at the western boundary of the plateau, and flowing towards the east. However, another possibility is that two separate groundwater bodies of different ages are represented, and that a groundwater divide in the regional aquifer lies west of the Rio Grande (Figure 2-11). The radiocarbon data consist of two geographically isolated sets of data. The older ages near the Rio Grande correspond to the region of waters with higher recharge elevations identified by Goff and Sayer (1980). The much older ages found here could reflect the longer flow path from the possible Sangre de Cristo recharge area, and support the hypothesis that the regional aquifer groundwater divide lies west of the Rio Grande. In addition, a separate flow regime may exist within the late Miocene trough of Purtymun (1984) (Figure 2-5), with major recharge occurring by southerly groundwater flow of younger water within the Rio Grande rift basin fill.

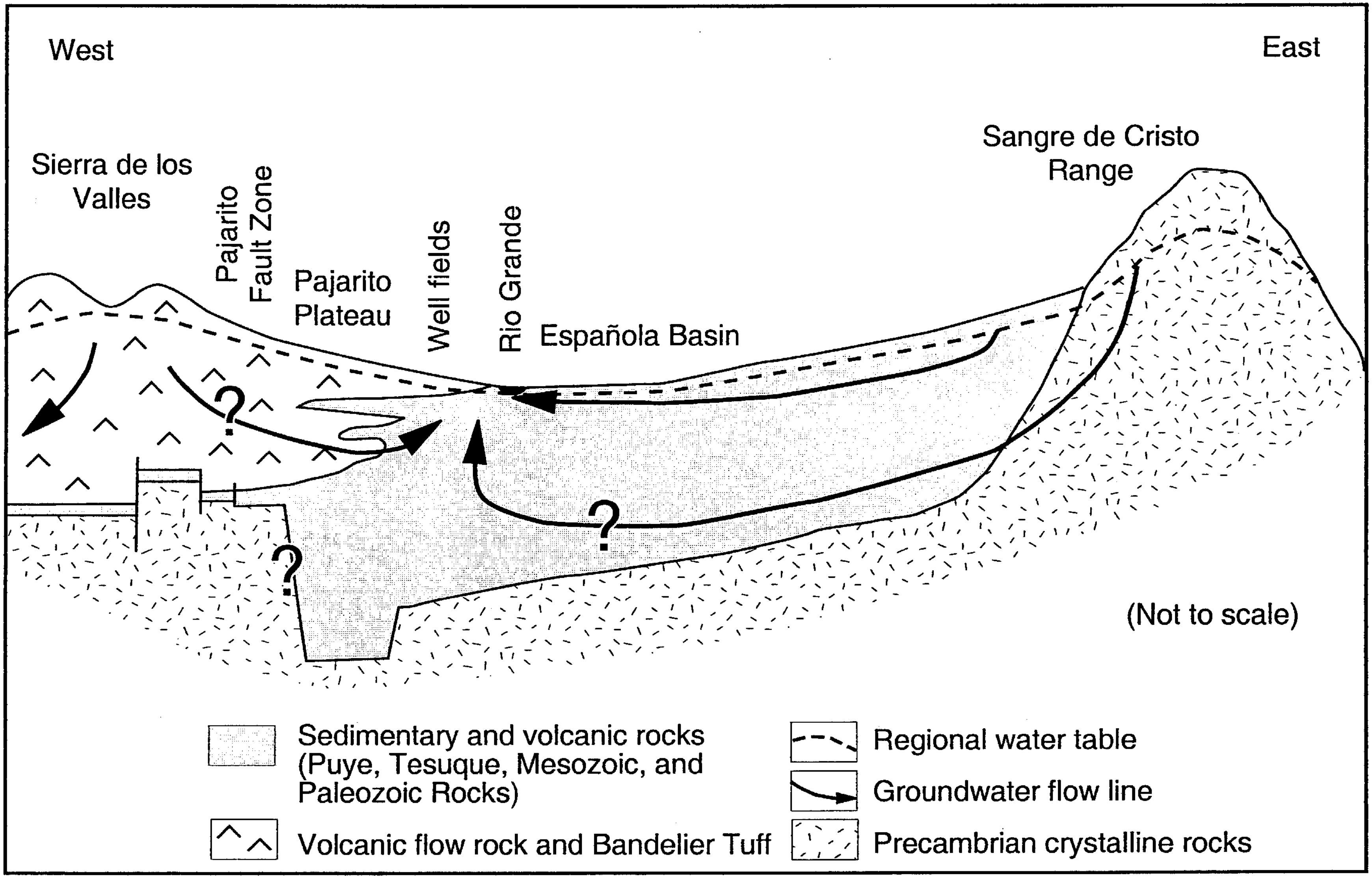


Figure 2-11. Conceptual sketch of groundwater flow paths in the Española portion of the northern Rio Grande Basin (after Stephens et al. 1993).

The existence of two separate groundwater masses of different ages is further supported by a discrepancy between carbon-14 ages and regional aquifer flow rates determined by Purtymun (1984). The flow rates range from about 250 ft/yr in the Puye Formation near well O-4, to about 20 ft/yr in the Tesuque Formation below the Los Alamos Well Field. For the 5.5 mi distance between wells PM-3 and LA-1B, these flow rates give a range of groundwater travel times between the wells of 115 to 1450 years. These travel times are far shorter than the 22,000 to 27,000 year difference in the carbon-14 ages for these wells (Rogers et al. 1996b).

Several measurements of tritium by extremely low-detection-limit analytical methods appear to show the presence of some recent recharge (within the last 40 years) in groundwater samples taken from five locations in the regional aquifer at locations near Los Alamos (Environmental Protection Group 1994 1995). Another thirty wells show no apparent influence of recent recharge on the regional aquifer. The tritium levels measured range from less than a percent to less than a hundredth of a percent of current drinking water standards and are less than levels that could be detected by the EPA-specified analytical methods normally used to determine compliance with drinking water regulations. The locations where tritium measurements clearly indicate the presence of recent surface recharge to the regional aquifer are: (1) TW-1 situated in Pueblo Canyon near the confluence with Los Alamos Canyon; (2) TW-3, in Los Alamos Canyon; (3) in old observation and water supply wells LA-1A and LA-2, located in Los Alamos Canyon near its confluence with the Rio Grande; (4) at TW-8, in Mortandad Canyon located about a mile downstream from the outfall of the RLWTF at TA-50; and (5) in household wells and springs at San Ildefonso Pueblo (Environmental Protection Group 1995; Blake et al. 1995).

2.2 Preliminary Conceptual Model for the Pajarito Plateau

For purposes of describing a conceptual model for the Laboratory, the hydrogeology of the Pajarito Plateau is broken into four components. Two of the components relate to physiography: mesas and canyons. Mesa tops are for the most part dry (Figure 2-12). Canyons are divided into wet and dry; the wet canyons contain ephemeral streams and contain groundwater in the canyon bottom alluvium (Figure 2-13). A third component, intermediate perched zone groundwater, is found at depths ranging from 100 to 400 ft, and is controlled by lithology. The fourth component, the regional aquifer is found at depths of about 600 to 1200 ft (Figures 2-3, 2-4, 2-9, 2-10). Important aspects of each component of the hydrogeologic system are listed below.

2.2.1 Mesas

Relatively small volumes of water move beneath mesa tops under natural conditions, due to low rainfall, high evaporation, and efficient water use by vegetation. Atmospheric evaporation may extend within mesas, further inhibiting downward flow.

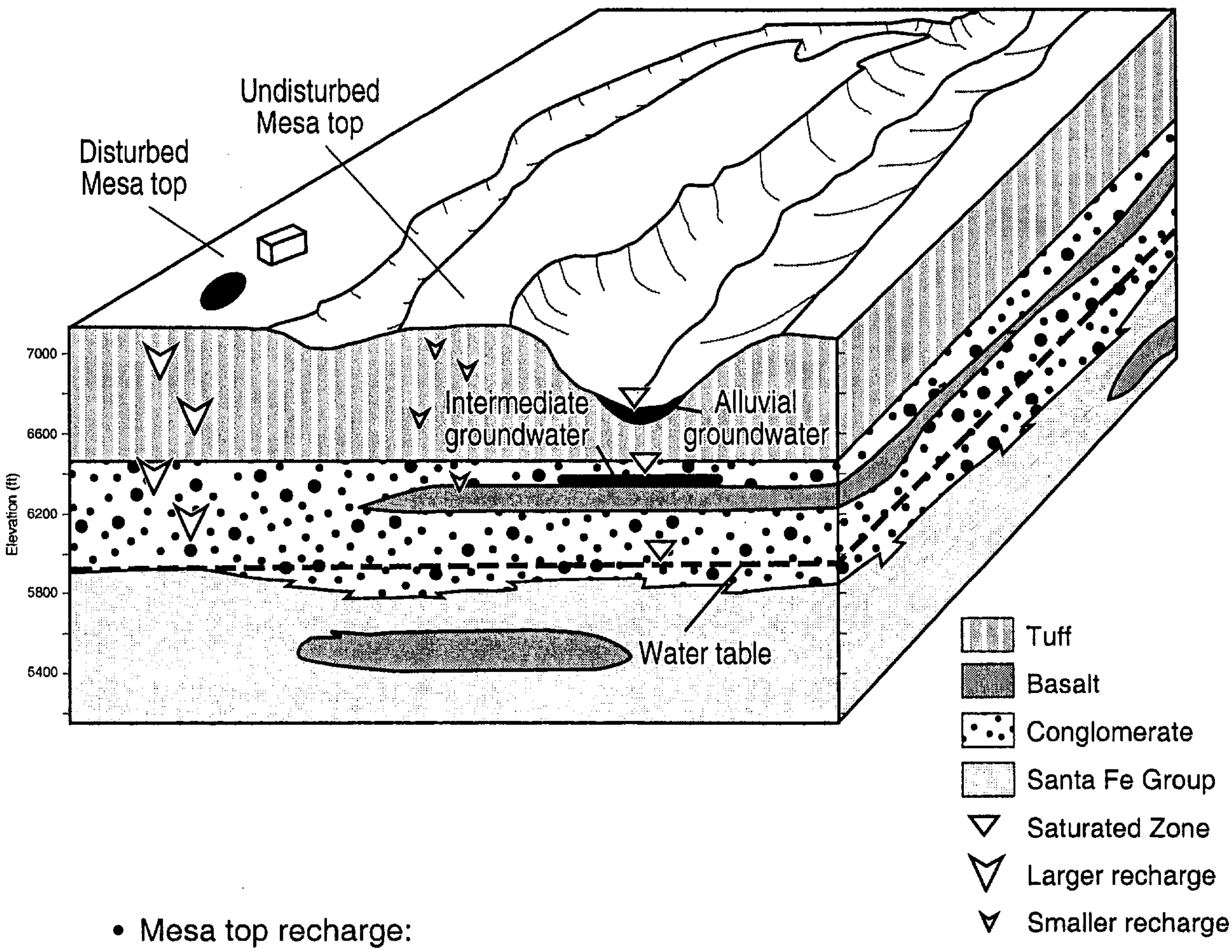
The amount of mesa top recharge along the western portion of Laboratory is uncertain. Higher rainfall, increased vegetative cover, and increased welding and jointing of the tuff might lead to different recharge rates than those observed in better studied portions of the Laboratory.

Mesa top recharge can be locally significant under disturbed surface conditions. Such change occurs when the soil is compacted, when the vegetation is disturbed, or when more water is artificially added to the hydrologic system by features such as blacktop, lagoons, or effluent disposal.

Fractures within mesas do not enhance the movement of dissolved contaminants unless saturation develops.

Contaminants in vapor form readily migrate through mesas. Vapors denser than air will sink.

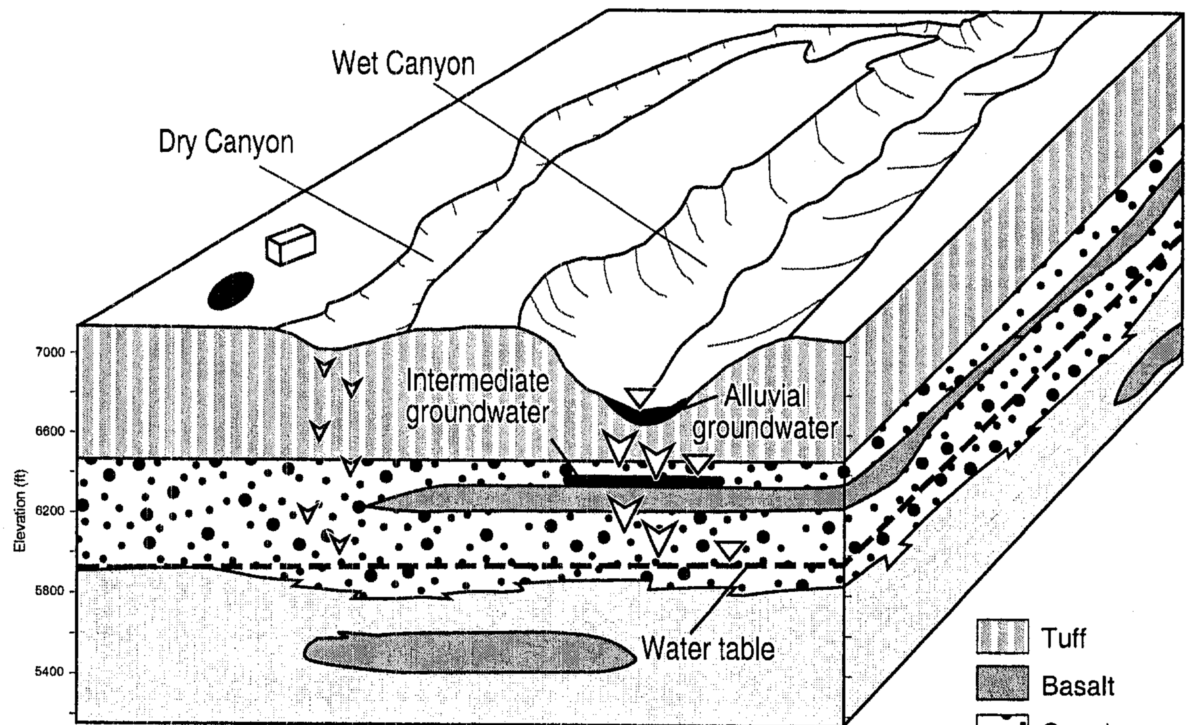
Hydrogeologic Conceptual Model for Mesas

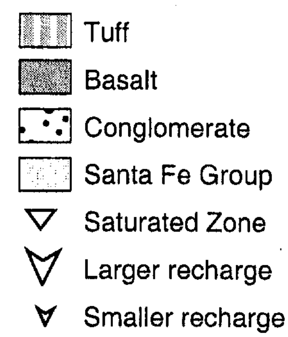


- Mesa top recharge:
  - Small under natural conditions
  - Significant under disturbed surface
  - Fractures don't enhance unless saturated
- Air movement may dry mesa interior
- Vapor phase contaminant movement likely

Figure 2-12. Hydrogeologic conceptual model for mesas.

Hydrogeologic Conceptual Model for Canyons





- Dry canyons:
  - Little recharge under natural conditions
  - Significant under disturbed conditions
- Wet canyons:
  - Source of recharge to intermediate groundwater and main aquifer
- Intermediate groundwater:
  - Significant contaminant transport path
  - Source of recharge to main aquifer
  - Occurs in larger canyon systems
  - Exists beneath canyons, not mesas?
  - Laterally extensive near Jemez Mountains?
  - Controlled by subsurface lithology

Figure 2-13. Hydrogeologic conceptual model for canyons.

2.2.2 Alluvial Groundwater

In drier canyon bottoms, groundwater may occur seasonally in the alluvium, depending on the volume of surface flow from snowmelt, storm runoff, and Laboratory NPDES-permitted effluents. As groundwater in the alluvium moves down the canyon, it is depleted by evapotranspiration and infiltration into the underlying rocks.

In wetter canyon bottoms, infiltration of NPDES-permitted effluents and natural runoff reaching the stream channel may maintain shallow groundwater in the alluvium. Groundwater levels are typically highest in late spring due to snowmelt runoff and in mid-to-late summer due to seasonal thunderstorms. Groundwater levels decline during the winter and early summer when runoff is at a minimum.

Alluvial groundwater is a source of recharge to underlying intermediate perched zones, usually by unsaturated flow. In wetter canyon bottoms, alluvial groundwater may also contribute recharge to the regional aquifer.

Dry canyon bottoms contribute relatively little recharge under natural conditions. Long-term addition of effluent to naturally dry canyon bottoms may result in recharge to intermediate perched zones.

In a few cases where saturated flow might occur, faults, fractures, joints, surge beds, and permeable geologic units (e.g. Guaje Pumice, Cerro Toledo, and Puye Formation) that underlie alluvial saturated zones or intermediate perched zones could provide pathways for downward water movement.

2.2.3 Intermediate Perched Zone Groundwater

Intermediate perched zones occur beneath major canyon systems, particularly those that head in the Jemez Mountains. Intermediate perched zones may receive recharge from watersheds west of the Laboratory.

In addition to availability of recharge from overlying alluvial groundwater, the location of intermediate perched zones is controlled by hydrogeologic characteristics of subsurface units, mainly lithology and permeability. In some cases, such as with interlayered basalts and conglomerates, intermediate perched zones could occur at several depths beneath a canyon.

The intermediate perched zones have not been observed to extend laterally beneath mesas. However, some lateral spreading of perched groundwater may occur down gradient, if the canyon course and the dip of the perched zone do not coincide.

Some hydrologic evidence suggests the existence of an intermediate perched zone within the Bandelier Tuff along the western portion of the Laboratory, but this can not be confirmed without further study.

Contaminant concentrations in water entering these intermediate perched zones are diluted. Lateral, down-canyon flow within intermediate perched zones could contribute to significant transport of contaminants away from their surface source.

2.2.4 Regional Aquifer

The slope of the top of the regional aquifer suggests that the flow of groundwater is generally towards the east or southeast, and towards the Rio Grande.

Intermediate perched zone and alluvial groundwater may be minor sources of recharge to the regional aquifer relative to the amount of public water supply pumping from the regional aquifer. The hydraulic connection between the regional aquifer and the land surface is not strong at most locations.

Regional aquifer groundwater within the eastern portion of the Pajarito Plateau (generally along the Rio Grande) is of different recharge origin than under the central part of the Plateau.

Sources of recharge to the regional aquifer are uncertain. Geochemical data show that the Valles Caldera is not the source of major recharge, contrary to statements in earlier Laboratory reports. Major recharge may occur by southerly flow along the late Miocene trough of Purtymun (1984), infiltration along the flanks of the Jemez Mountains, or possibly via percolation beneath canyon bottoms.

If present, Laboratory-derived contaminants in the regional aquifer are likely to vary in concentration. The contaminant concentrations are probably below maximum contaminant levels (MCLs) for drinking water because; (1) regional aquifer underflow dilutes contaminant concentrations in recharge; and (2) contaminant concentrations in alluvial and intermediate perched zone groundwater are expected to decrease with depth due to dilution and geochemical attenuation along vertical migration pathways.

3.0 INFORMATION INTERPRETATION AND MANAGEMENT

Hydrologic and water quality investigations have been conducted at the Laboratory for 50 years. Much of the historic data are contained in various publications and reports, many of which are out of print or unobtainable. To avoid duplicating earlier work and to maximize the usefulness of historic and newly collected data, the Laboratory has initiated an effort to develop and implement an integrated information and archiving system for groundwater data. A central database will be utilized for storing hydrologic, geologic, water quality, and other related data. In addition, the existing data will be evaluated for validity and assessed for trends. The validated data will be used as a framework for subsequent modeling and trend evaluation efforts. To further constrain the modeling data and interpretation efforts, a series of focused special characterization activities are proposed. A schedule and resource estimates for conducting the activities discussed in this section are provided in Section 1.0.

In addition to centralizing data and models, the Laboratory also will employ a Groundwater Integration Team (GIT) to oversee the implementation of this Workplan, and to ensure that characterization activities are performed on schedule and the data derived from those activities is integrated into the central database and Laboratory conceptual model. The GIT will consist of earth science specialists from the major groundwater programs at the Laboratory. The team will not only track deliverables and activities, but will also serve as the primary group for interpreting site-specific information from a Laboratory-wide context. The GIT is further described in Section 4.1 of this Workplan.

3.1 Central Database

The Laboratory's Environmental Restoration (ER) Project has invested significant resources in implementing a computer network database system, the Facility for Information Management, Analysis, and Display (FIMAD). The system has data storage, statistical analysis, and Geographic Information System (GIS) graphics capabilities. All ER analytical results are stored in the database.

To take advantage of this capability, the Groundwater Protection Management Program will use FIMAD as a central repository and archive for all groundwater-related data and provide appropriate access for internal and external customers. Presently, some water quality and hydrogeologic data are stored in the ORACLE and ARC/INFO databases through FIMAD. The database will incorporate data from all groundwater programs at the Laboratory, including spatial data (mapping), relevant hydrogeologic data, well-completion information, results of chemical analyses, radiological data, and modeling data and results. The database will incorporate data from all groundwater activities at the Laboratory including the Environmental Surveillance Program, ER Project, Waste Management Program, Seismic Hazards Project, Water Supply Utilities Program, and NEPA related activities such as environmental assessments and environmental impact statements.

There are three major steps involved in accomplishing this goal:

- Compile existing data in a central database and assess the validity.
- Consolidate newly-collected data in a central database.
- Implement Quality Assurance on the database.

3.1.1 Compile Existing Data in a Central Database and Assess the Validity.

Hydrogeologic data is inherently 3-dimensional: stratigraphic and hydrogeologic information obtained from wells needs to be visualized and interpreted in a 3-dimensional framework. An important aspect of the hydrogeologic database will be creating the capacity to analyze data such as stratigraphy and hydrologic properties in this spatial context. End-products for this analysis include creation of geologic cross sections and providing a basis for developing groundwater flow and contaminant transport models.

For groundwater models, 3-dimensional stratigraphic information is the foundation for generating computational meshes used in the models. Once a mesh representing the geometry of the stratigraphic units is generated, 3-dimensional information regarding hydrogeologic properties such as porosity and permeability provides the physical properties required to define the units can be developed. The 3-dimensional framework will also provide the ability to analyze spatial trends in contaminant concentrations within hydrostratigraphic units.

Key developments to date are as follows:

- 3-dimensional stratigraphy reviewed. Geologic contacts reinterpreted. Current interpretation of stratigraphy stored in FIMAD is being and will continue to be updated to include surface geology and stratigraphy from over 600 boreholes in the Los Alamos area.
- Developed and adopted a formal standardized stratigraphic nomenclature system for storage of existing and future drill hole data.
- Compiled and published all known Laboratory hydraulic property measurements for the Bandelier Tuff. Evaluated validity of the data set.
- 40+ years of Environmental Surveillance analytical data have been computerized in spreadsheet, including groundwater, surface water, and sediment data. Once the historical data are converted to standard nomenclature and units of measure, data will be copied into FIMAD.
- Spring location inventory entered into FIMAD by NMED DOE Oversight Bureau.
- Watershed maps based on current digital elevation model entered into FIMAD.

Future activities are focused on adding hydrologic property and structural data to the 3-dimensional stratigraphic model and on performing additional quality assurance checks of the datasets.

Once the Environmental Surveillance analytical data are reviewed for quality, trend analysis will be performed for key contaminants indicative of Laboratory effects; for example, tritium and gross alpha radioactivity. If any trends are suggested by the manual graphical analysis at a given sampling location, then a formal statistical analysis will be performed for those sampling locations. Highest priority will be given to assessing the trends in the White Rock Canyon springs and in the regional aquifer test wells.

3.1.2 Consolidate Newly-Collected Data in Central Database

The site-wide hydrogeologic characterization and RCRA Facility Investigation (RFI) activities underway throughout the Laboratory will generate significant additional data. In order for this data to be accessible by the entire earth science staff, it is vital that a central data management capability be maintained. FIMAD will provide the overall vehicle for such a capability. The three-dimensional stratigraphic model and database developed by the ER Project will be utilized to display new information and to view it in context with existing information.

As new data are generated, they will be first supplied to a draft database. After review in draft, the data is then transferred to a quality-assured database. The data will be qualified with indications of validity based on the source of the data. For environmental chemistry data, established ER Project criteria will be used to determine the validity of the data. For hydrogeologic data, the subject matter expert will determine if the data are valid and meet data quality objectives.

As new data are acquired, they will be continually used to refine the hydrogeologic conceptual model for the Laboratory. This type of analysis can be used to determine whether collection of additional field data is necessary for the groundwater characterization program.

3.1.3 Implement Quality Assurance on Database

As part of the process of adding data to a central database, one of the most difficult tasks is ensuring that the data are current and accurate. An important step in maintaining and building a central information system is to establish protocols for verifying and tracking the origin of each of the items in the database. Some of the issues associated with maintaining a database include:

- Defining formats for electronic deliverables. This includes issues such as use of EPA qualifiers related to chemical analyses. The qualifiers indicate whether the analytical value was above or below the detection limit, the results of the analyses of blanks, and other measures of quality, all intended to assist in data evaluation. Other issues related to data quality are the number of significant figures, reporting levels of uncertainty, and consistency of measurement units.
- Numerous problems arise from having many data contributors; the solution is to centralize data input and quality control.
- Part of quality control is ensuring faithful electronic data transfer. Fewer people are required for this if database design is carefully implemented.
- An additional part of the data transfer quality control relates to difficulties with duplicate records, which can arise from updates or multiple transfers.
- Care needs to be taken to assure that the sampling locations and samples are properly associated in the database, especially for older locations, and to properly associate field and lab data.

Additional personnel are required to validate analytical data once it is in the database.

3.2 Additional Non-Field Activities

3.2.1 Overview

As a complement to the regional and aggregate-specific hydrogeologic characterization programs described in following sections, a series of activities have been identified in the DQO Process (See Section 1.3) as being required to better quantify key environmental processes. These activities are designed to reduce the uncertainty of hydrological and geochemical parameters that are utilized in long-term contaminant migration and risk calculations. Although the activities are believed to be necessary, based on the current understanding of site conditions, as new information is collected and used to refine the conceptual model, some of these activities may be eliminated. Some of these activities have been, or will be, partially funded by the ER Project or by Waste Management. Resources are being sought for the currently unfunded activities. In addition, several infrastructure needs for basic data collection have been identified. Key steps, status, and future activities are summarized in Table 3-1.

1. *Determination of Vadose Zone Fluxes in Los Alamos Mesas Using Chloride and Stable Isotope Profiles.*

   Measurement of infiltration rates within the vadose zone of arid regions is difficult due to the large uncertainties inherent in physically based approaches, such as Darcy's Law and water balance determinations, which obscure the small flux values in arid regions.

Table 3-1. Status of Non-Field Activities

Task	Subtasks	1997 Status	Future Activities
Develop Geologic Model	Compile and publish drilling and completion data from all significant boreholes.	Prepared individual reports for alluvial and intermediate wells installed in Aggregate 1.	Develop completion reports for alluvial, perched intermediate, and regional aquifer wells as they are installed.
	Perform comprehensive review of 3-dimensional stratigraphy including analytical chemistry and mineralogy necessary to make stratigraphic correlations between boreholes; integrate newly-collected geologic data into structure-contour maps, isopach maps and cross-section.	Activities in FY97 were directed at supporting the site-wide 3-D Geologic Model.	Data from R-9 and other boreholes are being incorporated into cross-sections and structure contour maps. Correlations of basalt and tephras are being made through geochemical and geochronology studies.
	Develop 3-dimensional geological database to include surface geology, structural geology, and borehole stratigraphy.	QA performance on initial model as contact surfaces and isopachs evaluated to provide an internally consistent model of the 3-D stratigraphy.	A. QA of integrated model. B. Incorporation of basaltic unit into model. C. Incorporation of new drill hole and surface data into model. D. Development of integrated data management and analysis plan.
	Salvage of data from stratigraphic and geochemical analysis of available canyon bottom core samples.	No activities in 1997.	ER Project's Canyons Focus Area will hire a GRA in FY 98 to begin logging these sediments.
Develop Hydrologic Model	Compile and publish hydraulic characteristic data:		
	1) Bandelier Tuff – Assemble hydrologic laboratory test results of Bandelier Tuff core from across the Plateau. Evaluate test results for validity. Calculate unsaturated hydraulic properties from moisture retention characteristics. Summarize data by stratigraphic unit and locations.	1) Bandelier Tuff test results complete from tests conducted through 1994 (Rogers and Gallaher, 1995). Newer data from TA-21 and TA-49 are being incorporated into ER Project RFI reports for those sites.	1) ER Project RFI hydrologic reports for TA-21 and TA-49 will be published in FY98.
	2) Determination of vadose zone fluxes in Los Alamos mesas using chloride and stable isotope profiles. Analyze soil moisture for chloride mass and isotope ratios. Calculate fluxes from tracer profiles.	2) Completed profile work and flux calculations for Mesita del Buey, DP Mesa, and Frijoles Mesa (TA-49). Nine boreholes were examined for chloride and three boreholes were examined for stable isotopes.	2) A report will be written comparing the chloride profile results from DP mesa and TA-16.
	3) Hydrologic parameter estimation for the Pajarito Plateau, including in-situ hydraulic testing of wells. Load available hydrologic measurements in 3-dimensional database. Statistically describe zones and regions.	3) Basin-scale and site-scale hydrologic data was gathered and analyzed; slug tests were conducted in DP Canyon alluvium and in saturated zones encountered in R-9.	3) Hydraulic properties for regional aquifer to be incorporated into saturated zone model to be developed starting in FY98. Pump test new water supply wells GR-1, GR-2, GR-3, and GR-4 in Guaje Canyon during 1998 before these wells enter routine service. Run spinner logs in new supply wells GR-1, GR-2, GR-3, and GR-4 in Guaje Canyon during 1998 in conjunction with aquifer pump tests.

Table 3-1. Status of Non-Field Activities (continued)

Task	Subtasks	1997 Status	Future Activities
Develop Hydrologic Model	Water Quality Data:		
	1) Consolidate historical water quality data in database and perform trend analysis.	1) All of the historic environmental surveillance data for ground water, surface water, and sediments have been loaded into a Microsoft Access database. These data cover the period from the early 1950s to the present and include 173,000 records. All sample values and units have been corrected to a set of standard units to facilitate data analysis. We chose data collected on or near the San Ildefonso Pueblo as the first data for trend analysis. We have completed trend analysis for these data set and are writing up the results.	1)The historic data has not been adequately verified and QA-checked. We will continue to confirm that these data matches the published record. We will complete the write-up of the trend analysis on the San Ildefonso data and publish this report. We will continue trend analysis on the historic data and expect to focus on evaluating trends by drainage basins.
	2) Evaluate water quality variations and vertical stratification within the regional aquifer using water samples from supply wells. Pull permanent pump and isolate discrete sample zones (46-ft lengths) in each well using hydraulic packers. Sample with temporary pump.	2) In December 1996 O-1 was zonally sampled prior to its scheduled entry into routine service as a municipal water supply well.	2) Zonally sample new supply wells GR-1, GR-2, GR-3, and GR-4 in Guaje Canyon during 1998 before these wells enter routine service.
	Inventory springs on-site and near Lab boundaries by reviewing existing Laboratory and USGS reports for initial inventory. Perform additional field reconnaissance. Supplement with aerial photography where possible. Select springs with discrete discharge points. Install flow and monitoring probes.	Flow measurement equipment has been installed at 4 key TA-16 and TA-18 locations to determine nature of apparent spring discharges. The NMED DOE OB continued to make spot measurements of flow at selected discharge points. Flow and chemistry sampling equipment was installed at three springs. Quarterly sampling was conducted for major anions and cations, and contaminants. Daily sampling was conducted for bromide.	Continue to obtain field observations from Laboratory and NMED personnel. Continue ER Project investigations at critical discharge points (particularly TA-16 and TA-18) where there is uncertainty if flow is natural spring-fed or perennial. Continue monitoring of flow and for bromide tracer and other chemical constituents. Analyses of the flow and chemistry time series will be conducted.
	Long-term water balance estimates for the Pajarito Plateau. Install stream gages at upstream and downstream boundaries of the Laboratory. Continuously measure ET, Precipitation, and groundwater levels.	Data collected in most regional aquifer test wells, and some intermediate and shallow alluvial wells. Stream flow measurements collected from 19 stations. Precipitation data collected from 7 stations and ET data collected from 2 stations.	Water level, stream flow, precipitation and ET data will be collected on a continuing basis.
	Groundwater flow modeling using the FEHM code.	Organized stratigraphic information relating to Pajarito Plateau and surrounding Española Basin.	Establish geologic framework model for Pajarito Plateau and surrounding Española Basin. Create model grid for FEHM code. Assign hydrologic properties and boundary conditions. Sensitivity analyses and testing of hypotheses concerning flow directions and locations of recharge.

Table 3-1. Status of Non-Field Activities (continued)

Task	Subtasks	1997 Status	Future Activities
Develop Geochemical Model	Hydrogeochemical and statistical evaluation of solute distributions on the natural surface and groundwaters.	Prepared report detailing hydrochemistries of alluvium and perched intermediate groundwaters in Los Alamos and Pueblo canyons; conducted pilot surface water study in upper Los Alamos and Pajarito canyons.	Expand on statistical evaluation of solute distributions for LANL background groundwater investigations.
	Geochemical characteristics of key subsurface geohydrologic units.	Characterized groundwater in basalts and Puye Formation and major and minor chemistries of aquifer material.	Continue to characterize hydrochemistries of alluvium, perched intermediate zones, and regional aquifer and associated aquifer material.
	Geochemical modeling.	Performed speciation, mixing, and mineral saturation calculations using MINTEQA2 and PHREEQE; completed 4 quarters of sampling 15 LANL background groundwater stations.	Continue geochemical modeling to understand important processes occurring along groundwater flow paths; quantify mobilities of strontium-90, uranium, and other contaminants by determining sorption constants for these metals/radionuclides.

These uncertainties directly affect the ability to calculate the potential for deep contaminant transport. The evaluation of fluxes based on isotope and chemical profiles is an alternate approach. The objectives are to: (1) use natural chloride tracers to estimate mesa flux rates and vadose zone water ages; and (2) use natural stable isotope tracers (Oxygen-18 and Deuterium) to confirm the chloride interpretations and also to evaluate lateral water movement (e.g., atmospheric drying) in the mesa. These results will be used to refine the conceptual model and to better quantify the contaminant travel times from mesa top sources through the Bandelier Tuff. Preliminary data using this approach indicate that travel times through the Tuff may be ten times slower than would be otherwise calculated. This is particularly important to forecasting long-term rates of contaminant movement from Material Disposal Areas.

2. *Hydrogeochemical and Statistical Evaluation of Solute Distributions in the Natural Surface and Groundwaters.*

   Statistical evaluations of selected existing water quality data will be performed to determine preliminary background constituent concentrations. Background data for surface water and groundwater are required to distinguish between contaminated and non-contaminated waters at the Laboratory. A critical review of existing data is required prior to collection of new samples. This activity will help to establish approximate ranges of background water quality for near surface, intermediate and deep waters.

3. *Geochemical and Hydrological Characteristics of Key Subsurface Geohydrologic Horizons.*

   Buried soil horizons and lithology associated with the Guaje Pumice Bed and Cerro Toledo interval may control intermediate perched groundwater zones and may provide significant contaminant attenuation potential. Key geochemical and hydrogeological properties of well-developed buried soils associated with these units will be evaluated. Samples from both outcrop exposures and boreholes will be analyzed for chemistry, mineralogy, and hydrogeological characteristics. All work will contribute to the 3-dimensional stratigraphic model.

4. *Hydrologic Parameter Estimation for the Pajarito Plateau.*

   Existing and future hydrologic data will be used to develop parameters needed for subsurface contaminant transport modeling. The data will be used statistically to develop site-specific and regional estimates of hydrologic parameters. All work will contribute to the 3-dimensional stratigraphic model. Available hydrologic data for the vadose zone are principally derived from individual measurements of small rock samples. Before the individual measurements can be utilized in contaminant transport models, they must be generalized. In this activity, the data will be analyzed for general spatial trends and for possible correlation with geologic units. The goal is to develop quantitative estimates of hydrologic parameters (with uncertainties) at gridded locations for utilization in transport model computer codes. In addition, the statistical analysis will identify critical data gaps and uncertainties to focus future data collection strategies. For example, if there is little statistical variability in the properties of a particular geologic unit, there may be no need to collect more core from that unit for hydrologic testing. Any general hydrologic trends will be added to the 3-dimensional stratigraphy model and database.

5. *Salvage of Data From Stratigraphic and Geochemical Analyses of Available Canyon Bottom Core Samples.*

   This study will undertake examination, description, and analysis of available canyon bottom core samples, and selection of a sub-set of core for longer-term storage prior to disposal of redundant material. The focus will be on providing improved stratigraphic logs of canyon bottom core holes, particularly of buried soil horizons or geochemically altered units. The canyon bottom sediments constitute the initial medium for groundwater transport within alluvial groundwater that, in turn, may contribute recharge to deeper groundwater zones. Stratigraphic and associated permeability variations within the alluvium can be key in controlling flow paths. In addition, geochemical changes imparted by pedogenesis or alteration may affect the contaminant migration. Results of this study will be used in contaminant transport modeling by refinement of the 3-dimensional stratigraphic model.

6. *Long-term Water Balance Estimates for the Pajarito Plateau.*

   As an approximation to cumulative surface recharge on the Laboratory, estimates of the critical hydrologic cycle components will continue to be refined. The extensive network of stream gages, estimates of effluent discharges, measurements of precipitation and evapotranspiration at meteorological towers, and long-term groundwater level monitoring in all identified groundwater zones will be continued. All newly-installed intermediate depth and regional aquifer wells are proposed to be equipped with continuous recording pressure transducers for groundwater level measurements to enhance data collection.

7. *In situ Hydraulic Testing of Characterization Wells.*

   Short-term hydraulic testing will be performed on selected newly installed intermediate depth and regional aquifer characterization wells. Likely tests include bailer recovery (slug) tests or short-term aquifer pumping tests for hydraulic conductivity estimation, and direct downhole velocity measurement (for example, colloidal borescope and diffusion cell tracer tests). Results from these tests will refine the conceptual model and be incorporated into the saturated zone model, described below in Section 3.3.3. The results also will be utilized in the design of a long-term monitoring network.

8. *Chemical Stratification Within the Regional Aquifer.*

   Because of their great depth, existing municipal water supply wells offer access to deeper portions of the regional aquifer. A program has been initiated to conduct vertical water quality profiling of the regional aquifer using these wells. Tests of selected zones of the regional aquifer will be conducted by placing a temporary submersible pump and packer assembly at various depths in the well, whenever a permanent pump is pulled from a well for maintenance purposes. Results from these tests will be used to refine the conceptual model, to determine recharge, and to determine whether contamination is evident at depth in the regional aquifer.

9. *Aquifer Performance Testing of the Regional Aquifer.*

   Several long-term (greater than one week duration) aquifer pumping tests have been performed using municipal water supply wells. However, the utility of the data obtained has been limited by the lack of observation wells near the pumped well. The installation of many new characterization wells for this program provides the opportunity to conduct aquifer tests using more accurate pumping and observation well techniques. An excellent opportunity exists to conduct aquifer performance tests in the Guaje well field after replacement wells are installed in 1997. Data from these tests will be incorporated into the saturated zone model of the regional aquifer discussed in Section 3.3.3 below.

10. *Conduct Spring Discharge Measurements.*

    The flow characteristics of major springs, including those along White Rock Canyon, will be studied to better understand their relationship with the regional aquifer or intermediate perched groundwater zones. An attempt will be made to equip major springs with continuous recording flow and chemical (e.g., conductivity, temperature) measurement instruments.

11. *Maintain Core Storage Facility.*

    Newly collected core from the hydrologic characterization boreholes will be examined and catalogued. Critical and non-redundant core will be stored in the ER Project Core Storage Facility.

12. *Studies to Determine Subsurface Geology and Structure.*

    Based on core studies, selected samples of core will be used for geochemical studies (major and trace element analyses), mineralogical studies (modal and bulk rock), and age dating (ashes and basalts) for the purposes of identifying and correlating stratigraphic units, determining geometry and structural features, and providing input to 3-dimensional models.

3.3 Hydrogeologic Workplan Modeling Tasks

The following is a discussion of the modeling tasks to be performed which will provide information needed for siting of wells and filling data gaps. Expected project durations and resources are given on the Master Schedule, Figure 1-1 and the Resources table, Table 1-1.

3.3.1 Overview of Modeling

A central piece of the Hydrogeologic Workplan relates to prediction of hydrologic flow paths and resultant contaminant movement. Computer models are a tool for accomplishing this purpose.

Hydrologic modeling will play a major role in the task of data synthesis and evaluation, both before and during hydrogeologic characterization activities. In the project design phase, modeling will be used to examine hypotheses relating to the hydrogeologic conceptual model and determine where additional information is needed. In later project phases, modeling can be used to assess how recently-acquired information relates to earlier predictions, and can identify data gaps.

Hydrologic modeling within the Hydrogeologic Workplan will be applied at two levels: The first addresses evaluation of aggregate-specific issues, one example of which might be evaluating radionuclide transport at MDA G. A key product of the aggregate-specific models will be forecasts of contaminant movement through the vadose zone. A second level relates to the evaluation of site-wide issues, for example, the effect of water supply pumping on the regional aquifer. These models will be continually refined with new information. Both scales of models may be used to locate future wells.

3.3.2 3-Dimensional Stratigraphic Model

A 3-dimensional stratigraphic model for the Pajarito Plateau is being refined as part of activities funded through the Earth Sciences Technical Council of the ER project. Data from the 3-dimensional model is being used in conjunction with other hydrogeologic data sets to site the locations of the first regional aquifer boreholes. New data developed from these initial boreholes will be used to further refine the 3-dimensional model. Ultimately, the stratigraphic model will provide a framework for constructing flow and transport models.

3.3.3 Aggregate-specific Models

The purpose of aggregate-specific modeling is to address contaminant pathway and hydrologic questions in each area. Model analyses conducted for aggregate-specific issues include work done to support ER Project investigations as required by ER Project goals at each area, and the MDA G Radiological Performance Assessment.

Examples of ER Project areas which will be analyzed for contaminant transport are TA-49, TA-16, TA-21, and the ongoing MDA L vapor transport work.

With respect to evaluation of potential radiological doses from groundwater, the MDA G PA requires two different analyses: an evaluation of the radiological dose due to MDA G itself, and a composite analysis of the entire Laboratory radiological dose via a groundwater pathway.

Results of these analyses will be reviewed for consistency with existing conceptual models of the hydrogeology. When needed for further analyses of the regional aquifer, the results from the aggregate-specific modeling efforts will be integrated with any regional analyses to be performed. Results of aggregate-specific modeling efforts will be presented in reports on these activities such as RFI Reports from the ER Project, and summarized in the annual report on hydrogeology to be submitted each year.

3.3.4 Site-wide Saturated Zone Model

The site-wide model is viewed as a representation of the regional aquifer. Rather than creating a unified vadose zone-saturated zone model, a saturated zone model is called for as a practical measure. Numerical evaluation of water and contaminant movement in the vadose zone requires very fine discretization in time and space. The analysis of many different problems (contaminant transport, water balance, transient effects of pumping) would be prohibitive for a complex saturated-unsaturated model. In cases such as investigation of recharge or contaminant transport issues, it is more efficient to separately evaluate sources of contamination or recharge and input their results into a saturated zone model as boundary conditions or source/sink terms.

This site-wide saturated zone model will be used to address several complimentary questions, including:

- Test flow system hypotheses, such as evaluating sources of recharge.
- Evaluation of Laboratory-wide contaminant transport. Aggregate-specific model results can be used as input to site-wide saturated zone model.
- Analyze influence of water supply well pumping on the flow system and possible contaminant transport.
- Investigate water supply issues including effects of pumping on water quality and on the water supply availability and quality.
- Evaluate groundwater geochemistry as a source of information on the groundwater system. Data on geochemistry, chemical reactions, and isotopes can provide an important constraint on groundwater system flow paths and residence times. Improving the understanding of basic

groundwater geochemistry can enhance efforts to predict the migration of chemically-reactive contaminants in the subsurface.

- Evaluate the worth of and need for new data. This includes the capability to evaluate uncertainties in model parameters, such as recharge sources and permeabilities. This also includes the capability to suggest well placement strategies in order to decrease uncertainty.

The structure of the site-wide saturated zone model has not been resolved. It may be more economical to develop several different grids to test different questions. For example, the influence of particular water supply wells might call for a model with a grid refinement near that well. Such a grid refinement might not be necessary or economical for questions related to discharge areas. Efforts will be made to determine the most appropriate approach from a technical and cost standpoint. The construction of groundwater flow models depends on development of stratigraphic and geologic models, which will be supplied under the separately described database task.

The first task in constructing a site-wide saturated zone model will be to reproduce as nearly as possible results of the recent USGS model (Frenzel 1995) as a baseline check. Frenzel's model is based on several years of work and incorporates much of the current knowledge regarding groundwater flow in the area of the Laboratory. The model has several limitations (acknowledged by the author) which would prevent its use in evaluation of contaminant transport or a more detailed study of groundwater flow questions. These limitations include uncertainties in boundary conditions, the coarseness of grid spacing, and a need to refine the stratigraphic model used.

3.3.5 Information Support

The development of hydrogeologic models requires an information system to supply data on geochemistry, geology, hydrologic properties, and borehole information. FIMAD should provide the overall vehicle for such a capability. The site-wide hydrogeologic characterization and RFI activities throughout the Laboratory will generate significant additional data. A central data management capability will be developed and maintained so that this data can be readily accessed. The three-dimensional stratigraphic model and database developed by the ER Project will be utilized to display new information.

As new data are acquired, they will be continually used to refine the hydrogeologic conceptual model for the Laboratory. For example, new data will be compared with regional groundwater flow maps and model predictions to assess the level of understanding regarding recharge and discharge areas, groundwater flow directions, and interconnections between overlying groundwater-bearing zones and the regional aquifer. If there is good agreement, it will then be possible to incorporate reasonable assumptions into the groundwater modeling effort. This type of analysis can be used to determine whether it is necessary to collect additional field data for the groundwater characterization program.

3.4 Annual Groundwater Status Summary Reports

An annual report will be prepared by the Laboratory summarizing the status of groundwater characterization activities. The report will be due to NMED by January 15th , covering the activities of the previous Fiscal Year. The document will focus on two primary topics.

1. Results of the comprehensive analysis of data from the preceding Fiscal Year's characterization activities that add to the understanding of the conceptual and quantitative hydrogeologic framework.

2. Based on the results, identification of changes to the conceptual framework (i.e., locations of future wells and modeling to be performed) for characterizing the hydrogeologic system underlying the Laboratory.

Production of the annual status report will be the responsibility of the Laboratory's Water Quality and Hydrology Group (ESH-18), with major contributions from the GIT. The team will summarize key hydrogeologic findings and activities of the Environmental Surveillance Program, ER Project, Waste Management Program, Seismic Hazards Project, Water Supply Utilities Program, and NEPA related activities such as environmental assessments and environmental impact statements.

4.0 HYDROGEOLOGIC CHARACTERIZATION

This section describes the proposed hydrogeologic characterization of the strata beneath the Laboratory with the ultimate goal of establishing effective long-term monitoring and/or demonstrating that monitoring requirements can be waived. This requires knowing what subsurface water bodies to evaluate, at what locations, and for which parameters. The characterization program is intended to fulfill these requirements. Table 4-1 contains a summary of the rationale for the proposed deep wells. This table is intended to be a quick reference. More detail on the rationale for each well is included in Sections 4.2 and 4.3.

The data needs to complete the hydrogeologic characterization were developed by an interdisciplinary team applying the Data Quality Objective (DQO) process (EPA 1987). The outputs of this process are the decisions that will be made, questions that need to be addressed to support the decisions, existing data relevant to the questions, new data required to address the questions, decision rules for collection of the new data, and the design of the program to acquire the new data. The outputs from the DQO process are summarized in Appendix 4.

The data collection design established the number and approximate locations of wells; 32 deep wells and 51 alluvial wells were identified as being needed. The 51 alluvial wells are proposed to be installed by the ER Project, primarily through the canyons investigations, on a schedule discussed in the Core Document for those investigations (LANL 1996b).

The installation of the deep wells, each of which requires a significant commitment of resources in drilling equipment and manpower, must be scheduled in an optimum sequence. The optimum sequence was established based on the total score of eight criteria discussed below. These criteria reflect the concerns of the regulatory agencies regarding the needs for information, the logical flow of information from successive boreholes and wells, efficiencies to be gained by multiple installations in the same general area, and budgetary constraints. Each criterion was given a maximum score based on the relative importance of that criterion. The criteria and the maximum scores are:

1. **Reduce Hydrologic Setting Uncertainty -** This criterion is used to evaluate how much knowledge about the hydrologic setting is likely to be gained with the installation of a particular well. Factors that are considered include how much is already known about the hydrogeology of the area from previous wells, the potential to encounter perched intermediate zones, and proximity to ambiguous features such as the apparent high water level in well TW-1. (*5 points maximum*)
2. **Reduce Stratigraphic and Structural Uncertainty -** Points assigned are based on a consideration of how much additional knowledge of the stratigraphy and structure of the area is likely to be gained with the installation of a particular well. Factors used in making this assessment are how much is already known about the area stratigraphy from existing wells, boreholes, mapping, and other methods, and the potential presence of stratigraphic or structural features that may control the presence and flow of groundwater, such as faults or interfingered basalts. (*4 points maximum*)
3. **Contaminant Detection for Water Supply System -** This criterion is based on placement of the well between contaminant sources and a water supply well in order to provide detection of approaching contaminants. The primary factor that is considered is location of the well with respect to both a water supply well and the anticipated movement of contaminants from sources. (*4 points maximum*)
4. **Assessment of Nature and Extent of Potential Contamination in Groundwater -** This criterion reflects the degree of importance of a particular well to verify and provide detail on the nature and extent of suspected contamination in groundwater. Although the groundwater

encountered by all of the wells installed will be analyzed and will add to the knowledge of contaminant distribution, some wells will be located with the primary purpose of detecting contamination. Other wells have special value because they define upgradient water quality for an aggregate. (*4 points maximum*)

5. **Future Water Supply -** This criterion is used to evaluate the importance of a particular well in providing information related to the potential for additional water supply development. This potential is based principally on determining the extent of the high-permeability Miocene trough that is most productive in current water supply wells. (*3 points maximum*)
6. **Control of Timing and Construction of Other Wells -** This criterion is an indication of which wells should be installed first in a sequence of wells intended to provide a logical flow of information. The sequence may also be important in determining the location and construction of succeeding wells to optimize the information gained. Examples are the fully cored boreholes; these will serve as reference boreholes, and should be drilled before other boreholes so that the reference stratigraphy can be used in successive installations. (*2 points maximum*)
7. **Budget and Programmatic Constraints -** This criterion provides a judgment as to how important the purpose or resulting data from a particular well is to the funding program. (*2 points maximum*)
8. **Operational Efficiency -** This criterion indicates the savings related to logistics if a particular well is installed in the same mobilization as one or more other wells. Scheduling efficiencies could result in savings of program funds. (*1 point maximum*)

On a well-by-well basis, a score for each criterion was assigned by consensus of the interdisciplinary team. The score for each criterion was summed, thus deriving a total score for each well. Starting from highest to lowest scores, the wells were scheduled assuming three wells could be installed per year each by the Nuclear Weapons Technology Program (NWT) and ER Project. The resulting list and schedule of wells is summarized in Table 4-2. The detailed scoring sheets for each well are in Appendix 5.

Section 4.1 describes the procedures that will be used to drill the borehole and install, complete and sample the proposed wells. Section 4.2 describes the proposed characterization of the regional hydrogeologic framework. Section 4.3 describes the hydrogeologic characterization for each aggregate. Within each aggregate, a brief conceptual model is presented which summarizes the currently available data and the objectives of each of the proposed wells.

4.1 Introduction and Procedures

This section contains information regarding the general procedures and technical approaches that are proposed for collecting the hydrogeologic information through the activities described in this Workplan. The purpose of this section is to aid the reader in understanding the general technical nature of the Laboratory's procedures that are common to most of the activities detailed in subsequent sections. The bulk of the technical procedures and methods used will be the current protocols adopted by the Laboratory's ER Project and referenced in the ER Project's Quality Assurance Project Plan (QAPjP), Standard Operating Procedures (SOPs), RFI Work Plans, and Sampling and Analysis Plans (SAPs). This Workplan adopts by reference those documented practices and procedures

As described in Section 1, the Laboratory utilized a DQO Process to determine the data needs and data collection design necessary to characterize the hydrogeologic setting beneath the Laboratory.

Table 4-1. Rationale For Proposed Regional Aquifer Boreholes

Bore Hole[1]	*Timing Priority/ Funding Source*[2]	*Well Type*[3]	*Start Date*	*Location*	*Rationale for Borehole*
R-1	11 NWT	3/4	FY00	North of Los Alamos in Rendija Canyon	Site-wide characterization borehole R-1 is a multipurpose borehole located north of Aggregate 1 in Rendija Canyon. R-1 will be continuously cored to 500 ft below the top of the regional aquifer, and this core will support site-wide studies of the hydrogeologic framework of the Laboratory by serving as a stratigraphic reference section for the northern part of the Laboratory. Core from this borehole will be used constrain geologic and hydrologic relationships in nearby Type-2 boreholes R-2 and R-3. R-1 is sited along the northward projection of Purtymun's (1995) mid-Miocene high-permeability zone at the top of the Santa Fe Group, and this borehole could significantly extend the known northern limit of this important water-supply feature. This borehole is presently scheduled to be completed as a Type 3 well, but the option is preserved to advance the boreholes for these wells to a total depth 4000 ft and to include multiple completions of the wells if funding agencies decide further characterization of regional aquifer groundwater resources is required. Multiple completions in this borehole could identify groundwater capture zones for potential future water supply wells, and provide information on vertical hydraulic gradients, saturated hydraulic conductivities, vertical stratification of water-quality in the regional aquifer, and patterns of water-yielding characteristics within the high-permeability zones within the Santa Fe Group and the Puye Formation. Water level data for R-1 will provide information about the direction of groundwater flow in the regional aquifer, and these data will contribute to optimizing the placement of long-term monitoring wells for Aggregate 1. Water-level and water-quality data from this borehole will be used to test hypotheses concerning possible recharge to the regional aquifer from the north. R-1 is part of a north-south traverse of reference wells that includes R-14 and R-28.
R-2	9 NWT	2	FY00	Near TW-4 in upper Pueblo Canyon	Site-wide characterization borehole R-2 is located near the confluence of Acid Canyon and Pueblo Canyon within Los Alamos townsite. Laboratory surveillance data collected at nearby mesa-top borehole TW-4 indicate the presence of ^{90}Sr (6.2 pCi/l, MCL = 8 pCi/l) in the regional aquifer (EPG 1996). This remediated area (former TA-45) has documented releases of Am, Pu, NO_3, U, and other contaminants to alluvial groundwater in Acid and Pueblo Canyons in the late 1940's and early 1950's. R-2 is sited in Pueblo Canyon and is downgradient of the Rendija Canyon fault. Recharge contaminated from past releases may be reaching intermediate perched zones and the regional aquifer along this fault. Analyses of core and water samples collected from R-2 will be used to evaluate the fault as a preferential groundwater pathway. R-2 could replace TW-4 drilled by cable tool in 1950.

Table 4-1. Rationale For Proposed Regional Aquifer Boreholes (continued)

Bore Hole[1]	Timing Priority/ Funding Source[2]	Well Type[3]	Start Date	Location	Rationale for Borehole
R-3	13 ER	2	FY99	Upper Pueblo Canyon between TW-2/2A and TW-4	Aggregate characterization borehole R-3 is designed to provide water quality information for potential intermediate perched zones and for the regional aquifer beneath upper Pueblo Canyon downgradient of former TA-45 (see description of R-2). In the past, natural surface water flow in Pueblo Canyon was augmented by Laboratory releases and by effluent from the former sewage waste water treatment plant in upper Pueblo Canyon. Because of the augmented surface flow, upper Pueblo Canyon may have been a source of recharge to intermediate perched zones and the regional aquifer. Laboratory surveillance data (EPG 1996) show that from 1990 to 1994, NO_3-N concentrations increased from 1.4 to 13.7 mg/l in TW-2A, 0.75 mi to the east of R-3. TW-2A is completed within an intermediate perched zone within fanglomerates of the Puye Formation. Information is lacking about the geologic conditions controlling the perching of groundwater, and it likely that the coarse-grained deposits of the Puye Formation have high hydraulic conductivities conducive to providing recharge to the regional aquifer. TW-2A also contains elevated concentrations of ^3H (2,228 pCi/l, Blake et al. 1995). The available data suggest that mobile contaminants associated with former TA-45 (^3H, ^{90}Sr, and NO_3) are present in a groundwater plume that extends at least 1.75 mi down Pueblo Canyon and may extend further. Additional mapping of intermediate perched zones and characterization of water quality is needed to assess the nature of groundwater contamination in upper Pueblo Canyon. Hydrologic and geologic properties of pre-Bandelier units in R-3 will be used for ER Project assessments of the airport landfill in OU-1079. Water level data for R-3 will provide information about the depth to groundwater in the regional aquifer and contribute to optimizing the placement of long-term monitoring wells for Aggregate 1. R-3 could replace regional aquifer borehole TW-2 drilled by cable tool in 1949. A more detailed analysis of the placement of R-3 in Los Alamos Canyon will be prepared as an addendum to the ER workplan for Los Alamos and Pueblo Canyons.
R-4	18 ER	2	FY01	Middle Pueblo Canyon between TW-2/2A and the Bayo Sewage Treatment Plant	Aggregate characterization borehole R-4 is designed to provide water-quality and water-level information for potential intermediate perched zones and for the regional aquifer beneath middle Pueblo Canyon. R-4 will provide information about the downgradient extent of groundwater contamination from former TA-45 (see descriptions of R-2 and R-3). This borehole is located between TW-1A and TW-2A, both of which were completed in intermediate perched zones containing contaminant levels that are above background levels (see descriptions for R-3 and R-5). Data from existing test wells suggest that a significant intermediate perched zone(s) occurs beneath Pueblo Canyon. R-4 will place constraints on the lateral extent of the perch zone(s) and identify deeper perched zones within the Puye Formation and basalts in middle Pueblo Canyon near the northern Laboratory boundary. R-4 will also characterize groundwater water quality upgradient of the county's Bayo Sewage Treatment Plant, effluent from which has been shown to be a source of recharge to the intermediate perched zone aquifer in basalt in the recently completed ER borehole POI-4. Hydrologic and geologic properties of pre-Bandelier units in R-3 will be used for ER Project assessments of the airport landfill in OU-1079. A more detailed analysis of the placement of R-4 (ER borehole POI-2) in Pueblo Canyon is included in the ER workplan for Los Alamos and Pueblo Canyons.

Table 4-1. Rationale For Proposed Regional Aquifer Boreholes (continued)

Bore Hole[1]	Timing Priority/ Funding Source[2]	Well Type[3]	Start Date	Location	Rationale for Borehole
R-5	3 NWT	2	FY99	Near Water Supply Well Otowi-1 in Pueblo Canyon	R-5 is located in lower Pueblo between Otowi-1 and the Los Alamos County Sewage Treatment Plant. Laboratory surveillance data (EPG 1995 1996) show the presence NO_3 (TW-1, TW-1A, TW-2A), $^{239,240}Pu$ (TW-2A), and ^{137}Cs (TW-1A) at various activities and concentrations below MCLs, except for NO_3 (23 mg/l NO_3-N; MCL NO_3-N = 10 mg/l). Otowi-1 is located near POI-4, TW-1, and TW-1A. In 1996, ER well POI-4 confirmed the presence of NO_3, PO_4, Cl, and other solutes in intermediate perched zone groundwater at a depth of 160 ft to 181 ft in basalt. R-5 will also provide information on whether a recharge mound occurs below the canyon floor and is responsible for the anomalously-high regional aquifer water levels in TW-1. R-5 could serve as a replacement well for TW-1 drilled by cable tool in 1950.
R-6	24 NWT	3	FY01	Near Test Well H-19 in Los Alamos Canyon	Site-wide characterization borehole R-6, located in upper Los Alamos Canyon, is a fully-cored reference borehole that provides baseline information about the geology, hydrology, and water quality for the western boundary of the Laboratory. Core from this borehole will be used constrain geologic and hydrologic relationships in surrounding type-2 boreholes, including R-19, R-20, R-27, R-30, and R-31. This borehole will determine background water quality for intermediate perched zones and the regional aquifer upgradient of Aggregate 1. It also will provide information about the depth to the regional aquifer for the western part the Laboratory, and contribute to the construction of accurate groundwater maps for placing monitoring wells in this part of the Laboratory. R-6 is part of a southeasterly traverse of reference wells that includes R-14 and R-16 and a north-south traverse that includes R-25.
R-7	6 ER	2	FY98	Upper Los Alamos Canyon south of TA-21	Aggregate characterization borehole R-7 is designed to provide water-quality and water-level measurements for the intermediate perched zones and the regional aquifer in an area of Los Alamos Canyon that is in close proximity to release sites of contaminated effluent (TA-2 and TA-21) (see description of R-8). R-7 is located between existing boreholes LADP-3 and LAOI(A)1.1 in Los Alamos Canyon. These existing boreholes, and H-19 located west of Los Alamos Canyon bridge, penetrated the largest known intermediate perched intermediate zone on the Pajarito Plateau. This perched zone occurs in the Guaje Pumice Bed at the base of the Bandelier Tuff above a buried soil (?) atop the Puye Formation. This intermediate perched zone may be leaky because the top of the Puye Formation is saturated in LAOI(A)1.1. The saturated thickness in this perched zone ranges from 5 to 22 ft, and water-quality data suggest that it is recharged both by infiltration from overlying alluvium and by recharge sources in the mountains to the west. LADP-3 contains significant ^3H (up to 6000 pCi/l; Broxton et al 1995, Longmire et al. 1996), demonstrating recent recharge to depths of at least 300 ft in this area. The recharge pathway for ^3H must lie between LADP-3 and LAOI(A)1.1 because ^3H levels in LAOI(A)1.1 are at regional background levels (Longmire et al 1996). R-7 is sited in this area of suspected recharge and will provide information about stratigraphic and structural controls on infiltration. Also, R-7 will penetrate the full extent of saturation at the top of the Puye Formation and identify deeper intermediate perched zones beneath Los Alamos Canyon. Groundwater-occurrence and water-level data from R-7 will contribute to optimizing the placement of long-term monitoring wells for Aggregate 1. A more detailed analysis of the placement of R-7 (ER borehole LAOI-1.5) in Los Alamos Canyon is included in the ER workplan for Los Alamos and Pueblo Canyons. Hydrologic and geologic properties of pre-Bandelier units in R-7 will be used for ER Project assessments of mesatop sites at TA-21, TA-53, and TA-73.

Table 4-1. Rationale For Proposed Regional Aquifer Boreholes (continued)

Bore Hole[1]	*Timing Priority/ Funding Source*[2]	*Well Type*[3]	*Start Date*	*Location*	*Rationale for Borehole*
R-8	16 NWT	2	FY00	Near Water Supply Well Otowi-4 in Los Alamos Canyon	R-8, water-supply protection well for Otowi-4, is located near the confluence of Los Alamos Canyon and DP Canyon. When in service, Otowi-4 will provide ~25% of the water supply to Los Alamos County including the Laboratory. Laboratory surveillance data indicated the presence of ^{3}H (~50 pCi/l) and ^{90}Sr (35 pCi/l) in TW-3 located ~300 ft northeast of Otowi-4. Los Alamos Canyon has a long history of facility releases with contaminants detected in alluvial groundwater (^{3}H, ^{90}Sr , ^{137}Cs) and in an intermediate perched zone in the Guaje Pumice Bed (^{3}H). These perched zones may provide recharge to the regional aquifer. DP Canyon contains radionuclides released from the north side of TA-21. R-8 could be used as a replacement well for TW-3 drilled by cable tool in 1949.
R-9	12 ER	2	FY99	Los Alamos Canyon, at the eastern boundary of the Laboratory, completion of LAOI-7	Aggregate characterization borehole R-9, located at the eastern Laboratory boundary in Los Alamos Canyon, is designed to provide water-quality and water-level data for potential intermediate perched zones and for the regional aquifer downgradient of Aggregate 1. Los Alamos Canyon has received treated and untreated effluents from Laboratory operations since 1944. Laboratory surveillance data indicate the presence of multiple ^{3}H and ^{90}Sr plumes in alluvial groundwater originating from TA-2 and TA-21. The alluvial groundwater generally disappears west of R-9, suggesting that infiltration from the alluvium may be recharging deeper perched systems or the regional aquifer. Predictive modeling and hydrogeological data suggest that ^{3}H and ^{90}Sr released from TA-21 is possibly within an intermediate perched zone in the vicinity of R-9. The surface casing of R-9 has been set and the borehole is scheduled for completion by the ER program in FY-99. A more detailed analysis of the placement of R-9 (ER borehole LAOI-7) in Los Alamos Canyon is included in the ER workplan for Los Alamos and Pueblo Canyons.
R-10	17 ER	2	FY00	Upper Sandia Canyon	Aggregate characterization borehole R-10 is designed to provide water quality information for a potential intermediate perched zone in the Guaje Pumice Bed. The large intermediate perched zone in Los Alamos Canyon is located in this horizon and contains significant ^{3}H (see description of R-7). This perched zone appears to be largely confined to the area beneath Los Alamos Canyon west of TA-21 (the Guaje Pumice Bed was not saturated in boreholes 21-2523 and LADP-4 north of Los Alamos Canyon), but structure contour maps (Broxton and Reneau 1996; Davis et al. 1996) suggest that the gradient of the perching layer changes in the vicinity of R-7 and R-10, and water perched in this zone will move southward along the axis of a large pre-Bandelier paleo-drainage. R-10 is designed to investigate the southward extension of this perched system from the Los Alamos Canyon area. Hydrologic and geologic properties of pre-Bandelier units in R-10 will be used for ER Project assessments of the airport landfill in OU-1079. A more detailed analysis of the placement of R-10 (ER borehole SCOI-1) in Sandia Canyon is included in the ER workplan for Los Alamos and Pueblo Canyons.
R-11	25 NWT	2	FY01	Near Water Supply Well PM-3 in Sandia Canyon	R-11, water-supply protection well for PM-3, is located in middle Sandia Canyon east of the TA-72 firing range. PM-3 is downgradient from source terms with a long history of releases at TA-53 and TA-21. R-11 is located between PM-3 and the potential release sites. R-11 will also provide information about groundwater gradients near PM-3, which has water levels that are anomalously high compared to elevations expected from regional water level maps.

Table 4-1. Rationale For Proposed Regional Aquifer Boreholes (continued)

Bore Hole[1]	Timing Priority/ Funding Source[2]	Well Type[3]	Start Date	Location	Rationale for Borehole
R-12	2 ER	3	FY98	Sandia Canyon, at the eastern boundary of the Laboratory	Aggregate characterization borehole R-12, located at the eastern Laboratory boundary in Sandia Canyon, is designed to provide water-quality and water-level data for potential intermediate perched zones and for the regional aquifer downgradient of Aggregate 1. R-12 will be continuously cored to 500 ft below the top of the regional aquifer, and this core will support site-wide studies of the hydrogeologic framework by serving as a stratigraphic reference section for the northeastern part of the Laboratory. Core from this borehole will be used constrain geologic and hydrologic relationships in nearby type-2 boreholes R-9 and R-11. R-12 serves as a water-supply protection well for PM-1. Sandia Canyon has received treated effluents from Laboratory operations at TA-3, TA-53, TA-60, and TA-61) though no contaminants have been detected in nearby water supply well PM-1. Intermediate perched zone groundwater was encountered in basalt during drilling of the borehole for PM-1, but no water-quality data were collected. The surface casing of R-12 has been set and the borehole is scheduled for completion by the ER program in FY-98. A more detailed analysis of the placement of R-12 (ER borehole SCOI-3) in Sandia Canyon is included in the ER workplan for Los Alamos and Pueblo Canyons.
R-13	21 ER	2	FY01	Mortandad Canyon downstream of the TA-50 outfall	Aggregate characterization borehole R-13 is designed to provide water-quality and water-level data for potential intermediate perched zones and for the regional aquifer within Aggregate 7. Laboratory surveillance data collected in Mortandad Canyon show elevated concentrations or activities of NO_3, ^{3}H, ^{90}Sr, ^{137}Cs, $^{239,240}Pu$, ^{241}Am, and U in ephemeral surface water and in alluvial groundwater (see descriptions of R-14 and R-15). R-15 is located downstream of the outfall for the Laboratory's liquid radioactive waste treatment plant at TA-50. Unlike R-15, this location does not contain thick saturated alluvial deposits, and because of its proximity to the effluent outfall, there is the potential for direct infiltration into the Bandelier Tuff. Vertical migration of ^{3}H beneath the canyon floor has been documented by Stoker et al (1991). R-13 will be located near alluvial well MCO-4 which contains elevated concentrations or activities of NO_3, ^{3}H, ^{90} Sr, ^{137} Cs, ^{238}Pu, ^{239,240} Pu, and ^{241}Am (EPG 1996). R-13 will be completed in the Puye Formation and will supplement the stratigraphic, hydrologic, and geochemical data obtained from R-14 and R-15. A more detailed analysis of well placement in Mortandad Canyon will be included in the ER sample and analysis plan that will be prepared in FY-97.
R-14	20 NWT	3	FY01	Near Water Supply Well PM-5 on the mesa south of Mortandad Canyon	R-14 is a water-supply protection well for PM-5. Previous investigations and surveillance data show that surface water and alluvial groundwater in Mortandad Canyon contain ^{3}H, Pu, and NO_3 released from the Laboratory's liquid radioactive waste treatment plant at TA-50 (see description of R-15). Elevated activities of ^{3}H occurs in core samples collected 100-200 ft below the canyon floor (Stoker et al. 1991). Sampling of Test Well 8 confirmed the presence of ^{3}H (89 pCi/l), ^{90}Sr (2.1 pCi/l), $^{239,240}Pu$ (0.188 pCi/l), ^{241}Am (0.034 pCi/l), and NO_3 (as N, 5.1 mg/l) in the regional aquifer beneath Mortandad Canyon (EPG 1996). R-14 will provide information about the radius of influence of pumping from PM-5, and it's location will be optimized to detect the migration of contaminants from Mortandad Canyon towards the water supply well. R-14 is part of a southeasterly traverse of reference wells that includes R-6 and R-16 and a north-south traverse that includes R-1 and R-28.

Table 4-1. Rationale For Proposed Regional Aquifer Boreholes (continued)

Bore Hole[1]	*Timing Priority/ Funding Source*[2]	*Well Type*[3]	*Start Date*	*Location*	*Rationale for Borehole*
R-15	14 ER	2	FY00	Mortandad Canyon below confluence with Ten Site Canyon	Aggregate characterization borehole R-15 is located in Mortandad Canyon downstream from active and inactive outfalls at TA-5, TA-35, TA-48, TA-50, TA-52, TA-55, and TA-60. This borehole is designed to provide water-quality and water-level data for potential intermediate perched zones and for the regional aquifer within Aggregate 7. Laboratory surveillance data collected in Mortandad Canyon show elevated concentrations or activities of NO_3, ^{3}H, ^{90}Sr, ^{137}Cs, $^{239,240}Pu$, ^{241}Am, and U in ephemeral surface water and in alluvial groundwater. Some of the contaminants in alluvial groundwater exceed MCLs (e.g. 32 mg/l NO_3-N in MCO-5, MCL = 10 mg/l; 27.9 pCi/l ^{90}Sr in MCO-5, MCL = 8 pCi/l); and 10.91 pCi/l ^{241}Am in MCO-4, DCG = 1.2 pCi/l) (EPG 1996). TW-8, located 0.6 mi upstream of R-15, is completed in the regional aquifer within the Puye Formation, and it contains elevated activities or concentrations of NO_3, ^{3}H, ^{90}Sr, $^{239,240}Pu$ (see description of R-14). Contaminant distributions in alluvial groundwater and the observed mobility of ^{3}H, ^{90}Sr, and NO_3 in the unsaturated zone beneath the canyon floor (also see description of R-13) strongly support the need to install additional monitoring wells in Mortandad Canyon. R-15 may replace TW-8 completed in 1960; the location of R-15 will be based on results obtained from R-14. A more detailed analysis of well placement in Mortandad Canyon will be included in the ER sample and analysis plan that will be prepared in FY-97.
R-16	30 NWT	2	FY02	East side of White Rock	Site-wide characterization borehole R-16, located in White Rock, is fully-cored reference borehole that provides baseline information on the geology, hydrology, and water quality for a large uncharacterized area between the eastern boundary of the Laboratory and the Rio Grande. Numerous springs in White Rock Canyon probably represent discharge points for intermediate perched zones and the regional aquifer based on significant differences in major ion chemistry and stable isotopes. R-16 will determine background water quality for intermediate perched zones and the regional aquifer between the Laboratory and the Rio Grande, provide information about the depth to the regional aquifer for the eastern part the Laboratory, and clarify the relationship between springs in White Rock Canyon and various groundwater zones. These data will contribute to the construction of accurate groundwater maps for placing monitoring wells on the eastern side of the Laboratory. R-16 is part of a southeasterly traverse of reference wells that includes R-6 and R-14.
R-17	23 ER	2	FY02	Two Mile Canyon	Aggregate characterization borehole R-17, a major tributary to Pajarito Canyon, is designed to provide information about intermediate perched zones, depth to the regional aquifer, and water quality of intermediate perched zones and the regional aquifer in the poorly-characterized northwest part of the Laboratory. It is located downstream from Laboratory release sites at TAs 3, 6, 58, 59, 62, and 69, but is in an area that has not been characterized for either groundwater or contaminants. Water-level data from R-17 will be integrated with data from R-6, R-13, R-18, R-24, and R-25 to create an accurate water table map for the west-central part of the Laboratory; this map will be used for placement of long term monitoring wells for Aggregates 5, 6, and 7. R-17 will also provide upgradient water quality information for Aggregate 7. A more detailed analysis of well placement in Pajarito Canyon and it tributaries will be included in the ER sample and analysis plan that will be prepared in FY-98.

Table 4-1. Rationale For Proposed Regional Aquifer Boreholes (continued)

Bore Hole[1]	Timing Priority/ Funding Source[2]	Well Type[3]	Start Date	Location	Rationale for Borehole
R-18	10 ER	2	FY99	Pajarito Canyon above confluence with Two Mile Canyon	Aggregate characterization borehole R-18 is designed to provide information about intermediate perched zone groundwater, depth to the regional aquifer, and water quality of perched zones and the regional aquifer in the poorly-characterized west-central part of the Laboratory. It is located downstream from Laboratory release sites at TAs 8, 9 14, 22, 40, and 69, but is in an area that has not been characterized for either groundwater or contaminants. The occurrence of surface flow through most of the year indicates perched alluvial groundwater is present in this part of the canyon. Water-level data from R-18 will be integrated with data from R17, R-13, R-19, R-25, and R-27 to create an accurate water table map for the west-central part of the Laboratory; this map will be used for placement of long term monitoring wells for Aggregates 5, 6, and 7. R-18 is located east of the proposed NMED monitoring well TH-11, but it could fulfill the requirements of that borehole to explore for perched water in the Bandelier Tuff while providing additional information about possible recharge through the floor of upper Pajarito Canyon. A more detailed analysis of well placement in Pajarito Canyon will be included in the ER sample and analysis plan that will be prepared in FY-98.
R-19	22 ER	2	FY01	Pajarito Canyon upstream of TA-18	Aggregate characterization borehole R-19 is designed to provide information about intermediate perched zone groundwater, depth to the regional aquifer, and water quality in the poorly-characterized central part of the Laboratory. This portion of Pajarito Canyon is characterized by springs and alluvial groundwater. R-19 provides downgradient water-quality data for release sites in upper Pajarito Canyon and upgradient data for TA-18. R-19 will help constrain the location of the axis of the south-draining pre-Bandelier paleo-drainage which trends through this area (see description of R-10). Water-level data for intermediate perched zones and the regional aquifer measured in R-19 will be used to optimize the placement of monitoring well locations for surrounding Aggregates 2, 6, and 7. A more detailed analysis of well placement in Pajarito Canyon will be included in the ER sample and analysis plan that will be prepared in FY-98.
R-20	19 NWT	2	FY01	Near Water Supply Well PM-2 in Pajarito Canyon	R-20, water-supply protection well for PM-2, is located in lower Pajarito Canyon southwest MDA L and MDA G at TA-54. MDA L has an organic vapor plume(s) consisting of 1,1,1-TCA, TCE, CCl_4, that has migrated to a depth at least 500 ft within basalts under the Bandelier Tuff. MDA G contains numerous disposal pits filled with radioactive materials containing isotopes of Am, Np, Pu, and U. R-20 is sited between PM-2 and MDA L. Alluvial groundwater within lower Pajarito Canyon contains above background activities of solvents, high explosives, ^3H, NO_3, and U, all which are below MCLs. Intermediate perched zones may occur within the Bandelier Tuff, based on drilling logs for PM-2, and within basalts. Alluvial and intermediate perched zone groundwaters may provide a source of recharge to the regional aquifer.
R-21	31 ER	2	FY02	MDA L at TA-54	Aggregate characterization borehole R-21 is designed to evaluate and monitor hydrologic and geochemical conditions in the regional aquifer beneath MDA L. The ER Project has detected dense non-aqueous phase vapors beneath MDA L; these organic vapors have migrated through fractures in the Bandelier Tuff and the underlying basalts to a depth of 500 ft (see description of R-20). Data for R-21 will be compared to data for water-supply protection well R-21 near PM-2 to evaluate the migration of the organic contaminants beneath MDA L and their potential movement to PM-2 during pumping. A more detailed analysis of well placement at MDA L will be included in an addendum to the ER sample and analysis plan for OU-1148.

Table 4-1. Rationale For Proposed Regional Aquifer Boreholes (continued)

Bore Hole[1]	Timing Priority/ Funding Source[2]	Well Type[3]	Start Date	Location	Rationale for Borehole
R-22	8 ER	3	FY98	Pajarito Canyon, west of White Rock	Aggregate characterization borehole R-22, located near the southeastern Laboratory boundary in Pajarito Canyon, is designed to provide water-quality and water-level data for potential intermediate perched zones and for the regional aquifer downgradient of Aggregate 2. Aggregate 2 includes MDA L and MDA G (See description of R-20). In addition, this location is downgradient of numerous other Laboratory technical areas which released high explosives, radionuclides, organic solvents, and inorganic solutes. Alluvial groundwater within middle Pajarito Canyon (TA-18 and TA-36) contains elevated concentrations of NO_3-N, U, and 1-2 DCA (EPG 1996; ICF Kaiser 1996). Thinning of alluvium near the eastern Laboratory boundary suggests recharge to underlying basalts may be occurring in this area. Similar occurrences of intermediate perched zones have been found in Pueblo Canyon where alluvium thins over basalts. Large springs (e.g. Pajarito Spring) discharge from basalts in lower Pajarito Canyon into White Rock Canyon. Water-quality characteristics will be compared for R-22 and the springs to evaluate whether these groundwater-bearing zones are hydrologically connected. The continuous core collected this borehole will support site-wide studies of the hydrogeologic framework of the Laboratory by serving as a stratigraphic reference section for the southeastern part of the Laboratory. Core from this borehole will be used constrain geologic and hydrologic relationships in surrounding type-2 boreholes R-21 and R-23. A more detailed analysis of well placement in Pajarito Canyon will be included in the ER sample and analysis plan that will be prepared in FY-98.
R-23	26 ER	2	FY02	Potrillo Canyon 0.5 mi west of State Road 4	Aggregate characterization borehole R-23, located near the southeastern Laboratory boundary, is designed to provide water-quality and water-level data for potential intermediate perched zones and for the regional aquifer downgradient of active firing sites in in Potrillo Canyon. The main contaminants released from these sites are U and Be. R-23 is designed to evaluate the distribution of U and other contaminants and solutes beneath Potrillo Canyon. R-23 is sited within a hydrological sink, a broad area of infiltration on the canyon floor that typically marks the easternmost occurrence of surface water flow in this canyon. R-23 will evaluate the hydrological sink as a possible recharge zone for perched groundwater and for the regional aquifer. R-23 is part of a series wells including R-22, R-29, and R-32 that will evaluate groundwater leaving the southeastern part of the Laboratory. A more detailed analysis of well placement in Potrillo Canyon will be included in the ER sample and analysis plan that will be prepared in FY-02.
R-24	28 NWT	2	FY02	Near Pajarito fault system west of TA-16	Site-wide characterization borehole R-24 is located near the trace of the Pajarito fault system west of Aggregate 5. This borehole will provide water-quality and water-level data for intermediate perched zones and the regional aquifer on the upthrown block of a major spray of the Pajarito fault system. The location and occurrence of perched water and water level data for the regional aquifer, when compared with similar data from R-25 and R-26 on the downthrown block, will be used to evaluate the influence of the Pajarito fault system on the regional piezometric surface and provide information about its role as a recharge zone. R-24 will be used to establish boundary conditions on the western side of the Laboratory for numerical models of groundwater flow. Water-quality data from intermediate perched zone and regional groundwater in R-24 will define background conditions upgradient from the Laboratory, and in particular for Aggregate 5. These background geochemical data will be used to define potential impacts on groundwater from Laboratory facilities and to provide input data for geochemical and hydrological modeling of different groundwater systems.

Table 4-1. Rationale For Proposed Regional Aquifer Boreholes (continued)

Bore Hole[1]	Timing Priority/ Funding Source[2]	Well Type[3]	Start Date	Location	Rationale for Borehole
R-25	1 NWT	3	FY99	Near MDA P in Canon de Valle	Site-wide characterization borehole R-25 is a multipurpose borehole located adjacent to MDA P in Aggregate 5. Continuous core collected this borehole will support site-wide studies of the hydrogeologic framework of the Laboratory by serving as a stratigraphic reference section for a large, poorly-characterized area in the southwest part of the Laboratory. Core from this borehole will be used constrain geologic and hydrologic relationships in surrounding type-2 boreholes, including R-17, R-18, R-24, R-26, and R-27. This hole will provide critical information about the depth to the regional aquifer for this area; water-level measurements from nearby borehole SHB-3 suggest that the regional aquifer may be much higher than expected from projections based on current Laboratory water-level maps. R-25 will also provide water-quality data for intermediate perched zones and the regional aquifer downgradient from MDA P and from other release sites further west in the Canon de Valle watershed. Springs issuing from the upper Bandelier Tuff in this area are contaminated with high explosives, nitrate, and Ba. R-25 is part of a southeasterly traverse of reference wells that includes R-28 and R-32 and a north-south traverse that includes R-6.
R-26	29 NWT	2	FY02	Near Pajarito fault system in Water Canyon	Site-wide characterization borehole R-26 is located near the trace of the Pajarito fault system near the southwest corner of the Laboratory. This borehole will provide water-quality and water-level data for perched systems and the regional aquifer on the downthrown block of the Pajarito fault system. Numerous springs, including the large Water Canyon Gallery, issue from the Bandelier Tuff in Water Canyon. Water-level measurements from nearby borehole SHB-3 suggest that the regional aquifer may be much higher than expected from projections based on current Laboratory water-level maps. The location and occurrence of perched water and water level data for the regional aquifer, when compared with similar data from R-24 and R-25 on the downthrown and upthrown blocks, respectively, will be used to evaluate the influence of the Pajarito fault system on the regional piezometric surface and provide information about its role as a recharge zone. Water-quality data from intermediate perched zone and regional groundwater in R-26 will define background conditions in a large wet canyon upgradient from the Laboratory, and in particular for Aggregate 5. These background geochemical data will be used to define potential impacts on groundwater from Laboratory facilities and to provide input data for geochemical and hydrological modeling of different groundwater systems.
R-27	15 ER	2	FY00	Confluence of Water Canyon and Canon de Valle	Aggregate characterization borehole R-27 is designed to characterize baseline water quality in intermediate perched zones and in the regional aquifer groundwater upgradient of Aggregate 3. Degradation products of high explosives (2,4-dinitrophenol, 130 mg/l; pentachlorophenol 110 mg/l) were detected in the regional aquifer at test well DT-9 in Aggregate 3 (EPG 1995), however it is uncertain if these contaminants are derived from TA-49 or from firing sites in Aggregates 5 or 6. R-27 also will provide baseline information on the geology, hydrology, and water quality for the poorly-characterized south-central part of the Laboratory. These data will be used in conjunction with data from R-28 and R-30 to optimize placement of monitoring wells in the vicinity of Aggregates 3, 5, and 6. A more detailed analysis of well placement in Water Canyon and Canon de Valle will be included in the ER sample and analysis plan to be prepared by FY-00.

Table 4-1. Rationale For Proposed Regional Aquifer Boreholes (continued)

Bore Hole[1]	Timing Priority/ Funding Source[2]	Well Type[3]	Start Date	Location	Rationale for Borehole
R-28	5 NWT	3/4	FY99	Near WCO-1 in Water Canyon	Site-wide characterization borehole R-28 is a multipurpose borehole located in the middle reach of Water Canyon. The continuous core collected this borehole will support site-wide studies of the hydrogeologic framework of the Laboratory by serving as a stratigraphic reference section for the south-central part of the Laboratory. Core from this borehole will be used constrain geologic and hydrologic relationships in surrounding type-2 boreholes, including R-19, R-20, R-27, R-30, and R-31. This borehole will provide water quality information for potential intermediate perched zones and for the regional aquifer beneath potential release sites in Aggregate 6, and it will provide information for optimizing the placement of monitoring wells in this part of the Laboratory. R-28 is presently scheduled to be completed as a type 3 well, but the option is preserved to advance these boreholes to a total depth 4000 ft and to include multiple completions of the well if funding agencies decide further characterization of regional aquifer groundwater resources is required. Multiple completions in this borehole could identify groundwater capture zones for potential future water supply wells, and provide information on vertical hydraulic gradients, saturated hydraulic conductivities, vertical stratification of water-quality in the regional aquifer, and patterns of water-yielding characteristics within the mid-Miocene high-permeability zone of Purtymun (1995), the Puye Formation, and interbedded basalts. R-28 is part of a southeasterly traverse of reference wells that includes R-25 and R-32 and a north-south traverse that includes R1 and R-14.
R-29	27 NWT	2	FY02	Lower Water Canyon near confluence of Potrillo and Water Canyons	Site-wide characterization borehole R-29 is located in lower Water Canyon. It will provide information about the depth to the regional aquifer in a poorly-characterized area, and the water-level data will be used to optimize the placement of downgradient monitoring wells along the eastern Laboratory boundary. Because of its location, R-29 may be used to monitor the water quality of groundwater leaving the Laboratory. This borehole will also provide information about the distribution and characteristics of deep stratigraphic and hydrogeologic units in an area where deep borehole information is lacking. Water-quality data from perched and regional groundwaters in R-29 will be compared to similar data for springs in White Rock Canyon to identify potential groundwater flow paths near the Rio Grande.
R-30	32 ER	2	FY02	Deepening of existing borehole 49-2-700-1 at TA-49	Aggregate characterization borehole R-30 will deepen borehole 49-2-700-1 in Aggregate 3 from the current depth of 700 ft to approximately 1600 ft. This borehole will determine water quality in intermediate perched zones and in the regional aquifer beneath MDA AB, which was used for underground hydronuclear experiments. Shafts at MDA AB contain an estimated inventory of 2500 Ci of ^{239}Pu, ^{241}Am, and U, as well as 90,000 kg of Pb and 11 kg of Be. Because buried contaminants are likely to be capped and left in place at TA-49, R-30 and nearby boreholes R-27 and R-28 may be used as components of a regional monitoring system for this part of the Laboratory. A more detailed analysis of well placement in Water Canyon will be included in an addendum to the ER sample and analysis plan for OU-1144.
R-31	4 NWT	2	FY99	In Ancho Canyon down gradient of Aggregate 6 and downgradient of Aggregate 4	Site-wide characterization borehole R-31 is located downgradient of open burning/open detonation sites in Aggregate 6 and upgradient of firing sites in Aggregate 4. The primary objective of this borehole is to provide water-quality data for potential intermediate perched zones and for the regional aquifer. This borehole will contribute to the optimization of long-term monitoring wells for Aggregates 4 and 6 by placing better constraints on the geometry of the regional aquifer in this area.

Table 4-1. Rationale For Proposed Regional Aquifer Boreholes (continued)

Bore Hole[1]	Timing Priority/ Funding Source[2]	Well Type[3]	Start Date	Location	Rationale for Borehole
R-32	7 NWT	3	FY00	Near Ancho Spring in Ancho Canyon	Site-wide characterization borehole R-32 is located west of Ancho Spring in lower Ancho Canyon. This fully-cored borehole is designed to provide baseline information on the geology, hydrology, and water quality for the poorly studied southeastern boundary of the Laboratory. It will be the reference borehole for nearby type 2 boreholes R-19 and R-31. R-32 is located within Aggregate 4 and will provide water-quality and water-level data for intermediate perched zones and the regional aquifer in this area. Water-quality data for R-32 will compared to similar data for springs in White Rock Canyon to identify potential groundwater flow paths near the Rio Grande. Water samples from Ancho Spring contain high explosives and depleted U which probably originated from firing sites in Aggregates 4 or 6. R-32 is a potential monitoring well for contaminants leaving the Laboratory. R-32 is part of a southeasterly traverse of reference wells that includes R-25 and R-28.

[1] Boreholes are labeled from north to south. See Proposed Regional Wells map, Plate 2 in Appendix 6 for borehole locations. This hydrogeologic workplan is based on conceptual models derived from existing data sources. However, yearly assessments of newly acquired data could result in substantial revisions to the scope of the proposed work, including the number of boreholes to be drilled. Thus, inclusion in this table does not represent a commitment to drill the boreholes listed. Revisions to the Workplan will be negotiated with regulators on an annual basis.

[2] This hydrogeologic workplan integrates the technical and regulatory needs of its two funding sponsors, the Nuclear Weapons Technology Program's Monitoring Well Installation Project (NWT) and Environmental Management's Environmental Restoration Project (ER). Both projects adjusted their drilling schedules (generally moving the start dates of lower priority boreholes ahead of higher priority boreholes) to achieve a more unified and integrated drilling program, particularly in cases where boreholes drilled by one project provided information critical to the placement or design of boreholes for the other project. The ER Project will install three wells per year beginning in FY98. NWT wells will be installed at a rate of four per year beginning in FY99. To maintain maximum flexibility, the placement of boreholes are considered approximate and are subject to change as new data becomes available during the course of the drilling program. The placement of boreholes scheduled later in the schedule are more likely to change than those scheduled earlier because of improvements in the conceptual model with time. Additions or deletions of boreholes in this table are likely as the Laboratory's understanding of contaminant distributions and the hydrogeologic setting improves over time. Additional boreholes will be added to the schedule as necessary to monitor contaminated intermediate perched zones encountered in boreholes to the regional aquifer.

[3] Well Types: 2=regional aquifer well, single completion, limited core, drilled 500 ft into top of regional aquifer; 3=regional aquifer well, single completion, continuous core, drilled 500 ft into top of regional aquifer; 4=presently equivalent to Type 3 wells, but the option is preserved to advance the boreholes for these wells to a total depth of 4000 ft and to include multiple completions of the wells if funding agencies decide further characterization of regional aquifer groundwater resources is required.

Table 4-2. Installation Sequence for Proposed Wells

Borehole	*Timing Score*	*Year*	*Funding Program*	*Location*
R-9	15	FY98	ER	Los Alamos Canyon at eastern boundary of Laboratory
R-12	20	FY98	ER	Sandia Canyon at eastern boundary of Laboratory
R-25	20	FY98	NWT	Cañon de Valle near MDA P
R-5	19	FY00	NWT	Pueblo Canyon near water supply well Otowi-1
R-31	18	FY01	NWT	Ancho Canyon downgradient of Aggregate 6
R-28	18	FY01	NWT	Water Canyon near WCO-1
R-7	18	FY98	ER	Los Alamos Canyon south of TA-21
R-32	18	FY01	NWT	Ancho Canyon near Ancho Spring
R-22	18	FY98	ER	Pajarito Canyon at eastern boundary of Laboratory
R-2	17	FY00	NWT	Pueblo Canyon near TW-4
R-18	17	FY99	ER	Pajarito Canyon above Two Mile Canyon confluence
R-1	15	FY01	NWT	Rendija Canyon north of Los Alamos
R-3	15	FY99	ER	Pueblo Canyon between TW-2/2A and TW-4
R-15	15	FY00	ER	Mortandad Canyon near sediment traps
R-27	15	FY00	ER	Water Canyon and Cañon de Valle confluence
R-8	13	FY00	NWT	Los Alamos Canyon near water supply well Otowi-4
R-10	13	FY00	ER	Sandia Canyon south of TA-21
R-4	13	FY01	ER	Pueblo Canyon between TW-2/2A and LA County sewage treatment plant
R-20	13	FY02	NWT	Pajarito Canyon near water supply well PM-2
R-14	13	FY02	NWT	Mesa top well between Mortandad Canyon and water supply well PM-5
R-13	13	FY01	ER	Mortandad Canyon downgradient of TA-50 outfall
R-19	13	FY01	ER	Pajarito Canyon upgradient of TA-18
R-17	13	FY02	ER	Two Mile Canyon
R-6	12	FY03	NWT	Los Alamos Canyon at western boundary of Laboratory
R-11	12	FY03	NWT	Sandia Canyon near water supply well PM-3
R-23	12	FY02	ER	Potrillo Canyon at hydrologic sink
R-29	11	FY03	NWT	Water Canyon near eastern boundary of Laboratory
R-24	11	FY02	NWT	Mesa top west of TA-16 between Cañon de Valle and Pajarito Canyon
R-26	11	FY02	NWT	Water Canyon at western boundary of Laboratory
R-16	11	FY03	NWT	Canada del Buey on the east side of White Rock
R-21	11	FY02	ER	Mesita del Buey at TA-54, MDA L
R-30	10	FY02	ER	Frijoles Mesa at TA-49

The implementation of the DQO Process recognized the relevant hydrogeologic work performed by the ER Project and the Laboratory's Environmental Surveillance Program, as well as the prospective contributions from the Laboratory's Monitoring Well Installation Project (MWIP) being funded by the Nuclear Weapons Technology (NWT) Program on behalf of the DOE Defense Program's Landlord responsibilities. The NWT MWIP is budgeted as a FY99 (October 1998) new start project, however advance funding has been received in FY98 expediting the construction of well R-25. The ER Project activities are presently ongoing. Installation of both the NWT Program wells and the ER Project wells now make up the comprehensive MWIP. The NWT Program and ER Project are subject to DOE funding changes on an annual basis, with annual changed for the ER Project dependent on DOE's review of the ER Project's Annual Baseline Report. However, the RCRA/HSWA schedule of compliance will be met by the Laboratory.

The DQO Process prospectively identified 84 wells for installation: 51 alluvial wells; one intermediate perched zone well; and 32 regional aquifer wells, with the boreholes for the regional aquifer wells being used also to characterize any intermediate perched zones encountered during borehole advancement. The locations of the proposed wells are shown in Figures 4-1 and 4-2 and on large-scale plates in Appendix 6. Table 4-1 contains the rationale for each of the 32 regional aquifer wells and Table 4-2 lists the sequence of installation. Installation of these wells will be subject to negotiation with the NMED as described in the following paragraphs, and there is no commitment implied by the identification of prospective numbers and locations.

The Groundwater Protection Management Program Plan (GWPMPP) (LANL 1996a) requires the preparation of an annual groundwater status report summarizing groundwater protection activities. The annual status report will be prepared by the Laboratory, and distributed internally during December of each calendar year. Following internal review, the annual report will be transmitted to DOE and the New Mexico Environment Department (NMED) and presented to the Technical Review Committee by January 15th. The annual report, and comments received from the NMED and the Technical Review Committee will form the basis for ensuing negotiations with NMED regarding the next year's Workplan scope and schedule.

As discussed in Section 1, the Laboratory intends to continue the DQO Process throughout the implementation of this Workplan. As each activity is performed or well installed, the new data will be incorporated into a central database and will be input into modeling activities. Additionally, new data will be used in an iterative manner in reassessing DQOs for the Workplan. In March of each calendar year (beginning March 1998), the Laboratory and DOE will meet with NMED to review characterization results and reassess the future of characterization activities and the well installation program regarding the numbers, locations, sequence, and design. Commitments for future well installation beyond the three wells scheduled in FY98 (See Section 1.5) will be negotiated annually. Thus, this annual meeting will result in a renegotiation of all Workplan activities and the schedule for their performance.

Also, as previously discussed in Section 3.0, the Laboratory will establish a team (the GIT) with the Water Quality and Hydrology Group (ESH-18) being responsible for performance and project leadership. The purpose of the team will be to oversee the schedule for all Workplan activities, and to provide a forum for ensuring that the deliverables of Workplan activities are produced on schedule, that the data derived from those deliverables are fully integrated into the central database, that any revisions of the conceptual model indicated by the new data are made, and that the revised conceptual model and future data needs pursuant to that model are integrated with the other objectives of this Workplan. The GIT will meet as needed and its membership will represent multiple Laboratory organizations and projects germane to the objectives of this Workplan.

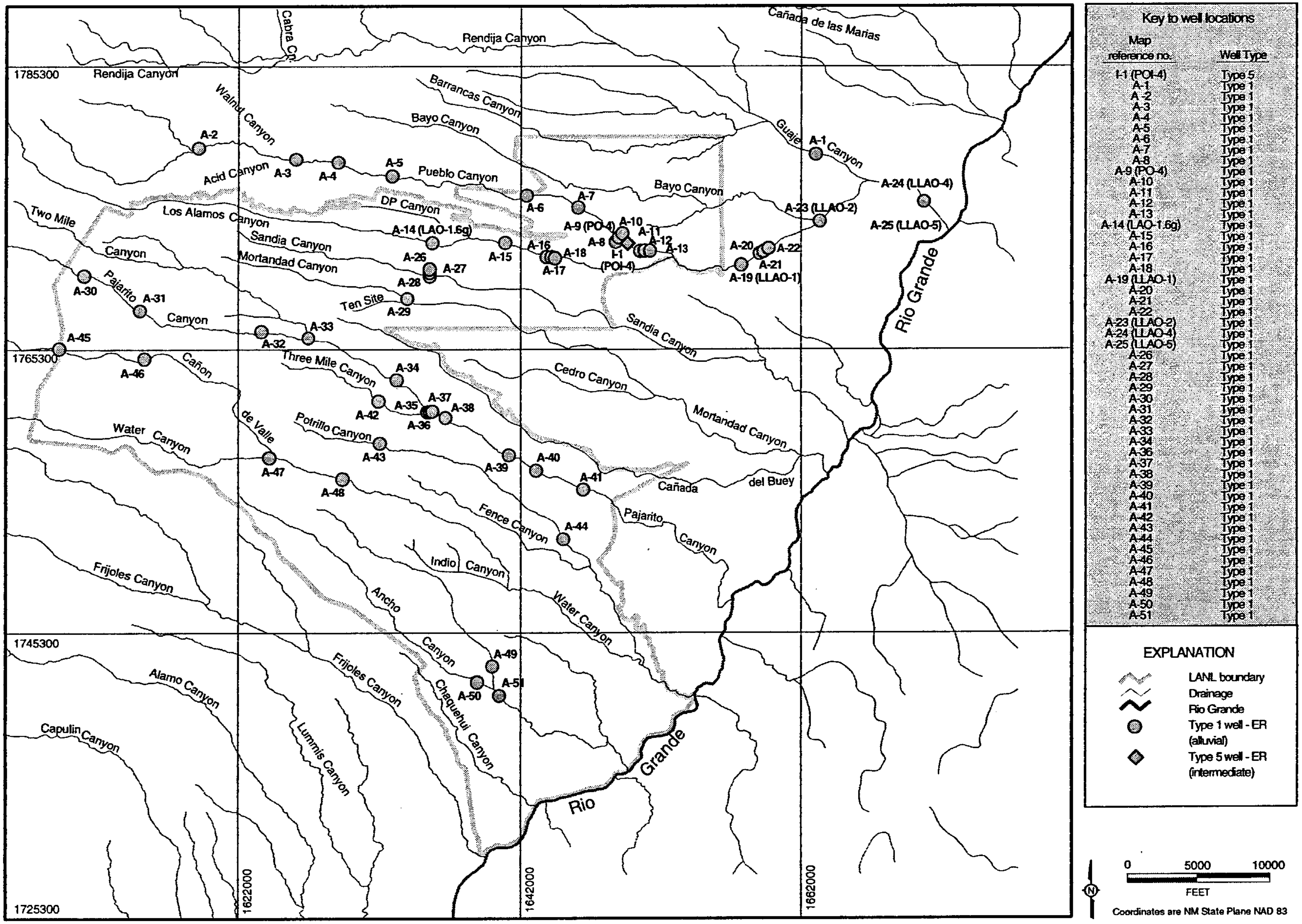


Figure 4-1. Proposed alluvial groundwater and intermediate perched zone well locations.

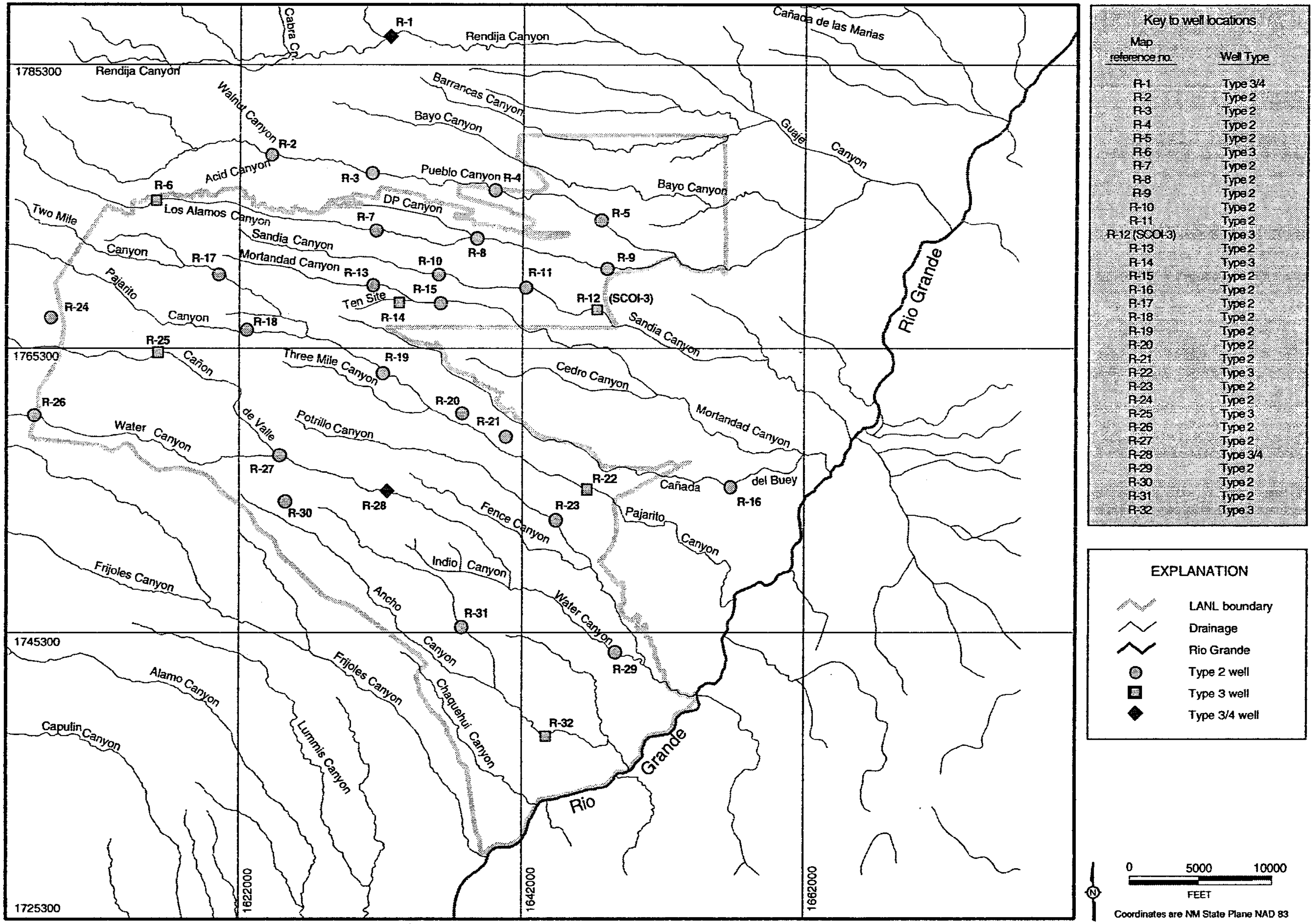


Figure 4-2. Proposed regional aquifer well locations.

4.1.1 Well Types

The DQO process identified both data needs and data collection designs. In those cases where the data collection design specified the use of a well, decisions were made as to what data would be collected and the borehole advancement and well installation specifications required to accommodate the data need. Five types of wells were identified — alluvial; intermediate perched zone; and three types of regional aquifer wells differentiated by depth and commensurate borehole dimensions, amount of core collected, and well completion details. The boreholes for all three 3 types of regional aquifer wells will be used to collect information on intermediate perched zones, the perching horizons, and the hydrogeology beneath the perched zone(s) that may be encountered in advancement.

The generalized specifications for the 5 borehole/well types are described briefly below. Regarding the well types 2 through 5, a detailed design will be prepared for each individual borehole/well, which may include various completion scenarios for budget estimate purposes. The detailed designs will be submitted to NMED for their review and comment. Final selection of the completion method, with details regarding screen length, will be proposed to NMED based on the characterization findings after reaching the total depth of the borehole.

4.1.1.1 Type 1 Wells

Type 1 wells are the alluvial wells that will be installed by the ER Project. The following borehole advancement and installation specifications apply to these wells. Figure 4-3 is a prototype drawing of the borehole and well.

Borehole Advancement and Well Installation Specifications

a) Boreholes will be advanced using a hollow-stem auger through the alluvium to a depth 5 ft into the underlying competent layer (e.g. tuff).

b) Borehole advancement strategy includes: hollow-stem auger through alluvium into tuff with 4.25 in I.D. (6.625 in O.D.) hollow-stem auger, and obtain 5 ft core at tuff interface; over-ream pilot hole with 6.625 in I.D. (10.75 in O.D.) hollow-stem auger creating a 12 in borehole

c) No coring in the alluvium, but approximately 5 ft of core will be collected in the competent layer. A well log will be prepared based on borehole cuttings.

d) Well casing and screen will consist of Schedule 40 PVC pipe and have a 4 in I.D. (4.5 in O.D.). Install 4 in PVC pipe inside hollow stem with 30 ft screen (0.010 in [#10] machine-slotted, flush threads) and 5 ft blank casing sediment sump (bottom capped with 3/8 in weep hole drilled in cap resting on gravel bed); and complete with filter material to form $\geq$3 in filter pack, unless alternative annulus spacing is proposed to NMED for approval. The slot size for screen and selection of filter pack materials will be based on sieve analysis of geologic cuttings in the zone to be screened.

e) A steel protective cover will be installed over the well casing extending above ground level. A lockable protective cover extending at least 2 ft below ground surface will be cemented in place.

f) The top of the well will be finished with a concrete pad 3 ft x 3 ft x 4 in. Installation of bollards will be optional (depending on location).

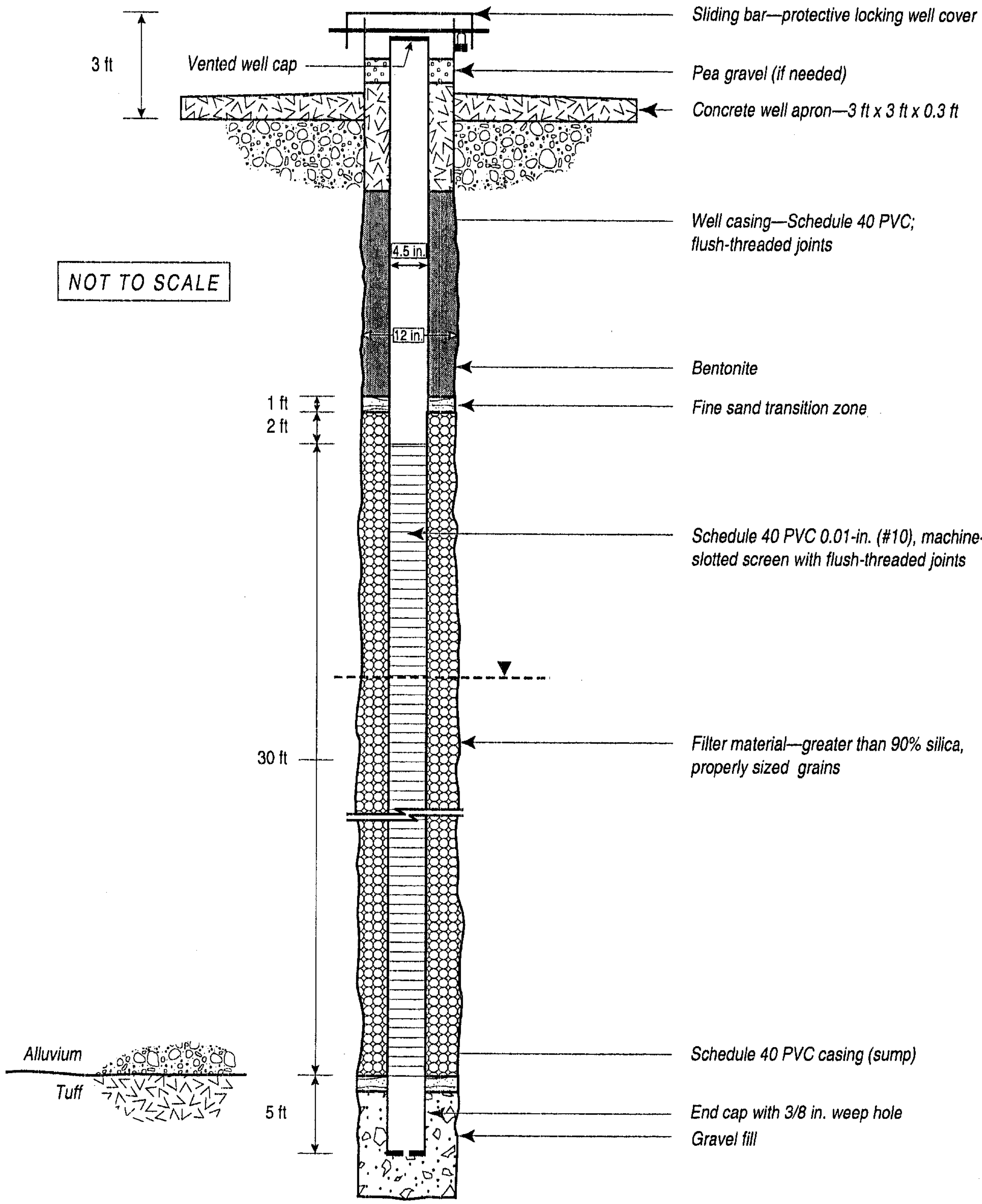


Figure 4-3. Type 1 (alluvial) well design.

4.1.1.2 Type 2 Wells

The Type 2 wells are regional aquifer wells, typically completed with a single well screen, although a multiple completion design may be considered, depending on data quality objectives and characterization findings from borehole advancement. The general objective of type 2 wells is to provide information on subsurface lithology and intermediate perched zone and regional aquifer groundwater quality. Intermediate perched zone groundwater encountered during drilling will be sampled for analyses after resting the borehole up to 24 hours. Because of the general geology, inherent drilling complexities, and currently available cost-effective installation techniques, the Laboratory may employ different drilling methods including, but not limited to hollow-stem auger, air-rotary/Odex™/Stratex™, air rotary/Barber rig, and mud-rotary drilling.

The boreholes for these wells will be drilled at least 100 ft, and potentially up to 500 ft, into the regional aquifer and approximately 10% of the borehole will be cored with emphasis at intermediate perched groundwater zones and stratigraphic contacts. Core will also be collected at other zones of hydrologic significance e.g. buried soil horizons and at the top of the regional aquifer. Core and cuttings will be collected and subjected to chemical analyses and physical testing, and the borehole will be subjected to a variety of geophysical tests describe later in this section. The number and length of the screened interval(s) in wells advanced to the regional aquifer will be determined on a site-specific basis and proposed to the NMED, with technical consideration of pertinent regulatory requirements and guidance. The slot size for screen(s) and selection of filter pack materials will be based on sieve analysis of geologic cuttings in the zone to be screened. The following borehole advancement and installation specifications generally apply to these wells. Figures 4-4 and 4-5 are general prototype drawings based on carbon steel casing and single screen completion of the borehole and well.

Borehole Advancement and Well Installation Specifications

a) A carbon steel surface casing approximately 20 in diameter will be set from the land surface to approximately 20 ft deep. In locations where alluvium is present, the surface casing will extend approximately 10 ft into the underlying competent layer and be grouted in place.

b) During borehole advancement, the drilling method will employ an outer temporary casing advanced to the total depth of the borehole (or utilize other technical methods) to minimize and/or prevent migration of fluids between any perched intermediate zones and the regional aquifer.

c) Boreholes will be advanced with 10% core collection to a depth of at least 100 ft, and potentially up to 500 ft into the regional aquifer. If the borehole is advanced more than 100 ft and a single completion is planned, then the borehole will be backfilled to the upper 100 ft of the regional aquifer. The design for final well completion will be determined upon completion of the borehole, and proposed to NMED. The number and length of the screened interval(s) in wells advanced to the regional aquifer will be determined on a site-specific basis and proposed to the NMED, with technical consideration of pertinent regulatory requirements and guidance. The slot size for stainless steel screen(s) and selection of filter pack materials will be based on sieve analysis of geologic cuttings in the zone to be screened.

d) The well will be constructed of 6 5/8 in O.D. mild carbon steel casing from land surface to the top of the stainless steel screen, unless other construction materials are proposed to NMED for approval. A transitional coupling will be installed between the two casing types to minimize the potential for corrosion. An annulus $\geq$ 3 in will be provided, unless alternative annulus spacing is proposed to NMED for approval. Approximately 10 ft of blank casing with an end cap will be set at the base of the screen. Centralizers will be used at approximately 100 ft intervals.

e) All backfill materials (grout, bentonite, sand) will be tremied/pressure grouted in place.

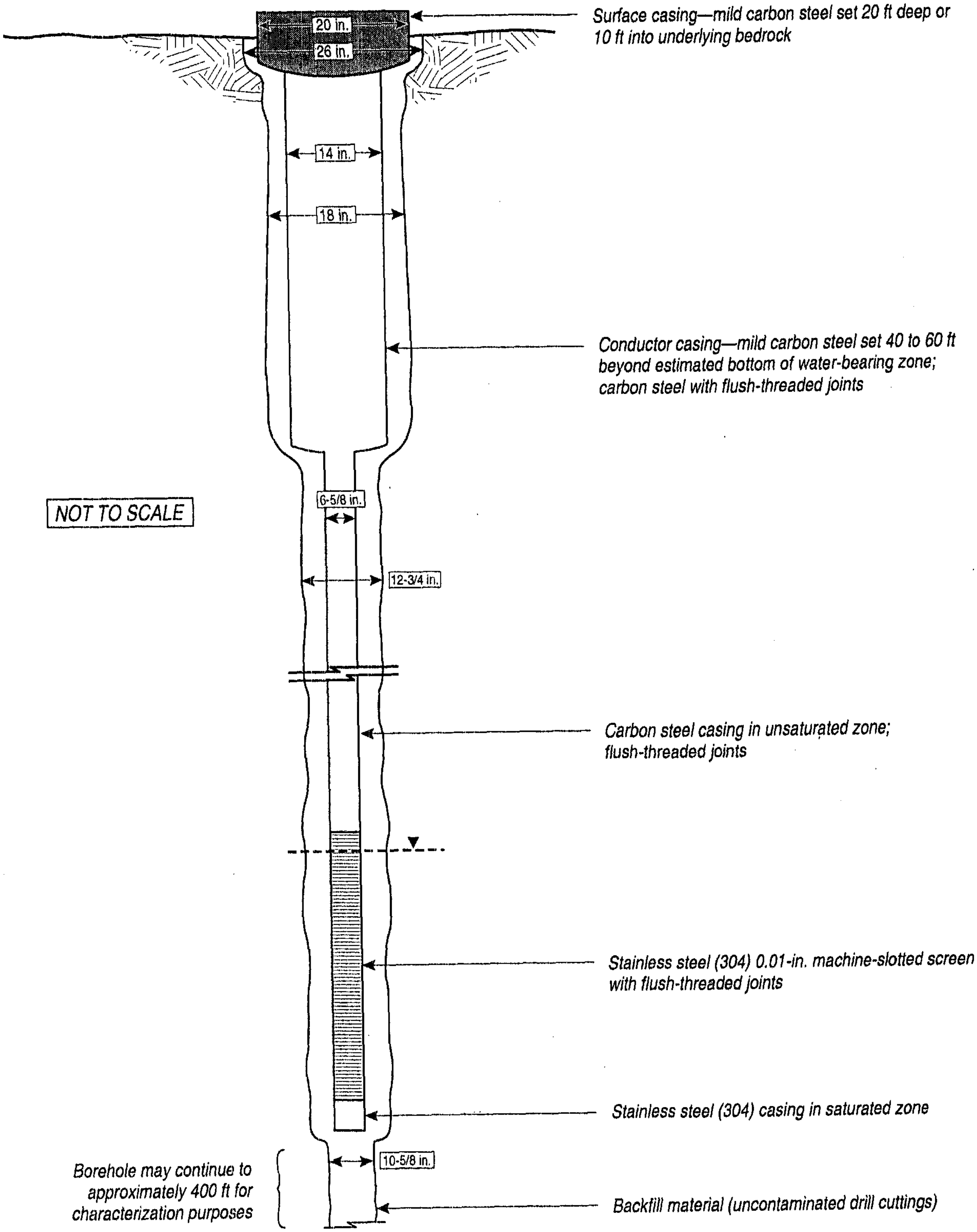


Figure 4-4. Types 2 and 3 (regional) well design.

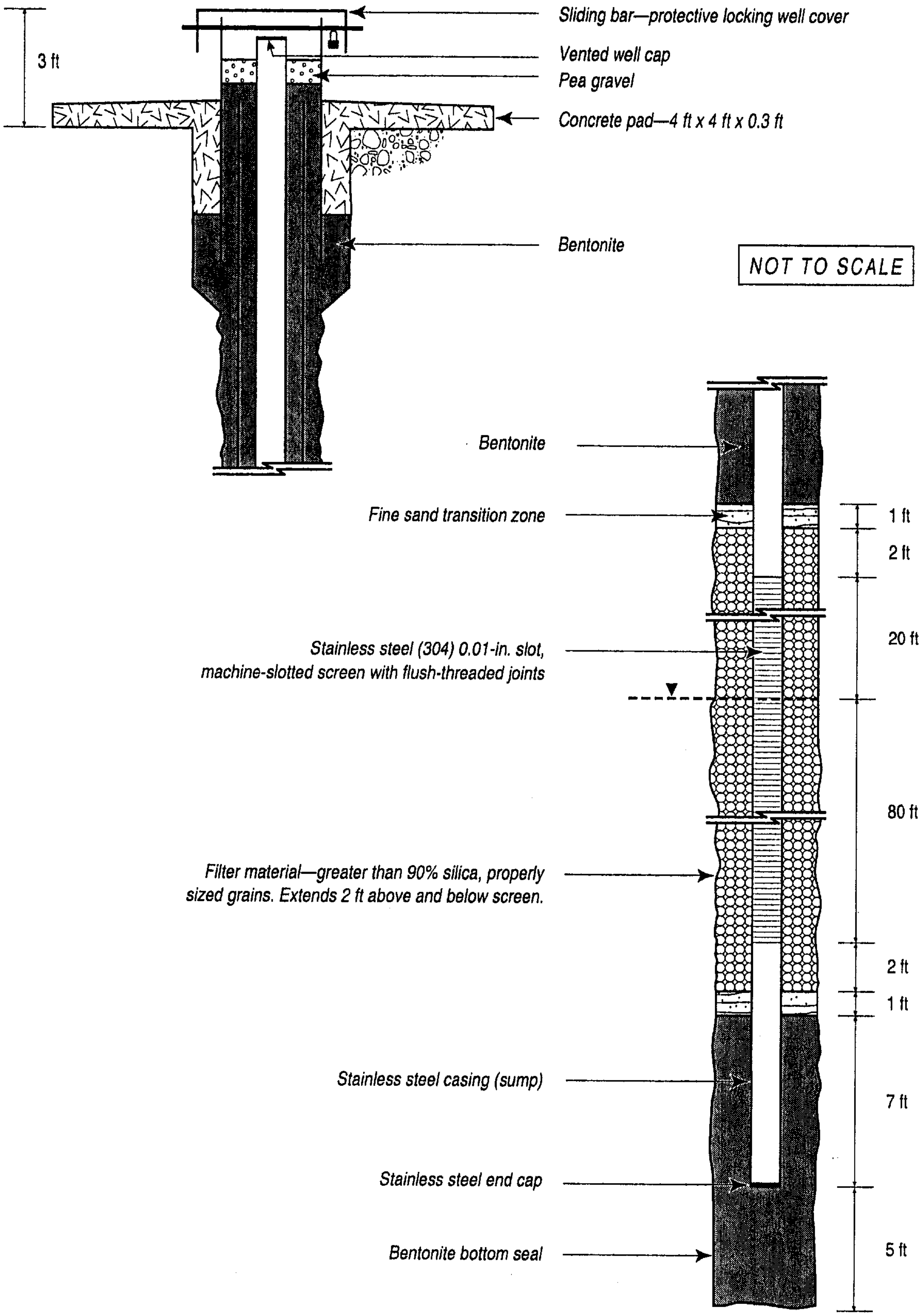


Figure 4-5. Types 2 and 3 (regional) well design detail.

f) A lockable steel protective cover will be cemented in place over the well casing extending at least 2 ft below ground surface.

g) The top of the well will be finished with a concrete pad 4 ft x 4 ft x 4 in. The wellhead will be fenced with 8 foot chain link fencing, topped with barbed wire, 15 ft on a side, with one side gated and padlocked.

h) A dedicated submersible pump and transducer will be installed in each well following well completion and development. If a well is completed with multiple screened intervals, a portable sampling device may be employed.

4.1.1.3 Type 3 Wells

The Type 3 wells are identical to the Type 2 wells except that greater than 10% of the core shall be recovered from the boreholes. Along with the two Type 4 wells described below, the boreholes for these wells will provide a library of lithologic information that can be used to create stratigraphic cross-sections across the Laboratory. These wells are referred to as "Library Wells" or "Library Core Holes". The description and borehole advancement and well installation specifications listed for Type 2 wells also apply to the Type 3 wells. Figures 4-4 and 4-5 are general prototype drawings based on carbon steel casing and single screen completion of the borehole and well.

4.1.1.4 Type 4 Wells

The Type 4 wells are similar to the Type 2 and 3 wells, except the boreholes will be advanced to the depth of 4,000 ft[1] and the wells completed using a multiple completion system, in order to collect groundwater zone data at multiple depths. There are many advantages of using a multi-completion well. They include: 1) the ability to conduct repeatable sampling and testing of discrete groundwater zones within the same well; 2) measurements of vertical gradients in discrete groundwater zones within the same well; and 3) provides the most information for multiple groundwater zones for the least cost. Similar to Type 3 wells, the boreholes for these wells will be cored >10% and ≤ 100% to a depth of at least 100 ft, and potentially up to 500 ft into the regional aquifer. These wells have been specifically located to provide the most useful pilot characterization information for development of future water supply for the Laboratory and Los Alamos County. Should the borehole advancement encounter perched intermediate zone(s) during drilling, the procedures for groundwater sampling described above for Type 2 and 3 wells will be followed.

These wells will be completed using a system of packers and multi-port Westbay-type casing. The following borehole advancement and installation specifications apply to these wells. Figure 4-6 is a general prototype drawing of the borehole and well and Figure 4-7 shows a Westbay-type design.

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[1] As of the date of publication of this Workplan, DOE has decided that at this time, the two Type 4 wells will be limited in depth to 500 ft below the top of the regional aquifer, providing hydrogeologic characterization information vital to the characterization objectives of the Workplan following the construction specifications of the Type 3 wells. The deeper advancement of the Type 4 wells has been separated i.e. R-1d and R-28d versus R-1 and R-28 in the drilling schedule and moved to the end of the drilling schedule i.e. 2004-05. Future DOE decision-making will determine whether the Type 4 wells will ultimately be completed to the 4,000 ft target depth or deleted from the project scope.

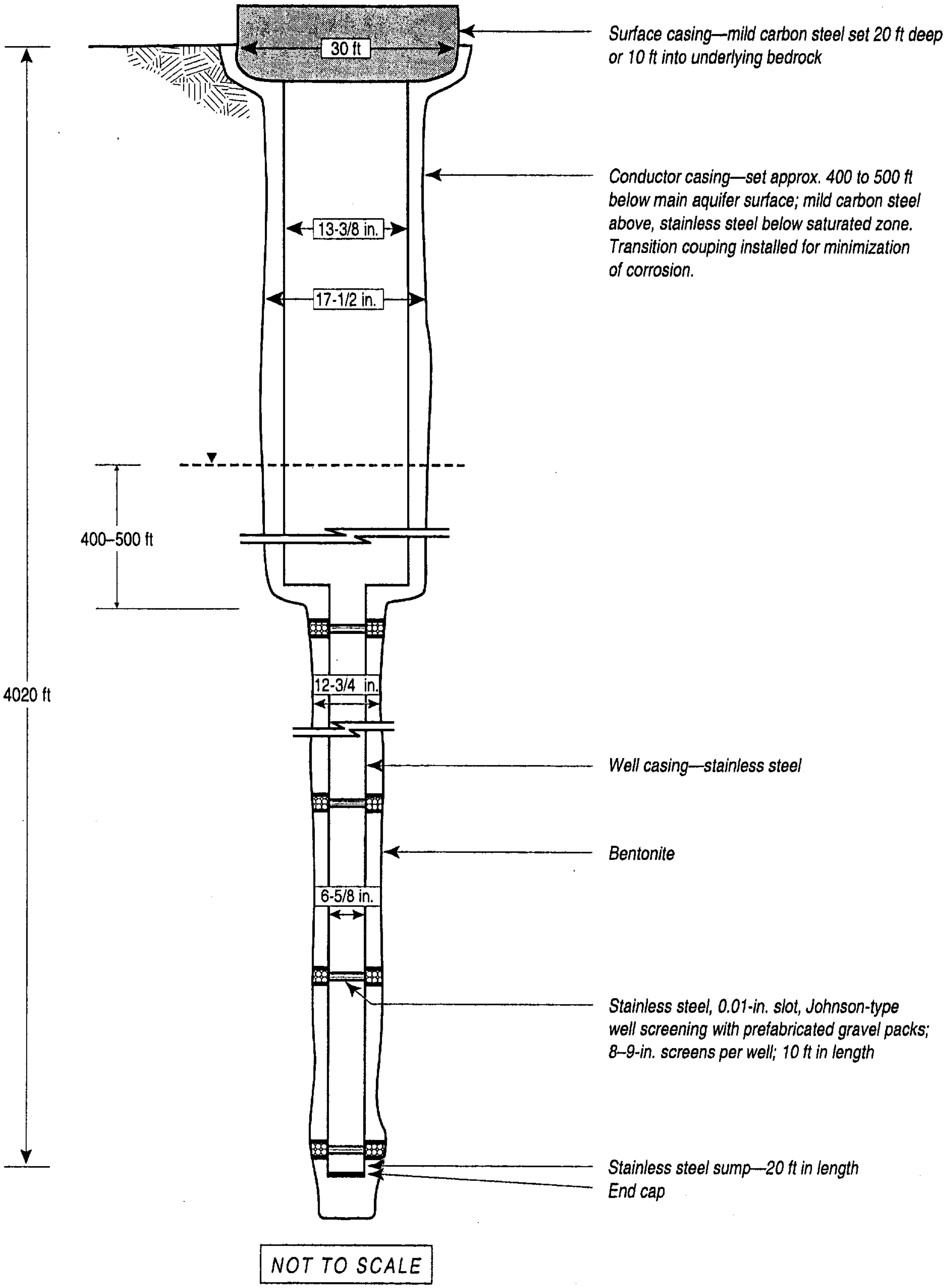

Figure 4-6. Type 4 (regional) well design.

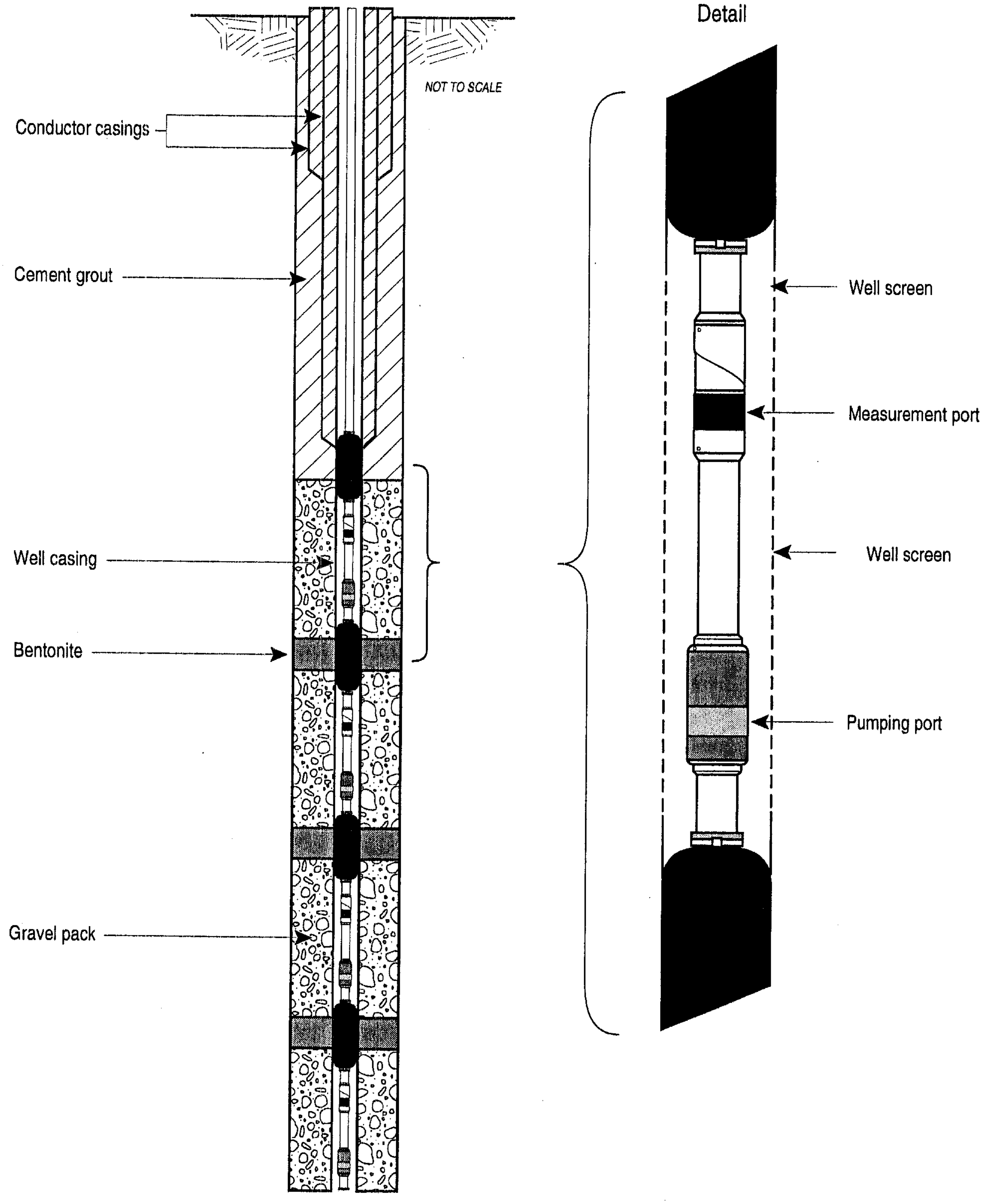

Figure 4-7. Westbay-type design for multi-level monitoring.

Borehole Advancement and Well Installation Specifications

a) Boreholes will be advance with >10% and ≤ 100% to a depth of at least 100 ft, and potentially up to 500 ft into the regional aquifer using air-rotary/Odex/Stratex, air-rotary/Barber rig, or other competent drilling system. Once the borehole is advanced ≥ 100 ft but < 500 ft into the regional aquifer, if conditions are favorable for mud-rotary drilling, mud-rotary drilling will be used to advance the borehole to a total depth of 4,000 ft.

b) A carbon steel surface casing approximately 30 in diameter (in an approximate 42 in borehole) will be set from the land surface to approximately 20 ft deep. In locations where alluvium is present, the surface casing will extend approximately 10 ft into the underlying competent layer.

c) During borehole advancement, the drilling method will employ an outer temporary casing advance to the total depth of the borehole (or utilize other technical methods) to minimize and/or prevent migration of fluids between any perched intermediate zones and the regional aquifer.

d) The primary casing string will consist of 6 5/8 in O.D. mild carbon steel casing from the land surface to approximately 50 ft above the regional aquifer. 6 5/8 in O.D. stainless steel well casing/screen will be used from this depth to the bottom of the well. A transitional coupling will be installed between the two casing types to minimize the potential for corrosion. The slot size for screen and selection of filter pack materials will be based on sieve analysis of geologic cuttings in the zone to be screened.

e) The wells will be completed with TAM™-style packer/port collar systems to facilitate successful emplacement of grout without adversely impacting screened intervals. An annulus ≥ 3 in will be provided, unless alternative annulus spacing is proposed to NMED for approval. Stainless steel Johnson-type well screens 10 ft in length with pre-fabricated gravel packs will be installed at selected intervals as part of the inner casing string. Well R-1 will have 8 screened intervals; well R-28 will have 9 screened intervals. Approximately 20 ft of blank casing with an end cap will be set at the base of the screen. Centralizers will be used at approximately 100 ft intervals.

f) All backfill materials (grout, bentonite, sand) will be tremied/pressure grouted in place.

g) A MP-55 Westbay™-type well casing string with the appropriate number of sample ports will be set inside the 6 5/8 in O.D. stainless steel casing.

h) A lockable steel protective cover extending at least 2 ft below ground surface will be cemented in place over the well casing.

i) The top of the well will be finished with a concrete pad 4 ft x 4 ft x 4 in. The wellhead will be fenced with 8 foot chain link fencing, topped with barbed wire, 15 ft on a side, with one side gated and padlocked.

4.1.1.5 Type 5 Wells

The Type 5 well(s) will be completed in an intermediate perched zone with either a single or multiple-screen completion similar to the Type 2 and 3 wells, e.g. final completion designs will be determined by characterization findings in the borehole and proposed to NMED. Borehole(s) will be advanced with ≤ 10% core collection over the total depth of the borehole. The following borehole advancement and installation specifications apply to Type 5 wells. Figure 4-8 is a general prototype drawing of the borehole and well.

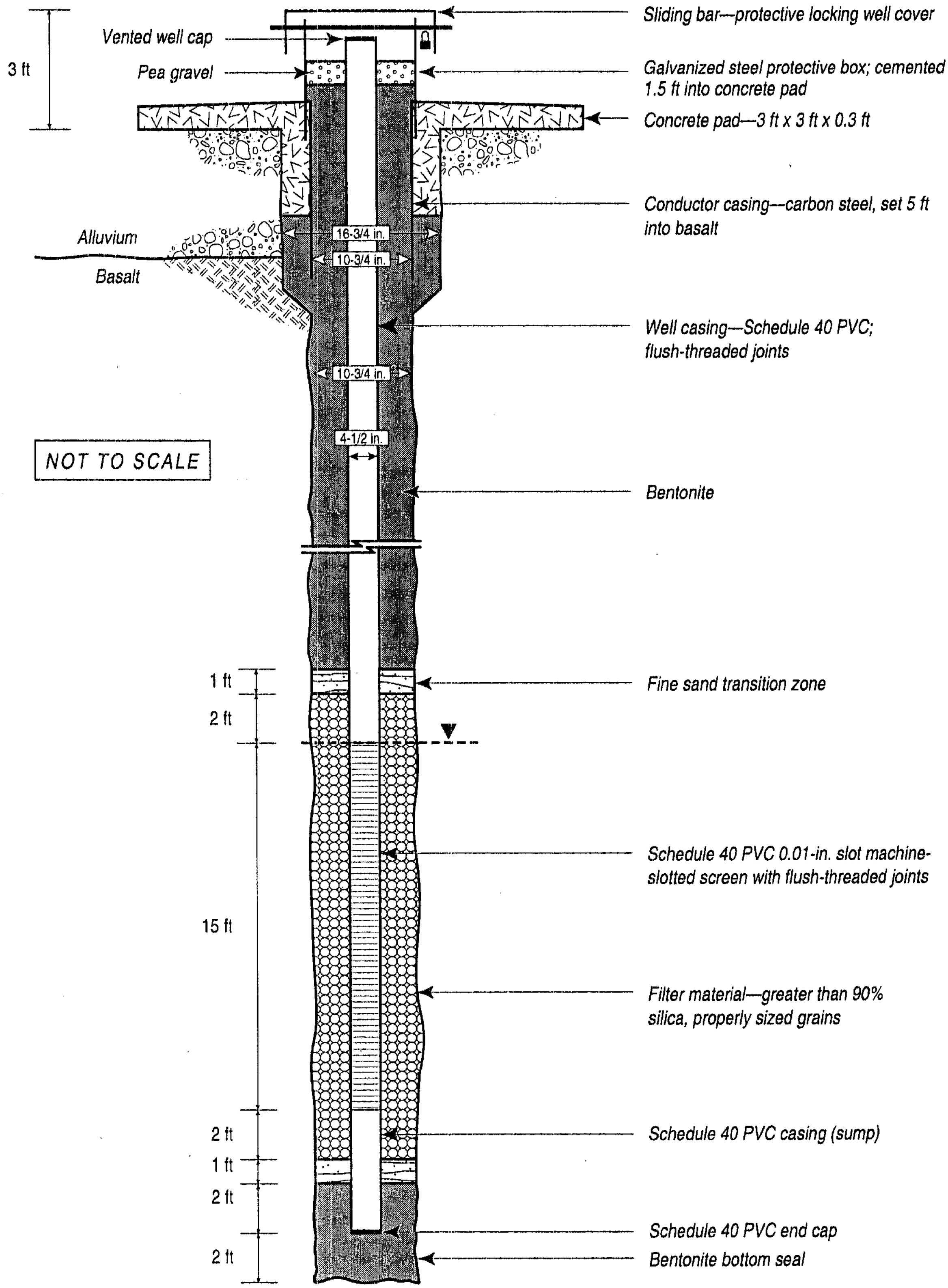

Figure 4-8. Type 5 (intermediate) well design.

Borehole Advancement and Well Installation Specifications

a) A carbon steel surface casing approximately 10 3/4 in diameter will be set from land surface to approximately 10 ft below the alluvium/tuff interface. In locations where alluvium is not present, the surface casing will extend approximately 20 ft into the underlying competent layer. To install the surface casing, a pilot borehole will be advanced through alluvium using a 4 1/4 in I.D. hollow-stem auger (borehole 8 1/2 in) collecting core with a split-spoon sampler. The pilot borehole will be over-reamed with a 14 1/4 in I.D. hollow-stem auger.

b) The borehole will be advanced using air-rotary/Odex™/Stratex™, or alternative drilling methods that may be recommended in the detailed design.

c) Install Schedule 40 PVC well casing with machine slotted screen and 25 foot blank casing sediment sump in the bottom.

d) The slot size for screen and selection of filter pack materials will be based on sieve analysis of geologic cuttings in the zone to be screened. An annulus ≥ 3 in will be provided, unless alternative annulus spacing is proposed to NMED for approval.

e) All backfill materials (grout, bentonite, sand) will be tremied/pressure grouted in place.

f) A lockable steel protective cover extending at least 2 ft below ground surface will be installed over the well casing.

g) The top of the well will be finished with a concrete pad 4 ft x 4 ft x 4 in.

h) A dedicated submersible pump and transducer will be installed in each well following well completion and development. If a well is completed with multiple screened intervals, a portable sampling device may be employed.

4.1.2 HSWA Module VIII Requirements

Special permit conditions included in the HSWA Module VIII requirements (EPA 1990) apply to the construction of monitoring wells. In particular, the following permit language is relevant to the construction of the wells proposed in this Workplan.

"The monitoring wells installed under this and following sections of this permit shall be constructed using flush-joint, internal upset, threaded (or an equivalent method of joining without rivets, screws and glues) casing manufactured from inert materials. The boreholes for casings and screens shall be a minimum of six (6) inches greater in diameter than the well casing or screen outer diameter. Filter pack and screen slot openings shall be sized based on formation grain size and characteristics. Well screen lengths shall be no more that (10) ten feet in length. The filter pack shall extend no more than (2) two feet above the top of the screen and shall not cross any clay layers which may act as aquitards. If a bentonite seal is used, the bentonite shall be allowed to hydrate a minimum of (12) twelve hours before emplacement of grout. Grout shall be emplaced using a tremie pipe to ensure a consistent seal at depths greater than 5 feet, and grout shall be allowed to set a minimum of twelve hours before initiating development."

"Development procedures shall include purging of the well until contaminants introduced during drilling can be assured of being removed. Development shall also include surging with a surge plug, and either bailing or pumping until the nephelometric turbidity units (N.T.U.) can be consistently measured at five (5) or less, if possible. Well head construction shall include a well pad keyed into the well annulus and a system to secure the well from traffic and unauthorized access. Within thirty (30) days of construction and development of the last well required under this section, the Permittee shall submit to the Administrative Authority a report and map including:

1) Survey of location of each well;
2) Surveyed ground level, top of casing and top of well pad referenced to known elevation datum (NGVD, 1929);
3) Static water level, referenced to mean sea level;
4) Well construction data (including a diagram for each well, detailing total depth, screen placement, gravel pack, annular seal, borehole and casing size [all measured to within 0.1 foot], and well log data; and
5) Well development data."

"Any saturated condition encountered will require grouting in a surface casing to prevent any downward migration of surface contamination along the wellbore. Any boring drilled into the main aquifer that encounters perched water shall set conductor pipe to the top of the main aquifer and hydraulically isolate the main aquifer from the perched aquifer. The annular space must be sealed with a bentonite grout or equivalent to prevent shrinkage cracking."

4.1.3 Borehole Sampling

The general goal for installing alluvial, intermediate perched zone, and regional aquifer wells is to provide characterization information on subsurface lithology and ground water quality. Geologic and groundwater samples will be collected from selected intervals during borehole advancement and following installation of each well. The wells to be installed by the ER Project will be constructed and sampled according to documented ER Project's QAPjP, SOPs and the specifics delineated in RFI Work Plans and SAPs.

In general, the following guidelines will apply to sampling the boreholes for the regional aquifer wells.

a) A comprehensive cased-hole geophysical logging suite will be run through the Odex™/Stratex™ drill string immediately prior to completion of each main aquifer well.

b) Core and cutting samples will be field screened for anomalous radioactive compounds using a Geiger-Mueller™ detector, and monitored for ionizable volatile compounds (TIVC) using a Photoionization Detector (PID). Field screening will be conducted at regular intervals during borehole advancement.

c) Borehole anemometry testing will be conducted in the Bandelier Tuff at 10 foot intervals in each borehole following removal of the hollow-stem auger and/or Odex™/Stratex™ casing. Average sample interval per well is approximately 340 ft, or 34 sample locations.

d) On boreholes for types 3 and 4 wells (e.g. R-1, R-6, R-12, R-14, R-22, R-25, R-28, R-32, R-1d, and R-28d), retrieved core samples will be analyzed for moisture content at 10 foot increments. Samples will not be analyzed for moisture content in the Puye Formation, basalts, or Tschicoma Formation.

e) For planning and conceptual design purposes, it has been assumed that five water-bearing zones will be encountered during advancement of each borehole: alluvial groundwater, three perched intermediate zones, and the regional aquifer. If possible, moisture profiling will be conducted on four core sample intervals per water-bearing zone. In general, groundwater samples (and possibly core pore water samples) will be collected from each water-bearing zone and analyzed for Appendix VIII and IX compounds, stable isotopes, and ^3H (low and high detection level). Laboratory analyses for Metals, Radiochemistry I, II, and III, Gamma Spec Scan, and General

Inorganics will be run on both filtered and unfiltered samples when the turbidity is less than 5 N.T.U. When turbidity is greater than 5 N.T.U. the analyses will be run on filtered samples only. It is recognized that specific parameters, e.g., tritium, require analysis from unfiltered samples regardless of the turbidity.

f) Physical properties analyses will be conducted on five core samples per borehole. Physical and hydraulic properties will be determined by a competent Laboratory. A "typical" list of hydraulic properties to be determined on most core samples includes the following: *in situ* water content, porosity, particle density, bulk density, saturated hydraulic conductivity, and water retention characteristics from 0 to 15300 cm suctions.

g) Ten samples of cuttings or core will be collected from each borehole for petrographic, X-ray fluorescence (XRF) and X-ray diffraction (XRD) analyses.

h) At five of the boreholes for well types 3 and 4, up to five samples will be collected for K-Ar or $^{39}Ar/^{40}Ar$ isotopic dating of basalts, or of tuff deposits in the Puye Formation.

i) Twenty samples of cuttings or core will be collected and analyzed for potential contaminant identification in each borehole location. The uppermost sample in each borehole will be analyzed for a full-range of compounds. Deeper samples will be analyzed for the presence of Radiochemistry I, II, III analytes, ^{3}H (low and high detection levels), and Metals. In addition, four samples per borehole will be analyzed for Volatile Organic Compounds (VOCs).

4.1.4 Groundwater Sampling

Groundwater samples from the ER Project's alluvial, intermediate perched zone, and regional aquifer wells will be sampled in accordance with procedures specified in the RFI Work Plans and SAPs. Groundwater from the NWT/MWIP wells will be sampled according to LANL standard operating procedures, and appropriate RCRA regulatory guidance documents, utilizing the following general procedures and assumptions:

a) As the regional aquifer boreholes are being advanced, 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 ground water; and the borehole will be rested for up to 24 hours prior to 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 re-analysis, if needed.

b) As the regional aquifer wells are completed, and the temporary Odex™/Stradex™ casing is retracted and the annulus grouted, specific intermediate perched zones may be re-sampled, as needed.

c) Following completion and development of the regional aquifer wells, groundwater samples will be collected from each screened interval or Westbay™-type port and analyzed for the presence of select Appendix VIII and IX constituents.

d) During the initial sampling event, groundwater samples will be collected from each well screen/port and analyzed for the presence of Radiochemistry I, II, and III analytes, ^{3}H (low and high detection levels), General Inorganics, stable isotopes, VOCs, and Metals. Subsequent sampling events will test for the presence of Radiochemistry I, II, and III analytes, ^{3}H (low and high detection levels), General Inorganics, and Metals. Filtered and unfiltered samples will be used for laboratory analyses when the turbidity is less than 5 N.T.U. When turbidity is greater than 5 N.T.U. the analyses will be run on filtered samples only. It is recognized that specific parameters, e.g., tritium, require analysis from unfiltered samples regardless of the turbidity.

The following physical data will be measured or collected to determine if two saturated zones are hydrologically and chemically connected: temperature and hydraulic gradient information. The following chemical data will also be measured or collected from the saturated zones: radionuclides (tritium, Sr-90, Cs-137, Am-241, plutonium isotopes, uranium isotopes, gamma spectrometry, and gross alpha, beta, and gamma), pH, specific conductance, alkalinity, stable isotopes (hydrogen, oxygen, and in special cases nitrogen), major ions (cations and anions), trace metals, and trace elements. Mobile species such as tritium, chloride (Cl^-), nitrate (NO_3^-), and boron ($B[OH]_3^0$) will be useful in determining if two or more saturated zones are interconnected within Los Alamos and Pueblo Canyons, especially at future R-12 relative to POI-4 and TW-1A. Tracer tests will be considered under special conditions to determine if a hydraulic connection occurs between two or more saturated zones. Potentiometric maps shall be constructed to determine flow directions and hydraulic gradients.

Use of chemical data for determining groundwater flow paths and contaminant chemistry require that baseline concentrations are well established for the different saturated zones found in the alluvium, Tschicoma Formation, Bandelier Tuff, basalts, Puye Formation, and Santa Fe Group beneath Los Alamos and Pueblo Canyons. Geochemical modeling consisting of mixing reactions based on chloride (or some other tracer) and reaction path modeling are useful in determining if two or more saturated zones are connected. Time-chemical species plots will be used to establish short- and long-term trends between two or more saturated zones. Hydrologic flow and solute transport modeling shall be used to quantify the degree of connection between different saturated zones.

4.1.5 Hydrologic Modeling

Hydrologic modeling will play a major role in the task of data synthesis and evaluation during hydrogeologic characterization activities. A central goal of this project relates to prediction of flow paths and resultant contaminant movement, and computer models are a convenient tool for this purpose. Such modeling can be applied at two levels. The first level relates to the evaluation of site-wide issues, for example, the overall water balance for the Laboratory. A second level addresses evaluation of aggregate-specific issues, one example of which might be the potential for vapor-phase contaminant transport at MDA G. Hydrologic modeling should be applied at all stages of the project. In the project design phase, modeling can be used to examine hypotheses relating to the hydrogeologic conceptual model and to determine where additional information is needed. In later project phases, modeling can be used to asses how recently-acquired information relates to earlier predictions, and can point out continuing data gaps.

As new data are acquired, they will be used continually to refine the hydrogeologic conceptual model. For example, new data will be compared with regional groundwater flow maps and model predictions to assess the level of understanding regarding recharge and discharge areas, groundwater flow directions, and interconnections between alluvial groundwater, intermediate perched zones, and the regional aquifer. If there is good agreement between the modeled features and the observed features, it will then be possible to incorporate reasonable assumptions into the groundwater modeling effort. This type of analysis can determine whether it is necessary to collect additional field data for the groundwater characterization program.

Key steps in refining the conceptual model are as follows:

1. Integrate Available Data for Laboratory Geology, Hydrology, and Water Quality
    - Hydrologic, stratigraphic, geophysical, and chemical data will be incorporated into a centralized data base (FIMAD).
    - Develop a 3-D representation of stratigraphy and geology at the site.
    - Model and display data related to geology, 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 Processes
   - Evaluate existing water quality, vadose zone, and water level data for the various zones of saturation with respect to trends and indications of interconnection.
   - Develop a site-wide model and evaluate data shortcomings with respect to siting characterization wells.
3. Refine Conceptual Model and Upgrade Groundwater Monitoring Network
   - Drill characterization borehole at highest priority location, that is, determine the sites with highest risk and most critical data needs.
   - Use information as each borehole is drilled to optimize placement and determine need for subsequent boreholes.

4.1.6 General Geophysical Procedures

Geophysical logging will be conducted on the 32 wells completed in the regional aquifer. The application of logging techniques will complement hydrogeologic data collected from sediment samples. Both open-hole and cased-hole wireline logging will be conducted on the regional aquifer boreholes and/or wells. However, only open-hole logging will be conducted on the deep portion of the two Type 4 wells, i.e., R-1d and R-28d to 4,000 ft[2]. It is assumed that two logging runs will be conducted for each of the regional aquifer well boreholes. Application of the various logging techniques will be determined on a well-by-well basis.

The upper 300 to 500 ft of each regional aquifer well borehole 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 1,000 ft. Due to the unconsolidated nature of the subsurface strata and utilization of air-rotary drilling, these boreholes will be cased prior to wireline logging. Cased-hole logging will be performed from surface to a total nominal depth of 1,000 ft.

Two open-hole wireline logging runs well be performed on each of the 4,000 foot boreholes. The assumption was made that these Type 4 wells will remain open for the logging runs through the implementation of mud-rotary drilling methods. The borehole for well R-1 will be advanced to the first casing interval depth of about 1,300 ft. Wireline logging will be performed in the mud-sealed open hole to this depth prior to installation of the 13 3/8 in O.D. conductor casing. The borehole will then be advanced to a total depth of 4,000 ft and logged before setting the final 6 5/8 in O.D. casing. Well R-28 will be logged in a similar manner as well R-1, but the first logging run will be made at a depth closer to 1,200 ft below surface grade.

In general, the following geophysical logs will be generated for all open-hole sections:

- Caliper
- Electromagnetic Induction
- Natural Gamma

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[2] This proposed logging may be altered because presently these wells may be limited in depth to 500 ft below the top of the regional aquifer.

- Magnetic Susceptibility
- Borehole Color Video (axial and sidescan)
- Fluid Temperature (saturated zone only)
- Fluid Resistivity (saturated zone only)
- Single Point Resistivity (saturated zone only)
- Spontaneous Potential (saturated zone only)

In general, the following geophysical logs will be generated for all cased-hole sections:

- Gamma-Gamma Density (focused at 4π)
- Natural Gamma
- Thermal Neutron

4.2 Regional Hydrogeologic Characterization

Regional hydrogeologic characterization (also known as Aggregate 9) focuses on the Laboratory as a whole to provide site-wide integration of several important data collection and interpretation needs. The overall goal of this Workplan (hydrogeologic characterization leading to the design of a groundwater monitoring system for the Laboratory) calls for understanding of contaminant transport and groundwater flow paths beneath the Laboratory. This understanding must be developed in a complex hydrogeologic and topographic setting which is presently only partially characterized. Achieving a fundamental understanding of the regional aquifer beneath the Pajarito Plateau is an important element in protecting groundwater resources from possible contamination.

4.2.1 History and Issues

There are significant uncertainties regarding the regional aquifer flow system that need to be resolved for contaminant transport to be evaluated. Frenzel (1995) recently completed a groundwater modeling study of the regional aquifer in the Los Alamos area and surroundings. The model was developed to evaluate possible effects of future water supply pumping scenarios, but is not suitable for predicting contaminant transport. Regarding data needs for further modeling, Frenzel (1995, p. 68) states:

> "An improved understanding of the flow system would be desirable if a contaminant transport model were to be constructed. ... a flow model would first need to be developed to provide a reliable approximation of flow path lines in the vicinity where a contaminant transport model might be attempted. ... a reliable simulation of ground-water flow path lines for contaminant transport would require a better understanding of the hydrologic characteristics of the Pajarito Plateau and adjacent areas."

With regard to specific data needs, in addition to noting the importance of information related to the Pajarito fault zone, Frenzel (1995, p. 69) comments that:

> "Water-level, geologic, and aquifer-characteristic data for the northern extremity of the Pajarito Plateau (north of Los Alamos County), especially between the county line and Santa Clara Canyon, would be useful. Geohydrologic characteristics of that area, which lies adjacent to the Guaje well fields, are almost completely unknown. ... The possible southward extent of the Chaquehui formation [sic] through the southern extremity of the Pajarito Plateau could have a bearing on flow paths because the Chaquehui is more permeable than the Tesuque Formation."

In a review of the Laboratory's hydrogeologic setting and issues, conducted for the ER Project, a panel of three hydrogeologists external to the Laboratory (Stephens, et al. 1993) came to similar conclusions. The panel noted that the overall flow system in the regional aquifer is not understood sufficiently for purposes of evaluating contaminant transport, and made specific suggestions for data needed to support this understanding. With respect to the importance of contaminant transport modeling, (Stephens, et al. 1993, p. 31) observed that:

> "The source of water in the three well fields which tap the main aquifer [referred to in this document as the "regional aquifer"] is important to the ER program [sic] if long-term performance assessments of individual operating units are required. For example, if nearly all pumped groundwater is derived from recharge on the Pajarito Plateau, then potential contaminants from operating units will not be mixed and diluted to any significant extent with other water."

Stephens, et al. (1993, p. 38) further found that:

> "... water level data are not adequate to evaluate vertical flow components or to establish sources of recharge. Vertical flow in the main aquifer is potentially important to the ER program to predicting deep pathways of contaminant migration."

In criticizing the lack of knowledge of overall recharge and flow in the regional aquifer, they noted that, while recharge from the Pajarito fault system has been assumed as a major recharge source, (Stephens, et al. 1993, p. 12)

> "...no subsurface data exist west of the Pajarito fault zone on which to base an evaluation of either the water table gradient or the transmissivity of the Tschicoma Formation. The steepening of the gradient in this area is based on two data points... located east of the Pajarito fault zone which are extrapolated to the west based on the assumption that the water table will rise toward the caldera".

More specifically, Stephens, et al. (1993, p. 14) state "At least two upgradient wells, one on each side of the Pajarito fault zone, are recommended to assess background water quality and recharge areas."

Stephens, et al. (1993) also noted the importance of evaluating the regional scale water budget, that is, determining the magnitudes of the major components of the hydrologic cycle: precipitation, transpiration, evaporation, infiltration, and runoff.

Although the Pajarito Plateau has been studied for decades, researchers have been limited in their ability to describe much of the geology or the groundwater system beneath the Laboratory due to a lack of borehole and well coverage. The database to establish the regional direction of groundwater flow includes test wells and springs. Within the approximately 50 square mile area comprising the Laboratory and areas east to the Rio Grande, there are only nine unpumped wells to measure water level elevations in the regional aquifer. Most of these wells are located on the central part of the plateau and penetrate substantial thicknesses of the regional aquifer. The well coverage is inadequate to evaluate the effects of municipal pumping on regional aquifer groundwater flow. Moreover, there is reduced certainty in the stratigraphy at depths below the Bandelier Tuff due to very limited availability of archived geologic samples from deep boreholes.

4.2.2 Site-Wide Investigations

The site-wide activities will focus on the following key areas:

- Site-Wide Stratigraphy — *reducing uncertainty.*
- Regional Aquifer Groundwater Flow — *establishing regional aquifer groundwater flow directions.*

- Upgradient Groundwater Quality — *establishing groundwater quality upgradient of the Laboratory.*
- Water Supply Issues — *evaluating the effects of municipal pumping by Los Alamos and by neighbors on groundwater flow directions, availability, and quality,* and *determining possible locations for future municipal water supply wells.*
- Recharge — *approximating recharge on the Pajarito Plateau.*

4.2.2.1 Site-Wide Stratigraphy

To assist in the development of site-wide stratigraphy, the boreholes of eight proposed regional aquifer hydrologic characterization wells are proposed to be substantially cored and completed as Type 3 wells. These wells are spaced approximately four miles apart across the Laboratory. The boreholes and cores will yield a broad definition of the stratigraphy and groundwater levels. Core will be archived at the ER Project Core Storage Facility for future reference; thus the boreholes for Type 3 wells (and Type 4 wells) are referred to as "Library Core Holes". Most of these boreholes also contribute to resolution of aggregate-specific questions, and have been selected to be substantially cored principally on the need for detailed stratigraphic and vadose zone hydrology information at those general locations. They are designated, from north to south, R-1, R-6, R-12, R-14, R-22, R-25, R-28, and R-32. Locations of the Library Core Holes (Type 3 and Type 4 wells) are shown in Figure 4-2.

The Library Core Holes are laid out in transects so that several detailed north-south and east-west hydrogeological cross sections may be constructed from the data. The boreholes for wells R-6 and R-25 will examine the stratigraphy near Pajarito fault zone and the west side of the Laboratory. The boreholes for wells R-1, R-14, and R-28 are to be drilled in the central portion of the Laboratory. The boreholes for wells R-12 and R-22 will be drilled near the eastern boundary of the Laboratory. Stratigraphic and hydrogeologic data generated from the examination of the cores from these boreholes will be incorporated into a 3-dimensional stratigraphic model that will serve as the basis for construction of numerical flow and contaminant transport models.

4.2.2.2 Direction of Groundwater Flow in the Regional Aquifer

Additional data are needed to define groundwater flow direction in the regional aquifer. Current maps of the piezometric surface indicate that the groundwater flow direction is easterly beneath the northern portion of the Laboratory and southeasterly beneath the southern portion of the Laboratory. Well coverage is inadequate to evaluate the effects of municipal pumping or permeability contrasts imposed by the Pajarito fault zone and the "Chaquehui Formation," the late-Miocene high permeability zone described by Purtymun (1984;1995) (see also Section 2.1.2.1 in this document). Municipal pumping may locally alter the regional flow direction both horizontally and with depth. The Pajarito fault zone may represent either a barrier or a conduit to groundwater flow. The north-south trend of the "Chaquehui Formation" may induce a more southerly flow component of the regional aquifer through the central portion of the Laboratory.

Defining the direction of groundwater flow in the regional aquifer will be an ongoing process. Flow directions will be continually re-defined after additional groundwater level data become available from new wells. Accurate long-term records of groundwater withdrawals and non-pumping hydraulic heads have been collected by the Laboratory for some wells. All regional aquifer test wells are currently equipped with continuous recording pressure transducers for measuring groundwater levels. Wells installed for this Workplan will be similarly equipped.

To determine whether the general flow direction in the regional aquifer is locally altered by pumping wells, six wells are proposed to be installed near existing municipal supply wells and the groundwater levels monitored. Well R-5 will be located near water supply well O-1 in Pueblo Canyon. Well R-8 will be located near water supply well O-4 at the confluence of DP and Los Alamos Canyons (see Appendix 6, Plate 2). Well R-11 will be located near water supply well PM-3. Well R-12 will be located near water supply well PM-1. Well R-14 will be located near water supply well PM-5 on Pajarito Mesa. Well R-20 will be located near water supply well PM-2 in Pajarito Canyon. This evaluation will be supplemented by data collected from aquifer pumping tests anticipated to be conducted within the Guaje Municipal Well Field as discussed in Section 3.2.

Three wells proposed to be installed along the western boundary of the Laboratory will provide insight on the effect of the Pajarito fault zone on regional aquifer conditions, recharge, and water levels. Frenzel (1995) noted that understanding this area is a critical data need for defining the regional aquifer flow system. From north to south, the proposed wells are designated as Wells R-6, R-24, and R-26. Well R-6 will be located in upper Los Alamos Canyon near existing well LAO-C; Well R-24 is located on the upthrown side of the Pajarito fault zone between upper Pajarito Canyon and Cañon de Valle; Well R-26 is located on the downthrown side of the Pajarito fault zone in upper Water Canyon.

Wells R-1 and R-28 will be sited in central portions of the Pajarito Plateau at locations projected to intercept the axis of the "Chaquehui Formation" near the northern and southern boundaries of the Laboratory. Wells R-1, R-2, R-3, R-4 and R-6 play important roles in defining boundary conditions in the relatively unstudied area north of the Laboratory. Frenzel (1995) cited better definition of northern boundary conditions as one of the critical data needs for understanding the regional aquifer flow system. The presence of the "Chaquehui Formation" at Well R-1 is inferred from recent surface geophysics data suggesting the presence of a significant geologic trough in this area (Ferguson et al. 1995).

4.2.2.3 Upgradient Groundwater Quality

Background groundwater quality must be established in order to properly detect any changes in groundwater quality across the Laboratory. Currently there are no wells that are hydraulically upgradient of the Laboratory.

Four wells are proposed to be installed at locations upgradient of the Laboratory. Three wells will be located on the western boundary of the Laboratory: Wells R-6, R-24, R-26. The remaining upgradient well, R-1, will be located in Rendija Canyon north of the Laboratory. Many of the other wells proposed to be installed will serve to define incremental impacts by potential contaminant sources.

4.2.2.4 Water Supply Issues

Although water supply issues are not the main focus of this Workplan, regional aquifer wells proposed for installation will help delineate the "Chaquehui Formation," a zone of high permeability; the information gained from the wells will guide the placement of future municipal water supply wells and will be useful in addressing issues related to Laboratory effects on groundwater supply availability and quality for Laboratory neighbors. Characterization of vertical chemical stratification in the regional aquifer could be accomplished by deepening wells R-1 and R-28 but, at present, these wells will be limited to a depth of 500 feet into the regional aquifer. The key contribution to assessment of future water supply obtained from these wells will be in mapping zones of high permeability and high groundwater quality.

The highest yielding municipal water supply wells at Los Alamos are completed in the late-Miocene high permeability trough (the "Chaquehui Formation") described by Purtymun (1984; 1995). Further delineation of this zone is critical to the development of high capacity wells in the future, to the evaluation of groundwater supply availability, and to the evaluation of the effects of pumping the groundwater supply on the regional aquifer flow system and potential contamination. A majority of the deep hydrogeologic characterization wells installed will penetrate 500 feet into the regional aquifer and may encounter the top of the "Chaquehui Formation." Information from the boreholes for these wells will help refine the understanding of the lateral extent and properties of this high permeability zone.

The Data Quality Objectives Process conducted for this Workplan resulted in a prospective determination to deepen wells designated R-1 and R-28 to a proposed depth of 4000 feet, penetrating the "Chaquehui Formation" and delineating the vertical dimensions of the trough. Within the context of this Workplan, there is no commitment to complete these wells past a depth of 500 feet into the regional aquifer. If R-1 and R-28 were to be deepened beyond 500 feet, they would be equipped with multi-depth sampling capability to establish vertical water quality (and hydraulic head) profiles in the "Chaquehui Formation." Future DOE decisions will determine the final completion depth of these two wells.

Chemical stratification within the regional aquifer will be evaluated using downhole zonal testing of existing municipal water supply wells, as discussed in Section 3. 2. Groundwater quality concerns are focused both on Laboratory-derived contaminants and on elevated levels of naturally occurring constituents. The naturally occurring constituents of most concern are arsenic and uranium. In 1976, use of municipal water supply well LA-6 was precluded due to high levels of arsenic (160 µg/L). An investigation found that the high concentration of arsenic occurs throughout the regional aquifer adjacent to the well (Purtymun 1977). Arsenic is widely observed in water supply wells in the Santa Fe Group in the northern Rio Grande Basin (Kelly and Reinhart 1996). Natural uranium concentrations near the Rio Grande have been shown to greatly exceed proposed EPA Drinking Water Standards. Mapping vertical and horizontal distributions of dissolved constituents in the regional aquifer is needed to prevent similar problems in the future and to guide the placement of new municipal supply wells.

4.2.2.5 Recharge

Hydrogeologic characterization activities discussed in this Workplan will increase insight into recharge on the Pajarito Plateau. An investigation has not been proposed to characterize the groundwater flow system in three dimensions. Rather the Workplan activities are designed to gain an approximation of recharge processes, sources, and magnitudes. Some of the key data collection efforts proposed to achieve this goal are discussed in Section 3.2 and summarized as follows:

1. Conduct long-term water balance measurements to quantify precipitation, evaporation, transpiration, infiltration, and runoff.
2. Collect cores from vadose zones beneath canyon bottoms and mesas to identify any active recharge zones through examination of hydraulic properties and degree of saturation.
3. Complete vadose zone characterization boreholes as wells in the regional aquifer and monitor groundwater level responses over time. Compare groundwater level patterns with other wells across the Pajarito Plateau to determine whether a given location is more "dynamic" and quicker to respond to, say, snowmelt, than other locations.
4. Install additional wells near Laboratory boundaries to define groundwater levels and to gain insight into hydrogeologic properties affecting recharge.
5. Test vadose zone and groundwater for key tracers (for example, chloride, tritium and stable isotopes) to determine age and altitude of recharge.
6. Maintain accurate long-term pumping and hydraulic head measurements.
7. Through laboratory analyses of core samples and conduct of regional aquifer performance tests, estimate vertical hydraulic properties of stratigraphic units.

8. Determine patterns of water-yielding characteristics of the late Miocene high permeability trough of Purtymun (1984; 1995), the Puye Formation, and interbedded basaltic rocks.

The descriptions of aggregates which follow provide substantial detail on the current hydrogeologic conceptual model for each canyon, mesa, or aggregate, hydrogeologic characterization issues to be addressed in each aggregate, and the installation of wells.

4.3 Descriptions of Aggregates

4.3.1 Aggregate 1

Table 4-3 lists the alluvial and regional aquifer wells proposed for installation in Aggregate 1. The rationale for these wells and the uncertainties they address are described below. Additional information about the rationale for the regional aquifer wells is given in Table 4-1. Figures 4-1 and 4-2 show the general proposed well locations. Appendix 6 provides large-scale maps with proposed well location plotted along with existing wells for reference.

Table 4-3. Summary of Potential Wells in Aggregate 1

Canyon or Mesa	*Alluvial Wells/Piezometer Transects (all ER)*[1]	*Intermediate Wells*	*Regional Aquifer Wells*
Pueblo Canyon	A-3	I-1 (ER)	R-2 (NWT)[2]
	A-4		R-3 (ER)
	A-5		R-4 (ER)
	A-6		R-5 (NWT)
	A-7		
	A-8, A-9, A-10		
	A-11, A-12, A-13		
Los Alamos Canyon	A-14		R-6 (NWT)
	A-15		R-7 (ER)
	A-16, A-17, A-18		R-8 (NWT)
	A-19		R-9 (ER)
	A-20, A-21, A-22		
	A-1		
Sandia Canyon	A-26, A-27, A-28		R-10 (ER)
			R-11 (NWT)
			R-12 (ER)

[1] Funded through Environmental Restoration Project
[2] Funded through Nuclear Weapons Technology Program

4.3.1.1 Area Description and History

Aggregate 1 is located in the north-central portion of the Laboratory (see Figure 1-3). It is bounded on the north by Pueblo Canyon, on the south by Sandia Canyon, on the east by State Road 4, and on the west by Los Alamos Bridge in upper Los Alamos Canyon (Figure 4-9 and Figure 4-10). The boundaries of Aggregate 1 were established to encompass a large number of Laboratory potential release sites within these canyons and the adjacent mesa tops.

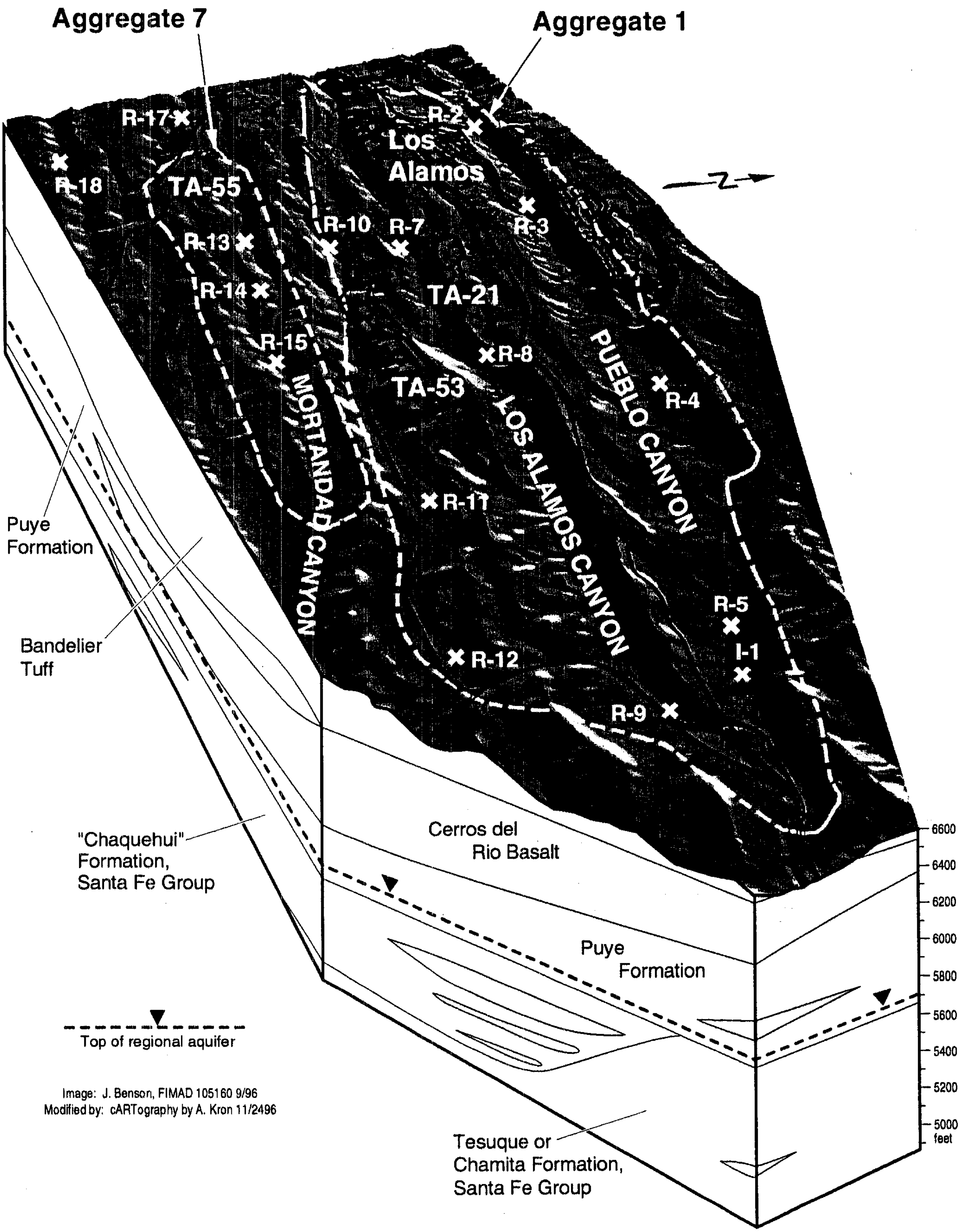


Figure 4-9. Block diagram showing the terrain and bedrock geology for Aggregates 1 and 7.

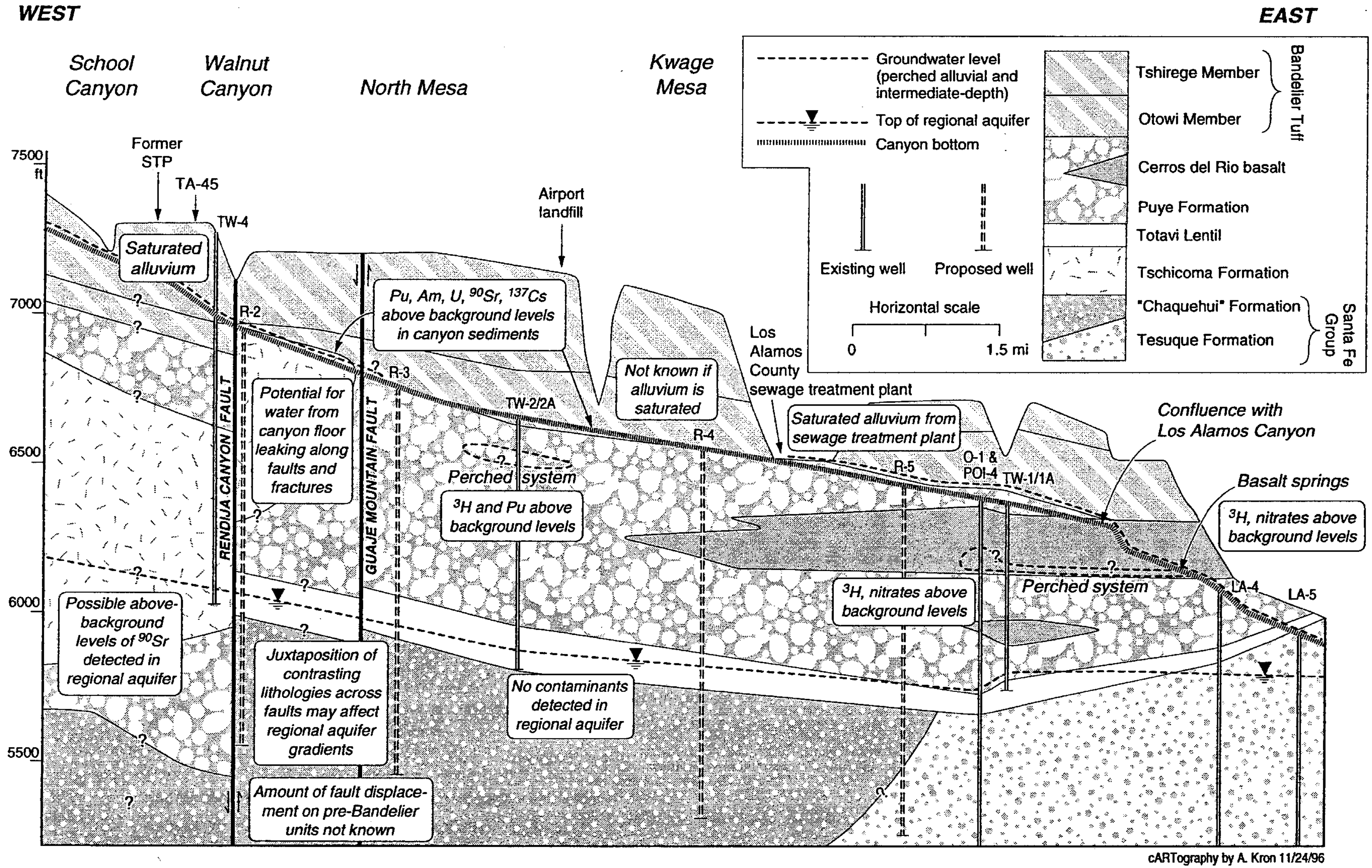


Figure 4-10. Schematic cross section showing conceptual model and proposed regional aquifer wells for Pueblo Canyon.

Aggregate 1 includes the Los Alamos townsite; Pueblo, Los Alamos, and Sandia Canyons; and Los Alamos Mesa, DP Mesa and Mesita de Los Alamos. Several currently active Technical Areas exist on the mesa tops and in the canyon bottoms as given below (see TA map Figure 2-2):

- TA-0, which is an area that includes the majority of the present-day townsite of Los Alamos and includes administrative and technical office space as well as a collection of areas that fell outside of currently defined TA boundaries that contain small potential releases sites with little or no liquids
- TA-2, which was the location of a series of nuclear reactors, located in upper Los Alamos Canyon
- TA-21, which is on DP Mesa, north of Los Alamos Canyon and includes Material Disposal Areas A, B, T, U, and V
- TA-41, which was used for testing of nuclear weapons components, located in upper Los Alamos Canyon
- TA-43, which is the site of the Los Alamos Medical Center, north of Los Alamos Canyon
- TA-53, which is the site of the Los Alamos Neutron Science Center (LANSCE) linear accelerator facility, above Sandia Canyon
- TA-73, which is the site of the DOE airport and former landfill, above Pueblo Canyon

The aggregate also includes two inactive TAs (TA-1 and TA-45). TA-1 includes the portion of the present-day Los Alamos townsite where the majority of the theoretical and technical work was accomplished at the Laboratory from 1943–1954. TA-45 was the site of a former liquid radioactive waste treatment plant whose outfall added significant quantities of effluent to Acid and Pueblo Canyons.

More detailed information about these active and inactive sites can be found in the Task/Site Work Plan for Operable Unit 1049, Los Alamos Canyon and Pueblo Canyon (LANL 1995d), the RFI Work Plans for Operable Units 1078 (LANL 1992c), 1079 (LANL 1992a), 1100 (LANL 1994b), 1106 (LANL 1991), and the FUSRAP report (i.e., "Formally Used MED/AEC Sites Remedial Action Program, Radiological Survey of the Site of a Former Radioactive Liquid Waste Treatment Plant (TA-45) and the Effluent Receiving Areas of Acid, Pueblo, and Los Alamos Canyons, Los Alamos, New Mexico," [LANL 1981]).

4.3.1.2 Pueblo Canyon

Surface Water

Surface water in Pueblo Canyon occurs as ephemeral runoff from precipitation and as perennial flow supported by effluent discharge from the Los Alamos County Sewage Treatment Plant (LANL 1995d). Generally ephemeral surface water occurs in the upper portion of Pueblo Canyon following summer rains and snowmelt events, and perennial surface water occurs in the lower portion of Pueblo Canyon because of discharges from the Los Alamos County Sewage Treatment Plant.

Surface water in Pueblo Canyon rarely flows across the length of the Laboratory. Most often surface waters are depleted by infiltration into canyon alluvium creating saturated zones of seasonally-variable extent.

Alluvial Groundwater

Two saturated zones are known to occur in the alluvium of Pueblo Canyon (see Figure 4-11 and 4-12). The first is in the upper reach from the headwaters to approximately the Rendija Canyon Fault. The eastern limit of this saturated zone has not been clearly defined and it may extend further down canyon. The second is in the lower reach downstream of the Los Alamos County Sewage Treatment Plant where saturated conditions are supported year-round due to effluent releases from the sewage treatment plant. The extent of saturation is variable due to variation in runoff and volume of effluent released during the year. The volume of effluent released into the canyon typically decreases during the spring and early summer months as wastewater from the plant is pumped up canyon for irrigation use on the municipal golf course (LANL 1995d).

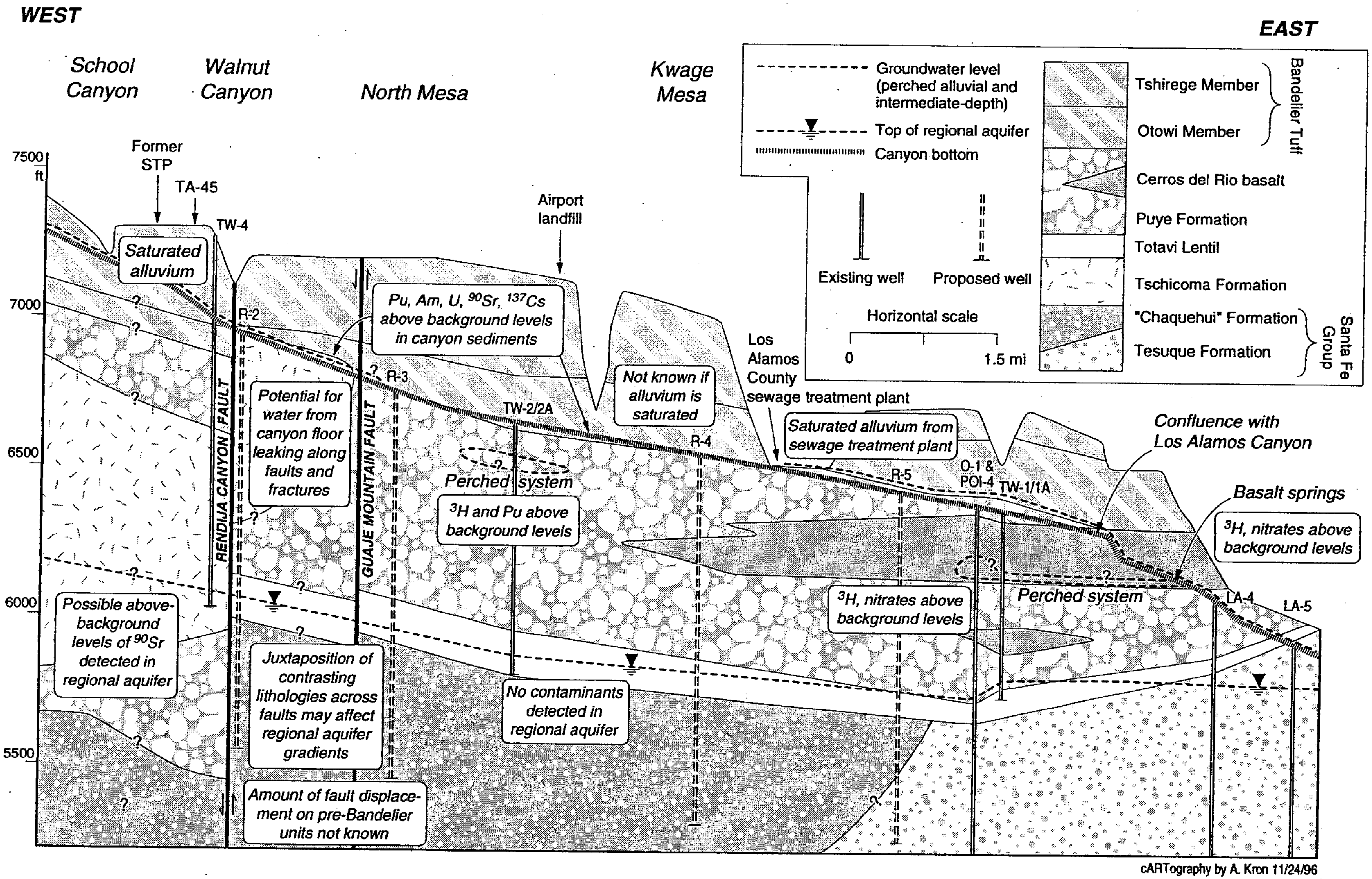


Figure 4-11. Schematic cross section showing conceptual model and proposed regional aquifer wells for Pueblo Canyon.

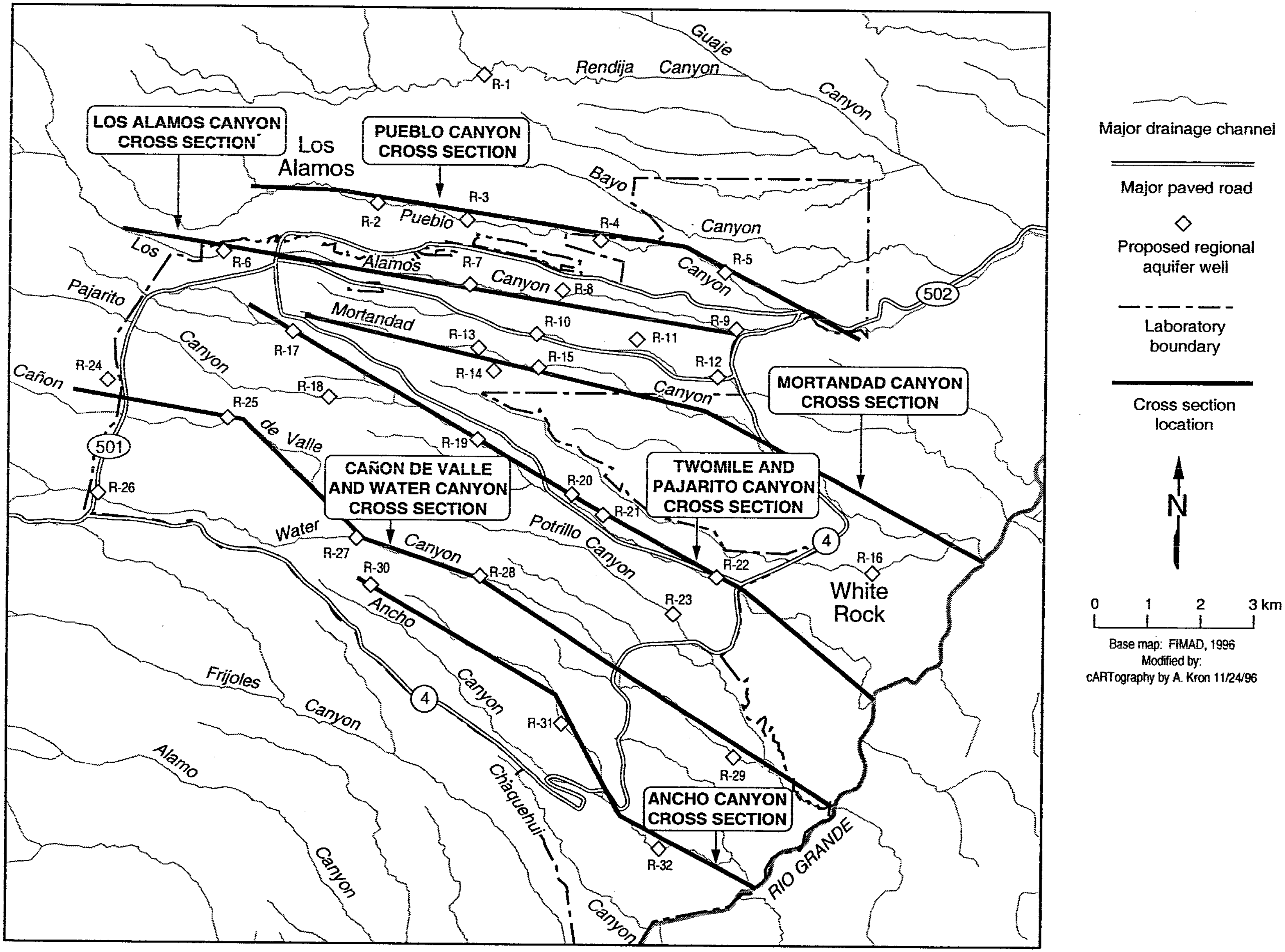


Figure 4-12. Location of geologic cross sections.

In the past (1951 - 1964), surface flow in the mid-reach of Pueblo Canyon was augmented by liquid effluent from the former TA-45 radioactive liquid waste treatment facility via Acid Canyon (LANL 1981; LANL 1992c). Known contaminants at former TA-45 include tritium, isotopes of uranium and plutonium, strontium-90, cesium-137, and gross-alpha radiation. In addition, Los Alamos County operated a sewage treatment plant in upper Pueblo Canyon (known as the Pueblo Sewage Treatment Plant) until the current Los Alamos County Sewage Treatment Plant came on-line in 1963 (LANL 1981). Effluent from these past sources likely supported sustained saturated conditions throughout the mid-reach of Pueblo Canyon as well as shallow bedrock springs such as Hamilton Bend Spring, just west of the current Los Alamos County Sewage Treatment Plant. This alluvial groundwater may have provided the source for infiltration to intermediate perched zone groundwater or the regional aquifer. Additionally, surface flow (particularly flood events) has transported contaminated sediments down canyon where they now form part of the alluvial deposits (LANL 1981; Graf 1995). Shallow spring flow (including Hamilton Bend Spring) ended following closure of TA-45 and the Pueblo Sewage Treatment Plant.

Alluvial Groundwater Investigations

Six individual wells and two transects with three piezometers each are identified in this Workplan for Pueblo Canyon. Some of these wells were first proposed as part of the Task/Site Work Plan for OU-1049: Los Alamos and Pueblo Canyon (LANL 1995d). From west to east, the individual wells are A-3, A-4, A-5, A-6, and A-7 and the transects are A-8, A-9, and A-10, and A-11, A-12, and A-13 (see Figure 4-1).

Well A-2 will be located near the headwaters of Pueblo Canyon upgradient from all townsite and Laboratory sources. The purpose of this well will be to establish background water quality for Pueblo Canyon.

Well A-3 will be located upgradient of former TA-45 and downgradient of the former Pueblo Sewage Treatment Plant and other townsite influences. The purpose of this well is to determine if townsite sources are entering Pueblo Canyon and perhaps complicating the assessment process used to identify past Laboratory sources and impacts. This will be accomplished by a comparison of chemical data between this well and background well A-2.

Wells A-4, A-5, and A-6 will be located below the confluence with Acid Canyon. The purpose of these wells is to determine the down-canyon extent of alluvial groundwater in the upper and middle parts of Pueblo Canyon. These three wells will be installed sequentially from west to east; wells A-5 and A-6 may be moved or eliminated depending on findings from the drilling for well A-4. Analyses of water samples from these wells will help to assess the degree to which Laboratory-derived contaminants adsorbed to sediments are being transported down-canyon by alluvial groundwater.

Well A-7 will be located downstream of the outfall from the Los Alamos County Sewage Treatment Plant. The purpose of this well is to characterize the baseline water quality of alluvial groundwater downstream of the plant.

A north-south piezometer transect (A-8, A-9, and A-10) will be located in lower Pueblo Canyon near the confluence with Los Alamos Canyon. The purpose of this perpendicular transect is to determine the width and thickness of saturated alluvium in lower Pueblo Canyon. Data collected will be used to define the width of the area through which alluvial groundwater may infiltrate to an intermediate perched zone known to occur in this area, and to support related evaluations including calculating seepage losses, and assessing mobilization of contaminants adsorbed to sediments. One of these wells may be used to monitor water quality upgradient of San Ildefonso Pueblo lands. One piezometer (A-9; labeled PO-4) was recently installed by the ER Project and encountered up to 40 ft of saturated alluvium.

Another piezometer transect (A-11, A-12, and A-13) is tentatively proposed also for lower Pueblo Canyon near the confluence with Los Alamos Canyon. The purpose of this longitudinal transect will be to investigate seepage loss as the canyon floor bedrock geology changes from Puye Formation fanglomerates to Cerros del Rio basalts. The need for this transect will be evaluated following the completion and subsequent data evaluation of upgradient alluvial wells.

Intermediate Perched Zones and Regional Aquifer

Intermediate perched zones have been identified below Pueblo Canyon in two areas, as shown on Figure 4-11. One zone is in the middle reach of Pueblo Canyon where Test Well (TW)-2A is completed within fanglomerates of the Puye Formation. The perched zone occurs at a depth of about 120 ft. The second is in lower Pueblo Canyon (wells TW-1A and POI-4) within a thick sequence of Cerros del Rio basalts, at a depth of about 188 ft. This intermediate perched zone may be one source of water contributing to the flow from Basalt Spring in Los Alamos Canyon.

The extent and geologic setting of the Puye Formation intermediate perched zone intercepted by TW-2A is presently unknown. Additional boreholes are needed to determine whether this zone is limited near TW-2A, or is part of a larger system. The lithology and the dip of the perching layer are not known; consequently, flow directions can not be determined with the available data. Analysis of water samples from TW-2A show that this perched zone contains Laboratory-derived contaminants (EPG 1996). From 1990 to 1994, nitrate-nitrogen concentrations increased from 1.4 to 13.7 mg/L (EPG 1996). Elevated activities of tritium (2,228 pCi/L) have also been detected (EPG 1995). This suggests that mobile contaminants associated with the former TA-45 treatment plant (tritium and nitrate) have infiltrated the canyon floor and are migrating vertically, at least to the depth of the intermediate perched zone at TW-2A.

Depth to the regional aquifer is known in three locations in Pueblo Canyon; at test well TW-4 in upper Pueblo Canyon, at well TW-2 in the middle reach, and at wells TW-1 and O-1 near the confluence with Los Alamos Canyon. Water level measurements taken in December 1993 show depths to water to be 1174 ft at TW-4, 793 ft at TW-2, and 704 ft at O-1 (EPG 1996). Based on Laboratory water-level maps, the general direction of groundwater flow in the regional aquifer is east in the vicinity of Pueblo Canyon (see Figure 2-10).

East of the Rendija Canyon Fault, the top of the regional aquifer is within the Totavi Lentil of the Puye Formation (Figure 4-11). Contaminants have been detected in the regional aquifer, particularly nitrate in TW-1 and strontium-90 in TW-4, indicating that the pathways for contaminant migration may be active at several locations along the canyon. The understanding of pathways of contaminant migration to the intermediate perched zone and the regional aquifer is critical for long-term monitoring and corrective action.

Intermediate Perched Zone and Regional Aquifer Groundwater Investigations

One intermediate perched zone well and four regional aquifer wells are proposed for completion in Pueblo Canyon. These wells will provide information on migration pathways to the regional aquifer, the distribution of contaminants within the upper portion of the regional aquifer, and data for assessments of mesa-top ER Project sites. The intermediate perched zone well is designated I-1 and the regional aquifer wells are designated, from west to east, R-2, R-3, R-4, and R-5 (see Figure 4-2 and Appendix 6, Plate 2). Section 4.1.4 discusses chemical data that will be collected to determine if two saturated zones are interconnected.

Well I-1 is located above the confluence with Los Alamos Canyon, between supply well O-1 and test wells TW-1 and TW-1A. It was completed by the ER Project in April, 1996 and is labeled as POI-4. The purposes of this well are to provide additional information regarding the lateral extent of the intermediate perched zone in the Cerros del Rio basalts and to investigate possible contaminant migration pathways through hydraulic connections with overlying alluvial groundwater. Data collected during drilling and subsequent sampling and analyses of groundwater suggests a continuous intermediate perched zone in the basalts extending at least 0.31 mi between TW-1A and POI-4, and the presence of vertical migration pathways. Well TW-1A saturation extends from 188 ft to 212 ft in depth and the groundwater contains elevated nitrate and cesium-137 concentrations. At one time it was believed that these contaminants may have leaked from the alluvium to the intermediate perched zone basalts along the well casing (LANL 1995d). However, annular leakage in TW-1A is now considered unlikely given preliminary water quality data from POI-4 which contains above background levels of nitrate, phosphate, chloride, and other solutes. The presence of these solutes in groundwater from POI-4 shows that most of the water in the intermediate perched zone infiltrated from the alluvium. The groundwater has a distinctive chemical signature similar to that of effluent from the Los Alamos County Sewage Treatment Plant.

Well R-2 will be located near the confluence of Acid Canyon and Pueblo Canyon. The purpose of this well is to investigate the possible presence of contaminants in the regional aquifer, looking particularly for strontium-90. Strontium-90 was detected in TW-4 which is located on the mesa top adjacent to this part of Pueblo Canyon. The location of well R-2 is also downgradient of the Rendija Canyon fault zone which is considered a potential recharge pathway (see Figure 4-13).

Well R-3 will be located in the upper-middle part of Pueblo Canyon, about a mile downgradient of well R-2. The purpose of this well is to investigate the continuity, water quality, and hydraulic characteristics of intermediate perched zone known to exist at TW-2A. Well R-3 is presently located near the anticipated upgradient edge of the intermediate perched zone in TW-2A. It will be the first of the two wells drilled to investigate intermediate perched zone groundwater near TW-2A (the other one is R-4) and its location may be adjusted based on findings in the drilling for well R-2. The location of well R-3 will also provide new stratigraphic information regarding displacement of units due to pre-Bandelier movement in the Rendija Canyon and Guaje Mountain fault zones. R-3 is downgradient of Acid Canyon and may be used to determine impacts of effluent release from the former waste line and radioactive liquid waste treatment plant (former TA-45) on intermediate perched zone and regional aquifer groundwater. R-3 will provide hydrologic and stratigraphic data on the pre-Bandelier geologic units for assessment of the Airport Landfill in OU 1079. Well R-3 may serve as a replacement for TW-2 which was drilled by cable tool in 1949.

Well R-4 will be located downgradient of TW-2, about 0.75 mi upstream of the Los Alamos County Sewage Treatment Plant. Similar to well R-3, the purpose of installing well R-4 is to investigate the continuity, water quality, and hydraulic characteristics of the intermediate perched zone known to exist at TW-2A. Its location may be adjusted based on findings in the drilling for wells R-2 and R-3. Data from the present location will provide information on the downgradient extent of contaminants entering Pueblo Canyon from Acid Canyon. Samples from well R-4 will be used to characterize the water quality upgradient of the Los Alamos County Sewage Treatment Plant. Data collected during the installation of well R-4 will supply stratigraphy and hydrologic properties to be used in the assessment of the Airport Landfill for OU 1079.

Well R-5 will be located between POI-4 and the Los Alamos County Sewage Treatment Plant. The purposes of this well are to further define the western limit of the intermediate perched zone and provide information about hydraulic head, flow direction, and saturated thickness of this zone. This well will also provide information about deeper perched zones. This location is between water supply well O-1 and upgradient sources in Pueblo Canyon. Also, well R-5 will be used to evaluate a potential recharge mound in the regional aquifer associated with infiltration of alluvial groundwater. Such a recharge mound is suggested by anomalously high water level readings at TW-1. Well R-5 may also be used as a replacement well for eastern boundary test well TW-1 which was installed in 1950.

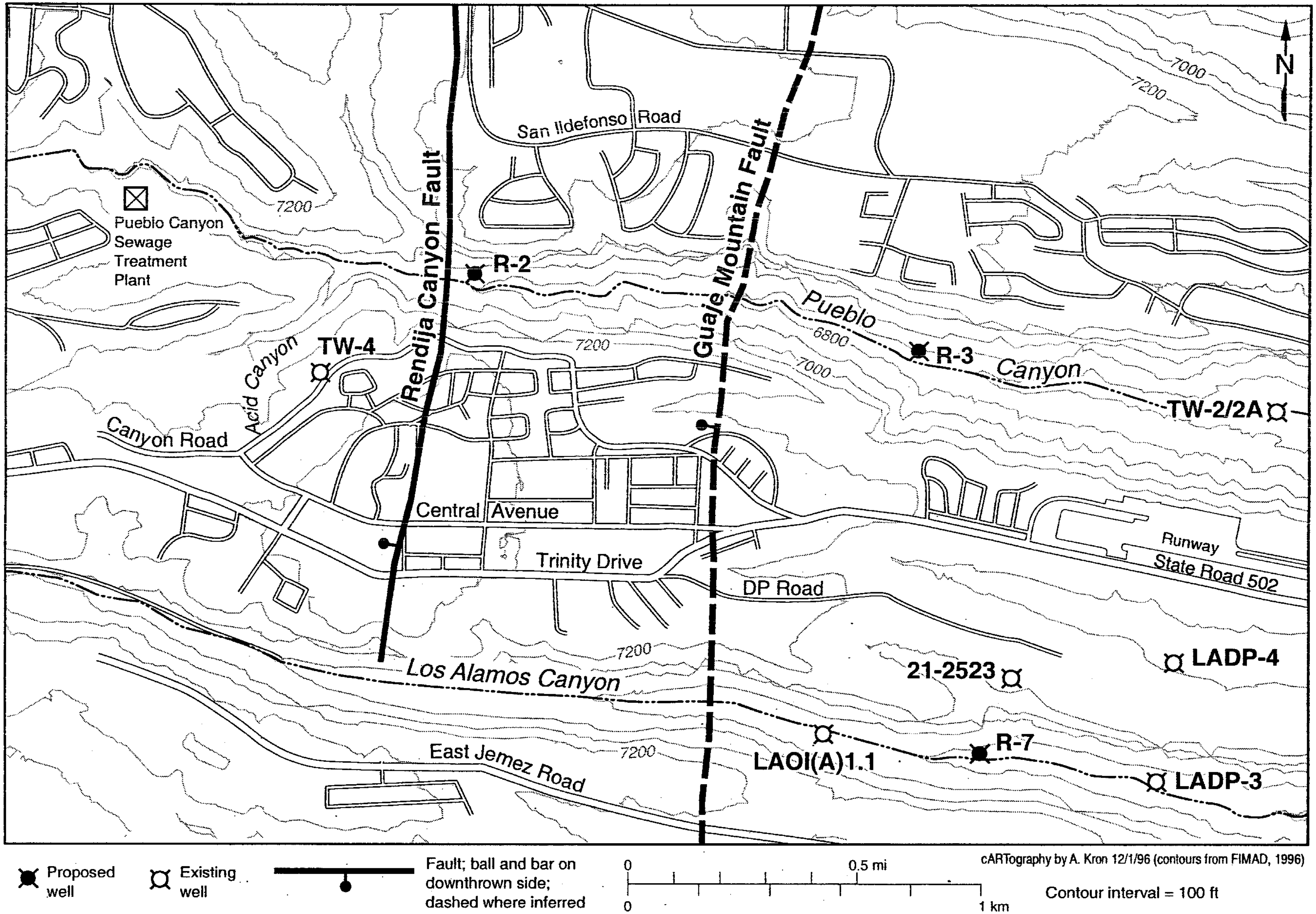


Figure 4-13. Map for part of Aggregate 1 showing location of proposed wells relative to the Rendija Canyon and Guaje Mountain faults.

4.3.1.3 Los Alamos Canyon

Surface Water

Surface water occurs in Los Alamos canyon as perennial flow in the upper reaches west of the Los Alamos Reservoir located west of DOE property, and in the lower reaches east of the confluence with Pueblo Canyon (Figure 4-14 and 4-12). Typically, the overflow of water from the reservoir during spring snowmelt results in nearly continuous surface water flow between the western Laboratory boundary and the vicinity of TA-2 for several weeks to several months each year (LANL 1995d). For most of the year, the only surface flow in Los Alamos Canyon is in lower Los Alamos Canyon due to discharge from the Los Alamos County Sewage Treatment Plant and discharge from Basalt and Los Alamos Springs east of the Laboratory boundary (LANL 1995d).

Surface water in Los Alamos Canyon rarely flows across the length of the Laboratory. Most often surface waters are depleted by infiltration into canyon alluvium creating saturated zones of seasonally-variable extent (LANL 1995d).

Surface flow in DP Canyon, a tributary to Los Alamos Canyon is generated by rainfall and snowmelt events. DP Spring, located in DP Canyon, discharges continuously except for a dry period during the winter-spring of 1996.

Alluvial Groundwater

Two saturated zones are known to occur in the alluvium of Los Alamos Canyon. The first is in the upper part of Los Alamos Canyon and extends eastward from the Los Alamos Reservoir to the vicinity of observation well LAO-4.5 west of State Road 4. The second is in the lower part of Los Alamos Canyon and extends from Basalt Spring to the Rio Grande.

Alluvial groundwater in lower Los Alamos Canyon near Basalt and Los Alamos Springs is chemically similar to surface water flow supported by these springs. The chemistry of the water discharging from Basalt Spring is similar to effluent from the Los Alamos County Sewage Treatment Plant (LANL 1995d). The chemistry of water discharging from Los Alamos Spring may represent an isolated perched system as is does not contain characteristic ions indicative of sewage effluent.

Alluvial groundwater in lower Los Alamos Canyon, from the confluence of Guaje Canyon and Los Alamos Canyon to the Rio Grande, shows chemical similarity to both regional aquifer water and surface water from the Rio Grande.

In middle and upper Los Alamos Canyon, the saturated thickness in the alluvium varies seasonally from a few feet in the winter months to 25 ft in the spring and summer months when recharge is the greatest (EPG 1994). Laboratory environmental surveillance and ER Project data, including water quality analyses from several alluvial wells in Los Alamos Canyon, suggest the presence of multiple contaminant plumes containing tritium and/or strontium-90. As shown in Figure 4-15, the alluvial groundwater may provide recharge to intermediate perched zones by infiltrating along preferential pathways such as faults or permeable bedrock units. The possibility of infiltration, infiltration rates, and the quality of the infiltrating water, are important unknowns that must be addressed in order to predict movement of contaminants in this canyon.

Alluvial groundwater has been found in DP Canyon at wells LAUZ-1 and LAUZ-2 installed for the ER investigation at TA-21. Strontium-90 and some organic compounds have been detected at LAUZ-1 (Davis et al. 1996).

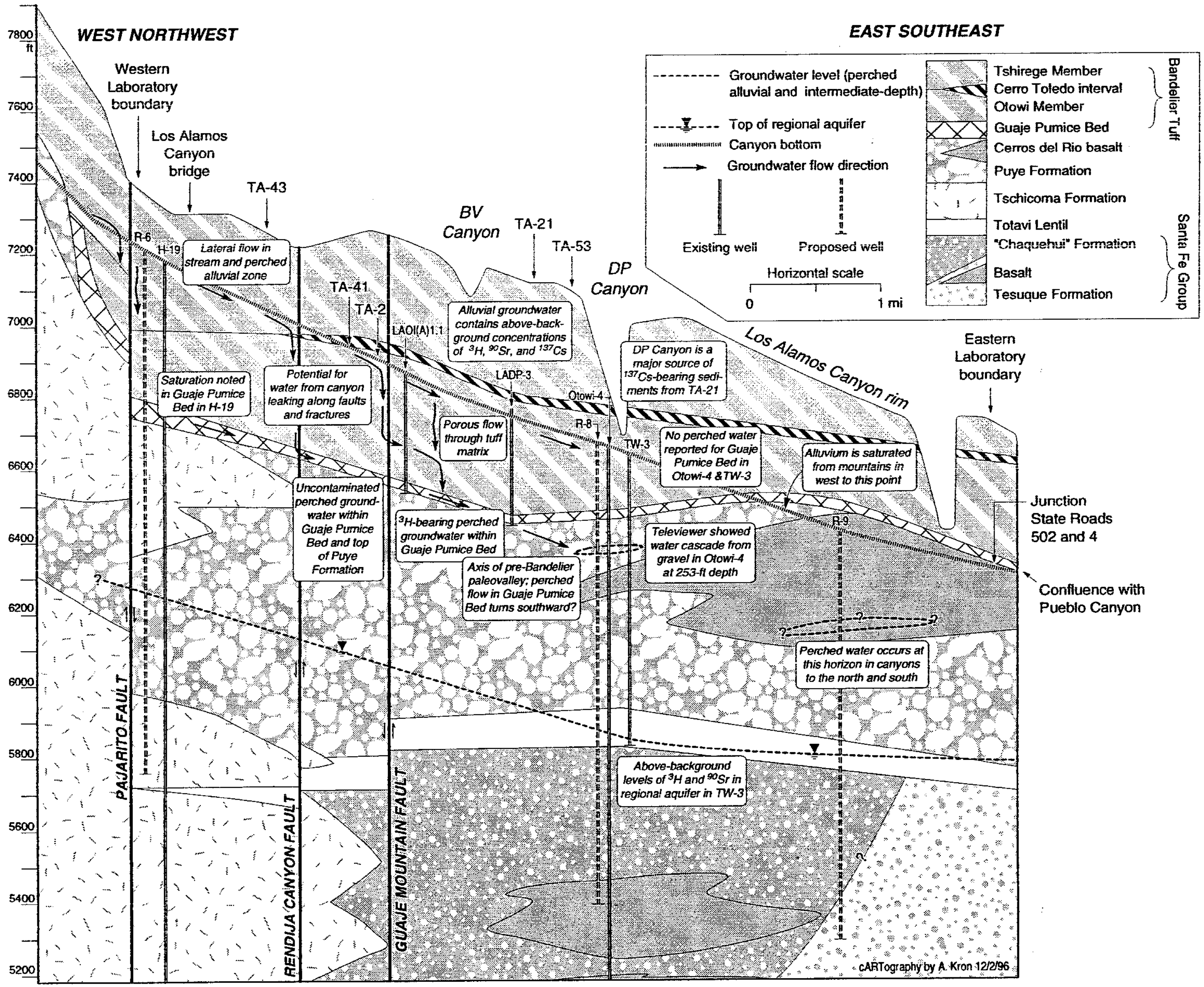
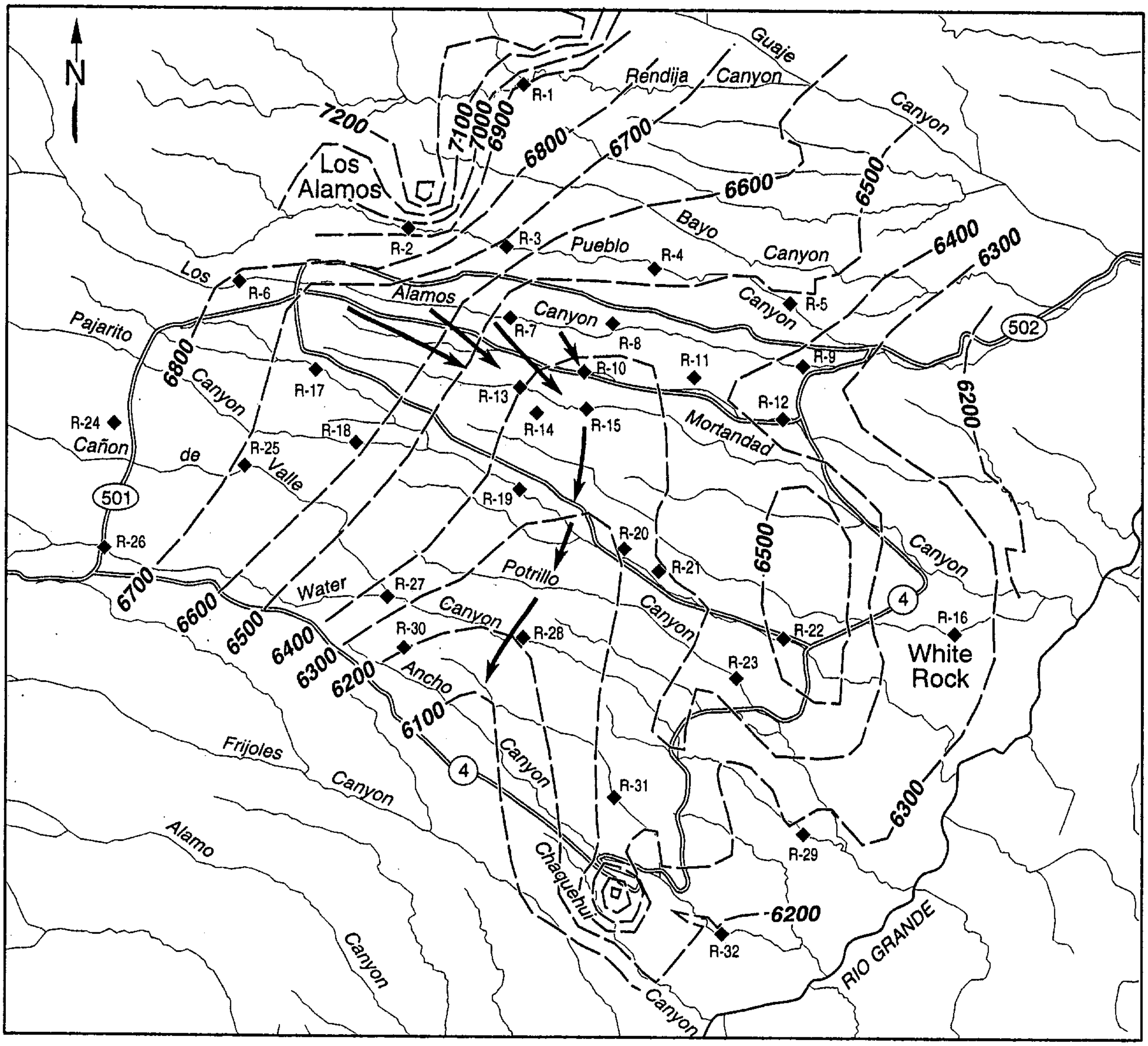


Figure 4-14. Schematic cross section showing conceptual model and proposed regional aquifer wells for upper Los Alamos Canyon.



Major drainage channel

Major paved road

Proposed regional aquifer well

6300 Structure contour (100-ft interval) at base of Bandelier Tuff

Inferred direction of flow for groundwater perched in the Guaje Pumice Bed

0 1 2 3 4 5 km

Source: Broxton and Reneau, 1996
Modified by: cARTography by A. Kron 12/2/96

Figure 4-15. Structure contour map for base of Bandelier Tuff showing inferred direction of perched groundwater flow in Guaje Pumice Bed from Los Alamos Canyon recharge area. Other potential groundwater flow paths in the Guaje Pumice Bed associated with major canyon systems are not shown.

Alluvial Groundwater Investigations

This hydrogeologic Workplan identifies six individual alluvial wells and two alluvial well transects in Los Alamos Canyon. These wells and transects were first proposed as part of the Task/Site Work Plan for OU-1049: Los Alamos Canyon and Pueblo Canyon (LANL 1995d) and most have been completed as part of ongoing ER investigations that were concurrent with the preparation of this document. From west to east, the individual alluvial wells are A-14, A-15, A-19, A-23, A-24, and A-25 and the transects are A-16, A-17, and A-18, and A-20, A-21, and A-22. There is also one well in Guaje Canyon, A-1 (see Figure 4-1).

Well A-14, located just upgradient of the confluence with DP Canyon, was completed and designated as Well LAO 1.6g by the ER Project in March, 1996. This well, paired with existing alluvial wells LAO-2 (DP Canyon) and LAO-3 (downgradient of the confluence with DP Canyon), is being used to identify and estimate contaminant migration into Los Alamos Canyon from DP Canyon, which historically received discharges of radioactive effluent from the north side of TA-21 (LANL 1995d).

Well A-15, located in Los Alamos Canyon east of the confluence with DP Canyon between existing alluvial wells LAO-3 and LAO-4, is designated as Well LAO-3.5 in the Task/Site Work Plan for OU-1049 (LANL 1995d). It has not yet been completed. The purposes of this well are to determine if alluvium is in contact with the Guaje Pumice Bed, if water is present in the Guaje Pumice Bed and, if present, what the chemical quality of that water is. Existing data show significant dilution of solutes in the alluvial groundwater between Wells LAO-3 and LAO -4, suggesting that alluvial groundwater may be mixing with underlying groundwater before reaching Well LAO-4. Previous investigations show groundwater present in the Guaje Pumice Bed at Well LAOI(A)-1.1 (Longmire et al. 1996). Completion of well LAO-3.5 in the Guaje Pumice Bed will help to resolve the hydrogeologic uncertainty in this area of the canyon.

Wells A-19, A-23, A-24, and A-25 are located in lower Los Alamos Canyon on San Ildefonso Pueblo land. Three of these wells (A-19, A-23, and A-25) were completed by the ER Project in the summer of 1996 (LLAO-1, LLAO-2, and LLAO-5). The purpose of these wells is to characterize the quality of the alluvial groundwater in this part of the canyon below Aggregate 1 sources. Outside of the Laboratory boundary, return flow from the alluvium, and perhaps from deeper perched zones, provides drinking water for wildlife and livestock (LANL 1995d). The location of these wells also provides additional monitoring capabilities between the Laboratory boundary and the Rio Grande where the vertical separation between the saturated alluvium and the regional aquifer decreases and eventually merges near the Rio Grande. The fourth well (A-24) has not yet been installed. It will be located downgradient of the confluence with Guaje Canyon and will be used to identify the mixing zone between alluvial groundwater and the regional aquifer.

Well A-1 has also not yet been installed. It will be located in lower Guaje Canyon and used to estimate both the amount and the quality of water being contributed to lower Los Alamos Canyon by Guaje Canyon.

Two piezometer transects are proposed for Los Alamos Canyon, one between the confluence with DP Canyon and the eastern LANL boundary (A-16, A-17, and A-18), and one between Basalt Spring and the confluence with Bayo Canyon (A-20, A-21, and A-22). The purpose of the transects is to identify zones of water loss due to seepage. This information is necessary to more accurately estimate the location and quantity of infiltration vertically from the alluvium that might be occurring. The first transect is located near the eastern limit of alluvial groundwater in upper Los Alamos Canyon. This area may represent an area of high infiltration because of changes in bedrock geology from tuff to interbedded Puye Formation and basalts down canyon. The transect will be arrayed longitudinally along the axis of the canyon across the contact between the tuff and underlying fanglomerates and basalts. The second piezometer transect will be arrayed longitudinally along lower Los Alamos Canyon across the contact between the Puye

Formation and the Santa Fe Group. Water-level measurements will be made at each piezometer location to identify changes in vertical gradients that indicate possible infiltration zones.

DP Canyon is being investigated as part of the ER Project efforts in TA-21. The sampling and analysis plan for this investigation is in preparation. Part of this effort will include a tracer test to determine if this water is the source of DP Spring.

Intermediate Perched Zones and Regional Aquifer

Two intermediate perched zones, one beneath the other, have been encountered in Los Alamos Canyon between TA-2 and the confluence with DP Canyon (Figure 4-13). The upper intermediate perched zone occurs within the Guaje Pumice Bed. This zone was encountered in boreholes LADP-3 (at 325 ft) and LAOI(A)-1.1 (at 295 ft) (Broxton et al. 1995b; Longmire et al. 1996). This same zone may have been penetrated by test hole H-19, west of the Los Alamos Canyon Bridge (Griggs 1964). The saturated thickness of this zone decreases from west to east, ranging from 22-ft at LAOI(A)-1.1 to 5-ft at LADP-3.

A deeper intermediate perched zone was encountered in LAOI(A)-1.1 in the Puye Formation at about 317 ft. Possibly the same zone was also observed at a depth of 253 ft in the Puye Formation on televiewer logs taken during development of water supply well O-4 (Purtymun and Stoker 1988). However, no intermediate perched zone was found at LADP-3 in the approximately 19 ft of the Puye Formation that was penetrated. Another hole was drilled from the mesa top at MDA V in TA-21 which is approximately midway between LAOI(A)-1.1 and LADP-3 to investigate the lateral extent of the Guaje Pumice intermediate perched zone under DP Mesa. The MDA V Deep Hole (Borehole 21-2523) did not find saturated conditions in the Guaje Pumice Bed at this location, indicating that this intermediate perched zone does not extend northward under DP Mesa. The infiltration pathways, continuity, and chemical quality of groundwater in these known intermediate perched zones is not well characterized. Also, it is not known if deeper perched zones exist above the regional aquifer. These unknowns need to be addressed in order to predict migration of contaminants and vertical recharge pathways to the regional aquifer.

Depth to the regional aquifer is known in several locations in Los Alamos Canyon; at TW-3 and O-4, at O-1 near the confluence with Pueblo Canyon, and at LA-5 and LA-1B in the lower reach. Water level measurements taken in December 1993 show depths to water to be 778 ft at TW-3, 704 ft at O-1, and -9 ft (artesian) at LA-1B ft (EPG 1996). Based on Laboratory water-level maps, the general direction of groundwater flow in the regional aquifer is east in the vicinity of Los Alamos Canyon (see Figure 2-10).

Intermediate Perched Zone and Regional Aquifer Groundwater Investigations

Four regional aquifer wells are proposed in Los Alamos Canyon for investigating the occurrence and quality of intermediate perched zone groundwater, for identifying possible infiltration pathways connecting shallow, intermediate, and deep saturated zones, to provide geologic and hydrologic information for the pre-Bandelier stratigraphic units for both canyon and mesa site investigations, and for providing long term monitoring of the regional aquifer. From west to east, these regional wells are R-6, R-7, R-8, and R-9 (see Figure 4-2).

Well R-6 will be located in upper Los Alamos Canyon, about 0.25 mile west of the Los Alamos Canyon Bridge, near existing alluvial well LAO-C. The purposes of this well are to provide background water quality information on intermediate perched zones and the regional aquifer, and to provide stratigraphic control in this area. This well location is upgradient of any known contaminant sources and the chemical and stratigraphic information obtained will be important in determining the impact of Aggregate 1 sources on the quality of groundwater beneath and downgradient of the sources. During the drilling of well R-6, the borehole will be fully cored to provide a reference for stratigraphy and hydrologic boundary conditions for the western portion of the Laboratory, including depth of the regional aquifer and the effect of the Pajarito Fault zone on hydrologic conditions. Hydrologic and geologic properties from well R-6 will also be used in ER Project assessments for mesa-top sites at TA-21.

Well R-7 will be located in the middle part of Los Alamos Canyon, between wells LAOI(A)-1.1 and LADP-3, about 2.5 mi upgradient of the confluence with DP Canyon. The purposes of this well are to identify possible infiltration pathways connecting overlying alluvial groundwater with known intermediate perched zones, and to identify additional intermediate perched zones which may exist between that already identified in the Puye Formation and the regional aquifer. The detection of high levels of tritium in intermediate perched zone groundwater in well LADP-3 (6000 pCi/L) suggests a hydraulic connection with overlying saturated alluvium. It is thought that the original tritium source is from TA-2 (cooling water leakage from a reactor) and that tritium-contaminated alluvial groundwater below TA-2 is providing recharge to the intermediate perched zone (Broxton et al. 1995b; Longmire et al. 1996). The occurrence of tritium in well LADP-3 raises questions about the possible recharge pathways from the alluvium to the intermediate perched zone. However, intermediate depth well LAOI(A)-1.1, which is between the source and the point of detection 0.7 mi downgradient, contains no significant tritium levels (i.e., above the background level of 60 to 350 pCi/L). It is possible that recharge pathways in this part of Los Alamos Canyon have both lateral and vertical components and that recharge rates are relatively rapid, reaching depths of at least 300 ft. Further, tritium concentrations in LADP-3 are decreasing with time, suggesting that the contaminant plume is migrating away from this area. Hydrologic and geologic properties from well R-7 will also be used in ER Project assessments for mesa-top sites at TA-21, TA-53 and the Airport Landfill in TA-73.

Well R-8 will also be located in the middle part of Los Alamos Canyon, near the confluence with DP Canyon, and near water supply well O-4. The purposes of this well are to monitor for contaminants in the regional aquifer in the vicinity of well O-4, to verify possible intermediate perched zones encountered in O-4 at 253 ft, and to identify any additional perched zones above the regional aquifer. The location of well R-8 between potential release sites at TA-21 and O-4 provides early detection monitoring of contaminants before they reach the water supply well.

Well R-9 will be located in lower Los Alamos Canyon, near the eastern boundary of the Laboratory and the confluence with Pueblo Canyon. The purpose of this well is to help define the down-canyon extent and flow directions of known intermediate perched zones. As previously described, the alluvium in a portion of Los Alamos Canyon from LAO-5 to west of the proposed R-9 location is not saturated. This suggests that water in the alluvium may be infiltrating and recharging intermediate perched zones or the regional aquifer. Predictive modeling and hydrogeologic data suggest that tritium and strontium-90 released from TA-21 may be in an intermediate perched zone in the vicinity of well R-9 (LANL 1995d). The surface casing of well R-9 has been set and the borehole is scheduled for completion by the ER Program in FY98.

4.3.1.4 Sandia Canyon

Surface Water

Surface water occurs in Sandia Canyon as ephemeral runoff from precipitation and as effluent discharge from the Laboratory sanitary wastewater sewage treatment plant. Significant snowmelt runoff does not occur within Sandia Canyon. Seepage loss occurs in the upper part of the canyon, and surface water rarely extends east of the TA-72 firing range (LANL 1993f).

Alluvial Groundwater

Little is known about the occurrence of alluvial groundwater in Sandia Canyon. Most likely, infiltration of surface water creates a saturated zone of seasonally-variable extent within the alluvium in the upper reach of the canyon. However, the extent and thickness of alluvial groundwater has not been characterized.

Two alluvial wells were installed in 1990 as part of the HSWA permit special conditions near the eastern boundary to investigate for alluvial groundwater. Both wells, SCO-1 and SCO-2 were dry at the time of installation (Purtymun and Stoker 1990). Periodic attempts to sample these wells as part of the Laboratory's annual environmental surveillance activities have failed due to lack of water in the wells (LANL 1995c).

Alluvial Groundwater Investigations

One piezometer transect (A-26, A-27, and A-28) is proposed for the upper part of Sandia Canyon below the TA-53 Los Alamos Neutron Science Center (LANSCE) (see Figure 4-1). This longitudinal transect will be located near the anticipated eastern limit of saturation in the alluvium perpendicular to the canyon axis. The purposes of this transect are to determine the width and thickness of saturation, and to characterize groundwater quality. This information will help define the width of possible infiltration pathways, calculate seepage losses, and assess transport of contaminants adsorbed to sediments within the alluvium.

Intermediate Perched Zones and Regional Aquifer

An intermediate perched zone has been identified in lower Sandia Canyon at a depth of approximately 450 ft within a thick section of the Cerros del Rio basalts. This intermediate perched zone, which was noted during drilling for water supply well PM-1, occurs at the same stratigraphic interval as perched water encountered in TW-1A and POI-4 in lower Pueblo Canyon. No water quality information is available for this perched zone. No information is available regarding the occurrence of intermediate perched zones beneath upper Sandia Canyon.

An intermediate perched zone is present within the Guaje Pumice Bed beneath much of upper Los Alamos Canyon to the north (see description above). This perched zone appears to be largely confined to the area beneath Los Alamos Canyon west of TA-21 (the Guaje Pumice Bed was not saturated in boreholes 21-2523 and LADP-4 north of Los Alamos Canyon), but structure contour maps (Broxton and Reneau 1996; Davis et al. 1996) suggest that the gradient of the perching layer changes direction in the vicinity of proposed well R-7, and that the perched groundwater in this zone may be moving southward down the axis of a large pre-Bandelier paleo drainage basin (see Figure 4-15).

Depth to the regional aquifer is known in Sandia Canyon in two locations; at supply well PM-3 and PM-1 near the eastern Laboratory boundary. Water level measurements taken in December 1993 show depths to water to be 771 ft at PM-3, and 756 ft at PM-1 (EPG 1996). Based on Laboratory water-level maps, the general direction of groundwater flow in the regional aquifer is east to southeast in the vicinity of Sandia Canyon (see Figure 2-10).

Intermediate Perched Zone and Regional Aquifer Groundwater Investigations

Three regional wells are identified in this Workplan for installation in Sandia Canyon. From west to east, the wells are R-10, R-11, and R-12 (see Figure 4-2).

Well R-10 will be located in upper Sandia Canyon about halfway between the west and east Laboratory boundaries. The purposes of this well are to investigate the possible presence of intermediate perched zone groundwater and to monitor water quality in the regional aquifer. The location of well R-10 was chosen to intersect the axis of the pre-Bandelier paleo drainage basin thought to occur here. The location of well R-10 will be refined, if necessary, using information from the drilling for well R-15 in Mortandad Canyon which is scheduled to be drilled earlier. Locating the suspected paleo drainage basin, and characterization of any saturated zones in the basin, will provide information regarding any lateral flowpaths and continuity of intermediate perched zones between Los Alamos and Sandia Canyons. Data from well R-10 will also provide information regarding water quality in the regional aquifer and help define groundwater flow directions in the central part of the Laboratory. Well R-10 will provide geologic and hydrologic data for TA-53 mesa-top ER Project assessments.

Well R-11 will be located in middle Sandia Canyon about 500 ft upgradient of water supply well PM-3. The purpose of this well will be to provide early detection of contaminants that may have reached the upper portion of the regional aquifer before they reach the water supply well. Data collected from this location will also provide information about local flow directions and water levels near PM-3, which appear to be anomalously high (EPG 1996).

Well R-12 will be located in middle Sandia Canyon near the eastern Laboratory boundary about 800 ft upgradient of water supply well PM-1. The purposes of this well are to investigate the possible occurrence of intermediate perched zone groundwater and to provide information on local water levels and flow directions in the regional aquifer. Well R-12 will be completely cored to provide a reference for stratigraphy for the eastern portion of the Laboratory. Chemical data from water samples will be compared with similar data from POI-4 and TW-1A to determine if these perched zones are interconnected. The location of well R-12 is downgradient of Aggregate 1 sources including effluent releases from TA-3,

TA-53, TA-60 and TA-61 directly into Sandia Canyon. This location will provide early detection capabilities for possible regional aquifer contaminants before they reach supply well PM-1. The surface casing of well R-12 has been set and the borehole is scheduled for completion by the ER program in FY98. A more detailed analysis of the placement of R-12 (ER borehole SCOI-3) in Sandia Canyon is included in the ER Work Plan for Los Alamos and Pueblo Canyons (LANL 1995d).

4.3.2 Aggregate 2

Table 4-4 lists the alluvial and regional aquifer wells proposed for installation in Aggregate 2. The rationale for these wells and the uncertainties they address are described below. Additional information about the rationale for the regional aquifer wells is given in Table 4-1. Figures 4-1 and 4-2 show the general proposed well locations. Appendix 6 provides large-scale maps with proposed well location plotted along with existing wells for reference.

Table 4-4. Summary of Potential Wells in Aggregate 2

Canyon or Mesa	*Alluvial Wells/Piezometer Transects (all ER)*[1]	*Regional Aquifer Wells*
Mesita del Buey		R-21 (ER)
Cañada del Buey		R-16 (NWT)[2]
Pajarito Canyon	A-30	R-17 (ER)
	A-31	R-18 (NWT)
	A-32	R-19 (ER)
	A-33	R-20 (NWT)
	A-34	R-22 (ER)
	A-35, A-36, A-37	
	A-38	
	A-39	
	A-40	
	A-41	
	A-42	

[1] Funded through Environmental Restoration Project
[2] Funded through Nuclear Weapons Technology Program

4.3.2.1 Area Description and History

Aggregate 2 is located in the east-central portion of the Laboratory (see Figure 1-3). It is bounded on the north by Cañada del Buey, on the south by Pajarito Canyon, on the west by the TAs-18 and -51, and on the east by the Laboratory boundary (Figure 4-16 and 4-17). The boundaries of Aggregate 2 were drawn to encompass the potential release sites associated with TA-54.

Aggregate 2 includes Cañada del Buey and the middle reach of Pajarito Canyon, and Mesita del Buey. One active technical area, TA-54, is included within the boundary of Aggregate 2.

TA-54, located on Mesita del Buey, contains four material disposal areas (MDAs) and supporting offices. The MDAs are situated on the mesa top, from west to east, in the following order: MDA H, MDA J, MDA L, and MDA G. The ER Project is presently investigating Mesita del Buey and Cañada del Buey as part of Operable Unit 1148 and Pajarito Canyon as part of Operable Unit 1092. Also, the MDAs are the subject of ongoing contaminant transport modeling for a Performance Assessment under DOE Order 5820.2A.

MDA H is designated as a permanent disposal facility for the Laboratory. It consists of nine shafts in which uncontaminated classified material and some radioactive material was deposited from 1960 until 1986. The facility is currently inactive (LANL 1992e).

MDA J is an active disposal facility and has been in use since 1961. Wastes disposed of at MDA J consist of administratively controlled waste and nonfriable asbestos (LANL 1992e). Land farming of petroleum-contaminated soil had been conducted at MDA J periodically in the past from 1991 to 1994 (LANL 1994c).

MDA L is an inactive chemical waste disposal facility in which chemical waste was deposited in pits, impoundments, and shafts from the late 1950s until 1985. Active chemical and mixed waste handling and storage units are now present on the surface. MDA L is permitted for hazardous waste storage and the Laboratory intends to reserve the space for this purpose indefinitely (LANL 1992e).

MDA G is an active disposal facility and has been in use since 1957. It has been the main low-level radioactive waste disposal facility for the Laboratory since 1960, and is the Laboratory's only currently active low-level radioactive waste disposal facility. MDA G is also used for the storage of low-level and transuranic (TRU) mixed waste, which is being nondestructively tested at a TA-54 facility (LANL 1992e).

Pajarito Canyon south of TA-54 contains a number of potential release sites. These include sewage lines (18-001b), sewage lagoons (18-001(a)), firing pits (27-002), and bazooka impact sites (27-003). Additional potential release sites are located upstream in Pajarito Canyon at TA-18. Cañada del Buey north of TA-54 contains no known potential release sites.

More detailed information about activities and potential release sites at TA-54 can be found in the RCRA Facilities Investigation Work Plan for Operable Unit 1148 (LANL 1992e), and the Solid Waste Management Units Report (LANL 1990).

4.3.2.2 Mesita del Buey

Surface Water

Surface runoff occurs on Mesita del Buey and in small drainages off the mesa for brief periods during spring snowmelt and intense summer thunderstorms (LANL 1992e). Infiltration beneath Mesita del Buey appears to be very low, possibly only 1 mm/yr. Infiltration occurs during snowmelts or intense summer thunderstorms, leading to slightly higher moisture contents within the uppermost few meters of the mesa surface. During dry periods, evapotranspiration removes moisture from the surface of the mesa, while permeable zones such as fractures and surge beds act as conduits for air and aid in the drying of the mesa (Turin and Rosenberg 1996). Net infiltration during these alternating infiltration episodes and normal drying conditions is difficult to quantify.

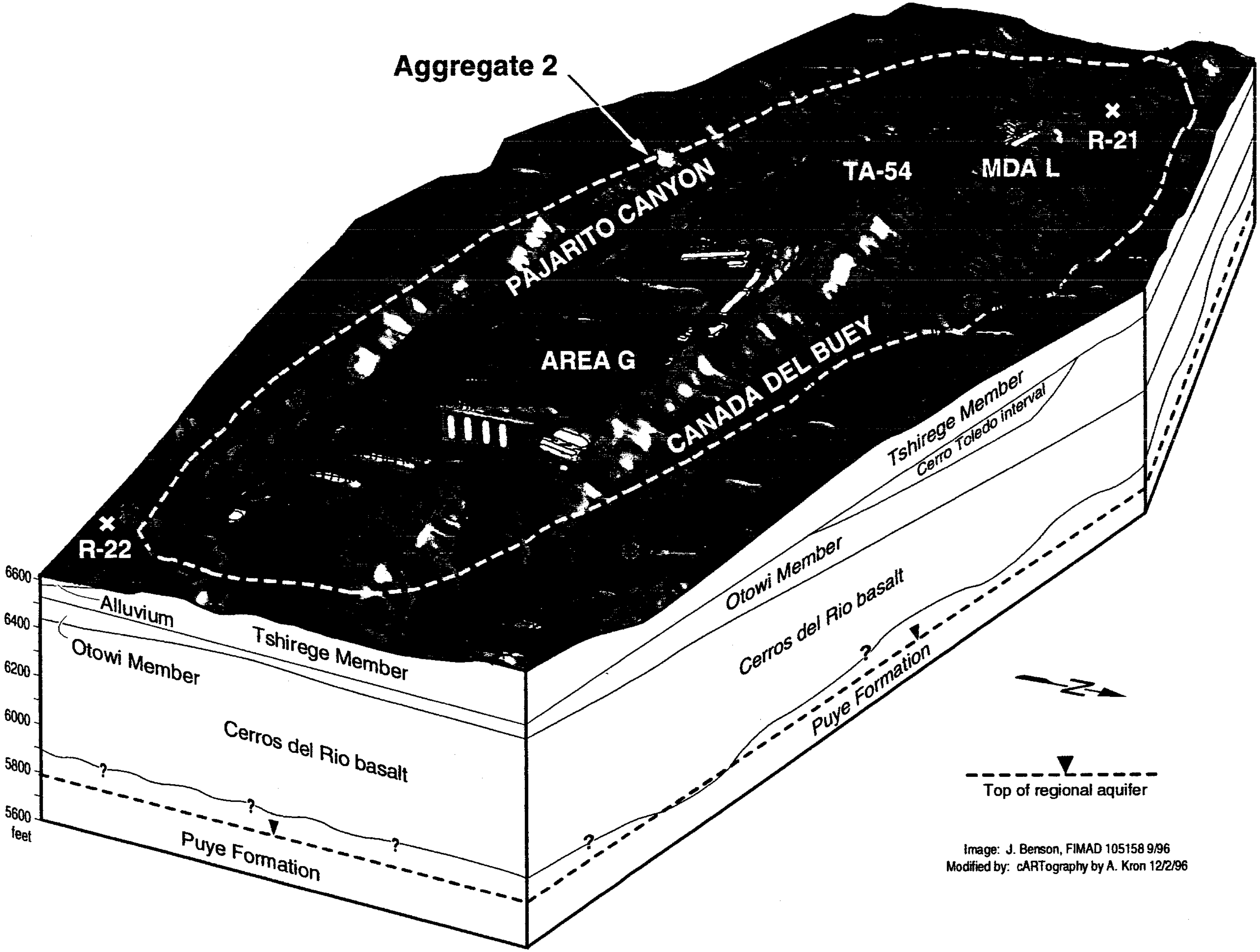


Figure 4-16. Block diagram showing the terrain and bedrock geology for Aggregate 2.

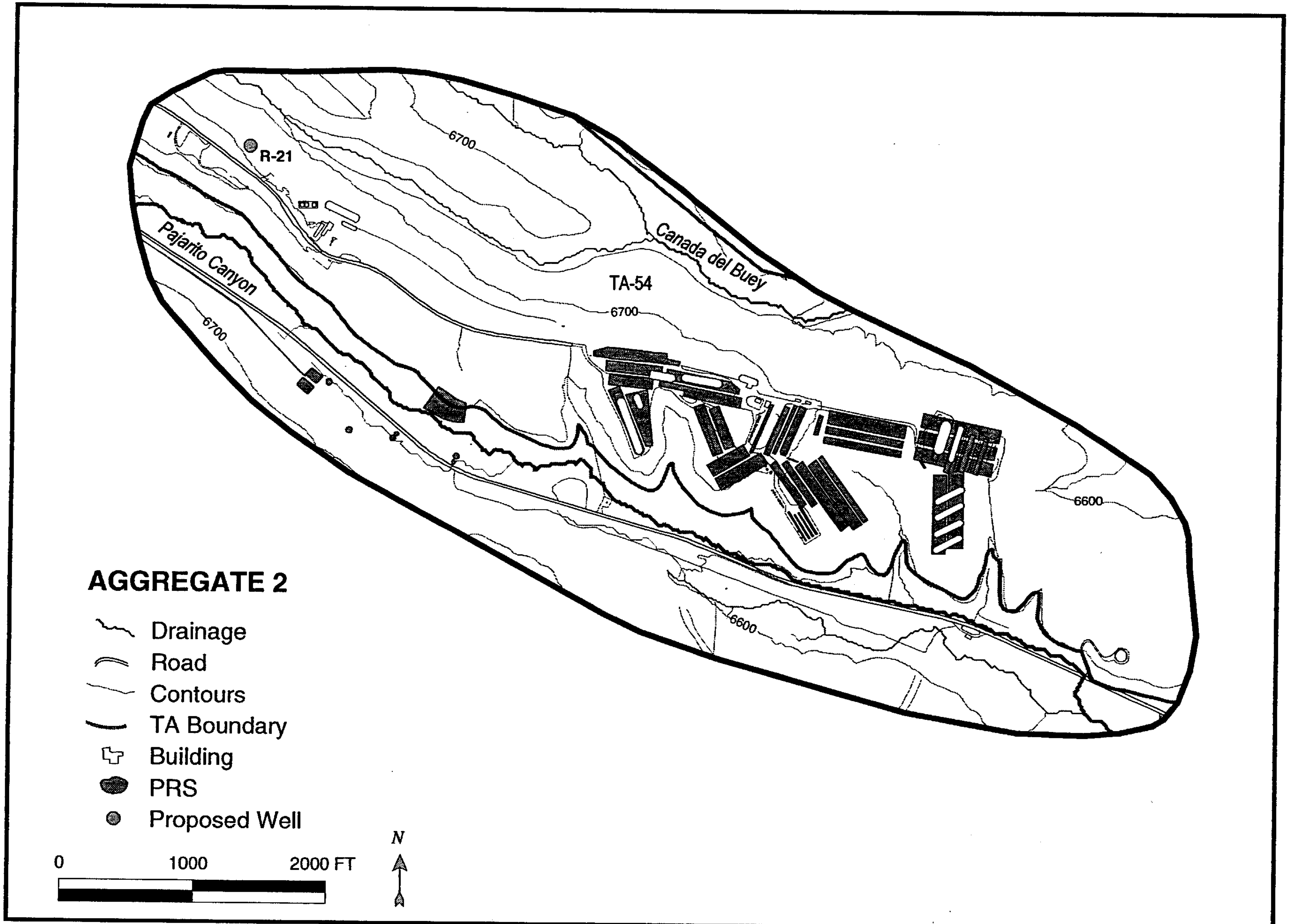


Figure 4-17. PRSs and proposed wells in Aggregate 2.

Alluvial Groundwater

Occurrences of alluvial groundwater to the north and south of Mesita del Buey are discussed in the Cañada del Buey and Pajarito Canyon Conceptual Models.

Alluvial Groundwater Investigations

Several alluvial wells are proposed for installation in Aggregate 2 and are discussed in the section describing Pajarito Canyon.

Intermediate Perched Zones and Regional Aquifer

No perched groundwater has been identified below Mesita del Buey.

On the basis of three test holes drilled in 1985 along the north edge of Pajarito Canyon, and many additional holes drilled into the Bandelier Tuff beneath Mesita del Buey, there is no evidence that the perched aquifer in Pajarito Canyon (described below) extends horizontally beneath Mesita del Buey (Devaurs and Purtymun 1985).

Depth to the regional aquifer is approximately 850 ft below the canyon bottom, as measured in water supply well PM-2. The top of the aquifer at PM-2 is within the Puye Formation (Figure 4-18). Based on Laboratory water-level maps (see Figure 2-10), the general direction of groundwater flow in the regional aquifer is southeast toward the Rio Grande. Projecting this flow direction, there are seven springs along White Rock Canyon that may be considered down gradient from Mesita del Buey. These include Springs 2A, 3, 3A, 3AA, 3B, 4, and 4A. There is no indication of water quality impacts in the regional aquifer in water from supply well PM-2 or the springs in White Rock Canyon (EPG 1996).

Contaminant migration has occurred from disposal facilities at MDA G and MDA L. At MDA G, underground movement of tritium has been documented from solid-waste storage shafts. Available data indicates that tritium is migrating in the vapor phase (Purtymun 1973). A major organic vapor plume has been documented at MDA L. The organic vapors are denser than air and thus have a tendency to spread both downward and laterally at a relatively rapid rate. The principal vapor phase contaminants are 1,1,1-trichloroethane (TCA), trichloroethene (TCE), and carbon tetrachloride. The plume dimensions are not fully known, but ER characterization activities to date have documented a width of approximately 1200 ft. Vertically, the plume apparently has passed through the Bandelier Tuff and into the Cerros del Rio Basalts (depths of approximately 500 ft). A pilot vapor extraction program is underway to control the spread of the organic plume. Because the vertical extent of the plume has not been determined, it is unknown if the plume has impacted the regional aquifer.

Intermediate Perched Zone and Regional Aquifer Groundwater Investigations

One regional aquifer well, R-21, is proposed for installation on Mesita del Buey (see Figure 4-2). Well R-21 will be located on the mesa top near MDA L. The purpose of this well will be to evaluate and monitor hydrologic and geochemical conditions in the regional aquifer beneath MDA L. The ER Project has reported the presence of organic contaminants in the vapor phase, including vapors from halogenated solvents, beneath Area L that have migrated through the tuff and the basalts to a depth of 500 ft. Data from well R-21 will be compared to data from well R-20 to evaluate the migration of the organic contaminants and their potential movement toward supply well PM-2.

4.3.2.3 Cañada del Buey

Surface Water

In Cañada del Buey, located north of Mesita del Buey, ephemeral surface water occurs during snowmelt or thunderstorms (Purtyman and Kennedy 1971; Devaurs and Purtyman 1985).

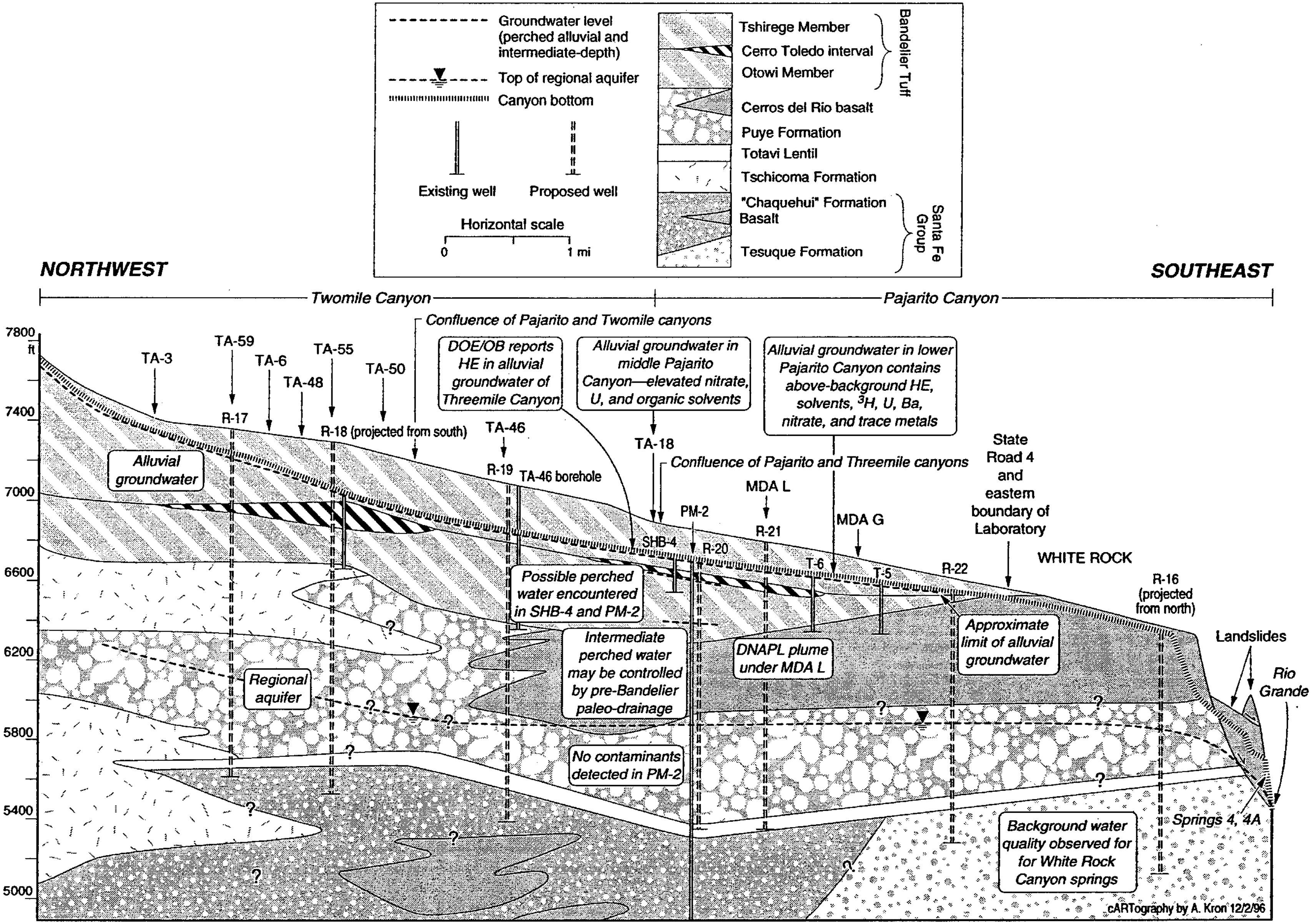


Figure 4-18. Schematic cross section showing conceptual model and proposed regional aquifer wells for Pajarito and Twomile canyons.

Alluvial Groundwater

Groundwater is present in the canyon along an approximate one-half mile reach near wells CDBO-6 and CDBO-7. Saturation has not been observed in other wells in the canyon. This saturation is contained within the weathered tuff and is immediately below the discharge point of municipal supply well PM-4. While the specific source of this water has not been determined, it is thought to be a result of water discharged from well PM-4 during start up of the pump. Well PM-4 began to produce water in 1982. Discharges from PM-4 still occur (under NPDES permit) but infrequently. The most recent discharge occurred on November 10, 1997. The discharge was for 20 minutes at approximately 1350 gallons per minute. Water levels in CDBO-6 since 1992 have ranged from 0 (dry) to 12 feet of saturation. Water levels in CDBO-7 since 1992 have ranged from 0 (dry) to 7 feet of saturation. Well CDBO-6 is sampled quarterly for nitrogen species, chloride, and total dissolved solids, and in the 3rd and 4th quarter for metals and radioactivity.

Two moisture access wells also have been installed to monitor moisture changes in the Tshirege Member of the Bandelier Tuff that underlies the alluvium in the canyon floor. No significant changes in moisture content have been observed in annual measurements since 1992, suggesting that minimal recharge is occurring in this dry canyon (Rogers et al. 1996).

Alluvial Groundwater Investigations

No alluvial wells are planned for Cañada del Buey because adequate coverage already exists. Existing borehole data indicates that this canyon does not contain alluvial groundwater.

Intermediate Perched Zones and Regional Aquifer

No intermediate perched zones are known to occur in this area.

Depth to the regional aquifer is approximately 850 ft below the canyon bottom, as measured in water supply well PM-2. The top of the aquifer at PM-2 is within the Puye Formation (Figure 4-18). Based on Laboratory water-level maps (see Figure 2-10), the general direction of groundwater flow in the regional aquifer is southeast toward the Rio Grande.

Intermediate Perched Zone and Regional Aquifer Groundwater Investigations

One regional well, R-16, is planned for installation in Cañada del Buey east of the aggregate boundary. The purpose of this well will be to provide stratigraphic and hydrologic control off-site near the Rio Grande and to provide an off-site monitoring point downgradient of Laboratory activities.

4.3.2.4 Pajarito Canyon

Surface Water

Pajarito Canyon has continuous stream flow for approximately two-thirds of the year, making Pajarito Canyon one of the wettest at the Laboratory. About 1 mile east of the Laboratory's western boundary, Homestead Spring supports a perennial flow in Pajarito Canyon for at least several hundred yards, followed by an intermittent and/or ephemeral reach that may extend to near the confluence with Threemile Canyon, just west of Aggregate 2. The flow in Pajarito Canyon east of its confluence with Threemile Canyon is ephemeral to the Laboratory's east boundary.

In the western portion of Pajarito Canyon, water occurs as springs on the sides of the mesas at elevations above the alluvium (Purtyman and Kennedy 1971). Many of these springs issue from hillslopes in the Tshirege Member of the Bandelier Tuff with typical discharge rates of 1 to 15 gallons per minute. The recharge source of these springs is likely both the Jemez Mountains and anthropogenic sources such as industrial outfalls. Organic compounds have been detected in the spring water, most likely originating from operations and PRSs associated with TA-8 and TA-9 in Aggregate 5.

Alluvial Groundwater

Infiltration of surface water has created a perched groundwater body in the alluvium of Pajarito Canyon (Figure 4-18). Saturated thickness in the alluvial groundwater is approximately 10 ft (Purtymun 1995). The drilling of seven test holes in 1985 showed that the saturation does not extend laterally under Mesita del Buey near MDAs G and L (Devaurs 1985; Devaurs and Purtymun 1985). Three of the alluvial test holes were completed as groundwater monitoring wells (PCO-1, -2, -3) and are routinely sampled as part of the Laboratory's Environmental Surveillance Program.

Quality of the alluvial groundwater is variable in Pajarito Canyon. Occasional above-background levels of americium-241, barium, nitrate, total dissolved solids, and chloride have been observed (EPG 1996). In addition, a number of trace metals have been detected in well PCO-2 (1994) and PCO-3 (1993). These trace metal concentrations, however, were not above background in the 1995 sampling. The levels of barium suggest the impact of high explosives work in the canyon. In middle Pajarito Canyon, above background concentrations of nitrate, uranium, and 1,2-dichloroethane (1,2-DCA) have been measured (EPG 1996; ICF Kaiser 1996).

Alluvial Groundwater Investigations

Nine individual alluvial wells and one piezometer transect are proposed for the length Pajarito Canyon. One alluvial well is proposed in Threemile Canyon, a major tributary. Some of these alluvial wells will be used to investigate the extent of alluvial groundwater and its quality in the upper part of Pajarito Canyon and its tributaries Twomile Canyon and Threemile Canyon. These wells will also be used to evaluate the impacts of PRSs within Pajarito Canyon and its tributaries. Data from these wells will be used to evaluate the amount of alluvial water that could provide recharge to underlying groundwater as well as the contaminant concentrations that could infiltrate with the alluvial water. From west to east, the individual wells are A-30, A-31, A-32, A-33, A-34, A-38, A-39, A-40, A-41, and A-42 (Threemile Canyon). The transect consists of wells A-35, A-36, and A-37 (see Figure 4-1).

Well A-30 will be located in Pajarito Canyon, near the western boundary of the Laboratory, upgradient of Laboratory activities. The purpose of this well will be to identify the presence of alluvial water and establish background water quality for the canyon. These data will be used to determine the impact of PRSs on alluvial water further down canyon.

Well A-31 will be located within the boundary of Aggregate 5. The purpose of this well will be to identify the possible presence of contaminants in the canyon from high explosives manufacturing and testing which occurred at TA-8, TA-9, and TA-16.

Wells A-32, -33, and -34 are located in Pajarito Canyon above TA-18 and Aggregate 2, and below Aggregate 5. The purpose of these wells is to identify the extent of alluvial saturation and water quality between these two areas. The wells will be used to evaluate the groundwater pathway within the alluvium.

Well 38 will be located below the confluence with Threemile Canyon at TA-18 . The purpose of this well will be to identify the extent of alluvial saturation down canyon.

Wells A-39, A-40, and A-41 will be located within Aggregate 2 south of MDA G. The purpose of these wells will be to provide additional information regarding saturation and possible contamination in this portion of Pajarito Canyon. The extent of alluvial water in Pajarito Canyon has been partially delineated just south of TA-54 by data from wells PCO-1, PCO-2, and PCO-3. The installation of wells A-39, A-40, and A-41 will provide additional information and monitoring capabilities.

One alluvial well transect (A-35, A-36, and A-37) will be located at TA-18 where Threemile Canyon joins Pajarito Canyon. The purpose of this transect will be to define the extent of saturation across the width of the canyon for both water budget analysis and detection of contaminants.

Well A-42 will be located in Threemile Canyon, which is a major tributary to Pajarito Canyon. The purpose of this well will be to identify the presence of alluvial water and possible contamination from Threemile Canyon. The upper part of Threemile Canyon borders Aggregate 6, an area of open detonation and open burning of high explosives. The location of well A-42 will provide a monitoring point for assessment of quantity and quality of water contributed from Threemile Canyon to Pajarito Canyon.

Intermediate Perched Zones and Regional Aquifer

Intermediate perched water is known to exist in lower Pajarito Canyon, but knowledge of its extent and quality is incomplete. Perched water was indicated in two boreholes drilled on the western edge of Aggregate 2. A "show of water at 335 ft" was noted in the Otowi Member of the Bandelier Tuff during the cable-tool drilling of supply well PM-2 (Cooper et al. 1965). In SHB-4, the core tube and core from the top of the Otowi Member from about 125 ft to 145 ft came out of the hole wet (Gardner et al. 1993) (Figure 4-18). Intermediate perched water was not encountered, however, in the drilling of two other test holes located further downstream. Both of these dry test holes penetrated stratigraphic horizons that are likely perching layers. Test Hole 5 was drilled through the Bandelier Tuff and into basalts at a total depth of 263 ft. Test Hole 6 was also drilled through the tuff and into basalts to a total depth of 300 ft (Griggs 1955).

The middle segment of Pajarito Canyon overlies the projected trace of a south-dipping pre-Bandelier paleo-valley. In Los Alamos Canyon, intermediate perched water has been found within this paleo-valley. The presence of this feature may control the flow of intermediate perched water such that it is possible for water to be present in Pajarito Canyon at this location.

Depth to the regional aquifer is approximately 850 ft below the canyon bottom, as measured in water supply well PM-2. The top of the aquifer at PM-2 is within the Puye Formation (Figure 4-18). Based on 1994 water level data (EPG 1996), the general direction of groundwater flow in the regional aquifer is southeast toward the Rio Grande.

Assessing the infiltration from alluvial groundwater to intermediate perched water or to the regional aquifer is essential in determining contaminant transport pathways.

Intermediate Perched Zone and Regional Aquifer Groundwater Investigations

Five regional aquifer wells are proposed in Pajarito Canyon to identify the presence of intermediate perched zones, measure the thickness of the zones, and analyze for the presence of contaminants within those zones that would indicate contaminant transport is actively occurring. From west to east, these wells are R-17 (in Twomile Canyon), R-18, R-19, R-20, and R-22 (see Figure 4-2). Two of these wells (R-20 and R-22) are directly related to Aggregate 2 and the other three wells provide information about sources in aggregates upgradient of Aggregate 2.

Well R-17 will be located in Twomile Canyon, a major tributary of Pajarito Canyon. This borehole will provide information about perched groundwater, depth to the regional aquifer, and water quality information for perched and regional groundwater systems in a poorly characterized part of the Laboratory. It is located down gradient from potential release sites at TAs -3, -6, -58, -59, -62, and -69. R-17 will support the ER assessment of MDA C in Aggregate 7 by providing data on the pre-Bandelier stratigraphy and hydrologic properties of these units.

Well R-18 will be located the furthest up canyon in Pajarito Canyon, downstream from potential releases from Aggregate 5. The purpose of this well will be to investigate for intermediate perched water and to characterize the quality of that water. Water level data from well R-18 will be used to create an accurate water table map for the regional aquifer in the west-central part of the Laboratory, supporting the placement of long-term monitoring wells for Aggregates 5, 6, and 7.

Well R-19 will be located in middle Pajarito Canyon, about halfway between the confluences with Twomile and Threemile Canyons. The purpose of this well will be to provide hydrogeologic control in the central portion of the Laboratory. The location of well R-19 is downgradient of release sites in upper Pajarito Canyon and upgradient of TA-18 activities.

Well R-20 will be located in middle Pajarito Canyon, about 0.25 mi east of supply well PM-2. The purpose of this well will be to provide early detection monitoring of contaminants that may reach the regional aquifer before they reach the water supply well. The location of this well near PM-2 also allows for the investigation of intermediate perched zone groundwater that was noted in PM-2.

Well R-22 will be located about 500 ft west of the eastern Laboratory boundary in Pajarito Canyon. The purpose of this well will be to determine the presence and quality of intermediate perched water downgradient of the TA-54 disposal areas. The location of well R-22 is in a part of the canyon where the alluvium and Bandelier Tuff thins over Cerros del Rio basalts. Occurrences of intermediate perched water have been found in Pueblo Canyon (Aggregate 1) in similar circumstances. Well R-22 will be continuously cored to provide a reference stratigraphy for the east-central portion of the Laboratory. Water chemistry from intermediate and regional groundwater will be compared to the water chemistry of springs in White Rock Canyon to evaluate the potential hydrologic connections between these groundwater bodies. Data for the geologic units below the Bandelier Tuff are needed from well R-22 to support the MDA G Performance Assessment (a Waste Management activity) and ER assessment activities.

4.3.3 Aggregate 3

Table 4-5 lists the alluvial, intermediate, and regional aquifer wells proposed for installation in Aggregate 3. The rationale for these wells and the uncertainties they address are described below. Additional information about the rationale for the regional aquifer wells is given in Table 4-1. Figures 4-1 and 4-2 show the general proposed well locations. Appendix 6 provides large-scale maps with proposed well location plotted along with existing wells for reference.

Table 4-5. Summary of Potential Wells in Aggregate 3

Canyon or Mesa	*Alluvial Wells/Piezometer Transects (all ER)*[1]	*Regional Aquifer Wells*
Frijoles Mesa		R-30 (ER)

[1] Funded through Environmental Restoration Project

4.3.3.1 Area Description and History

Aggregate 3 is located in the south-central portion of the Laboratory (see Figure 1-3). It is bounded on the north by Water Canyon, on the south by State Road 4, on the west by the TA-49 boundary, and on the east by the easternmost extent of activities on Frijoles Mesa, i.e., the small landfill east of Area 10 (SWMU 49-005[a]) (Figure 4-19 and 4-20). The boundaries of Aggregate 3 were established to encompass the potential release sites associated with TA-49.

Aggregate 3 includes only Frijoles Mesa. The hydrogeology of Water Canyon and Ancho Canyon are addressed in the discussions of Aggregates 6 and 4. One active technical area, TA-49, exists within Aggregate 3 boundaries on top of Frijoles Mesa.

TA-49 was used for underground hydronuclear testing in the early 1960s. The testing consisted of criticality, equation of state, and calibration experiments involving special nuclear materials. The testing left large inventories of radioactive and hazardous materials such as isotopes of uranium and plutonium, lead, beryllium, and explosives such as TNT, RDX, HMX, and barium nitrate. Much of this material was disposed of in shafts on the mesa top.

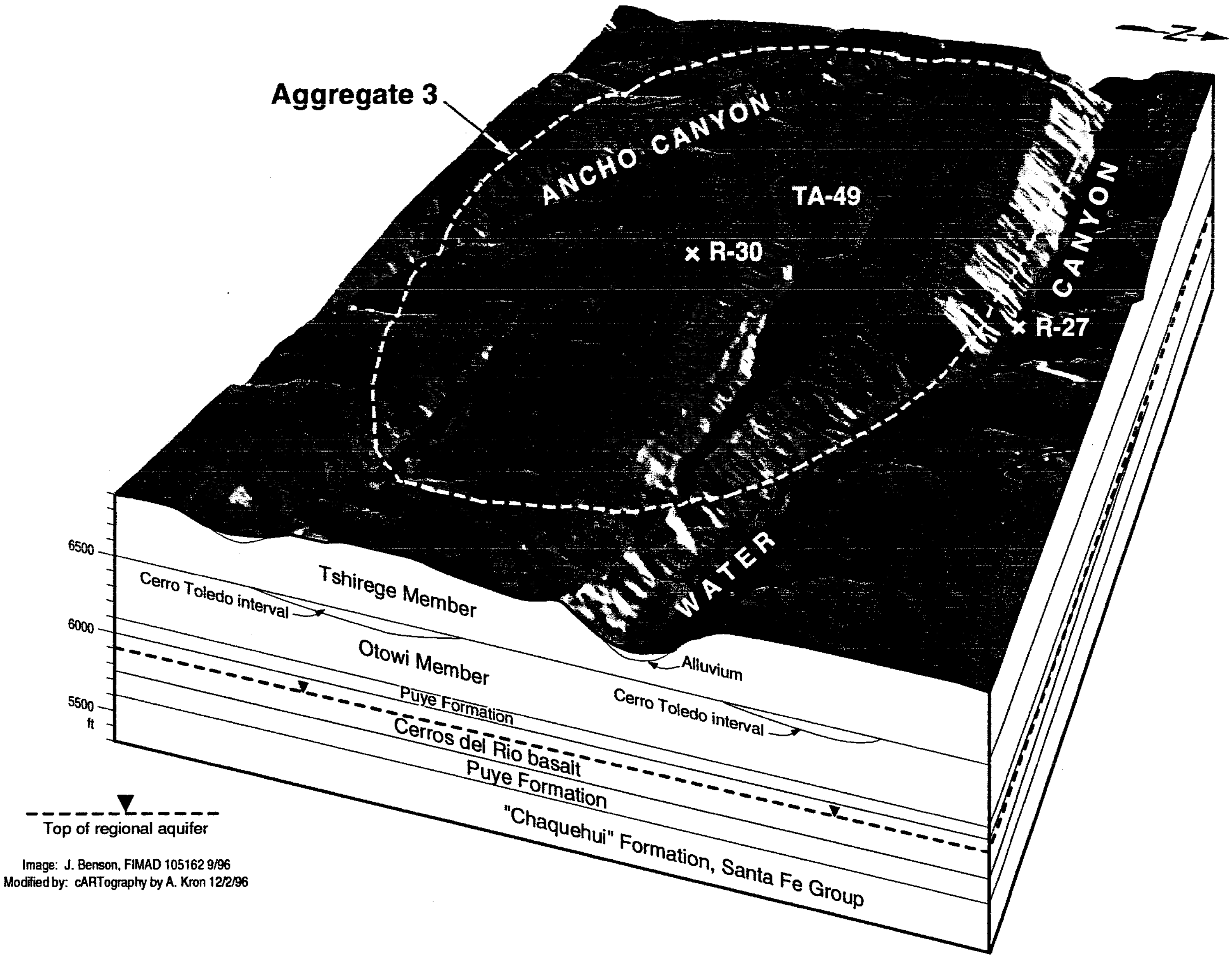


Figure 4-19. Block diagram showing the terrain and bedrock geology for Aggregate 3.

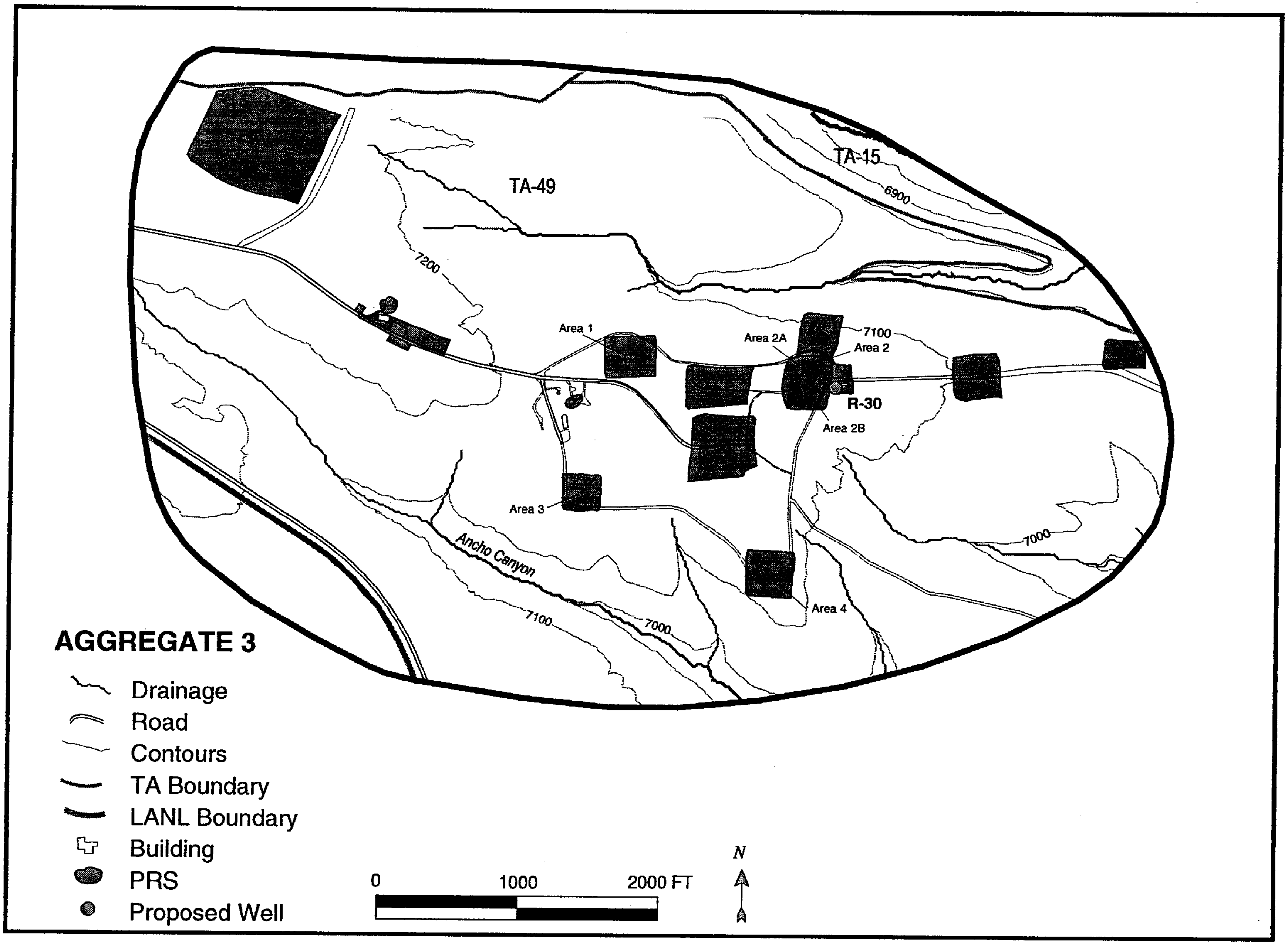


Figure 4-20. PRSs and proposed wells in Aggregate 3.

Further information about activities and potential release sites at TA-49 can be found in Thorne and Westervelt (1987), Stoker and Purtymun (1987), The Solid Waste Management Units Report (LANL 1990), and the RFI Work Plan for Operable Unit 1144 (LANL 1992f). The RFI Work Plan also describes the planned ER investigations which focus on identifying and quantifying migration of contaminants from the shafts.

4.3.3.2 Frijoles Mesa

Surface Water

Surface water occurs to the north of Frijoles Mesa in Water Canyon and to the east in Ancho Canyon. Flow in these canyons is ephemeral and intermittent in the vicinity of TA-49. There are no springs in the vicinity of TA-49 (LANL 1992f). On Frijoles Mesa, surface water occurs as storm water runoff or as snowmelt. Surface runoff flows either northward into Water Canyon, eastward into a tributary of Ancho Canyon, or southward into Ancho Canyon. Surface water data has been collected for about 30 years at the Beta Hole surface water station in Water Canyon, upgradient of TA-49, in Water and Ancho Canyons at State Road 4, and sporadically in drainages leading from MDA AB following intense rainfall events.

Surface water chemistry results show contaminant levels at detection or background levels over this period (LANL 19920).

Alluvial Groundwater

A discussion of the occurrence of alluvial groundwater in Water and Ancho Canyons can be found in the discussions of Aggregates 6 and 4.

Alluvial Groundwater Investigations

There are no alluvial wells designated for installation with respect to Aggregate 3. Installation of alluvial wells A-47 and A-48, which are located near and downgradient of TA-49, will be addressed in the discussion of Aggregate 6.

Intermediate Perched Zones and Regional Aquifer

Before TA-49 activities on Frijoles Mesa began, the U.S. Geological Survey (USGS) conducted hydrogeologic investigations to evaluate the suitability of the site for testing purposes. These investigations, described in Weir and Purtymun (1962) and Purtymun and Stoker (1987) included the completion of the three deep test wells mentioned above and two other deep drill holes which did not reach the regional aquifer, DT-5 at 962 ft and DT-5P at 692 ft (Purtymun 1995. Four core holes (CH-1, CH-2, CH-3, and CH-4) were drilled to depths of 300 to 500 ft at the main experimental area. In addition, more than 50 experimental holes were drilled as deep as 142 ft in Areas 1, 2, 2A, 2B, 3, and 4 from 1959 to 1961. No perched water was encountered in any of the holes and all holes have remained dry with the exception of core hole CH-2, which on several occasions between 1979 and 1992 has contained up to 100 ft of standing water (LANL 1992f). The 20-ft slotted interval of CH-2 straddles the Unit 1v/1g contact. There was no water loss during the drilling of CH-2; the hole was drilled with air. After the drilling was completed, water was added to CH-2 to facilitate borehole geophysical logging. In the logging of CH-2, a significant amount of fluid was lost below a depth of about 300 feet, indication the presence of a relatively permeable formation in stratigraphic Unit 1v and/or Unit 1g.During the drilling and logging of CH-2, a "large but unquantified" volume of drilling fluid was lost in the core hole.

A large amount of fluid was also lost during the drilling of deep test well DT-5A (perhaps 2.5 to 10 million gallons) at about 285 ft in depth near the Unit 1v/1g contact (LANL 1992f). In 1994, the water level in CH-2 was measured at 150 m (493.3 ft) below the surface casing, which is about 14 ft of standing water (EPG 1996). One possible mechanism for the source of water in CH-2 is the drainage of surface runoff from the asphalt pad through a hole in the asphalt caused by the collapse of one of the test holes associated with the hydronuclear experiments (Purtymun and Stoker 1987). Several other possibilities, including a possible undetected natural perched zone, are given in the RFI Work Plan for Operable Unit 1144 (LANL 1992f). This latter hypothesis seems unlikely, however, given the relatively extensive site characterization performed to date and the fact that this recharge pathway apparently developed more than a decade after the hole was completed. No intermediate perched water other than that in CH-2 has been found at TA-49.

As part of the ER Project's RFI activities, two 150-ft deep holes were drilled through the asphalt pad at TA-49, Area 2. These two boreholes showed increased water content in the tuff over water contents found in a 700 foot deep borehole (49-2-700-1) drilled in an undisturbed location to the east of Area 2. This increase is thought to be caused by a collection of moisture under the asphalt pad.

Depth to the regional aquifer has been established at three well locations on the mesa top as, from west to east: 1183 ft in DT-5A, 1097 ft in DT-10, and 1014 ft in DT-9 (EPG 1996). Elevations of the water table at these wells are 5961 ft in DT-5A, 5923 ft in DT-10, and 5921 ft in DT-9 (EPG 1996). Based on Laboratory water-level maps, the general groundwater flow direction in the regional aquifer is almost east to southeast in this portion of the Laboratory.

Water quality of the regional aquifer is routinely monitored by the Environmental Surveillance Program through sampling of the DT wells. Above background concentrations of lead, strontium-90, arsenic, plutonium-238, and antimony have been detected at times in these wells. The 1993 environmental surveillance sampling showed organic compounds in well DT-9 (2,4-dinitrophenol, pentachlorophenol, and acetone) and hole CH-2 (toluene) (EPG 1995).

The presence of at least one high permeability zone beneath Frijoles Mesa, increased moisture content in areas covered by asphalt and disturbed surface soils, and levels of contaminants above background detected in regional aquifer wells demonstrates the need for hydrologic investigations at Frijoles Mesa.

Intermediate Perched Zone and Regional Aquifer Groundwater Investigations

Only one regional well, R-30, is proposed for Aggregate 3 because of the extensive studies previously completed in the area. Well R-30 will be located east of Area 2 on Frijoles Mesa (see Figure 4-2). It will be in the same location as existing ER Project borehole (49-2-700-1). The borehole will be reamed and deepened from 700 ft to approximately 1600 ft. The primary purposes of this well are to refine the understanding of the hydrological and chemical properties of the stratigraphic units below the Bandelier Tuff with respect to contaminant transport pathways and to improve understanding of contaminant distribution in the regional aquifer. Also, data from R-27 will be used to support the ER assessments at TA-49.

Because buried contaminants are likely to be capped and left in place at TA-49, Well R-30 may be used in conjunction with nearby wells R-27 and R-28 as components of a regional monitoring system for this part of the Laboratory.

4.3.4 Aggregate 4

Table 4-6 lists the alluvial and regional aquifer wells proposed for installation in Aggregate 4. The rationale for these wells and the uncertainties they address are described below. Additional information about the rationale for the regional aquifer wells is given in Table 4-1. Figures 4-1 and 4-2 show the general proposed well locations. Appendix 6 provides large-scale maps with proposed well location plotted along with existing wells for reference.

4.3.4.1 Area Description and History

Aggregate 4 is located in the southeastern corner of the Laboratory (see Figure 1-3). It is bounded by Ancho Canyon on the north, the Rio Grande on the east, Bandelier National Monument on the south, and

TA-39 on the west (Figure 4-21 and 4-22). The boundaries of Aggregate 4 were drawn to encompass potential release sites associated with activities in this area of the Laboratory.

Table 4-6. Summary of Potential Wells in Aggregate 4

Canyon or Mesa	*Alluvial Wells/Piezometer Transects (all ER)*[1]	*Regional Aquifer Wells*
Ancho Canyon	A-49	R-31 (NWT)[2]
	A-50	R-32 (NWT)
	A-51	
Chaquehui Canyon		

[1] Funded through Environmental Restoration Project
[2] Funded through Nuclear Weapons Technology Program

Aggregate 4 includes the lower part of Ancho Canyon, Chaquehui Canyon, and the un-named mesa top between them. Two technical areas are included in this Aggregate:

- TA-33 was used as a firing site and for production of tritium. PRSs include landfills, septic systems, and burn areas It is situated on a mesa top and is being investigated by the ER Project as Operable Unit (OU) 1122. If contaminants are released from TA-33, they may impact Ancho Canyon, Chaquehui Canyon, or the Rio Grande.
- TA-39 is located on the floor of Ancho Canyon, and it was used for open-air testing of high explosives. PRSs in this technical area include five firing sites, a number of landfills, and septic systems. This technical area is being investigated as OU 1132 by the ER Project.

More detailed information about the operational history, the PRSs and the planned investigations can be found in the RFI Work Plans for Operable Units 1122 (LANL 1992d), and 1132 (LANL 1993b)

4.3.4.2 Ancho Canyon

Surface Water

Surface water occurs in Ancho Canyon as ephemeral runoff from precipitation events. Flash flooding associated with intense summer thunderstorms can be severe as was demonstrated in the summer of 1991 when roads and buildings at TA-39 were damaged.

Streamflow in Ancho Canyon below State Road 4 is monitored by a recently installed gauging station. Streamflow was observed for five days in the 1995 water year (Shaull et al. 1996). Storm water collected at the gauging station in one of the 1995 runoff events contained 50.9 pCi/L strontium-90, and the runoff event had a peak flow of 40 ft^3/s.

Alluvial Groundwater

Little is known about the presence of alluvial groundwater in Ancho Canyon. Ancho Canyon contains thick alluvium that could host perched groundwater, and three bore holes (ASC-15, ASC-16, and ASC-18) drilled by the ER Project encountered 4 ft to 9 ft of saturation in alluvium below MDA Y. Several boreholes drilled downgradient of MDA Y encountered no alluvial groundwater, suggesting the occurrence of alluvial groundwater in this area is limited in extent.

The conceptual model of Ancho Canyon is summarized on Figure 4-23. Alluvium deposited by ephemeral streams is present within Ancho Canyon. The alluvium is quite permeable in contrast to the underlying Bandelier Tuff and basalt in the canyon.

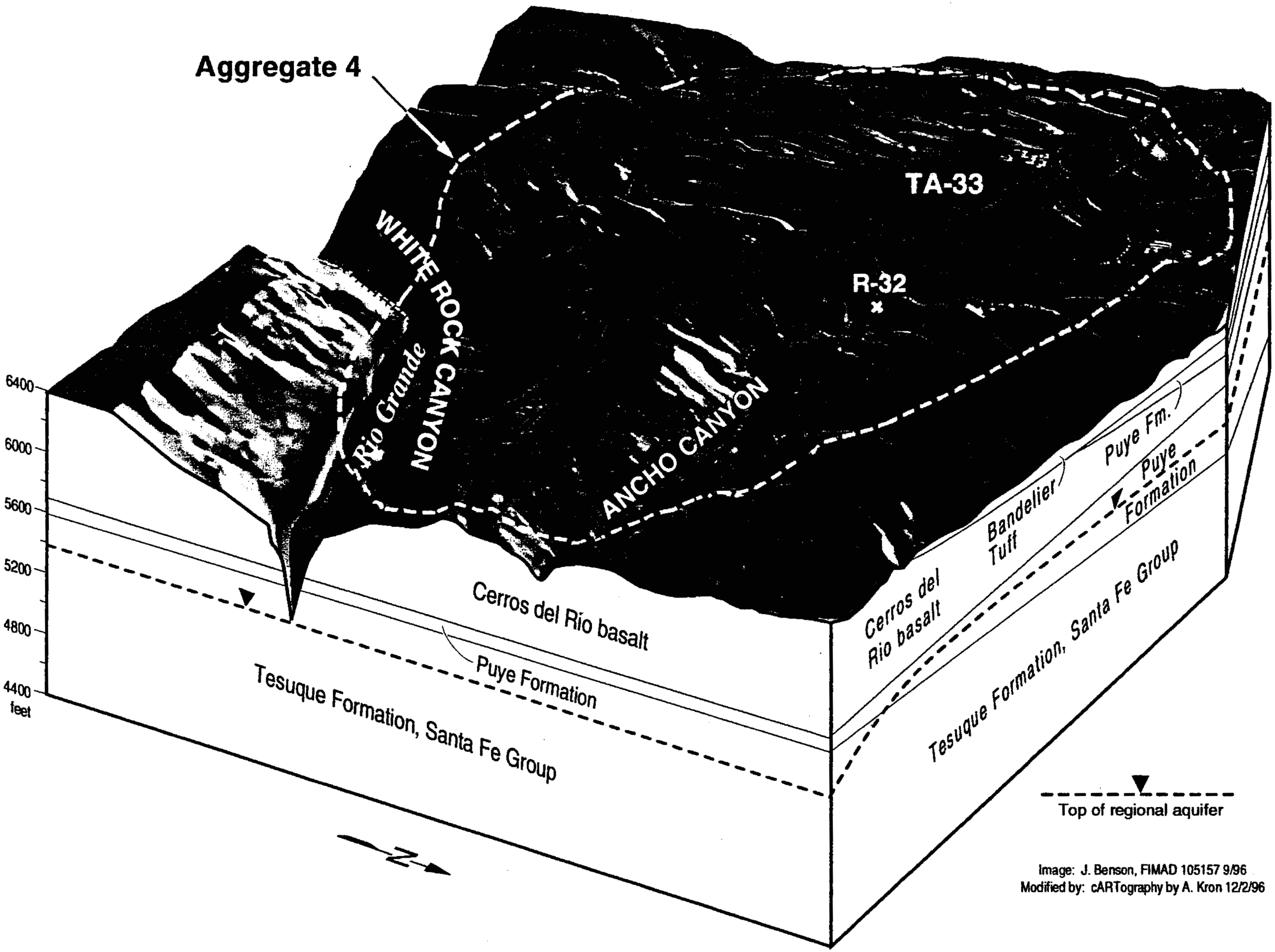


Figure 4-21. Block diagram showing the terrain and bedrock geology for Aggregate 4.

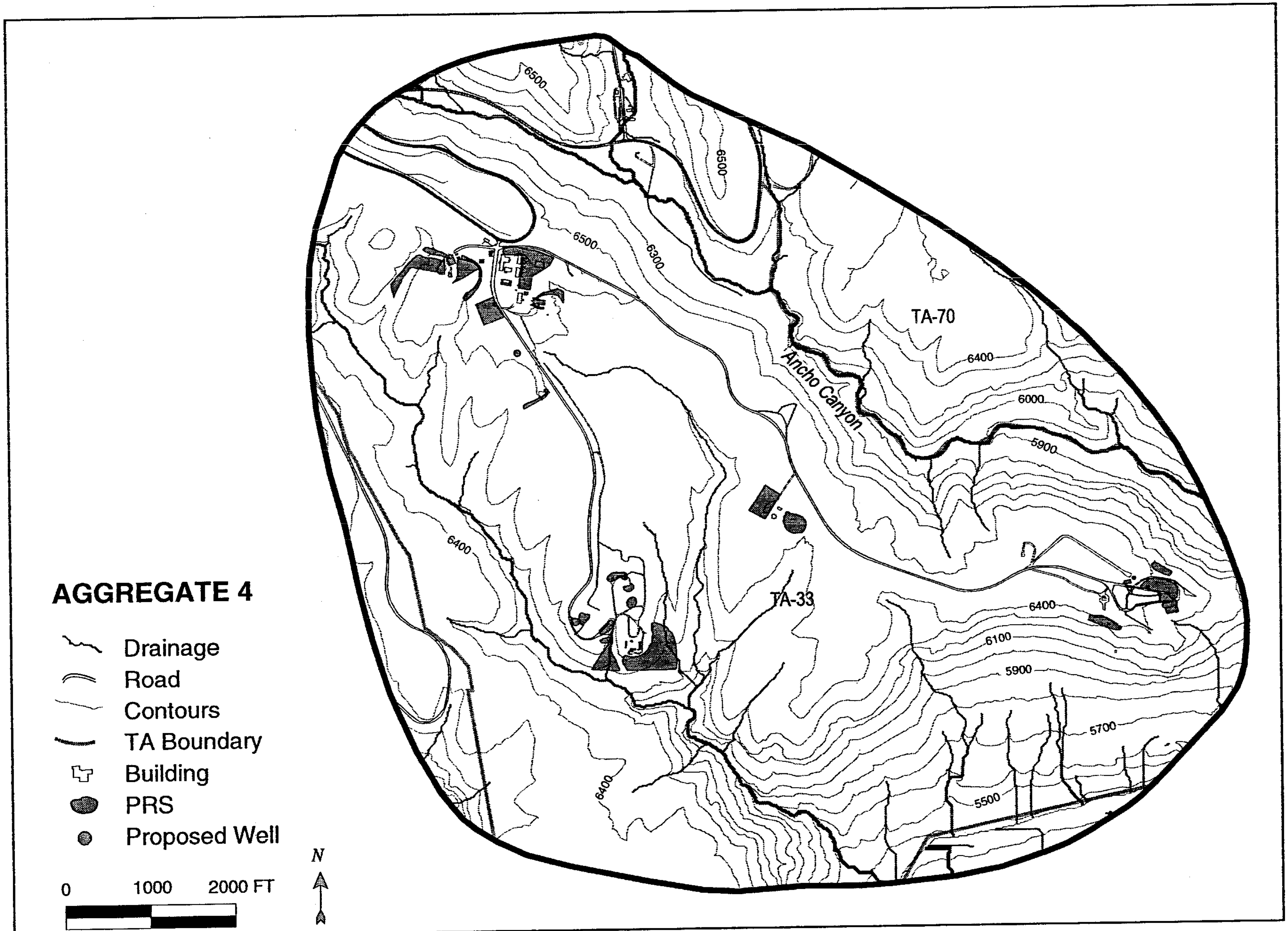


Figure 4-22. PRSs and proposed wells in Aggregate 4.

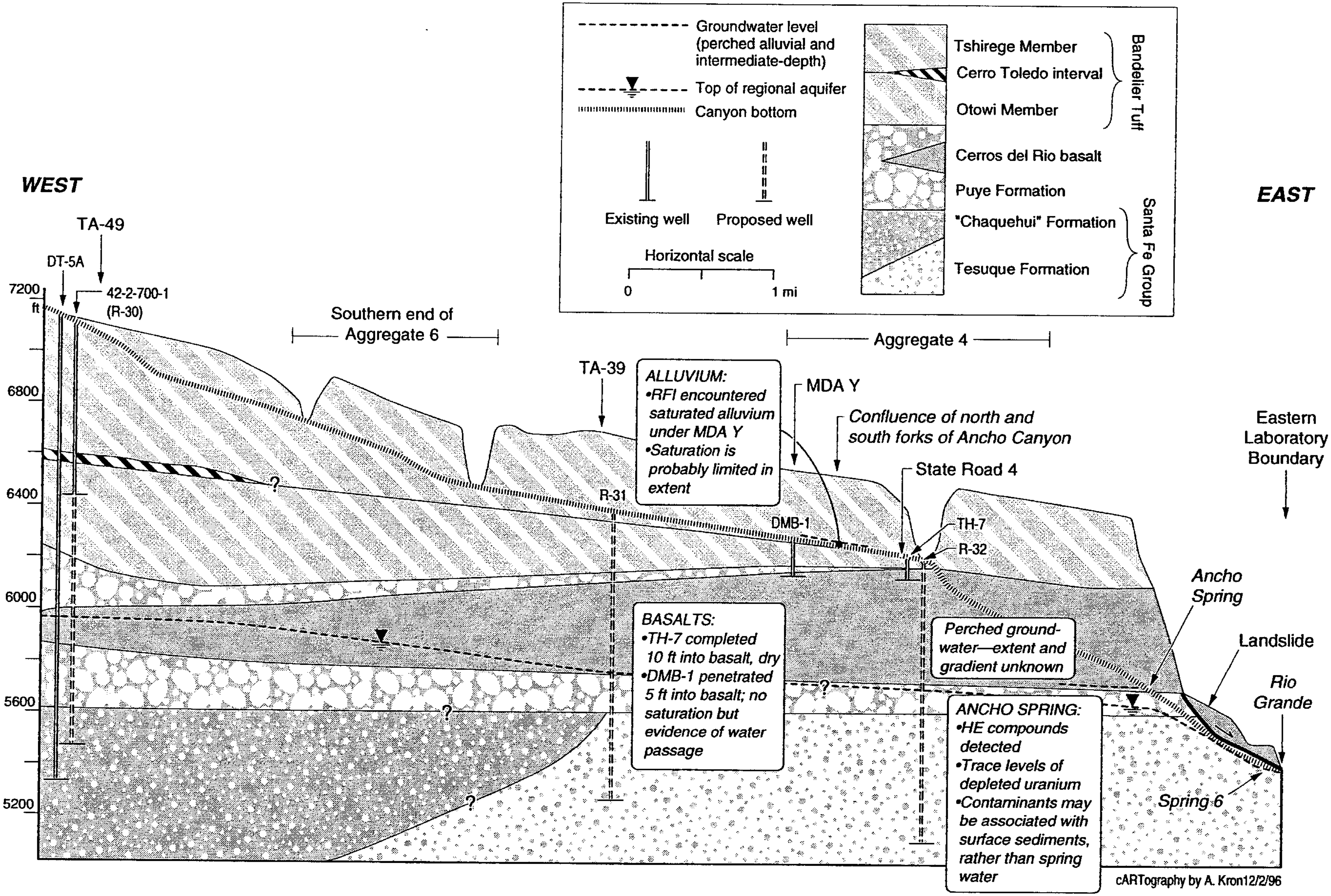


Figure 4-23. Schematic cross section showing conceptual model and proposed regional aquifer wells for Ancho Canyon.

Better delineation of alluvial groundwater occurrences in Ancho Canyon is important for defining potential contaminant transport pathways.

Alluvial Groundwater Investigations

Three alluvial wells are proposed in this Workplan for installation in Ancho Canyon. These wells are A-49, A-50, and A-51 (see Figure 4-1).

Well A-49 will be located in the north branch of Ancho Canyon about 0.5 mi from the confluence with the south branch. The purpose of this well will be to identify the quantity and quality of alluvial saturation contributed by the north branch to the main channel.

Well A-50 will be located in the south branch about 0.25 mi from the confluence with the north branch. Like well A-49, the purpose of this well will be to identify the quantity and quality of alluvial saturation contributed by the south branch to the main channel.

Well A-51 will be located in the main channel, about 300 ft downstream from the confluence of the north and south branches. This well will identify the combined quantity and quality of alluvial water below the operational areas of TA-39.

Intermediate Perched Zones and Regional Aquifer

The occurrence of intermediate perched zones beneath Ancho Canyon can not be determined because there is little sufficiently-deep borehole information for this area.

ER borehole DMB-1, drilled between building 69 and the Administrative Area at TA-39, penetrated 119 ft of Bandelier Tuff and 5 ft of Cerros del Rio basalts. No intermediate-depth perched water was encountered in this hole, but clay-lined fractures and vesicles in the basalt suggest the periodic passage of groundwater through these rocks may occur.

A test hole (TH-7) drilled 10 ft into basalts in Ancho Canyon below State Road 4 was dry. The hole was drilled in 1950 and has since then been plugged (Griggs 1955).

Analysis of water at Ancho Spring by the Environmental Surveillance Program indicates the presence of numerous high explosives and trace levels of depleted uranium. Because the spring issues from the canyon floor, it is uncertain whether these contaminants are being transported by groundwater or if they are being mobilized from sediments in the canyon. Also, because the spring is located about 300 ft above the Rio Grande, it is possible that water from the spring is representative of an intermediate perched zone. In either case, Ancho Spring is downgradient of explosives testing sites.

No deep wells penetrate the regional aquifer in the area of TA-33, however, Purtymun (1984) estimates that the depth to the top of the water table is about 1000 ft below the mesa tops. Also, no deep wells penetrate the regional aquifer in Ancho Canyon in the area of TA-39, however, Purtymun (1984) estimates that the water table is about 600 ft below the canyon bottom.

Intermediate Perched Zone and Regional Aquifer Groundwater Investigations

Two regional aquifer wells, R-31 and R-32, are proposed for Aggregate 4. Both wells will fill significant data gaps in an area of the Laboratory which has been little studied. In addition, these wells provide potential monitoring sites for the eastern and southern Laboratory boundaries (see Figure 4-2).

Well R-31 will be located in the north branch of Ancho Canyon about 1.0 mi northwest of the confluence with the south branch. The purpose of this well will be to provide information on the presence, depth, and quality of water in any intermediate perched zones and the regional aquifer. The location of well R-31 is downgradient from Aggregate 6 open burning/open detonation sources and upgradient from Aggregate 4 sources. Water level data from well R-31 will contribute to the optimization of placement of long-term monitoring wells for Aggregates 4 and 6 by placing better constraints on the geometry of the regional aquifer in this area.

Well R-32 will be located about 1.0 mi east of the confluence of the north and south branches of Ancho Canyon. The purposes of this well will be to 1) identify intermediate perched water; 2) evaluate the potential flow paths near the Rio Grande by comparing water collected from the well to the water in the springs; 3) provide water level and water quality data for the regional aquifer; and 4) provide baseline information on the geology, hydrology, and water quality for the poorly studied southeastern boundary of the Laboratory. The location of well R-32 is downstream of sources in TA-39 and close to Ancho Spring. This location provides monitoring of possible migration of high explosive compounds and depleted uranium from TA-39 to the spring. Geologic logging of the R-32 borehole will provide data on pre-Bandelier stratigraphy and hydrologic properties for ER investigations of TA-33 and TA-39.

4.3.4.3 Chaquehui Canyon

Surface Water

The occurrence of surface water in Chaquehui Canyon is ephemeral from its headwaters to a point approximately 0.5 mi upstream from its confluence with the Rio Grande. A perennial spring, Doe Spring, is located at that point and supports perennial flow for a short distance, followed by a short intermittent reach. Spring 9 and 9A, located about 0.25 mi upstream from the confluence with the Rio Grande, support perennial flow again. Perennial flow occurs from these two springs to the Rio Grande. No significant snowmelt runoff occurs in Chaquehui Canyon (LANL 1996b).

Alluvial Groundwater

Little is known about the presence of alluvial groundwater in Chaquehui Canyon. Chaquehui Canyon is unlikely to contain perched alluvial water because most of its course forms a steep narrow drainage through basalts that are swept free of alluvium by storm runoff.

Alluvium deposited by ephemeral streams is present within Chaquehui Canyon. The alluvium is quite permeable in contrast to the underlying Bandelier Tuff and basalt in the canyon. Infiltration of water into the Bandelier Tuff is demonstrated at TA-33 by one drill hole at MDA-K where high tritium concentrations are observed at depths of 100 ft and 170 ft.

Alluvial Groundwater Investigations

No alluvial groundwater investigations are proposed for Chaquehui Canyon in this Workplan.

Intermediate Perched Zones and Regional Aquifer

Springs issue from basalts near the Rio Grande in the area of Chaquehui Canyon (Springs 8A, 9, 9A, and Doe) and Ancho Canyon (Ancho Spring). These springs are located 130-200 ft above the Rio Grande, and they may represent discharge points for intermediate-depth perched water bodies. Alternatively, these springs may represent discharge from the regional aquifer in White Rock Canyon.

No deep wells penetrate the regional aquifer in the area of TA-33 and TA-39, but Purtymun (1984) estimates that the groundwater table is about 600 ft below Ancho Canyon and about 1000 ft below the surrounding mesa tops. Based on Laboratory water-level maps, the general groundwater flow direction in the regional aquifer is southeast in this portion of the Laboratory (see Figure 2-10).

Intermediate Perched Zone and Regional Aquifer Groundwater Investigations

No intermediate perched zone or regional aquifer investigations are proposed for this canyon in this workplan.

4.3.5 Aggregate 5

Table 4-7 lists the alluvial and regional aquifer wells proposed for installation in Aggregate 5. The rationale for these wells and the uncertainties they address are described below. Additional information about the rationale for the regional aquifer wells is given in Table 4-1. Figures 4-1 and 4-2 show the general proposed well locations. Appendix 6 provides large-scale maps with proposed well location plotted along with existing wells for reference.

Table 4-7. Summary of Potential Wells in Aggregate 5

Canyon or Mesa	*Alluvial Wells/Piezometer Transects (all ER)*[1]	*Regional Aquifer Wells*
Cañon de Valle	A-45	R-24 (NWT)[2]
	A-46	R-25 (NWT)
		R-26 (NWT)

[1] Funded through Environmental Restoration Project
[2] Funded through Nuclear Weapons Technology Program

4.3.5.1 Area Description and History

Aggregate 5 is located in the southwest corner of the Laboratory (see Figure 1-3). It is bounded on the north by Pajarito Canyon, on the south and west by the Laboratory boundary, and on the east by the eastern boundary of TA-11 (Figure 4-24 and 4-25). The boundaries of Aggregate 5 were established to encompass the potential release sites and hydrologic issues associated with activities in this area. These areas have similar operational histories that included the discharged large volumes of water. Also, this part of the Laboratory has a distinctly different climatic and vegetative environment and the hydrologic system is expected to reflect these differences.

Aggregate 5 includes Cañon de Valle, Threemile Mesa, and the un-named mesa upon which TA-16 is located. No discussion of the individual mesas is included in this aggregate description as a general description of the contributions of mesa tops to the conceptual models has already been given (see Section 2.2). This discussion of Aggregate 5 includes sources from the following technical areas (see Figure 2-2):

- TA-8 which was used for research, development, manufacturing, and testing of high explosives (HE) since 1944.
- TA-9 was used for research, development, manufacturing, and testing of high explosives (HE) since 1944.
- TA-11, known as K-site, is the location of the high explosives test area.
- TA-14 which was used for research, development, manufacturing, and testing of high explosives (HE) since 1944.
- TA-16 operations center around nuclear weapons warhead research and conventional weapons/chemical explosives research and processing. MDA P is located at TA-16.
- TA-28 consists of five magazines used for storage of high explosives. Because of careful operations in the past, no PRSs exist.

Four former TAs (TA-13, TA-24, TA-25, and TA-29) existed within TA-16 boundaries. These have been decommissioned and absorbed into TA-16. Any PRSs associated with these sites are now a part of TA-16.

More detailed information on activities and potential release sites in this area can be found in the RFI Work Plan for Operable Unit 1082 (LANL 1993d), and the Solid Waste Management Units Report (LANL 1990).

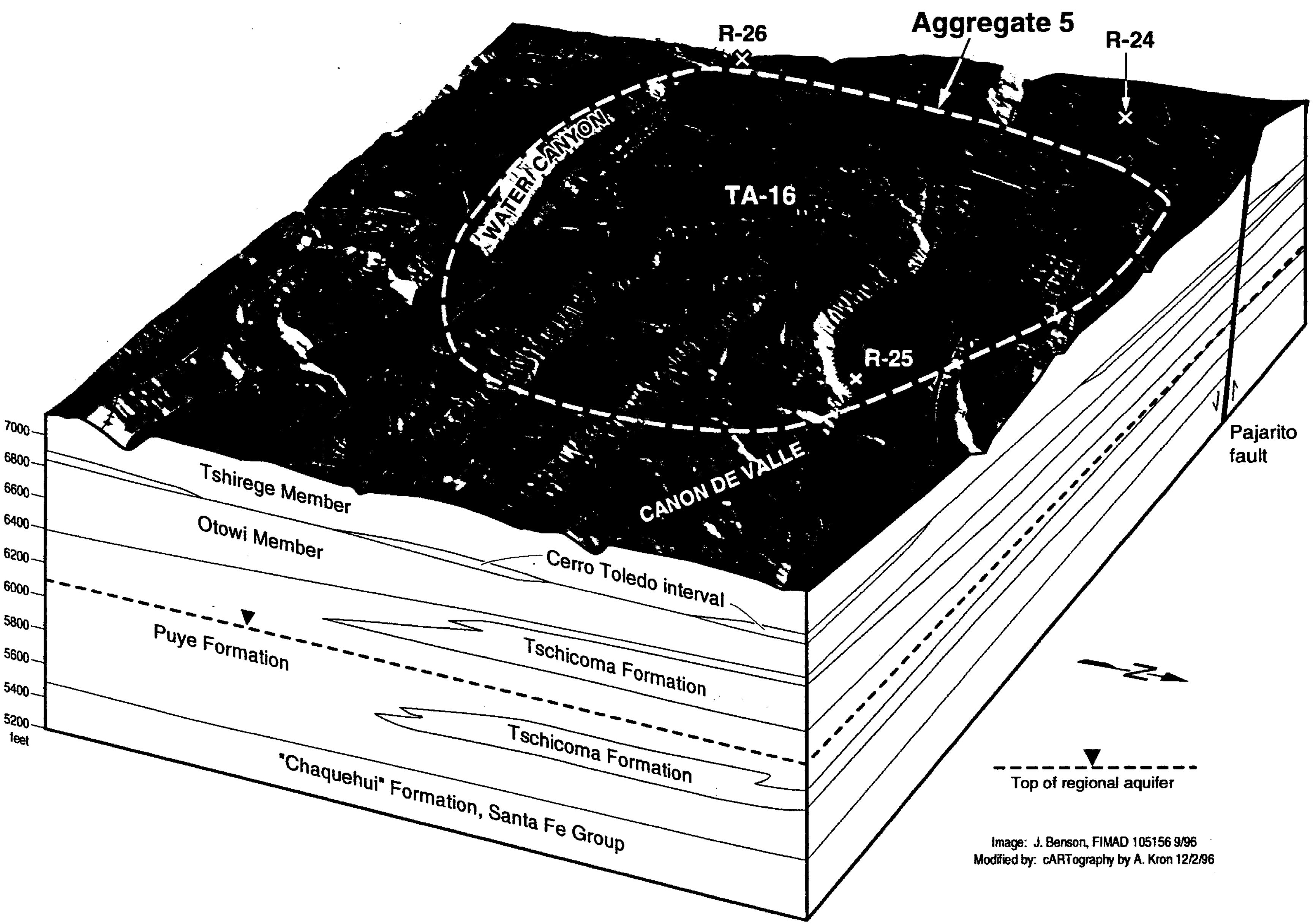


Figure 4-24. Block diagram showing the terrain and bedrock geology for Aggregate 5.

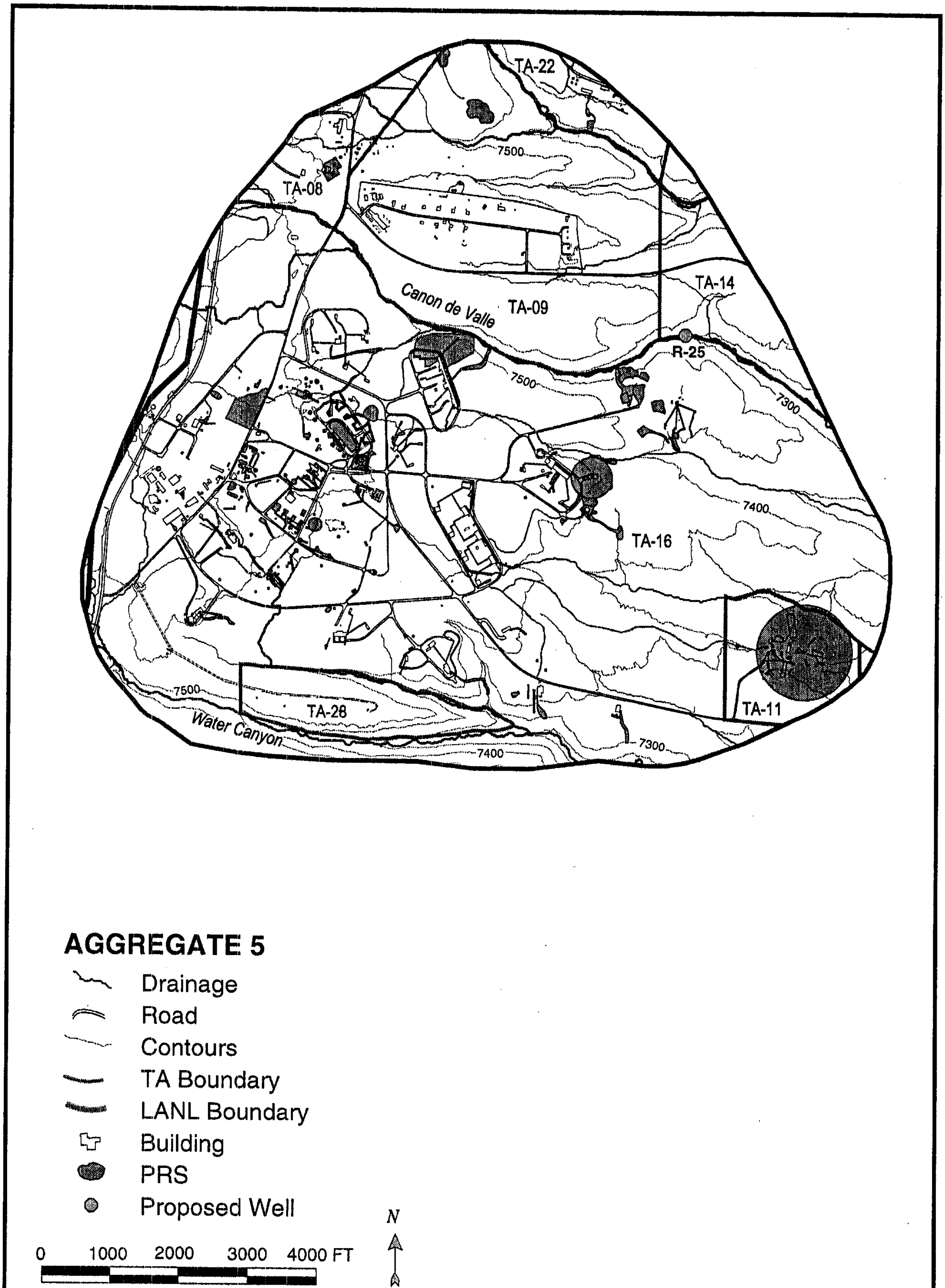


Figure 4-25. PRSs and proposed wells in Aggregate 2.

4.3.5.2 Cañon de Valle

Surface Water

Perennial and intermittent surface water exists in Cañon de Valle, from natural and anthropogenic sources. One perennial reach, between outfall TA-16-260 and a location east of MDA-P, has flowed continuously since initial ER Project investigations began in 1992.

The quality of the surface water has been analyzed as part of the ER Project Framework Studies, New Mexico Environment Department DOE Oversight Bureau, and non-RFI related hydrogeologic sampling at TA-16. Based on this work, surface waters in Cañon de Valle show concentrations of some constituents at levels above background. Two constituents, barium (2-3 ppm) and the high explosive RDX (>100 ppb) have been found at levels above the New Mexico maximum concentration level (MCL). Chlorine, sodium, and manganese are above the regional background for spring waters. The water from the springs has also been analyzed and found to contain barium, boron, HE, and solvents at concentrations above background.

Alluvial Groundwater

Several springs issue from the Bandelier Tuff in Cañon de Valle and add to the surface water flow. Based on the presence of these springs and some perennial flow segments, it is assumed that saturated alluvium exists in at least some portions of Cañon de Valle (see Figure 4-26). Several small saturated areas are present in tributaries to Cañon de Valle.

The movement of water within shallow soil layers has been studied in nearby TA-69 by Wilcox et al. (1996) and Newman (1996). They found that significant interflow (lateral subsurface flow) occurs in the soil horizon following rainfall or snowmelt events. The mechanism of interflow is important for understanding streamflow generation and possible infiltration to deeper groundwater.

The assumed presence of saturated alluvium, presence of contaminants in the water, and evidence of infiltration provide the source and pathway for contaminant migration to deeper water systems. The nature of these sources and pathways need to be investigated in order to protect the regional water supply.

Alluvial Groundwater Investigations

Two alluvial wells, A-45 and A-46, are proposed to confirm the presence of alluvial saturation, to measure the parameters in the alluvium that control contaminant migration, and to analyze the quality of the alluvial water (see Figure 4-1).

Well A-45 will be located at the western boundary of the Laboratory in Cañon de Valle. This location is upgradient of Laboratory activities and provides the background water quality characteristics of the alluvial water.

Well A-46 will be located in Cañon de Valle downstream of the operational TAs within Aggregate 5. In addition to identifying the presence of alluvial water, the quality of the water will be compared to the background water quality in A-45 to assess the impacts of operational practices on the alluvial water.

Intermediate Perched Zones and Regional Aquifer

The presence of intermediate perched zones in the western portion of the Laboratory is not well documented. The presence of springs in Cañon de Valle and Water Canyon suggests that there may be one or more intermediate perched water zones. No wells, with the exception of Seismic Hazard Borehole SHB-3, have been installed in this area.

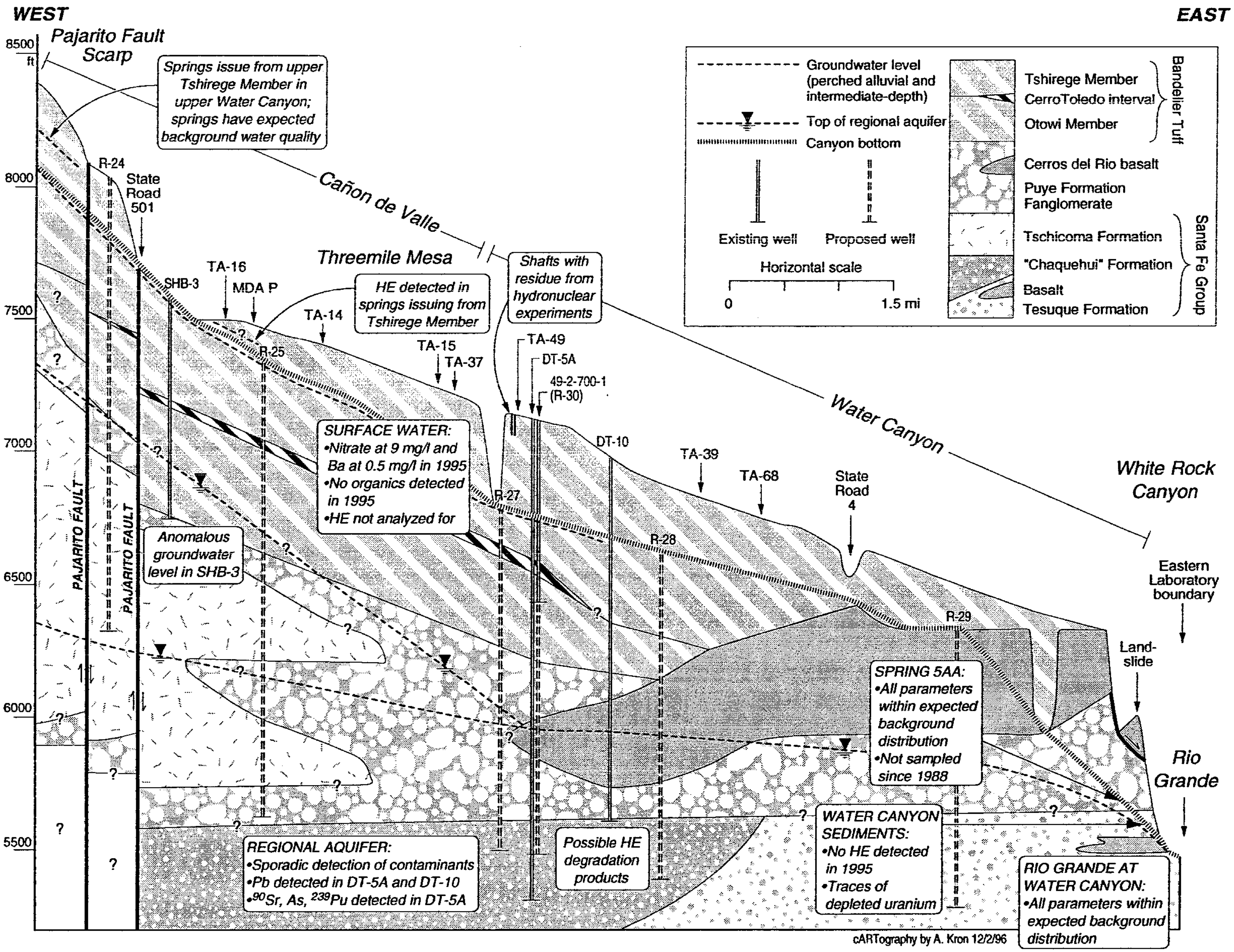


Figure 4-26. Schematic cross section showing conceptual model and proposed regional aquifer wells for Cañon de Valle and Water Canyon.

Water encountered during the drilling of SHB-3 supports the possibility of an intermediate perched zone. SHB-3 was drilled on the mesa top in TA-16, to the north of Water Canyon. This well penetrated through the Bandelier Tuff and into the Puye Formation (Gardner et al. 1993). At present, the static water level is at 665 ft (elevation 6944 ft as compared to an expected water table elevation of about 6400 to 6500 ft) (EPG 1995). The hydrologic context of the water found in SHB-3 is unknown. It could either be from an intermediate perched water body or from the top of the regional aquifer, as shown in Figure 4-21. The relationship of the water in SHB-3 to the top of the regional aquifer needs to be clarified, as does the effect of the Pajarito Fault system on the regional piezometric surface.

As in other canyons, understanding the role of intermediate perched water as a contaminant transport mechanism is critical for making decisions regarding long-term monitoring in the regional aquifer.

Intermediate Perched Zone and Regional Aquifer Groundwater Investigations

Three regional aquifer wells are identified in this Workplan as part of Aggregate 5 hydrogeologic characterization efforts. The geologic logging of these boreholes will support the ER Project OU 1082 mesa top investigations by providing information about the stratigraphy and hydrologic properties of geologic units beneath the mesa. These wells are R-24 and R-25 in Cañon de Valle, and R-26 in Water Canyon (see Figure 4-2). Well R-26 is presented here because of its close association with Aggregate 5, although the Water Canyon conceptual model is presented in Aggregate 6.

Well R-24 will be located near the trace of the Pajarito Fault system west of the Laboratory boundary (Figure 4-27). The purpose of this well will be to provide water quality and water level data for intermediate perched water on the upthrown block of a major splay of this fault system. The water level data from well R-24 will be compared to similar data from wells R-25 and R-26 to evaluate the influence of the Pajarito Fault system on the regional aquifer piezometric surface and evaluate the role of the fault as a recharge zone for the regional aquifer. Water quality data from R-24 will define the expected background distribution of constituents upgradient from Laboratory operations. This background data will be used to estimate the impact of Laboratory operations and provide input data for geochemical and hydrological modeling of the groundwater systems.

Well R-25 will be located adjacent to MDA P. The purpose of this well will be to provide needed regional aquifer water level and water quality information. It will also provide water quality data for intermediate perched zones encountered. The borehole will be fully cored and will support site-wide studies of the hydrogeologic framework by serving as a reference stratigraphic section for a large poorly characterized area in the southwest portion of the Laboratory. This section will be used to constrain geologic and hydrologic relationships in surrounding limited cored boreholes R-17, R-18, R-24, R -26 and R-27.

Well R-26 will be located just east of the Pajarito Fault system in Water Canyon. The purpose of this well will be to provide water quality and water level data for intermediate perched water encountered on the downthrown block of the fault system. Data from well R-26 will provide critical information for evaluating the nature and extent of groundwater encountered in SHB-3, which is located 1 mi northeast of the proposed well site. Data from well R-26 regarding the occurrence of intermediate perched water and the water level in the regional aquifer, when compared to similar data from R-24 and R-25, will be used to evaluate the influence of the Pajarito Fault system on the regional piezometric surface and evaluate the role of the fault as a recharge zone for the regional aquifer. R-26 will also be used to define background water quality upgradient from the Laboratory. Because of lack of knowledge about the hydrogeology in this area, data from wells R-24, R-25, and R-26 will provide important information on flow conditions near the Laboratory boundary. This information will be an important contribution to groundwater flow modeling.

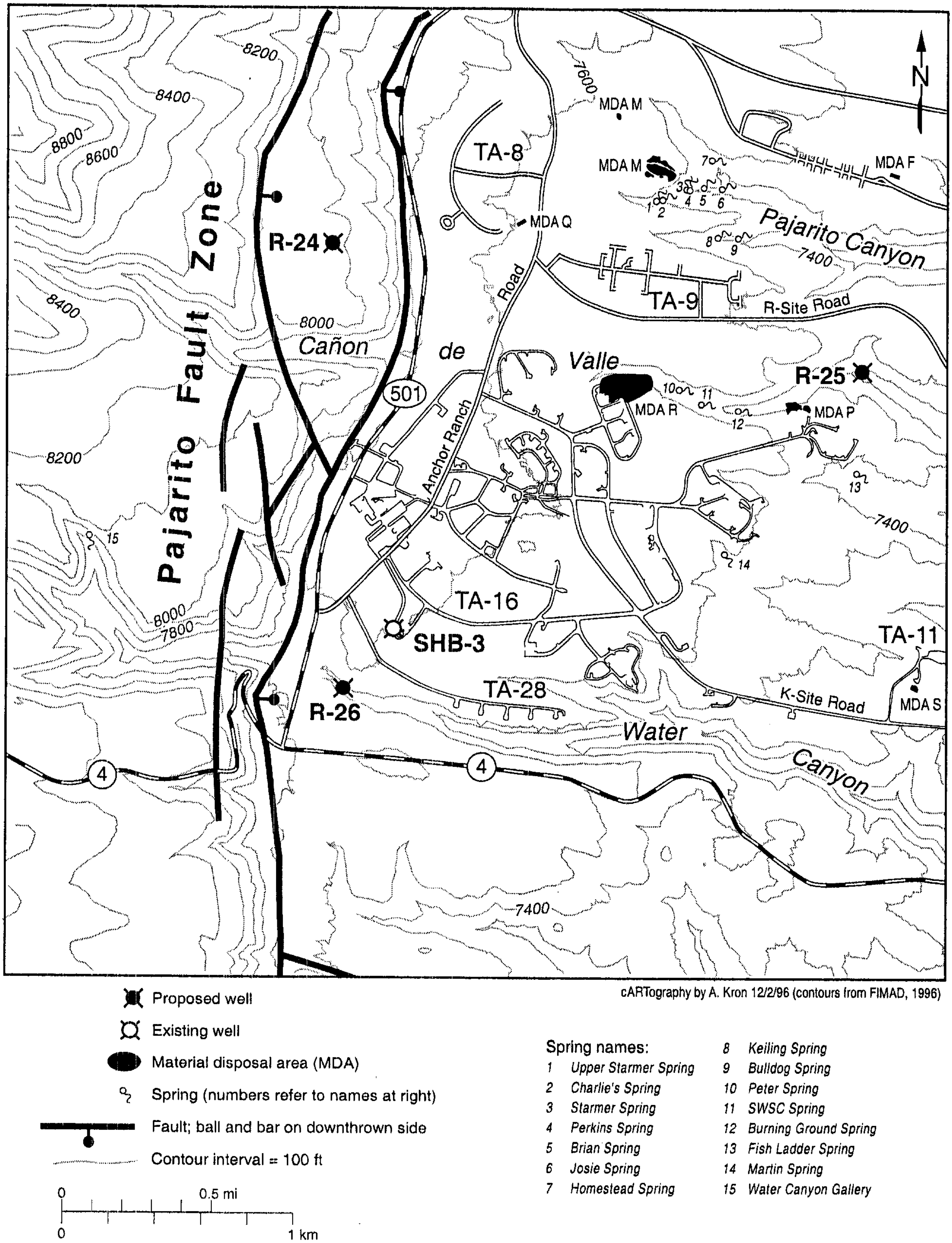


Figure 4-27. Map of Aggregate 5 showing location of proposed wells relative to the Pajarito Fault zone and local springs.

Other planned activities in this area include those of the ER Project. The ER Project investigations for OU 1082 will drill four wells to a depth of 200 ft. to investigate the springs found on the east side of TA-16. Hydrologic properties of the Bandelier Tuff units to a depth of 200 ft. will be obtained from these four boreholes. For springs emanating on the south side of Cañon de Valle, a number of wells (as many as 10) will be drilled by the OU 1082 investigation to determine source areas and characteristics for these springs too. These OU 1082 wells are not part of this Workplan. A tracer study is planned to determine flowpaths and travel time from a surface effluent discharge location to the springs assumed to be connected to this source location.

4.3.6 Aggregate 6

Table 4-8 lists the alluvial and regional aquifer wells proposed for installation in Aggregate 6. The rationale for these wells and the uncertainties they address are described below. Additional information about the rationale for the regional aquifer wells is given in Table 4-1. Figures 4-1 and 4-2 show the general proposed well locations. Appendix 6 provides large-scale maps with proposed well location plotted along with existing wells for reference.

Table 4-8. Summary of Potential Wells in Aggregate 6

Canyon or Mesa	*Alluvial Wells/Piezometer Transects (all ER)*[1]	*Regional Aquifer Wells*
Potrillo Canyon	A-43	R-23 (ER)
	A-44	
Fence Canyon		
Water Canyon	A-47	R-27 (ER)
	A-48	R-28 (NWT)[2]
		R-29 (NWT)

[1] Funded through Environmental Restoration Project
[2] Funded through Nuclear Weapons Technology Program

4.3.6.1 Area Description and History

Aggregate 6 is located in the south-central portion of the Laboratory (see Figure 1-3). The aggregate is elongated from northwest to southeast and is bounded by Threemile Canyon on the north, TA-33 to the south, Frijoles Mesa on the west, and Pajarito Mesa on the east (see Figure 4-28 and 4-29). The boundaries of Aggregate 6 were drawn to encompass the technical areas where testing with high explosives (HE) and open burning and open detonation (OBOD) are part of routine operations.

This aggregate includes Potrillo, Fence, and Water Canyons, and Mesita de Potrillo, Threemile Mesa, and the southern extension of Frijoles Mesa. The general contributions of mesas to the conceptual model are discussed in Section 2.2 and will not be addressed here. This aggregate also includes three technical areas which contain four RCRA-regulated thermal treatment units.

- TA-14 is a firing site located in the western portion of LANL on the southern edge of Threemile Mesa. TA-14 was established in 1944. TA-14 contains two thermal treatment units, one for open burning of explosives-contaminated materials and one for open detonation of hazardous explosive waste.
- TA-15 is another firing site in continuous use since 1944. The TA-15-184 thermal treatment unit for open detonation of hazardous and mixed explosive waste is bordered by Potrillo Canyon to the north and Water Canyon to the south.
- TA-36, a firing site occupied since 1950, is spread over several mesa tops between a branch of Pajarito Canyon to the north and Water Canyon to the south. The TA-36-8 thermal treatment unit for open detonation of hazardous and mixed explosive waste is located in the vicinity of the headwaters of Fence Canyon.

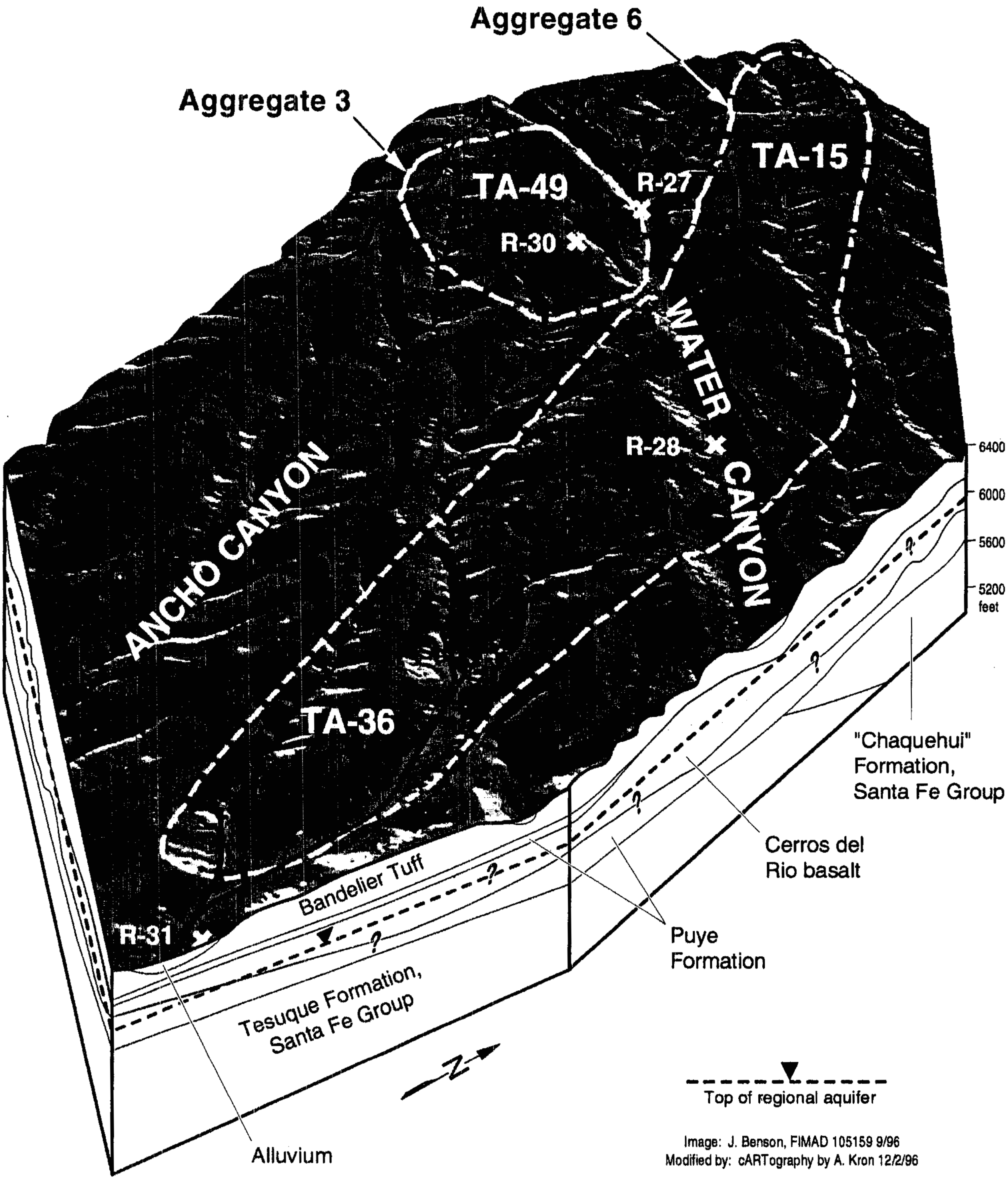


Figure 4-28. Block diagram showing the terrain and bedrock geology for Aggregate 6.

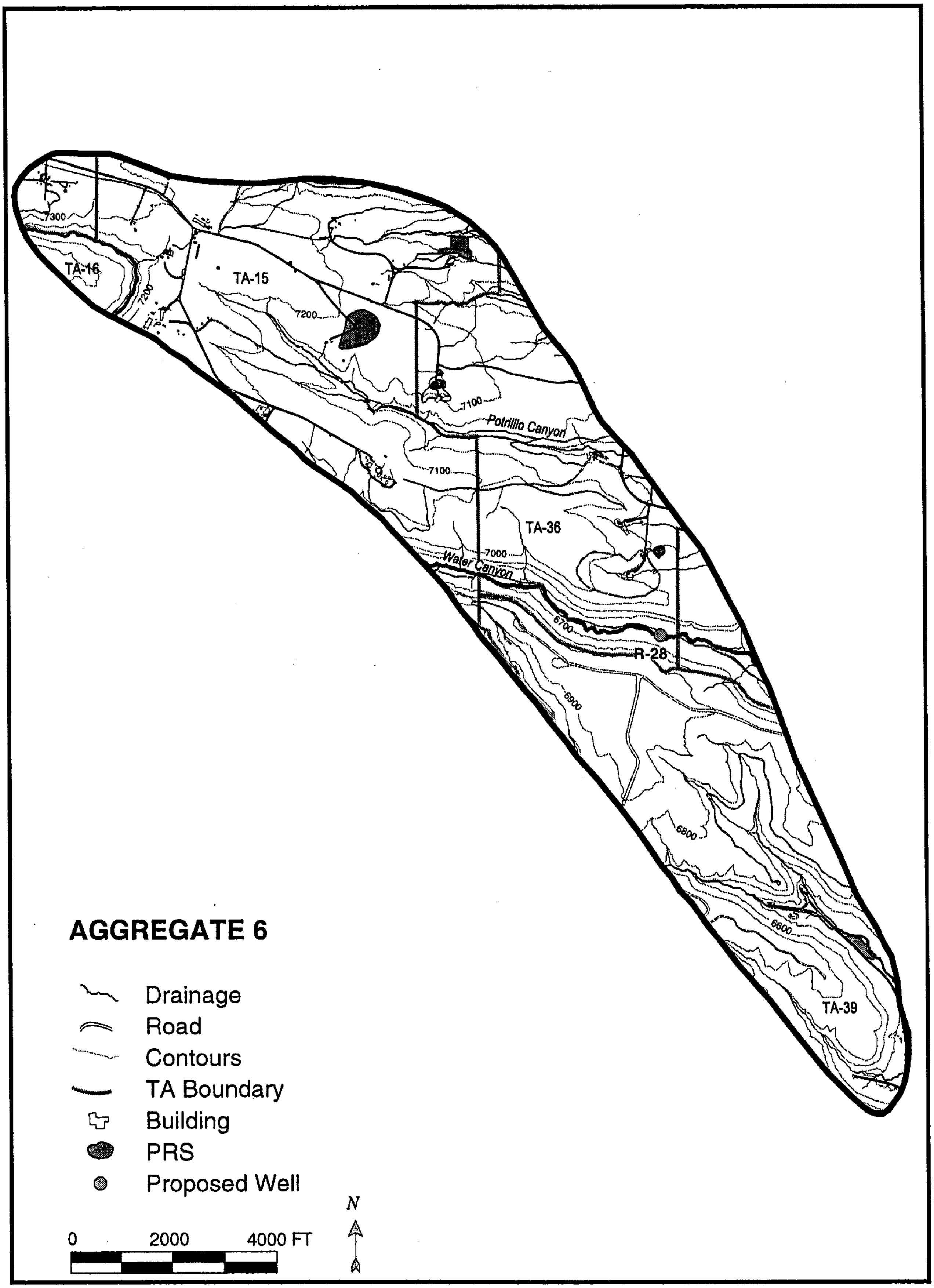


Figure 4-29. PRSs and proposed wells in Aggregate 6.

Explosive compounds commonly used at these sites include: nitrated organic compounds such as TNT, nitrocellulose, trinitramines, and pentaerythritol tetranitrate (PETN). Metals may also be associated with the explosives (uranium, barium, beryllium, lithium hydride, lead, mercury, copper, and zinc). Soils in several of these operational areas have high levels of uranium contamination. Waste explosive materials may be in the form of discrete pieces, chips, or scraps (CEARP 1986).

All waste sites within this aggregate are located on mesa tops. The canyons are the receiving areas for all waste constituents that are carried in surface runoff and historically active outfalls. The ER Project has investigative activities planned for mesas and canyons in this area. Mesa investigative activities are described in the Operable Unit Work Plans and canyon activities will be described in work plans for the Canyons Operable Unit.

More detailed information about activities and PRSs at these TAs can be found in the RFI Work Plans for Operable Units 1085 (LANL 1994a), 1086 (LANL 1993e), and 1130 (LANL 1993a), and the Solid Waste Management Units Report (LANL 1990).

4.3.6.2 Potrillo Canyon

Surface Water

Potrillo Canyon contains streams that are entirely ephemeral with no perennial springs or perennial reaches. No significant snowmelt runoff occurs within this canyon (LANL 1993f). It is located entirely on the Pajarito Plateau, and is mostly contained within the Laboratory. Surface water flow originating upstream in Potrillo Canyon rarely extends beyond the downstream edge of the discharge sink defined by the location of the POTO wells and POTM moisture access holes shown on Figure 2-8 and discussed by Becker (1993).

The discharge sink is an area where inflow exceeds outflow, stream velocities decrease and flow infiltrates into the channel, and where there is sediment deposition. There is no defined channel at this location, only a broad valley. Surface water and sediments were sampled during an extensive study of uranium migration from firing sites within Potrillo Canyon (Becker 1993). This study showed concentrations of uranium significantly greater than background in soil (up to 4580 ppm) and surface water (11.9 ppb) near the firing sites, yet no significant elevation in concentrations at State Road 4, below the discharge sink, have been detected during annual environmental surveillance sampling. Becker (1993) observed that the discharge sink appears to absorb all incoming stream flow and sediment load.

According to Becker (1993), the probable feature that creates the discharge sink is an underlying fault below the alluvium at the upstream end of the discharge sink. An alternative possibility is the relatively permeable sediment of the Cerro Toledo interval may subcrop beneath the alluvium, creating an optimum condition for stream flow infiltration. The discharge sink will be investigated during site characterization activities.

Alluvial Groundwater

There is only one known occurrence of alluvial groundwater in Potrillo Canyon. It was detected during the installation of moisture access hole POTM-2 in 1989 in the upper-middle part of the canyon (Becker 1993). Several other boreholes have been drilled near this area to define the extent of the groundwater found in POTM-2 but all are dry (see Figure 2-8).

Information about the occurrence of alluvial groundwater in Potrillo Canyon is limited to the part of the canyon from 0.2 mile upstream of the discharge sink to 1 mile downstream of the discharge sink. No other investigations have been conducted to date.

Potrillo Canyon has been the focus of some of the most detailed near-surface characterization activities at the Laboratory. A partial list of subsurface instrumentation already installed within or adjacent to the discharge sink includes 3 neutron moisture access tube clusters and 2 multi-level observation wells. These stations monitor the vertical moisture movement and the occurrence of saturation within the discharge sink (the observation wells have remained dry since their installation in 1991). Monitoring results from these holes and data from additional surface water and sediment monitoring activities will be evaluated to guide the design, placement, and number of additional wells needed to characterize this site.

Alluvial Groundwater Investigations

Two alluvial wells (A-43 and A-44) are proposed for installation in Potrillo Canyon.

Well A-43 will be located upgradient of the discharge sink to identify the presence and quality of alluvial groundwater. The location of well A-43 on the boundary of the aggregate and will serve to track contaminants moving out of the aggregate in the alluvial groundwater.

Well A-44 will be located downgradient of the TA-36 firing sites, about 0.25 mi west of the confluence with Fence Canyon. The purpose of this well will be to evaluate the presence and quality of alluvial groundwater.

Intermediate Perched Zones and Regional Aquifer

No intermediate perched zones have been encountered beneath Potrillo Canyon, but wells may not have been completed deep enough to find it.

Based on water supply well PM-2, the regional aquifer is expected to be approximately 730 ft below the bottom of Potrillo Canyon.

Intermediate Perched Zone and Regional Aquifer Groundwater Investigations

One regional aquifer well, R-23, is proposed for installation in Potrillo Canyon in this Workplan. This well will be located about 1.0 mi downgradient of the discharge sink and about 0.25 mi downgradient of borehole PCTH-1, which was drilled to a depth of 74 ft, and then plugged and abandoned because no perched groundwater was found. The purpose of well R-23 will be to investigate the presence of intermediate perched zones and to characterize the water quality of these zones downgradient of the Potrillo Canyon firing sites. Data from well R-23 will also be used to provide water quality data for the regional aquifer at this location.

4.3.6.3 Fence Canyon

Surface Water

Fence Canyon contains streams that are entirely ephemeral with no perennial springs or perennial reaches. No significant snowmelt runoff occurs within Fence Canyon.

Alluvial Groundwater

No occurrences of alluvial groundwater have been documented for Fence Canyon. A single subsurface penetration has been made in Fence Canyon, well FCO-1. It is located near State Road 4, in the lower segment of the canyon. At that location the alluvium is 14 ft thick and is dry. The boring extended to a depth of 29 ft, bottoming in weathered tuff. Alluvial groundwater is not expected to occur in this canyon, because it heads on the Pajarito Plateau with no infiltration sources other than rainfall.

Alluvial Groundwater Investigations

No alluvial wells are proposed for Fence Canyon in this Workplan.

Intermediate Perched Zones and Regional Aquifer

The occurrence of perched intermediate water below Fence Canyon can not be determined from available drill hole data. Based on water supply well PM-2, the regional aquifer is expected to be at an elevation of 5890 ft (Purtymun 1995), which is approximately 620 ft below the bottom of Fence Canyon.

Intermediate Perched Zone and Regional Aquifer Groundwater Investigations

No regional aquifer wells are proposed for Fence Canyon in this Workplan.

4.3.6.4 Water Canyon

Surface Water

Water Canyon contains an interrupted stream fed by several perennial springs in the upper reaches of the canyon, including Armistead Spring, American Spring, and others in the upper reaches of Cañon de Valle. These springs support perennial reaches followed by intermittent reaches limited to the area west of the Laboratory boundary. Flow in Water Canyon is ephemeral from the western boundary across Laboratory land to a point below the confluence with Potrillo Canyon. At this point, a perennial spring known as Spring 5AA, supports a short perennial reach. This flow does not extend to the Rio Grande. Snowmelt runoff on Water Canyon seldom extends downstream as far as the eastern boundary; however, occasionally it extends to the Rio Grande (LANL 1993f).

Surface water collected for the Environmental Surveillance Program in 1995 near the confluence of Water Canyon with Cañon de Valle, had above-background concentrations of nitrates and barium. No organic contaminants were detected. Based on the results of spring sampling in Cañon de Valle, HE, solvents and barium may be reaching Water Canyon via Cañon de Valle. In 1994 and 1995, VOCs and HE were detected in several Cañon de Valle springs located upstream of Aggregate 6, in Aggregate 5. Surface water from these springs may introduce contaminants into Water Canyon alluvial groundwater.

Alluvial Groundwater

A conceptual model of Water Canyon is shown on Figure 4-21. Water is assumed to be present in the alluvium in the upper portion of the canyon, based on the amount of surface water west of the Laboratory boundary. Alluvial groundwater was encountered when WCM-1 and WCM-2 were drilled in 1960 (Purtymun 1995). However, no water was encountered in the alluvium when WCO-1, WCO-2, and WCO-3 were drilled and has not been present when these wells have been monitored. The locations of WCM-2 and WCO-1 are fairly close, thus the downstream extent of alluvial groundwater may be between these two wells.

The quality of alluvial groundwater in Water Canyon is assumed to be similar to that of the surface water and springs in the canyon. West of the Laboratory, water from the Water Canyon Gallery springs has been analyzed and water quality is within the expected background distribution.

Sediment samples collected at the confluence of Water Canyon and the Rio Grande showed the no presence of HE, although trace levels of depleted uranium were present. The sampling location is down wind of the OBOD areas of the Laboratory, and the presence of depleted uranium could be the result of surface water runoff or air deposition.

Alluvial Groundwater Investigations

Two alluvial wells (A-47 and A-48) are proposed for installation in Water Canyon to evaluate the presence of alluvial groundwater and the possible migration of contaminants from Cañon de Valle into Water Canyon alluvium (see Figure 4-1).

Well A-47 will be located at the confluence of Water Canyon and Cañon de Valle. The purposes of this well will be to investigate the presence of alluvial water, and measure the saturated thickness, water quality, and parameters controlling infiltration and contaminant migration.

Well A-48 will be located upstream of wells WCM-2 and WCO-1. The purposes of this well will be to investigate the presence of alluvial water, and determine the downstream extent.

Intermediate Perched Zones and Regional Aquifer

There has been no confirmed presence of perched intermediate zones beneath Water Canyon. However, it is considered likely that intermediate perched zones may exist based on the amount of water available in this canyon for infiltration, and the fact that it heads in the Sierra de los Valles. The middle segment of Water Canyon overlies the southern projection of the late Miocene high-permeability zone described by Purtymun (1995) (see Figure 2-5).

Two existing wells in or near Water Canyon are deep enough to have potentially encountered intermediate perched water. The first well, Beta Hole, north of TA-49, was dry. It was drilled to a depth of 180 ft, penetrating the Tshirege Member of the Bandelier Tuff. The second well, SHB-3, at TA-16, did encounter water but, as previously discussed in Aggregate 5, it is unclear whether this water is representative of an intermediate perched zone or the regional aquifer.

The quality of water in the regional aquifer beneath Water Canyon has been measured in wells DT-5A, DT-9, and DT-10 at TA-49. Water samples from these wells have shown some constituents above background (see Aggregate 3 for discussion). The constituents detected in the regional aquifer at these wells do not appear to be related to waste sites or activities within Aggregate 6.

Intermediate Perched Zone and Regional Aquifer Groundwater Investigations

Three regional wells are proposed in this Workplan for installation in Water Canyon for identifying intermediate perched zones, establishing water quality of perched zones and the regional aquifer, and providing hydrogeologic control in the central and eastern portions of the Laboratory. From west to east, these wells are R-27, R-28, and R-29 (see Figure 4-2).

Well R-27 will be located in Water Canyon, about 100 to 200 ft below the confluence with Cañon de Valle. The purpose of this well will be to identify intermediate perched zones and the depth to the regional aquifer. Data from this well will be used to characterize the water quality in the intermediate perched zones and in the regional aquifer upgradient of Aggregate 3.

Well R-28 will be located about 200 ft upgradient of WCO-1 in an area that is expected to intersect the late-Miocene high-permeability trough (see Figure 2-5). The purposes of this well are to provide a stratigraphic reference section for the south-central part of the Laboratory; provide water quality information for any intermediate perched water zones and the regional aquifer. Well R-28 is presently scheduled to penetrate 500 ft into the top of the regional aquifer. Contingency plans exist for deepening this well to a total depth of 4000 ft to investigate water supply issues. If deepened to 4000 ft, this well could provide additional information on vertical hydraulic gradients, saturated hydraulic conductivities, and vertical stratification of water quality in the regional aquifer by use of multiple completions. The DOE and funding organizations will decide if water supplies in the regional aquifer require further characterization.

Well R-29 will be located in lower Water Canyon about 1.0 mi west of the confluence with Potrillo Canyon. The purpose of this well will be to provide water quality information for any intermediate perched water zones and the regional aquifer, and provide regional aquifer water level information. Water chemistry data from intermediate perched water and the regional aquifer from this well will be compared to that from springs to identify potential flow paths near the Rio Grande.

4.3.7 Aggregate 7

Table 4-9 lists the alluvial and regional aquifer wells proposed for installation in Aggregate 7. The rationale for these wells and the uncertainties they address are described below. Additional information about the rationale for the regional aquifer wells is given in Table 4-1. Figures 4-1 and 4-2 show the general proposed well locations. Appendix 6 provides large-scale maps with proposed well location plotted along with existing wells for reference.

Table 4-9. Summary of Potential Wells in Aggregate 7

Canyon or Mesa	Alluvial Wells/Piezometer Transects (all ER)[1]	Regional Aquifer Wells
Mortandad Canyon	A-29	R-13 (ER)
		R-14 (NWT)[2]
		R-15 (ER)

[1] Funded through Environmental Restoration Project
[2] Funded through Nuclear Weapons Technology Program

4.3.7.1 Area Description and History

Aggregate 7 is located in the central portion of the Laboratory (see Figure 1-3). It is bounded by Sigma Mesa (the finger mesa between Sandia and Mortandad Canyons) on the north, Mortandad Mesa on the south, TA-48 on the west, and the Laboratory boundary on the east (Figure 4-9 and 4-30). The boundaries of this aggregate were drawn to encompass Mortandad Canyon and its tributary, Ten Site Canyon, and the mesa-top potential release sites that would impact Mortandad Canyon.

Aggregate 7 includes only Mortandad Canyon. Mortandad Canyon is the focus of this aggregate for two reasons: it has received the largest volume of liquid effluent of any canyon at the Laboratory, and it will continue to receive effluent from Laboratory operations into the foreseeable future.

The source of effluent to Mortandad Canyon has been from two liquid waste treatment plants. One is the NPDES-permitted outfall from the TA-50 Radioactive Liquid Waste Treatment Facility. It has been used to treat liquid radioactive waste from Laboratory operations from 1963 to the present. A second radioactive wastewater treatment plant at TA-35 treated wastes from reactor experiments from 1951 to 1963. It did not operate well, and large volumes of wastewater were released into Ten Site Canyon.

Other mesa-top sites that could impact Mortandad Canyon include the Area C landfill (TA-50) and three waste oil surface impoundments (TA-35) (closed in 1989). More information about the history of these sites and planned investigations can be found in the RFI Work Plans for OU 1129 (LANL 1992b) and OU 1147 (LANL 1992h).

4.3.7.2 Mortandad Canyon

Surface Water

Surface water flow in Mortandad Canyon is ephemeral and intermittent in Aggregate 7. There are no springs in the vicinity; however, there is surface water flow from the outfall of the waste-water treatment plant at TA-50 and cooling tower outfalls for approximately 1 mi downstream from the point of discharge (LANL 1992b). Stream loss caused by infiltration into the underlying alluvium and evapotranspiration typically prevents surface flow from discharging across the eastern boundary of the Laboratory. During periods of excessive storm runoff or snowmelt, surface flow may reach the Rio Grande (Abeele et al. 1981, 0009).

On Sigma and Mortandad Mesas, surface water occurs as storm water runoff or as spring snowmelt. Surface runoff flows into Mortandad Canyon, Ten Site Canyon, or Cañada del Buey.

Alluvial Groundwater

The extent, quality, and flow of alluvial groundwater in Mortandad Canyon is known from the investigations that have been completed (Baltz et al. 1963; Purtymun 1977; Purtymun et al. 1983; Purtymun 1988; Stoker et al. 1991; Koenig and McLin 1993; Stone 1995; and Rogers et al. 1996). Major recharge to the alluvium occurs from effluent released in the upper canyon (Purtymun et al. 1983). The alluvial groundwater extends about 2 mi downstream from the TA-50 outfall. The saturated thickness varies with effluent discharge rates and storm runoff, although the typical saturated thickness is about 10 ft. The conceptual model of Mortandad Canyon is shown on Figure 4-31.

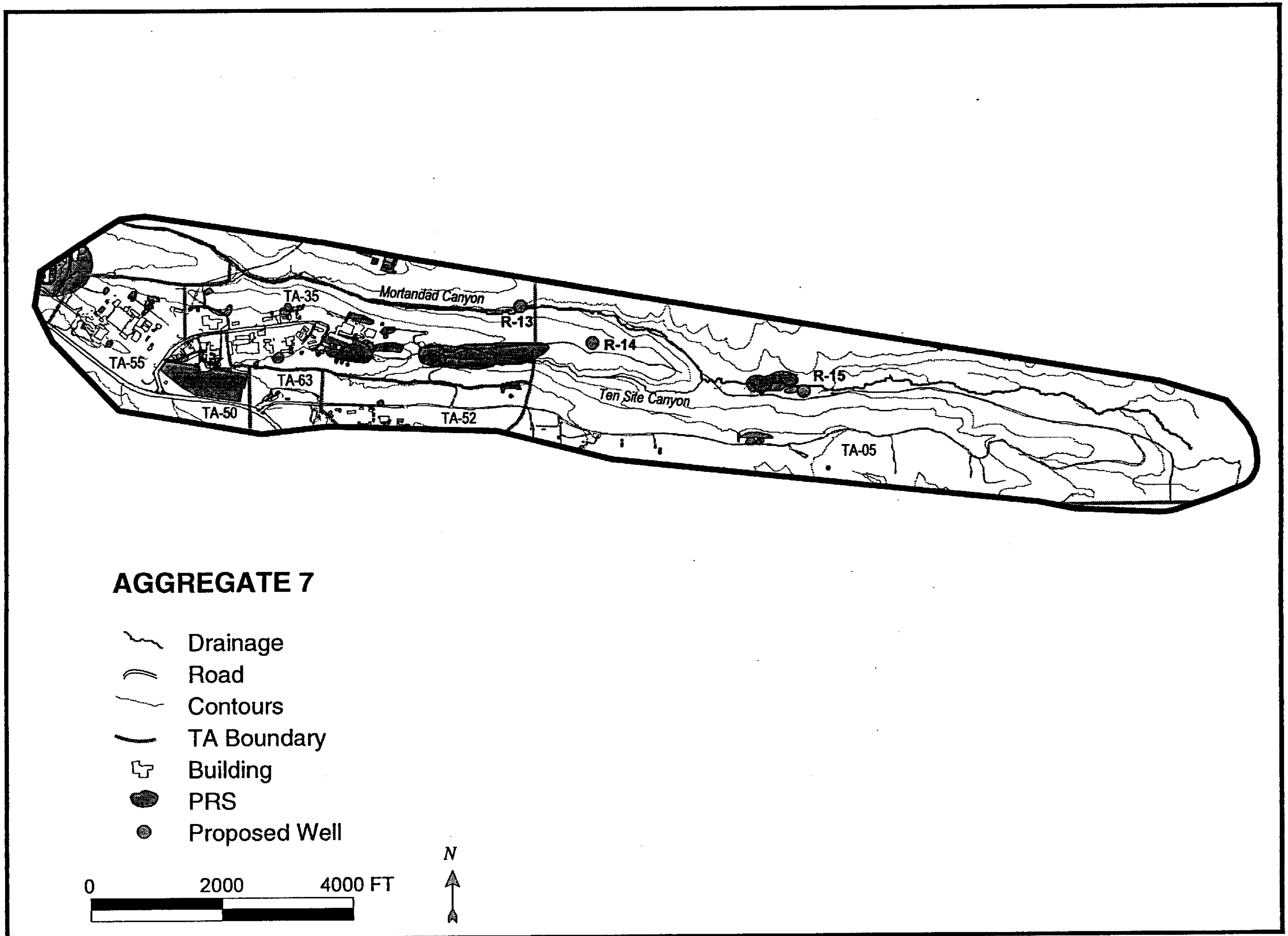


Figure 4-30. PRSs and proposed wells in Aggregate 7.

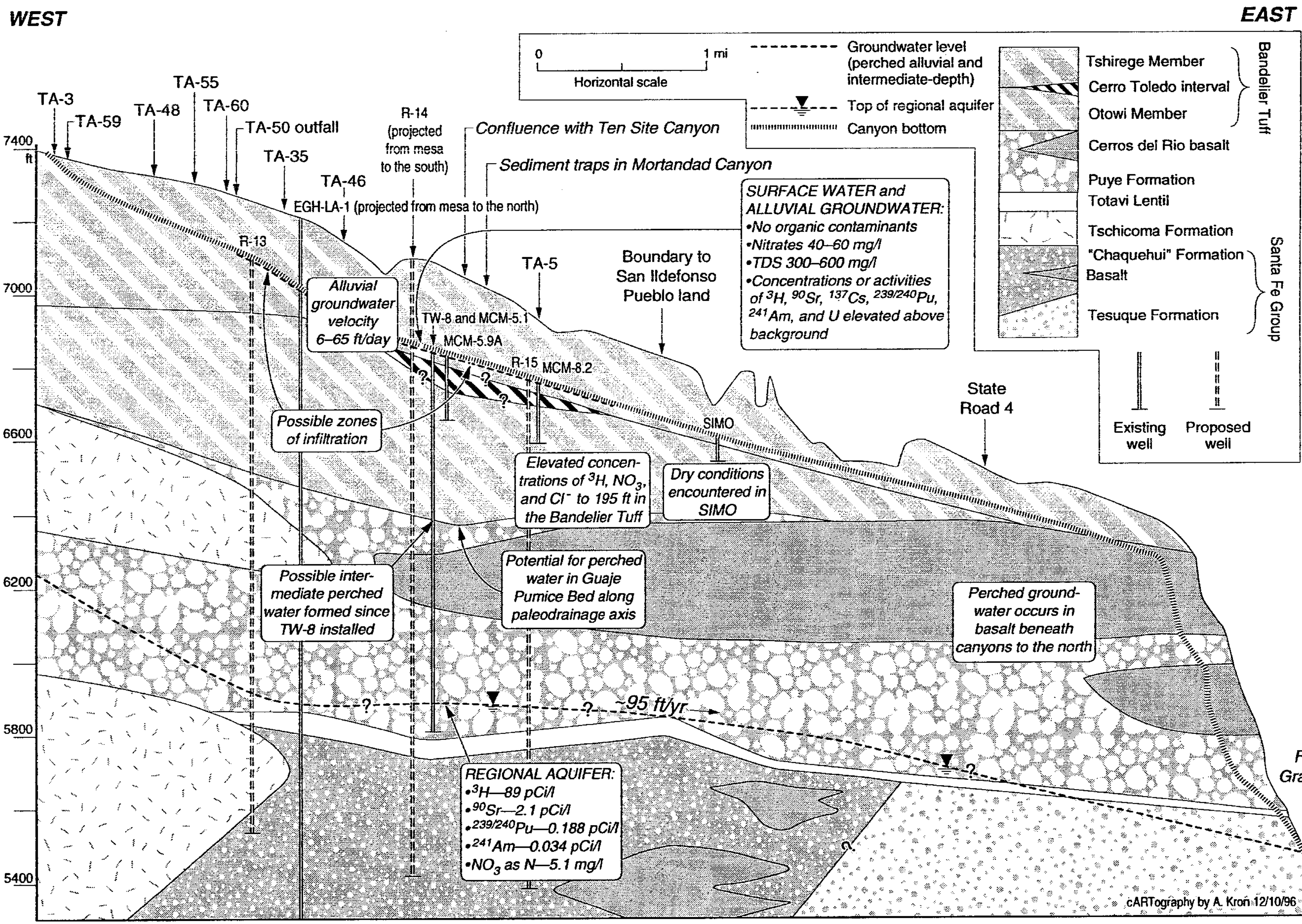


Figure 4-31. Schematic cross section showing conceptual model and proposed regional aquifer wells for Mortandad Canyon.

Two water balance studies in Mortandad Canyon were based on the same observations but used different methodologies. Purtymun (1977) estimated average annual infiltration of surface water ranged from 64,000 to 150,000 m^3 of water per year from 1963 through 1974. Koenig and McLin (1993) estimated total infiltration of 177,000 m^3 for a two-year period from 1963 to 1965. Whereas Purtymun (1977) concluded that most of the infiltration occurred in the upper and middle canyon, Koenig and McLin (1993) concluded that more of the surface water loss occurred near the sediment traps.

Purtymun estimates the annual surface water loss in Mortandad Canyon to be "about the same volume that entered the canyon each year." Regarding the mechanisms of loss, he says "The losses attributed to evapotranspiration were estimated at about 15%..." (of the total loss) "with infiltration accounting for the remainder".

Assuming that Purtymun's values can be divided in half for 1963 and 1965 to represent the latter and first halves of these years, a rough approximation of 244,500 m^3 comes from his values for this time period.

Alluvial Groundwater Investigations

One well, A-29, is proposed for installation in this aggregate (see Figure 4-1). The location of this well will be in Ten Site Canyon which drains into Mortandad Canyon. The purpose of this well will be to investigate the occurrence and quality of alluvial water in Ten Site Canyon, and evaluate the types of contaminants that may be contributed to Mortandad Canyon.

There are no new data needs for the alluvial groundwater in Mortandad Canyon because of the extensive network of existing alluvial wells and the long history of previous investigations.

Intermediate Perched Zones and Regional Aquifer

Water that infiltrates beneath the alluvium may form an intermediate perched water body in the underlying geologic units. No intermediate perched water was reported during drilling of test well TW-8 in 1960, but this borehole was completed 3 years before the TA-50 Radioactive Liquid Waste Treatment Facility began releasing effluent to the canyon. Based on the water balance studies of Purtymun (1977) and Koenig and McLin (1993), recharge from the alluvial system may have been sufficient to cause intermediate perched groundwater bodies to form.

Alluvial groundwater may infiltrate directly to the regional aquifer based on data from the Laboratory's Surveillance Program. Regional aquifer water from test well TW-8 contains elevated activities or concentrations of tritium. Nitrate, strontium-90, and plutonium-239/240 were detected in one sample. Recharge pathways to the regional aquifer may include flow through the porous rock matrix and fracture flow or leakage along the ungrouted annular space of TW-8.

Depth to the regional aquifer is known at TW-8 in Mortandad Canyon. Water level measurements taken in December 1993 show the depth to water to be 993 ft (EPG 1996). Based on Laboratory water-level maps, the general direction of groundwater flow in the regional aquifer is almost due east in this part of the Laboratory (see Figure 2-10).

Intermediate Perched Zone and Regional Aquifer Groundwater Investigations

Three wells are proposed for this aggregate to investigate the possible occurrence of intermediate perched zones below Mortandad Canyon. These wells will also be used to investigate the nature and extent of contaminant distribution and evaluate possible regional aquifer contamination pathways. The wells are R-13, R-14, and R-15 (see Figure 4-2).

Well R-13 will be located down gradient of the TA-50 outfall where the alluvial sediments are relatively thin. The purpose of this well will be to provide water-quality and water-level data for potential perched groundwater systems and for the regional aquifer within Aggregate 7. Well R-13 will be located near alluvial well MCO-4 which contains elevated concentrations or activities of NO_3, tritium, strontium-90, cesium-137, plutonium-238, plutonium-239,240 and americium-241 (EPG 1996). Well R-13 will be completed in the Puye Formation and will supplement the stratigraphic, hydrologic, and geochemical data obtained from R-14 and R-15. A more detailed analysis of well placement in Mortandad Canyon will be included in the ER sample and analysis plan that will be prepared in FY-97.

Well R-14 will be located on Mortandad Mesa. The primary purpose of well R-14 is to provide early detection of contaminants at the top of the regional aquifer moving toward water supply well PM-5, which is down gradient of Mortandad Canyon. However, its location will also provide additional information about the nature and extent of perched water bodies in aggregate 7.

Well R-15 will be located at the easternmost extension of the sediment traps in Mortandad Canyon. The purpose of this well will be to investigate for intermediate perched zones at this location where Koenig and McLin (1993) suggest rates of infiltration are high. Sampling of the R-15 borehole and the completed well will provide contaminant distribution data for ER investigations of Mortandad Canyon.

4.3.8 Aggregate 8

Table 4-10 lists the alluvial and regional aquifer wells proposed for installation in Aggregate 8. The rationale for these wells and the uncertainties they address are described below. Additional information about the rationale for the regional aquifer wells is given in Table 4-1. Figures 4-1 and 4-2 show the general proposed well locations. Appendix 6 provides large-scale maps with proposed well location plotted along with existing wells for reference.

Table 4-10. Summary of Potential Wells in Aggregate 8

Canyon or Mesa	*Alluvial Wells/Piezometer Transects (all ER)*[1]	*Regional Aquifer Wells*
Rendija Canyon		R-1 (NWT)[2]

[1] Funded through Environmental Restoration Project
[2] Funded through Nuclear Weapons Technology Program

4.3.8.1 Area Description and History

Aggregate 8 is located in the northeast part of the Laboratory with the largest area of the aggregate on Santa Fe National Forest land (see Figure 1-3 and 4-32). It is bounded by, and includes within its boundaries, Rendija Canyon on the north, Bayo Canyon on the south, the confluence with Cabra Canyon on the west, and the Laboratory boundary on the east. The boundaries of Aggregate 8 were drawn to encompass canyons which are part of the ER Project Canyons investigations and may be sources of recharge for groundwater in the northern portion of the Laboratory.

The discussion of this aggregate includes Rendija, Guaje, Barrancas, and Bayo Canyons. Portions of two technical areas, one active and one inactive, also fall within the boundaries of Aggregate 8.

- TA-74 was established in 1989 when the Laboratory redefined the technical area boundaries. This area is primarily a buffer zone for the laboratory, and has not been used for any Laboratory operations. It contains no PRSs.
- Former TA-10 was operated in Bayo Canyon from 1944 to 1963. It consisted of a liquid waste disposal complex for the radiochemistry laboratory. PRSs at this site are located one mile west of the Bayo treatment plant. TA-10 underwent decontamination and decommissioning in 1963 (LANL 1990). A large amount of surface material was excavated during 1963, up to 18.6 ft in depth, but ongoing ER investigations show elevated levels of strontium-90 in the surface material, canyon alluvium, and underlying tuff.

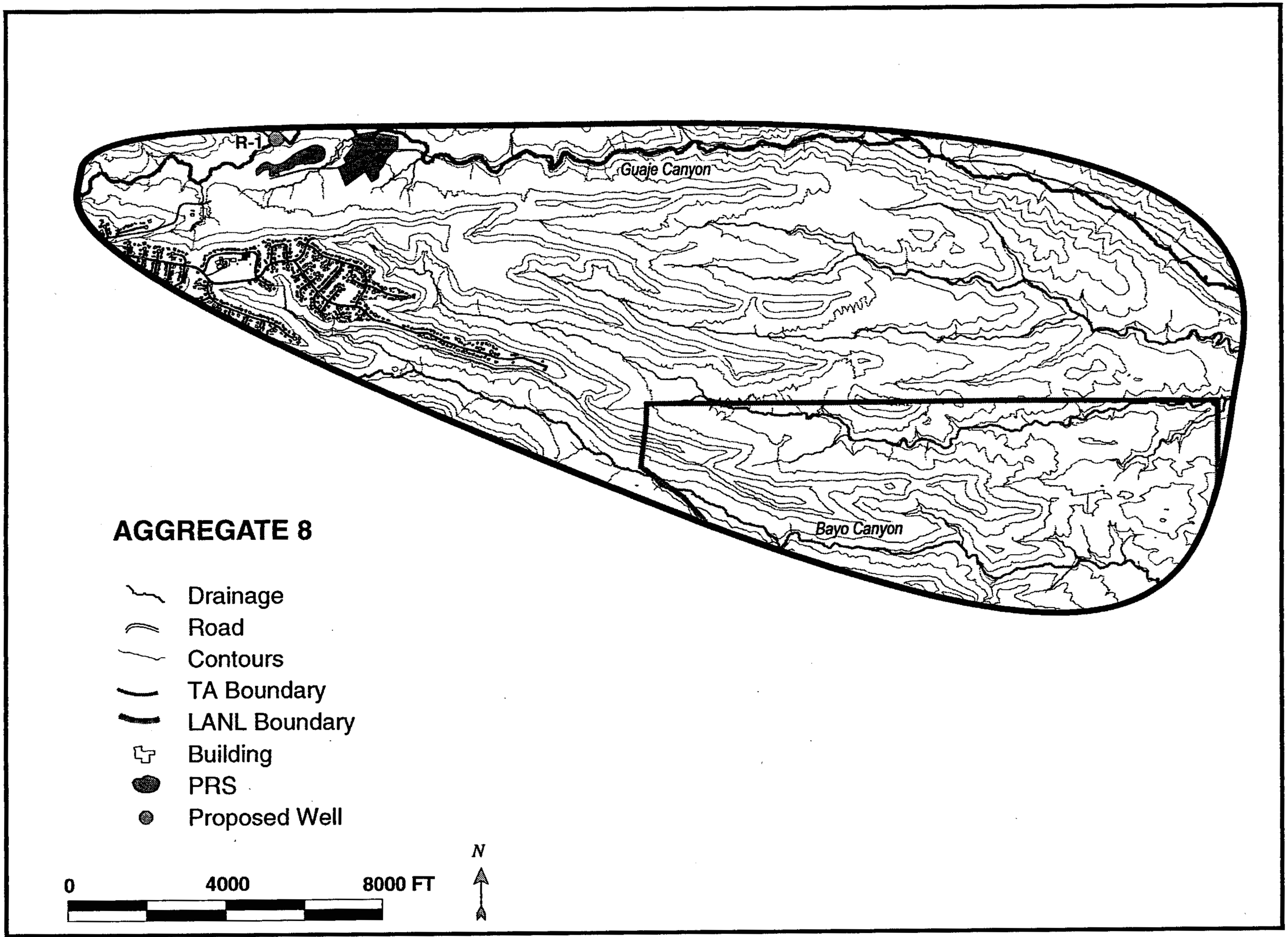


Figure 4-32. PRSs and proposed wells in Aggregate 8.

A number of potential release sites are located in Rendija Canyon, which is Los Alamos County land. Three are near the Guaje Pines Cemetery and include an inactive small arms firing range, an asphalt batch plant, and an ordinance impact area. Four ordinance impact areas are located in the middle reach of Rendija Canyon near Cabra Canyon. More detailed information on these areas can be found in the RFI Work Plans for Operable Units 1079 (LANL 1992a), and 1071 (LANL 1992g), and the Solid Waste Management Units Report (LANL 1990).

4.3.8.2 Guaje Canyon

Surface Water

On a regional scale, Guaje Canyon contains an interrupted stream. It has a perennial reach extending from springs located upstream of Guaje Reservoir to some distance downstream of the reservoir and an intermittent reach downstream to the confluence with lower Los Alamos Canyon. Snowmelt runoff does not reach the Rio Grande.

Guaje Canyon is not located within Laboratory boundaries. However, the facilities of the Guaje water supply well field, which provide a portion of the water supply to the Laboratory and to Los Alamos County, are located within Guaje Canyon and lower Rendija Canyon. Guaje Canyon crosses San Ildefonso Pueblo land and continues to its confluence with lower Los Alamos Canyon approximately a mile west of the Rio Grande. Guaje Canyon and Rendija Canyon are crossed by at least two fault zones: the Guaje Mountain fault and the Rendija Canyon fault.

Alluvial Groundwater

Only two alluvial wells have been installed in Guaje Canyon to investigate the presence of alluvial groundwater. These wells were completed in the perennial reach of the canyon and alluvial groundwater was encountered near the stream level (Davis et al. 1996).

Within Guaje Canyon, it is not known if saturated conditions were encountered in the alluvium during drilling of the supply wells based on review of the Guaje test and production well logs. It is possible that saturated flow conditions occur seasonally within lower Guaje Canyon near its confluence with lower Los Alamos Canyon.

Alluvial Groundwater Investigations

One alluvial well, A-1, is proposed for lower Guaje Canyon, just above it's confluence with Los Alamos Canyon. The purpose of this well is to investigate the presence of alluvial groundwater in this part of the canyon and estimate the quantity and quality contributed to Los Alamos Canyon.

Intermediate Perched Zones and Regional Aquifer

Because of a lack of subsurface information in this area, it is not known if intermediate perched zones occur within Guaje Canyon. If intermediate perched zones exist, they may be similar to those in Pueblo and Los Alamos Canyons. In these canyons, perched water occurs within the Guaje Pumice Bed, the Puye Formation, and Cerros del Rio basalts.

The regional aquifer occurs in the Puye Formation and the Santa Fe Group in vicinity of Aggregate 8. The regional aquifer probably includes rocks of the Tschicoma Formation in the western part of the aggregate. Depths to groundwater within the regional aquifer measured at the Guaje well field range from 230 ft (G-1) to 572 ft (G-6, Rendija Canyon) (Purtymun 1995). Based on Laboratory water-level maps, the general groundwater flow direction is southeast in this area (see Figure 2-10).

As described in Section 2 of this Workplan, the water supply wells in the Guaje Well Field produce from the mid-Miocene high-permeability zone described by Purtymun (1995). Contaminants of concern, related to Laboratory activities, generally have not been identified in samples from this well field. However, concentrations of arsenic (0.0427 mg/L) have been detected in samples from G-2 (US EPA maximum contaminant level is 0.050 mg/L) (EPG 1996). The elevated arsenic concentrations probably represent natural conditions because there are no known anthropogenic sources in Guaje Canyon. It is possible that long-term pumping of G-2 has captured groundwater of poorer quality at greater depths within the regional aquifer. Another possibility is that the operation of the pump in well G-2 may cause changes in pH, partial pressure of CO_2 gas, and oxidation-reduction conditions, all of which influence desorption of arsenic from aquifer material within the Santa Fe Group.

Intermediate Perched Zone and Regional Aquifer Groundwater Investigations

No regional aquifer wells have been identified in this Workplan for installation in Guaje Canyon. However, DOE is supporting the construction of four replacement water supply wells for the Guaje and Otowi well fields in FY98 and FY99. These wells will provide stratigraphic and hydrologic data that supplement the site-wide information being collected as part of this Workplan.

4.3.8.3 Rendija Canyon

Surface Water

Rendija Canyon heads on the flanks of the Sierra de Los Valles on Santa Fe National Forest land. It contains an ephemeral stream with no springs or perennial reaches. Snowmelt runoff does not reach the Rio Grande.

Alluvial Groundwater

The occurrence of alluvial groundwater in Rendija Canyon is not well documented. There have been no alluvial wells installed in this Canyon.

Alluvial Groundwater Investigations

No alluvial groundwater investigations are proposed for Rendija Canyon in this workplan.

Intermediate Perched Zones and Regional Aquifer

Because of a lack of subsurface information in this area, it is not known if intermediate perched zones occur within Rendija Canyon.

Intermediate Perched Zone and Regional Aquifer Groundwater Investigations

One regional aquifer well, R-1, has been proposed within this aggregate. It will be located at the confluence with Cabra Canyon (see Figure 4-2). The primary objectives of this well are: to serve as a stratigraphic reference for the poorly characterized northern portion of the Laboratory; to constrain the northern boundary of the mid-Miocene high permeability zone; to test hypotheses concerning recharge of the regional aquifer from the north; and to provide information on the direction of groundwater flow in the regional aquifer.

4.3.8.4 Barrancas Canyon

Surface Water

Barrancas Canyon heads on the Pajarito Plateau on land owned by Los Alamos County and extends southeast and east to its confluence with Guaje Canyon. Barrancas Canyon drains a portion of the northeast part of Los Alamos County. Surface water flow in Barrancas Canyon is ephemeral and intermittent. There are no springs in the vicinity. Stream loss caused by infiltration into the underlying alluvium and evapotranspiration typically prevents surface flow from discharging to Guaje Canyon. On the mesa tops, surface water occurs as storm water runoff or as spring snowmelt.

Alluvial Groundwater

Surface water occurring in ephemeral reaches within Barrancas Canyon potentially creates a saturated zone of variable thickness and length within the alluvium.

Alluvial Groundwater Investigations

No alluvial groundwater investigations are proposed for Barrancas Canyon in this workplan.

Intermediate Perched Zones and Regional Aquifer

Because of a lack of subsurface information in this area, it is not known if intermediate perched zones occur within Barrancas Canyon.

Intermediate Perched Zone and Regional Aquifer Groundwater Investigations

No regional aquifer wells are proposed for this canyon in this workplan.

4.3.8.5 Bayo Canyon

Surface Water

Bayo Canyon heads on the Pajarito Plateau on land owned by Los Alamos County and extends across the northeast portion of the Laboratory (TA-74), crosses San Ildefonso Pueblo land to the east, and terminates at its confluence with lower Los Alamos Canyon near Totavi. Surface water flow in Bayo Canyon is ephemeral and intermittent and there are no springs in the vicinity. Stream loss caused by infiltration into the underlying alluvium and evapotranspiration typically prevents surface flow from discharging to Los Alamos Canyon. On the mesa tops, surface water occurs as storm water runoff or as spring snowmelt (LANL 1996b).

Alluvial Groundwater

Surface water occurring in ephemeral reaches within Bayo Canyon potentially creates a saturated zone of variable thickness and length within the alluvium. However, approximately 90 boreholes were drilled in former TA-10 within Bayo Canyon and alluvial water was not encountered at the site. However, elevated levels of strontium-90 were encountered in the alluvium and underlying Bandelier Tuff during the drilling (LANL 1992a), suggesting that infiltration occurs in this part of the canyon.

Alluvial Groundwater Investigations

No alluvial groundwater investigations are proposed for Bayo Canyon in this workplan.

Intermediate Perched Zones and Regional Aquifer

Because of a lack of subsurface information in this area, it is not known if intermediate perched zones occur within Bayo Canyon.

Intermediate Perched Zone and Regional Aquifer Groundwater Investigations

No regional aquifer wells are proposed for this canyon in this workplan.

5.0 SUMMARY AND IMPACTS ON FUTURE ACTIVITIES

The objectives of the activities described in this Workplan are to address the four issues raised in the NMED correspondence dated August 17, 1995 (Appendix 2) as discussed in Section 1 of this Workplan, and to provide answers to the following three questions:

> Is characterization of the hydrogeologic system beneath Los Alamos National Laboratory adequate to determine where uppermost subsurface water, alluvial groundwater, intermediate perched zone groundwater, or regional aquifer groundwater exists and whether concentrations of contaminants in alluvial groundwater, intermediate perched zone groundwater or regional aquifer groundwater exceed regulatory limits or risk levels?;
>
> Is the characterization information sufficient either to establish detection monitoring programs pursuant to 40 CFR 264.91-100 for regulated units or to demonstrate that groundwater monitoring requirements could be waived, or to provide appropriate groundwater monitoring as part of corrective actions pursuant to 40 CFR 264.101 for Solid Waste Management Units that have been determined to have had a release that is a threat to human health or the environment?; and
>
> Is the characterization information sufficient to satisfy the conditions of the Hazardous and Solid Waste Amendments (HSWA) portion of the Laboratory's Resource Conservation and Recovery Act (RCRA) operating permit?

The Data Quality Objectives (DQO) Process was applied to the development of this Workplan in order to identify the data needs that must be fulfilled to answer these questions and address the four NMED issues. As the Workplan is implemented, the DQO Process will continue to be applied as new data become available to ensure that the right data necessary to make decisions is being collected. This iterative application of the DQO Process will form the basis for annual renegotiation of the scope and schedule of the Workplan implementation with NMED.

The information required to address the NMED issues and to answer the above questions results from the activities described under Information Interpretation and Management (Section 3) and Hydrogeologic Characterization (Section 4). These activities are interactive and iterative, each providing input and using outputs.

All hydrogeologic characterization activities and ER Project RFI activities will produce data that will be stored and managed by the information management system described in Section 3. The information management system will be the principle source of input to the modeling tasks described in Section 4. As more data becomes available, modeling results will be refined. The combination of modeling, information management, and ER Project investigations (indicative of where monitoring may or may not be needed) will be used to enhance the groundwater monitoring program and/or demonstrate that monitoring requirements can be waived. If the modeling activities suggest that different kinds of data or data from different locations are necessary to adequately define groundwater flow or contaminant transport, then data collection will be modified.

The expected outcomes of the activities described in this Workplan are:

- Refined understanding of the hydrogeologic framework at the facility, including recharge areas, hydraulic interconnections, flow paths, and flow rates, synthesized by modeling simulations;

- Information sufficient either to design and implement a detection monitoring program that meets applicable requirements and/or to demonstrate that monitoring requirements can be waived; and

- Defined areas of existing or potential groundwater contamination, and the potential pathways of contaminant transport from the surface to the regional aquifer, with predictions of directions and rates of movement and risk based on modeling simulations.

If it is determined, as a result of this characterization effort, that enhanced groundwater monitoring is necessary, an inter-disciplinary Laboratory group will develop a proposed amendment to the Groundwater Monitoring Plan that will be reviewed and endorsed by the Technical Review Committee (TRC) prior to submittal to the appropriate regulatory agency(ies).

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7.0 GLOSSARY

Adsorption	Adherence of molecules, ions, or water to the surfaces of soil or mineral particles with which they are in contact.
Aggregate	One of eight specific areas encompassing geographic groupings of PRSs or areas of similar operational functions for the purpose of groundwater characterization and remediation and remediation of potential sources of groundwater contamination.
Air-rotary	A drilling method in which air is used in place of other types of drilling fluids for the purpose of cooling the drill bit and removing the cuttings.
Alluvial	Pertaining to or composed of alluvium (clay, silt, sand, gravel, or similar unconsolidated detrital material deposited during comparatively recent geologic time by a stream or other body of running water as a sorted or semi-sorted sediment in the bed of the stream), or deposited by a stream or running water.
Alluvial Perched Groundwater	This term is used to refer to the localized bodies of shallow groundwater that occur in the alluvial materials in the bottoms of the canyons cutting across the Pajarito Plateau. The alluvial is typically from 10 or 20 feet to over 100 feet wide and from 10 to 40 or more feet thick. The water in the alluvium is perched on the underlying tuff or basalt and has a surface that fluctuates in elevation as a direct response to input or loss from stream channels. None of the water in the canyons within the Laboratory is used for municipal, industrial, or agricultural supply.
Alternative Concentration Limit	Alternative concentration limits will be proposed by LANL to NMED when current methods of establishing RCRA concentration limits are not appropriate to the specific water use to be protected.
Anemometry	Specifically borehole anemometry. A test of the permeability of the geologic formation or formations involving the placement of packers within the borehole to isolate specific sections and the pumping of air into the section.
Annulus	The space between the casing placed in the center of a borehole and borehole wall.
Anthropogenic	Of, relating to, or resulting from the influence of human beings on nature.
Aquifer	A body of rock that contains sufficient saturated permeable material to conduct water to yield economically significant quantities of water to wells and springs.
Aquifer Test	A test involving the withdrawal of measured quantities of water from, or addition of water to, a well and the measurement of resulting changes in hydraulic head in the aquifer both during and after the period of discharge or addition.
Aquitard	A confining geologic bed that retards but does not prevent the flow of water to or from an adjacent aquifer. It does not readily yield water to wells or springs, but may serve as a storage unit for groundwater.
Aquiclude	A body of relatively impermeable rock that is capable of absorbing water slowly but does not transmit it rapidly enough to supply a well or spring.
Background	The abundance of an element, or any chemical property of a naturally occurring material, in an area in which the concentration is not anomalous.

Bentonite	A colloidal clay, largely made up of the mineral sodium montmorillonite, which is used in the annuli of monitoring wells to form a seal between groundwater zones to prevent cross-contamination in the borehole.
Bollards	Short posts set in a series for the exclusion of vehicular traffic.
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980. Also known as Superfund, this law authorizes the federal government to respond directly to releases of hazardous substances that may endanger health or the environment. The EPA is responsible for managing Superfund.
CFR	Code of Federal Regulation. A codification of all regulations developed and finalized by federal government agencies in the *Federal Register.*
COC	Chain-of-Custody. A method for documenting the history and possession of a sample from the time of collection, through analysis and data reporting, to its final disposition.
Competent Layer	Synonymous with aquitard or aquiclude as used in the Hydrogeologic Workplan
Conceptual Model	A working hypothesis or precise simulation, by means of description, statistical data, or analogy, of a phenomenon or process that cannot be or is difficult to observe directly.
Confluence	A place of meeting of two or more streams; the point where the tributary joins the main stream.
Contaminant Plume	The extent in a localized area, described in three-dimensional space, of substances or properties preventing the use or reducing the usability of groundwater for ordinary purposes.
Contamination	The deposition of unwanted radioactive or hazardous material on the surface of structures, areas, objects, or personnel.
Continuous Stream	A stream that does not have interruption in space; it may be perennial, intermittent, or ephemeral, but it does not have wet and dry reaches.
Controlled Area	Any Laboratory area to which access is controlled to protect individuals from exposure to radiation and radioactive materials.
Core Sample	A cylindrical section of rock or soil obtained while drilling and brought to the surface for geologic examination and/or laboratory analysis.
Cutting Sample	Soil or rock chips cut by the drilling tool or augers, brought to the surface, and collected for geologic examination and/or laboratory analysis.
Desorption	The release of molecules, ions, or water from the surfaces of soil or mineral particles to which they are attached.
Direct Runoff	The surface runoff that enters stream channels immediately after rainfall or snowmelt.
DOE	U.S. Department of Energy. The federal agency that sponsors energy research and regulates nuclear materials used for weapons production.
DOE-OB	DOE-Oversight Bureau. Formerly the NMED-AIP. A bureau within the New Mexico Environment Department, funded by the DOE, and dedicated to overseeing environmentally related activities at DOE facilities
Downstream	Toward, at, or from a point near the mouth of a stream; in a direction toward which a stream is flowing.

EA	Environmental Assessment. A report that identifies potentially significant environmental impacts from any federally approved or funded project that may change the physical environment. If an EA shows significant impact, an Environmental Impact Statement is required.
Effluent	A liquid that has been treated to some degree and discharged as a waste, such as water from a factory or the outflow from a sewage works; water discharged from a storm sewer or from land after irrigation.
EIS	Environmental Impact Statement. A detailed report, required by federal law, on the significant environmental impacts that proposed major federal action would have on the environment. An EIS must be prepared by a government agency when a major federal action that will have significant environmental impacts is planned.
Environmental Surveillance	The collection and analysis of samples of air, water, soil, foodstuffs, biota, and other media to determine environmental quality of an industry or community. It is commonly performed at nuclear facilities.
EPA	Environmental Protection Agency. The federal agency responsible for enforcing environmental laws. Although state regulatory agencies may be authorized to administer some of this responsibility, EPA retains oversight authority to ensure protection of human health and the environment.
Ephemeral Stream	A stream or reach of a stream that flows briefly in direct response to precipitation or snowmelt in the immediate locality; its channel bed is always above the water table of the region adjoining the stream.
Evapotranspiration	The loss of water from a land area through the transpiration of plants and evaporation from the soil and surface-water bodies.
Exposure Pathways	The means by which organisms may be open to harmful agents, i.e. respiration, skin contact, ingestion, etc.
Extrapolate	To estimate the value of a variable based on at least two known values on only one side of the unknown variable.
Fanglomerate	A sedimentary rock consisting of slightly water-worn, heterogeneous fragments of all sized, deposited in an alluvial fan and later cemented into firm rock.
Field Screening	Selecting samples for analysis while at an area of investigation, either by direct observation or by using portable instrumentation.
Flow	Relative to streams, it is natural flow ensuing from the earth's hydrologic cycle, i.e., atmospheric precipitation resulting in surface and/or groundwater runoff. Natural in-stream flow may be interrupted or eliminated by dams and diversions.
Geologic Contacts	A plane or irregular surface between two types or ages of rocks.
Groundwater	That part of the subsurface water that is the zone of saturation, including underground streams.
Groundwater Runoff	The runoff that has entered the ground, become groundwater, and been discharged into a stream channel.

Grout	A fluid mixture of cement and water of a consistency that can be forced through a pipe to a predetermined height in a well annulus and, upon curing, form an annular seal that effectively segregates perched groundwater zones and prevents the well annulus from becoming a conduit for water migration.
Hazardous Waste	The specific substance in a hazardous waste that makes it hazardous and therefore subject to regulation under Subtitle C of RCRA. Wastes exhibiting any of the following characteristics: ignitability, corrosivity, reactivity, or EP-toxicity (yielding toxic constituents in a leaching test). In addition, EPA has listed as hazardous other wastes that do not necessarily exhibit these characteristics. Although the legal definition of hazardous waste is complex, the term more generally refers to any waste that EPA believes could pose a threat to human health and the environment if managed improperly. Resource Conservation and Recovery Act (RCRA) regulations set strict controls on the management of hazardous wastes.
Hollow Stem Auger	A drilling method employing hollow metal pipes equipped with hard-edged "flights" such as the whorls on a screw to remove cuttings from the borehole. Used primarily in unconsolidated material.
HSWA	Hazardous and Solid Waste Amendments of 1984 to RCRA. These amendments to RCRA greatly expand the scope of hazardous waste regulation. In HSWA, Congress directed EPA to take measures to further reduce the risks to human health and the environment caused by hazardous waster.
Hydraulic Conductivity	The rate of flow of water, i.e., permeability coefficient, through a cross section of geologic material one square foot under a unit hydraulic gradient.
Hydraulic Head	The height to which groundwater will rise in a monitoring well due to subsurface pressure.
Hydrologic Modeling	A working hypothesis or precise simulation, by means of description, statistical data, or analogy, of a phenomenon or process of natural water systems that cannot be or is difficult to observe directly.
Hydrologic Setting	The spatial and temporal occurrences of both surface and groundwater and the degree of interconnectedness and associated travel times within a defined region, e.g. the hydrologic setting of the Pajarito Plateau.
Hydrology	The science dealing with the properties, distribution, and circulation of natural water systems.
Intermittent Perched Groundwater	A subsurface zone of unconfined saturation that is present only at certain times of the year due to specific recharge phenomena.
Intermittent Stream	A stream or reach of a stream that flows only at certain times of the year, such as when it receives water flow from springs or some surface source, melting snow, or localized precipitation.
Interrupted Stream	A stream that contains perennial reaches with intervening intermittent or ephemeral reaches.
Legacy Source	Contamination or potential release sites incurred during the years the Laboratory was operating as part of the Manhattan Project and shortly after.
Lithology	The description of rocks, especially in hand specimen and in outcrop, on the basis of color, mineralogy, and grain size.

Maximum Contaminant Levels	Concentrations below which the threat to ecological systems or organisms have been determined to be non-hazardous.
Monitoring Well	A hole drilled into the ground to a sufficient depth that penetrates water-bearing soil or rock and completed with well casing and screen to allow formation water to enter the well. Used in field investigations for obtaining hydrologic data by allowing groundwater sampling and water level measurements.
Mud-Rotary	A drilling method in which drilling fluid or "mud" is forced into the borehole for the purpose of cooling the drill bit and removing the cuttings. Used primarily when drilling deep wells in consolidated materials.
Nephelometric Turbidity Units	A unit of measurement used to describe the amount of suspended or slow-settling material in a liquid.
NPDES	National Pollutant Discharge Elimination System. This federal regulation, under the Clean Water Act, requires permits for discharges into surface waterways.
Outfall	The vent or end of a drain, pipe, sewer, ditch, or other conduit that carries waste water, sewage, storm runoff, or other effluent into a stream.
Packer	A short expansible-retractable device set in a cased or uncased borehole to prevent vertical fluid movement.
Pedogenesis	The mode of soil origin referring to the development from parent materials.
Perched Groundwater	Unconfined groundwater separated from an underlying main body of groundwater by an unsaturated zone. Perched groundwater most typically forms over a perching bed; that is a body of rock, usually stratiform, with a permeability sufficiently low that the perched water does not readily permeate.
Perennial Stream	A stream or reach of a stream that flows continuously throughout the year in all years. Its upper surface, in general, is lower than the water table of the region adjoining the stream.
Photoionization Detector	A portable instrument used in field screening for volatile organic compounds.
Piezometric Surface	This is also called potentiometric surface. This is the level to which water will rise in a well tightly cased into an aquifer.
QA	Quality assurance. The routine application of procedures within environmental monitoring and measurement to obtain required standards of performance. QA procedures include calibration of instruments, control charts, and analysis of replicate and duplicate samples.
RCRA	Resource Conservation and Recovery Act of 1976. RCRA is an amendment to the first federal solid waste legislation, the Solid Waste Disposal Act of 1965. In RCRA, Congress established initial directives and guidelines for EPA to regulate hazardous wastes.
Recharge	The absorption and addition of water to the zone(s) of saturation, due primarily to precipitation.
Regional Aquifer	The main body of groundwater which underlies the Los Alamos area and has surface expression in the Rio Grande River.
Runoff	That part of precipitation appearing in surface streams. It is more restrictive than streamflow as it does not include stream channels affected by artificial diversions, storage, or other works of man.

SARA	Superfund Amendments and Reauthorization Act of 1986. This act modifies and re-authorizes CERCLA. Title II of this act is also know as the Emergency Planning and Community Right-to-Know Act of 1986.
Snowmelt	The water resulting from the melting of snow.
Split-Spoon Sampler	A hollow soil sampling tube that is driven into the bottom of a borehole by a weighted hammer thus lodging the sample within the tube. The ends of the tube unscrew, allowing the rest of the tube to open along its axis to reveal the sample.
Stable Isotope Geochemistry	A study of the distribution and amounts of non-spontaneously radioactive substances in rocks, soils, water and the atmosphere.
Static Water Level	The hydraulic head of a well that is not affected by withdrawal of groundwater.
Stratification	The formation, accumulation, or deposition of material in layers; the arrangement or disposition of sedimentary rocks in layers.
Stratigraphic Cross Section	A "cut away" diagram showing an extrapolation of the subsurface geology, hydrology and tectonic features based on data obtained during subsurface exploratory methods such as drilling a borehole or using seismic geophysics.
Stream Channel	The hollow bed where a natural stream of water runs or may run; the long, narrow, sloping trough-like depression shaped by the concentrated flow of a stream and covered continuously or periodically by water.
Streamflow	A type of channel flow applied to that part of surface runoff traveling in a stream, whether or not diversion or regulation affects it.
Subsurface Water	Water in the lithosphere in solid, liquid, or gaseous form; includes all water beneath the land surface and beneath bodies of surface water.
Surface Runoff	The runoff that travels over the soil surface to the nearest surface stream; runoff that has not passed beneath the surface since precipitation.
Surging	Forcing water into and out of a monitoring well by operating a plunger up and down in the well casing.
Suspended Sediment	Particles that are mixed with but undissolved in a fluid.
SWMU	Solid Waste Management Unit. Any discernible unit at which solid wastes have been placed at any time, irrespective of whether the unit was intended for the management of solid or hazardous waste. Such units include any area at or around a facility at which solid wastes have been routinely and systematically released. Potential release sites include, for example, waste tanks, septic tanks, firing sites, burn sites, sumps, land fills (material disposal areas), outfall area, LANL canyons, and contaminated areas resulting from leaking product storage tanks (including petroleum).
Tephra	A general term for all particles ejected during a volcanic eruption.
Transducer	A device that is actuated by power from on system and supplies power, usually in another form, to a second system.
Transect	A linear sampling area chosen for studying a particular environmental problem.
Tremied	Placed in the annulus through a down-borehole pipe to prevent bridging (air pockets occurring in the annular pack).

Tritium	^3H. A radionuclide of hydrogen with a half-life of 12.3 years. The very low energy of its radioactivity decay makes it one of the least hazardous radionuclides.
Tuff	Rock of compacted volcanic ash and dust.
Vadose Zone	Unsaturated zone or zone of aeration. The partially saturated or unsaturated region above the water table that does not yield water to wells. Water and/or gases contained are usually under less than atmospheric pressure.
Vapor-Phase Contaminant Transport	Movement of a contamination plume while in a gaseous state.
Vesicle	A cavity of variable shape in a rock formed by the entrapment of a gas bubble during solidification from lava.
Water Balance	An accounting of the inflow to, outflow from, and storage in a hydrologic unit such as a drainage basin or aquifer.
Water Rights	New Mexico water law is based on the doctrine of prior appropriation, and the rights to use water are established through the State Engineer's Office.
Water Table	The water level surface below the ground at which the unsaturated zone ends and the saturated zone begins. It is the level to which a well is screened in the unconfined aquifer and would fill with water.
Water Year	October through September.
Watershed	The region drained by, or contributing waters to, a stream, lake or other body of water and separated from adjacent drainage areas by a ridge or summit of high ground.
Well Log	A graphic record of the observed, measured, or computed physical characteristics of the rock section encountered in a well, plotted as a continuous function of depth.
Wetland	A lowland area, such as a marsh or swamp, that is inundated or saturated by surface water or groundwater sufficient to support hydrophilic vegetation typically adapted for life in saturated soils.

APPENDIX 1

NMED Letter to DOE/LAAO, May 30, 1995

State of New Mexico
ENVIRONMENT DEPARTMENT
Hazardous & Radioactive Materials Bureau
525 Camino De Los Marquez
P.O. Box 26110
Santa Fe, New Mexico 87502
(505) 827-4358
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GARY E. JOHNSON
GOVERNOR

MARK E. WEIDLER
SECRETARY

EDGAR T. THORNTON, III
DEPUTY SECRETARY

CERTIFIED MAIL
RETURN RECEIPT REQUESTED

May 30, 1995

Mr. Larry Kirkman,
Acting Area Manager
Department of Energy
Los Alamos Area Office
528 35 Street
Los Alamos, New Mexico 87545

RE: Denial of the Los Alamos National Laboratory's Ground-Water Monitoring Waiver Requests

Dear Mr. Kirkman:

As stated in the New Mexico Environment Department's (NMED's) May 5, 1994 letter regarding ground-water monitoring waiver documentation, NMED deferred a decision regarding ground-water monitoring waivers pending reevaluation of the hydrogeologic conditions beneath the facility and consideration of new ground-water data. Closure plans for the below named units have been submitted to NMED for closure under 20 NMAC 4.1, Subpart VI, 40 CFR 265 Subpart G:

TA-54 Areas G & L (March, 1987)
TA-16 Surface Impoundment & Area P Landfill (December, 1987)
TA-35-125 & 85 Surface Impoundments (March, 1989)
TA-53 Surface Impoundments (1992)

Through evaluation of the submitted supporting documentation, NMED has determined that the information provided does not fulfill Part 265 standards. This letter serves to document the bases for regulatory denial of ground-water monitoring waiver proposals [20 NMAC 4.1 Subpart VI, 40 CFR 265.90] as submitted by Los Alamos National Laboratory (LANL) to NMED. General technical rationale, specific waiver requests, and reasons for denial of the ground-water monitoring waivers are provided in the enclosed Attachment.

Because these demonstrations, have not met the technical standards necessary for approval of ground-water monitoring waivers at the sites listed above, ground-water monitoring program plans will be required for LANL to be in compliance with 20 NMAC Subpart VI, 40 CFR 265 Subpart F regulations.

Although NMED does not relinquish any of New Mexico's regulatory or statutory authorities, these denials do not require immediate submittal of ground-water monitoring program plans for each closure. Instead, in light of DOE/LANLs budgetary constraints, a comprehensive ground-water monitoring program plan should be developed which addresses both site-specific and site-wide ground-water monitoring objectives. This may be achieved by modifying the existing site-wide Groundwater Protection Management Program Plan, Revision 1.0, March 6, 1995 to include regulatory site-specific considerations. NMED intends to coordinate with DOE/LANL in this site-wide approach. If DOE or LANL staff wish to discuss this issue, please contact Ronald Kern, manager of the RCRA Technical Compliance Program, to arrange a meeting. If you have any questions regarding this matter, please contact Ms. Lee Winn or Ms. Teri Davis of my staff at (505) 827-4308.

Sincerely,

Benito J. Garcia, Chief
Hazardous & Radioactive Materials Bureau

CC: Ron Kern, Manager, RCRA Technical Compliance Program
LANL 1995 Red File
Barbara Hoditscheck, Manager, RCRA Permitting Program
Neil Weber, DOE Oversight Bureau
Marcy Leavitt, Ground Water Protection & Remediation Bureau

File:WAIV.ERDE.NAL

ATTACHMENT

GENERAL TECHNICAL RATIONALE FOR DENIAL OF GROUND-WATER MONITORING WAIVERS

Los Alamos National Laboratory (LANL) has provided inadequate and incomplete information pertaining to the unsaturated and saturated conditions across the Parajito Plateau in support of ground-water monitoring waivers for the various RCRA-regulated units (TA-54 Area G & L, TA-16 Surface Impoundment & Area P Landfill, TA-35-125 & 85 Surface Impoundments, and TA-53 Surface Impoundments). Basic geology, hydrogeology, and pathways for contaminant transport have not been adequately addressed to date. Listed below are the general technical concerns of LANL, U.S. Environmental Protection Agency (EPA), and the New Mexico Environment Department (NMED) regarding the lack of understanding of the hydrogeologic system at this facility. These technical concerns and data gaps support denial of LANL's ground-water monitoring waiver requests.

1. LANL's Installation Work Plan Revision 3, November 1993

Within LANL's Installation Work Plan Revision 3, November 1993, specific data gaps were listed and data needs were identified explicitly throughout the environmental setting section of this document. These data gaps are relevant to the ground-water monitoring waiver issue. These are specifically:

- Absence of facility-wide geologic mapping . The lack of geologic mapping in the intervening areas causes the validity of the correlations to be uncertain. [section 2.6.1.2.9]

  "Stratigraphic features in the tuff, such as volcanic surge deposits, ***may locally provide a preferential migration pathway for moisture and contaminants in the subsurface*** [emphasis added] (Purtymun 1973, 0710; Crowe et al. 1978, 0041). Purtymun (1973, 0710) noted increased rates of vapor phase migration of tritium away from storage shafts at TA-54 along a stratigraphic boundary that includes surge layers. Individual flow units in the Tshirege Member contain vertical cooling joints that may or may not cross flow unit boundaries. In ash flow tuffs, cooling joints spacing varies primarily with the thickness of the unit, emplacement temperature, substrate temperature, and topography. Joint density tends to be greatest in welded tuff and least in non welded tuff. Hydraulic conductivities are generally greatest in the fractured, welded parts of ash flow tuffs and least in the non-welded parts (Crowe et al. 1978, 0041)."(Section 2.6.1.2.9, page 2-17).

- "Dransfield and Gardner (1985, 0082) integrated a variety of data to produce structure contour and paleogeologic maps of the pre Bandelier Tuff surface beneath the Pajarito Plateau. Their maps reveal that subsurface rock units are cut by a series of down-to-the-west normal faults: the overlying Bandelier Tuff is not obviously displaced by these buried faults. However, where detailed fracture studies have been done plateau, they have shown that fracture abundances and apertures increase in the Bandelier Tuff over fault projections, which indicates tectonic fracturing mentioned above (Vaniman and Wohletz 1990, 0541). In addition, small-scale offsets along fractures have been observed in various parts of the Laboratory, including ***Area G at TA-54*** [emphasis added] (Rogers 1977, 0216), that suggest additional unmapped fault zones. Unfortunately, detailed fracture studies on the Pajarito Plateau are few." (Section 2.6.1.4, page 2-19).

- "Perched water bodies occur in the conglomerates and basalts beneath the alluvium in the mid and lower reaches of Pueblo and Los Alamos canyons and in the lower reach of Sandia Canyon. Depth to perched water ranges from about 90 ft in the midreach of Pueblo Canyon to about 450 ft in lower Sandia. ***The vertical and lateral extent of the perched groundwaters, the nature and extent of perching units, and the potential for migration of perched water to the main aquifer is not fully understood by investigators to date.*** [emphasis added] " (Section 2.6.2.3.2, page 2-29).

2. LANL's Groundwater Protection Management Program Plan, 1995

Comments and Recommendations found in LANL's "Groundwater Protection Management Program Plan, Appendix I" - (March 6, 1995, Revision 1.0) identified numerous deficiencies in the conceptual hydrogeological understanding at LANL. Major concerns and recommendations are listed below:

Appendix I - Los Alamos National Laboratory E S & H Self-Assessment Report (August 91):

"Not enough is yet known about the fundamental processes controlling movement of water or contaminants through the unsaturated zone to completely understand whether contamination could ever reach the main aquifer." (3.2.4, par.2)

"Fundamental research is necessary in basic geology, unsaturated zone geology and hydrology, and saturated zone geology and hydrogeology." (3.2.4, par. 5)

"Basic Geology: Basic geology of the Laboratory area includes structural features, stratigraphy, fracture and fault zone (knowledge of both the Pajarito fault zone on the western margin of the plateau and the plateau itself where faults and fractures may control erosional patterns and potential infiltration zones are crucial to understanding ground water recharge). geomorphology, seismic history, and geochemistry. (3.2.4, 1st bullet)

"Saturated Zone Geology and Hydrology: Information on recharge of the main aquifer and lithology is incomplete; knowledge of the upper surface of the main aquifer, especi... ...ard the west, is incomplete; temporal variation of the ground water surface is not well described; information is lacking on vertical and horizontal permeability variation, horizontal and vertical pore-water velocities, pore-water flow gradients, extent of phreatic versus confined zones, geologic structure beneath the Bandelier tuff, spatial variations of natural ground water quality, and areal continuity of data." (3.2.4, 2nd bullet)

"Unsaturated or Vadose Zone Geology and Hydrology: Unsaturated hydrologic property measurements are lacking for the Otowi and Guaje Members of the Bandelier tuff, the Chino Mesa Basalts, the Puye conglomerate, and the unsaturated portions of the Santa Fe group sediments." (GW.2 Implementation of Ground Water Protection Programs)

Appendix I - Hydrogeologic Review for the Environmental Restoration Program at Los Alamos National Laboratory. LANL Hydrogeology Panel Final Report, Summary of Comments on Issues Identified by the Program:

"Issue 3: Do we know enough about the role of fractures?

"The panel is somewhat divided on this question. On one hand, some geologic evidence suggest that fractures lack connectivity over great depths and fractures may provide capillary barrier to unsaturated flow. On the other, roots and weathering patterns suggest that some fractures on the mesa tops may be preferential paths for infiltration. Our primary concern for liquid flow in fractures is in canyon bottoms where fractures in bedrock may intersect perched alluvial aquifers. There are few field data on the role of fractures, but there is also very little one can do to adequately and quantitatively characterize variably saturated fracture flow and transport coefficients. At small site scales, the role of fractures as transport pathways and their connections to regional pathway will likely have to be addressed for each site individually."

The above statement about the uncertainty of location and connection, and flow in fractures is important reasoning for requiring ground-water monitoring wells to detect releases.

"Issue 4: Can we defensibly model LANL hydrogeology using a porous continuum model?

"Much of the experimental and environmental monitoring data suggests that a porous media flow model would be appropriate. However, porous media models should be used to predict observed behavior in order to validate the model and to confirm the validity of the porous medial approach."

Because of fractures, cooling joints, faults, bedding planes, a porous media model seems flawed. The above statement, suggest the need for empirical data to confirm modeling information. The complexity of the vadose zone supports the rejection of porous media flow conceptual models presented in the ground-water monitoring waiver requests.

"Issue: 5: Are we sufficiently certain of ground water flow direction regionally that we can know ground water flow direction at a specific OU? Additionally, is there any reason to believe that there are local ground water gradients?

"Local effects undoubtedly occur near the well fields, and it is possible that small perturbations may occur in the main aquifer beneath perched aquifers or other potential recharge areas. Additional information is required to monitor horizontal and vertical pathways and to confirm sources of recharge. Mapping details of drawdown and "zones of capture" around the well fields would add to this knowledge base.

"Issue 6: Can we defensibly state there is no connection between any perched zones and the main aquifer?

"Existing data are insufficient to state that no perched water percolates to the main aquifer. In fact, recent work at Mortandad Canyon shows that vertical transport has occurred in the Bandelier Tuff to at least 150 ft (46m) beneath the perched alluvial aquifer. Little is known of vapor phase transport in these areas.

"Issue 8: Do we know enough that modeling as a homogeneous, steady state system adequately defines the system? Alternatively, do we know enough to model as a nonhomogeneous, transient system?

"Except for scoping calculations, field observations and model studies show that some degree of heterogeneity will need to be incorporated into the conceptual models of flow and transport in the vadose zone, in the perched aquifers, and in the main aquifer. Transient effects will need to be considered to simulate transport at least within perched alluvial aquifers, and in pumping scenarios for the main aquifer.

"Available data are scarce, and details of experimental procedures need to be published. A model study using existing sorption data underestimated observed radionuclide transport. Available data do not appear to be sufficient to defend ER objectives."

3. EPA Concerns

Major relevant EPA concerns, as documented in the March 16, 1994 Comprehensive Ground Water Monitoring Evaluation (CME), are expressed in the following questions:

1. "Has a ground water monitoring program (capable of determining the facility's impact on the quality of ground water in the uppermost aquifer underlying the facility) been implemented as per 40 CFR subparagraph 265.90? Uppermost aquifer means the geologic formation nearest the natural ground surface that is an aquifer as well

lower aquifers that are hydraulically interconnected with this aquifer within the facility's property boundary.

"No, the facility does not have a ground water monitoring program capable of determining all of the facility's impact on the uppermost aquifer. LANL has ground water monitoring waivers on file for each unit requiring ground water monitoring"

2. "Has the facility adequately identified the uppermost aquifer?

"No, based upon the reviewed documents, the uppermost aquifer has not been adequately characterized. Additional studies are required. Each ground water monitoring waiver needs to be evaluated to determine its appropriateness. If the ground water monitoring waiver does not meet the requirements of 40 CFR 265.90(c), LANL will be required to submit additional information or install ground water monitoring wells at each regulated unit."

4. State Concerns

In addition to the specific data gaps and needs described by LANL and EPA above, the state has additional concerns:

- Water-level contour maps presented in the submitted supporting ground-water monitoring waiver documentation are not adequate. The ground-water elevation data obtained from supply and test well data has been compiled together. It is generally not accepted practice to contour such data. The test wells are screened over short intervals (10 feet), presumably at the top of the aquifer, whereas the production wells are screened over much greater lengths (1500-2500 feet), starting typically hundreds of feet below the presumed top of the aquifer. Compiling such data may give a nonrepresentive picture of the hydraulic head distribution within the aquifer(s). Additionally, elementary contouring errors have apparently been reproduced from document to document, which have resulted in compounded errors in water-level contours..

- Individual zones of saturation beneath LANL have not been adequately delineated, and the "hydraulic interconnection" between these is not understood. Inadequate and incomplete knowledge concerning the geometries and boundary conditions of the zones of saturation beneath the facility exists. A facility-wide description of the hydrogeologic characteristics affecting ground-water flow beneath the facility can not be made without adequate delineation of the perched-intermediate aquifer(s) beneath LANL.

- The recharge area(s) for the main and perched-intermediate aquifers have not been identified. It is unknown at this time if any significant quantity of water is recharging the main aquifer through the fracture-fault zones which occur on the Pajarito Plateau. Characterization of these site-wide fault zones as potential pathways for aqueous migration is not complete. It is unknown what effect, if any, these zones may have on the direction of ground-water flow and hydraulic gradient of the main and perched-intermediate aquifers.

- The ground-water flow direction(s) of the main aquifer and perched-intermediate aquifer(s), as influenced by pumping of production wells are unknown.

- Detection of low-level tritium in the main aquifer in Los Alamos, Pueblo, and Mortandad Canyons (all of which have monitoring wells in them) refutes fundamental assumptions supporting low or no potential of migration of constituents of concern to the uppermost aquifer.

SITE-SPECIFIC GROUND-WATER MONITORING WAIVER REQUESTS & DENIALS

1. March 1987, *"Hydrogeologic Assessment of Technical Area-54 Area G & L, Los Alamos National Laboratory"*

In addition to the general technical reasons listed in the previous section, denial is based on the following observations:

- The presence of an alluvial aquifer in lower Pajarito Canyon is of concern from a horizontal contaminant transport standpoint. The continuing degradation of water quality within Pajarito Canyon from PCO-1 to PCO-3 is of concern. No apparent principal release site other than Area G & L exist that may account for the observed change in water quality.

- Section 3.0 Hydrologic Characterization of the Vadose Zone, page 3-1, first paragraph which states, "No perched water has been detected above the main aquifer; therefore, studies of moisture movement have been concentrated on unsaturated flow processes." As noted by N.D. Rosenburg and H.J. Turin (1993), Summary of Area G Geology, Hydrogeology, and Seismicity for Radiological Performance Assessment, a seismic hole drilled by J. Gardner in 1993 recorded wet core approximately 125 to 145 feet below ground-level, suggesting the possible existence of a perched-intermediate aquifer. The seismic drill hole is located approximately 700 feet NW of production well PM-2 which is located immediately downstream of the confluence of the Pajarito and Three Mile Canyons (TA-18).

- The potential for perched water below the base of the basaltic units beneath Areas G & L is of concern. Springs 4A discharge near the basalt - Santa Fe Group contact in Pajarito Canyon at an elevation hundreds of feet above the surface of the Rio Grande. The river is believed to represent the surface of the top of the main aquifer through this stretch of the Rio Grande (Cushman, 1965). As noted in LANL's May 1993 OU 1148 RFI Workplan: "Perched (intermediate) aquifers, recharged from the alluvial aquifer in Pajarito Canyon, may exist in the subsurface in the southern vicinity of OU 1148, although no drill holes are available to determine if they exist."

U.S. EPA's 1994 CME supports these reasons by relating the following:

"The ground water monitoring waiver for TA 54 Area L & G states: 1) there is not a perched water table at these areas, and 2) there is not any hydraulic connection to the main aquifer. However, there are not any ground water monitoring wells in the vicinity of Area L & G which verify this statement. It is understood that LANL was preparing to install a monitoring well penetrating the main aquifer, just east of TA 54, which could have been used to provide this information. However, it is also understood that due to budget constraints, the proposed installation of this well has been halted. It is recommended that this well be installed as expeditiously as possible in order to verify the ground water conditions in this area."

2. **December 15, 1987, *"Supporting Documentation for the Ground-Water Monitoring Waiver at the TA-16 Surface Impoundment".***

The above referenced documentation for the ground-water monitoring waiver at TA-16 Surface Impoundment has been reviewed. In addition to the general technical reasons listed in the previous section, the following technical issues support denial of the ground-water monitoring wavier at this RCRA regulated unit:

- Contaminant transport through the tuff is probable, based on field observations in Mortandad Canyon and low-level detection of tritium in the main aquifer.
- Recharge to the main aquifer is likely from the Pajarito fault zone and associated fracture-fault zones across the Plateau.
- Canon de Valle surface water is perennial within this stretch of the canyon. In addition, the wetlands in Canon de Valle appear to bisect the toe of the landfill. The wetlands areas could be in direct communication with a potential migration pathway.
- The depth to the uppermost aquifer is unknown.

Furthermore, the site has a documented release which requires a corrective action program plan be implemented.

3. March 1989, *"Supporting Documentation for the Ground-Water Monitoring Waivers at the TA-35 TSL-85 and TSL-125 Surface Impoundments".*

In addition to the general technical reasons listed in the previous section, denial of the ground-water monitoring waiver request is based on inadequate documentation. A general technical reason which is particularly relevant to this site is that in nearby Mortandad Canyon, low levels of tritium have been detected at a depth of 200 feet in the Bandelier Tuff. This finding indicates that there is vertical transport within the tuff and therefore a potential for migration which must be addressed.

4. April 1992, *"Ground-Water Monitoring Waiver Demonstration for Surface Impoundments at Technical Area-53".*

LANL 's reasoning for demonstrating "low potential for migration of hazardous waste or hazardous waste constituents to the uppermost aquifer" is described as:

> "(1) the unsaturated characteristics of the vadose zone below the TA-53 surface impoundments on Mesita de Los Alamos demonstrate low gravimetric moisture content..., and
>
> "(2) the annual evaportranspiration equals or exceeds the annual mean precipitation, resulting in a negative annual infiltration at TA 53."

In addition to the general technical reasons listed in the previous section, denial of the waiver is based on the following:

(a) There has been no site characterization to determine the uppermost aquifer below the site. The two canyons adjacent to Mesita de Los Alamos, Los Alamos and Sandia, both have perched water beneath the canyon bottoms.

(b) In point (1) quoted above, saturated porous media flow is assumed as the only transport model. Vapor phase flow of contamination and fracture flow are not adequately characterized or addressed in the supporting documentation, and

(c) Regarding point (2) quoted above, using a mean annual precipitation to calculate evapotranspiration is not adequate to account for all possible water balance at the site. Recharge mechanisms are also inadequately understood.

APPENDIX 2

NMED Letter to DOE/LAAO, August 17, 1995

State of New Mexico
ENVIRONMENT DEPARTMENT
Harold Runnels Building
1190 St. Francis Drive, P.O. Box 26110
Santa Fe, New Mexico 87502
(505) 827-2850

GARY E. JOHNSON
GOVERNOR

MARK E. WEIDLER
SECRETARY

EDGAR T. THORNTON
DEPUTY SECRETARY

17 August 1995

Mr. Larry Kirkman
Acting Area Manager
Department of Energy
Los Alamos Area Office
528 35th Street, Mail Stop A316
Los Alamos, NM 87544

RE: Comments Concerning Ground-water Contamination and Protection at Los Alamos National Laboratory(LANL), Los Alamos, New Mexico

Dear Mr. Kirkman:

The New Mexico Environment Department(NMED), Department of Energy Oversight Bureau(DOE OB) and Hazardous and Radioactive Material Bureau(HRMB) staff have assessed LANL's ground-water protection program, and have concluded that several problems concerning ground-water contamination and protection exist. The following summarizes major concerns of the NMED in relation to ground-water protection at LANL:

- From 1989 to 1993, water at approximately 271 ground-water monitoring stations(wells) exceeded Department of Energy, Environmental Protection Agency, New Mexico State drinking water standards or maximum contaminant levels, and NMED Water Quality Control Commission (WQCC) standards.

- Results of historical tritium concentration trend analyses, performed for seven LANL regional aquifer monitoring wells indicate that past laboratory releases of tritium-contaminated water may have commingled with the regional aquifer.

- LANL's Environmental Surveillance group recently released preliminary data which indicate that the regional aquifer near production well O-4 contains strontium-90 at levels four(4) times the New Mexico State drinking water standard and NMED WQCC standard.

o Both LANL and NMED DOE OB analytical data obtained from on-site and off-site springs are showing elevated concentrations of chlorinated solvents, high explosives, nitrates/nitrites as nitrogen and radionuclides.

o Preliminary modeling of the water balance in Mortandad Canyon by NMED suggests radionuclide-bearing effluent from LANL's liquid radioactive waste treatment facility(Tech Area 50) can leak out of the shallow(alluvium) aquifer and thus percolate towards the regional aquifer.

The above conditions warrant NMED's previous recommendations to develop a site-wide ground-water monitoring system to ascertain the impacts of laboratory operations to the groundwater regime. Currently, the impact to human health and the environment is unknown. **A plan is required to determine adequately** the effect **past, current, and future laboratory operations have** on the ground-water regime. The inadequacy of LANL's current ground-water monitoring system, the lack of basic hydrologic information, and the lack of compliance with both HSWA and RCRA ground-water monitoring requirements have previously been conveyed by NMED through memoranda, presentations, and letters. *(c.f. NMED internal letter, August 26, 1992; NMED letter to Jerry Bellows, November 25, 1992; NMED Initial Ground-Water Assessment Report, December 1992; NMED internal memo, February 5, 1993; NMED presentation at San Ildefonso, February 16, 1993; NMED/LANL meeting February 19, 1993; NMED letter to Diana Webb, March 10, 1993; NMED letter to Diana Webb, July 1, 1993; NMED letter to distribution, August 6, 1993; NMED memo to EPA, August 5, 1993; NMED internal memo, November 23, 1993; NMED letter to Diana Webb, February 28, 1994; NMED internal memo, February 22, 1994; NMED internal presentations, May 13, 1994; NMED letter to Joseph Vozella, July 7, 1994; NMED letter to EPA, January 23, 1995; NMED letter to EPA, January 24, 1995; NMED/DOE meeting, April 13, 1995; NMED letter to Larry Kirkman, May 30, 1995; NMED internal memo, July 5, 1995).*

Basic geology, hydrogeology, and pathways for contaminant transport have not been adequately addressed to date. At present, the following fundamental hydrogeologic issues/questions remain unresolved at LANL.

- Individual zones of saturation beneath LANL have not been adequately delineated, and the "hydraulic interconnection" between these is not understood. A facility-wide description of the hydrogeologic characteristics affecting ground-water flow beneath the facility cannot be made without adequate delineation of the perched-intermediate aquifer(s) beneath LANL.

- The recharge area(s) for the main and perched-intermediate aquifers have not been identified. It is unknown at this time if any significant quantity of water is recharging the main aquifer through fracture-fault zones which occur on the Pajarito Plateau. Characterization of these site-wide fault zones as potential pathways for aqueous migration is not complete. It is unknown what effect, if any, these zones may have on the direction of ground-water flow and hydraulic gradient of the main and perched-intermediate aquifers.

- The ground-water flow direction(s) of the main aquifer and perched-intermediate aquifer(s), as influenced by pumping of production wells are unknown.

- Aquifer characteristics cannot be determined without additional monitoring wells installed within specific intervals of the various aquifers beneath the facility. Locations of wells designed for aquifer testing cannot be addressed adequately without the delineation of individual zones of saturation beneath LANL.

At present, it appears that several different organizations(i.e., Environmental Restoration, Environmental Surveillance and Earth and Environmental Science divisions) at LANL are performing activities related to ground-water protection, monitoring and characterization. NMED does not consider that LANL's individual programs are adequately addressing the necessary requirements for a comprehensive ground-water protection program.

The hydrogeologic projects underway lack the integration necessary to meet the specific requirements of the HSWA permit and to address the fundamental hydrogeologic issues mentioned above. The lack of knowledge surrounding these fundamental hydrogeologic issues does not allow for compliance with the regulatory requirements of a site-wide characterization.

NMED is currently evaluating what work needs to be conducted and to what level of detail to assure compliance with both the HSWA hydrogeologic permit requirements and the requirements for ground-water monitoring of RCRA regulated units. This evaluation should be completed in October, 1995, and provided to EPA and then available to LANL.

During the course of NMED's investigation for the RCRA hydrogeologic evaluation, it has become evident to NMED that a RCRA site-wide hydrogeologic workplan should be developed and submitted to NMED and EPA for review and approval. A site-wide hydrogeologic workplan developed under the driver of RCRA will provide a mechanism to assure a compliance schedule with specific tasks to meet the permit objectives. The workplan should address both the HSWA hydrogeologic permit requirements and RCRA regulatory ground-water monitoring requirements.

Thank you for your attention in this matter. Should you have any questions concerning either technical or regulatory issues please contact Ms. Teri Davis of HRMB at (505) 827-1560. If you have any questions concerning technical matters please contact Mr. Michael Dale of DOE OB at (505) 672-0449.

Sincerely,

Ed Kelley PhD, Director, Water and Waste Management Division
New Mexico Environment Department

cc: Theodore Taylor, DOE LAAO, AAMEP, MS A316
Joseph Vozella, DOE LAAO, MS A316
Ivan Trujillo, DOE LAAO, MS A316
Matt Johansen, DOE LAAO, MS A316
Ken Zamora, Scientech/LAAO, MS A316
Barbara Driscoll, EPA Region 6
Gilbert Sanchez, San Ildefonso Pueblo, Environmental Director
Mark Weidler, NMED, Secretary
Peter Maggiore, NMED, Environmental Protection Division
Neil Weber, NMED, Chief, DOE Oversight Bureau
Benito Garcia, NMED, Chief, HRMB
Jim Piatt, NMED, Chief, SWQB
Marcy Leavitt, NMED, Chief, GWPRB
Sig Hecker, LANL, Laboratory Director, MS A100
Tom Baca, LANL, EM, MS J591
Jorg Jansen, LANL, EM/ER, MS M992
Steve Rae, LANL, ESH-18, MS K490

APPENDIX 3

Los Alamos National Laboratory Groundwater Protection Strategy, August 15, 1996

DRAFT
LOS ALAMOS NATIONAL LABORATORY
GROUND WATER PROTECTION STRATEGY
August 15, 1996

PURPOSE

This strategy provides a basis and direction for ground water protection at Los Alamos National Laboratory (Laboratory), and serves as a guide for the development of a Hydrogeologic Workplan (Workplan). The Workplan will describe ground water protection activities, with an emphasis on monitoring and characterization, that fulfill regulatory requirements (federal and state) derived from the Resource Conservation and Recovery Act (RCRA) and the Hazardous and Solid Waste Amendments (HSWA) to RCRA. The Workplan will also encompass hydrogeologic activities that satisfy institutional objectives found in the Laboratory's Ground Water Protection Management Program (GWPMP) Plan, many of which share the same need for monitoring and characterization information required by RCRA/HSWA. Thus, this strategy also provides direction for implementation of the GWPMP Plan. This strategy not only provides a common vision of ground water protection principles, but will help to guide discussions between the Laboratory, Department of Energy (DOE), New Mexico Environment Department (NMED), Indian Tribes, other regulators and stakeholders.

This strategy is the foundation for the Workplan, which will provide integrating documentation of the Laboratory's coordination of cost-effective, current and planned activities to understand and protect the hydrogeologic environment. These integrated Laboratory activities will be documented in the Workplan, with specific details regarding their contribution to ground water protection in descriptive text and referenced activities, e.g. Environmental Surveillance Program, Environmental Restoration Project activities. The Workplan will define the activities necessary to meet the goals of this strategy, primarily focusing on the hydrogeologic monitoring and characterization activities deemed necessary to comply with RCRA/HSWA regulatory requirements, including those described by current permit language, and further described by recent regulatory correspondence. Any similar or GWPMP-specific hydrogeologic activities necessary for compliance with DOE Order 5400.1 (10 CFR 834), New Mexico Water Quality Control Commission Regulations (20 NMAC 6), Natural Resource Trusteeship, and other applicable regulations will be incorporated in the Workplan for the sake of comprehensive integration, ensuring the avoidance of actual (or perceived) duplication of effort, but will not be viewed as subject to RCRA/HSWA review, approval and/or implementation.

CONTEXT FOR STRATEGY DEVELOPMENT

Background

The Laboratory is administered for the DOE by the University of California. Since its inception in 1943, the principal mission of the Laboratory has been the design, development, and testing of weapons for the nation's nuclear arsenal. This effort is supported by research programs in nuclear physics, hydrodynamics, conventional explosives, chemistry, metallurgy, radiochemistry, and biology. In addition to the weapons program, Laboratory personnel are involved in medium energy physics; space nuclear systems; controlled thermonuclear fusion; laser research; environmental research; geothermal, solar, and fossil energy research; nuclear safeguards; computer science; biomedical research; and space physics. In 1992, the Laboratory expanded its mission to include development of new programs in three nationally significant areas for which it has special capabilities: health and biotechnology, environmental technologies, and industrial partnerships.

Research and development facilities are located in 33 active Technical Areas (TAs) across the 43 mile^2 Laboratory site, which rests on the Pajarito Plateau on the eastern flank of the Jemez Mountains (Figure 1). The Pajarito Plateau consists of a series of fingerlike mesas separated by deep canyons containing ephemeral and intermittent streams that run from west to east (Figures 2, 3). Mesa tops range in elevation from approximately 7,800 ft. on the flank of the Jemez Mountains to about 6,200 ft. at their eastern termination above the Rio Grande valley. The eastern margin of the plateau stands 300 to 900 ft. above the Rio Grande. Underlying the plateau is a thick sequence of volcanic rock i.e. pyroclastic flow and pumice fall (Bandelier Tuff) that emanated from the Jemez Mountains. Two major volcanic eruptions in the Jemez Mountains occurred about 1.6 and 1.2 million years ago, producing widespread and voluminous ash flow sheets. The latest eruption in the Jemez Mountains occurred about 60,000 years ago. These volcanic rocks are interfingered with sedimentary and volcanic rocks deposited in the Rio Grande Rift. These deposits, include the Santa Fe Group, which is made up of poorly consolidated sands, clays, and gravels, and the Puye formation, which is made up of volcanic sediments. These deposits are important because the regional aquifer occurs in them. Depth to the regional aquifer beneath Laboratory sites ranges from 600 to 1200 ft. (Figure 2).

The zone between the mesa tops and the top of the regional aquifer is a *vadose zone*, , which is defined as "the geological profile extending from ground surface to the upper surface of the principal water-bearing formation. As pointed out by Bouwer (1978), the term "vadose zone" is preferable to the often-used term "unsaturated zone" because saturated regions are frequently present in the vadose zone " (USEPA, 1986b.) There are at least three modes of ground water occurrence beneath the Pajarito Plateau (Figures 2, 3), the first two of which occur in the vadose zone: (1) ground water in alluvium in some canyons, (2) perched intermediate ground water (ground water above a less permeable layer that is

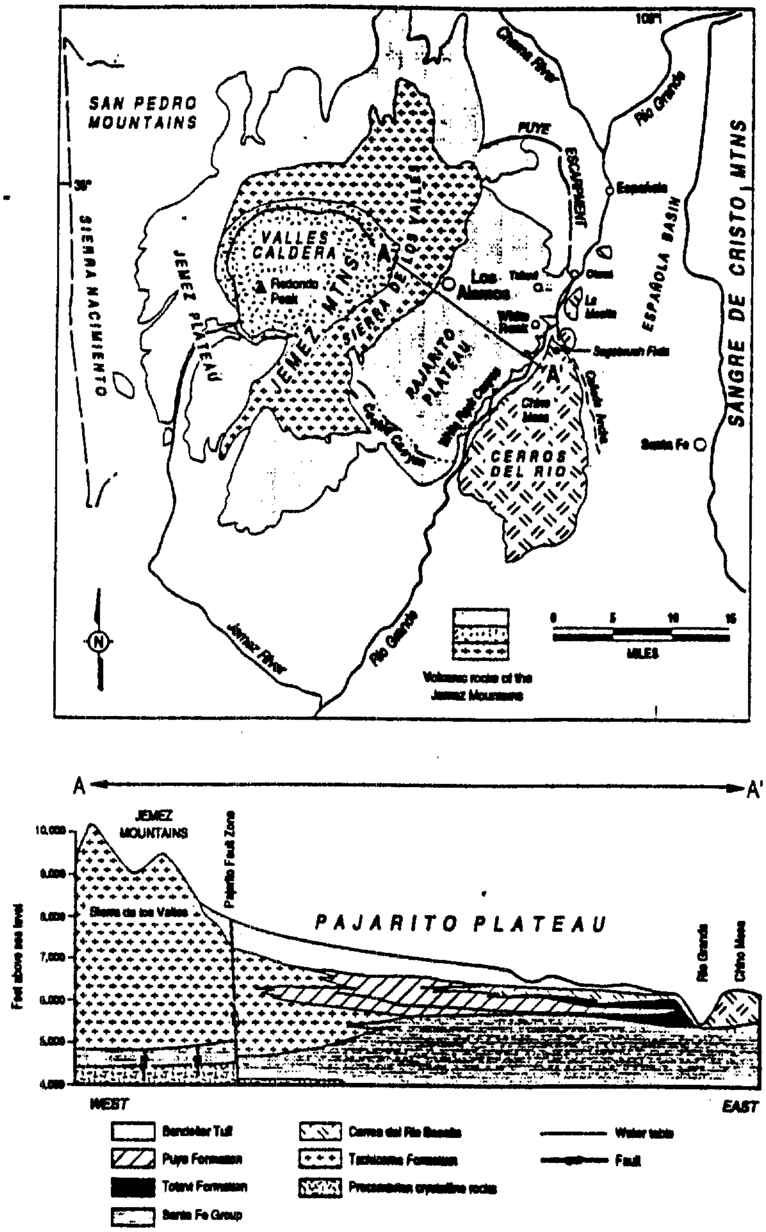


Figure 1. General geographic location, topographic features, and simplified geologic units in the vicinity of Los Alamos, NM.

separated from the underlying ground water by an unsaturated zone at intermediate depths (150-400 ft), and (3) the regional aquifer, which is separated from the upper ground water by hundreds of feet of tuff, basalts and volcanic sediments in the western portion of the Laboratory, with the vadose zone becoming thinner to the east. The intermediate perched ground water occurrence is controlled by the stratigraphic variations at the base of the Bandelier Tuff and in the underlying conglomerates and basalts.

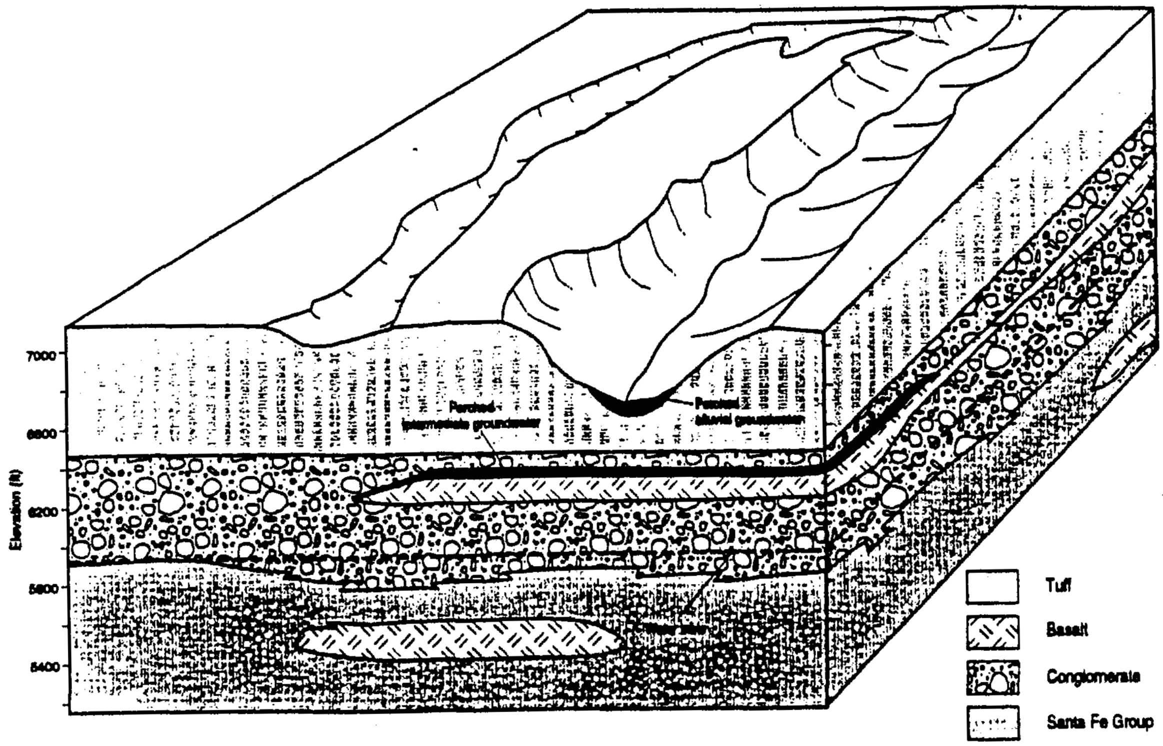


Figure 2. Generalized conceptual illustration of geologic-hydrologic relationships in the Los Alamos area

Later in this document, the specific goals of this strategy will be addressed. A comprehensive set of water quality standards, to be applied to each of these three ground water zones, is proposed. The strategy states that application of these standards will vary according to the particular ground water zone, the uses that water in that zone can support, and the relationship that zone has as a contaminant pathway to other zones. In certain instances, a ground water zone may even serve as a source for surface water, and specific standards relevant to surface water will be applied. Two terms, used in the strategy that follows, require definition. The term, *ground water* is defined as: interstitial water which occurs in saturated earth material and which is capable of entering a well in sufficient amounts to be utilized as a water supply (NMWQCC, 1995). The second term, *subsurface water* is defined as ground water and water in the vadose zone that may become ground water or surface water in the reasonably foreseeable future or may be utilized by vegetation (NMWQCC, 1995).

The majority of Laboratory TAs are located on mesa tops, and the activities occurring at the TAs over the past 50 years have included manufacturing, machining, testing and disposing of high explosives; creating, machining, and testing radioactive materials; storage of chemical and transuranic waste; disposal of low level radioactive solid waste; machining, plating, and disposing of metal

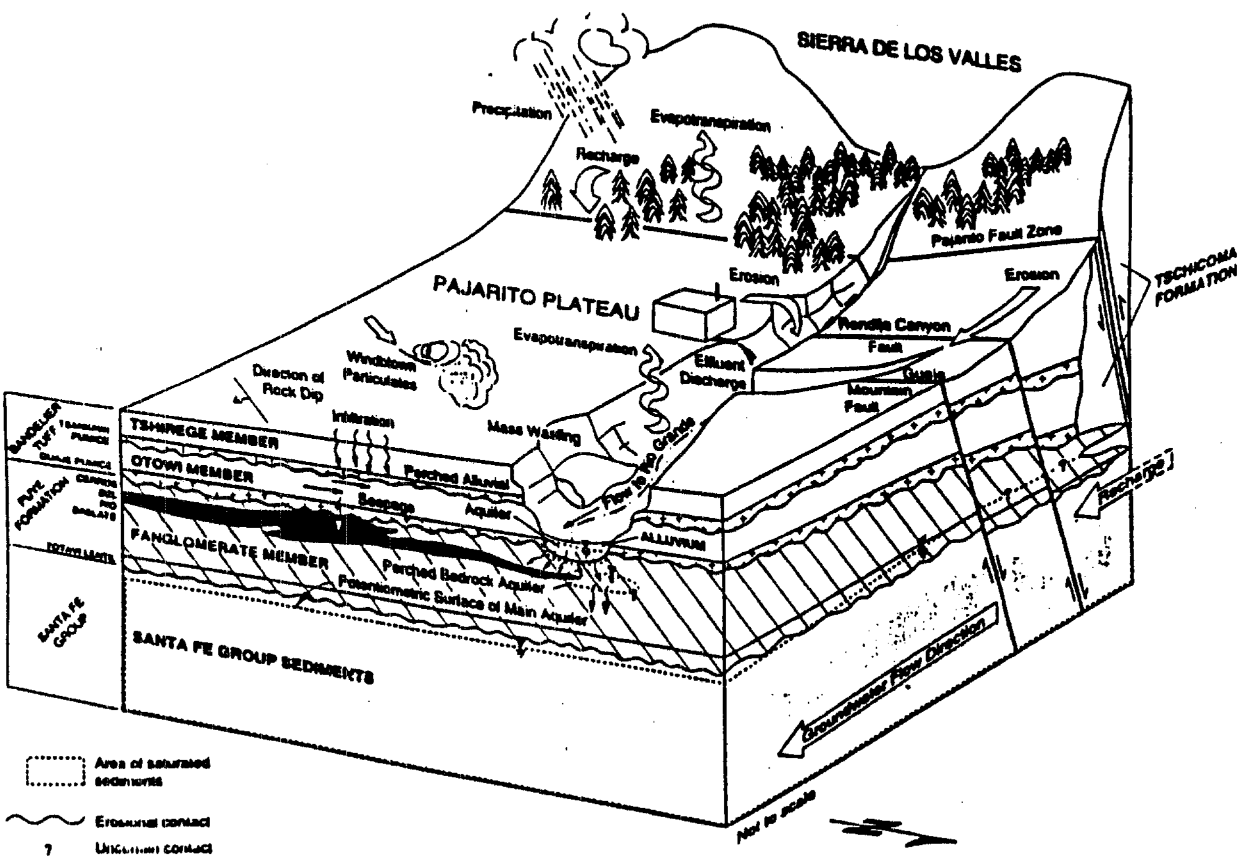


Figure 3. Conceptual geohydrologic model and general relation of major geologic units for Operable Unit 1071 on the Pajarito Plateau, Los Alamos, NM. (From Aldrich et al., 1992.)

waste-related materials; use of underground storage tanks for petroleum products; use of septic tanks for sewage; use of lagoons for storage and disposal of sewage and industrial liquid waste; disposal of solid-type waste in piles, pits, and shafts; and discharge of liquid effluents onto the mesa top. Laboratory activities in the canyon bottoms include discharge of liquid sewage and industrial effluents; use of lagoons for storage and disposal of sewage and industrial liquid waste; discharge of radioactive liquid waste; testing of explosives and assembled devices; and operation of laboratory facilities, including nuclear reactors. The sites where releases of radioactive and hazardous materials have the potential to occur is documented in RCRA Facility

Investigation (RFI) Work Plans and other reports prepared by the Laboratory's Environmental Restoration (ER) Project.

Although present Laboratory activities are regulated by federal and state environmental requirements and permits, some of the earlier activities took place in the 1940's, 1950's and 1960's prior to comprehensive regulations, and therefore they present possible human health or environmental risks. The potential impacts from these earlier Laboratory activities are the subject of characterization, assessment, risk-modeling, and as necessary, remediation under the Laboratory's ER Project, which is regulated by the HSWA module of the RCRA permit. Within the permit, approximately half of the Potential Release Sites (PRS is an acronym for Solid Waste Management Units [SWMUs] and Areas of Concern [AOCs]) identified from previous Laboratory activities, are listed. The remaining PRSs are identified on the Laboratory's PRS list. The goal of the ER Project is to characterize and assess each PRS so as to ultimately remove it from the HSWA permit, or remove it from the Laboratory PRS list, acknowledging that the site no longer represents a threat to human health or the environment. In addition, the present Laboratory activities, although regulated and permitted, must also be assessed and monitored to determine if adequate human health and environmental protection is ensured.

Concerns

Laboratory activities may have resulted in contaminant releases in solid, liquid, or gaseous form. Laboratory sites on the mesa tops may have released contaminants into the underlying tuff, which forms the vadose zone above ground water. In the vadose zone below the mesas, vapor transport of contaminants has been documented. Fractures in the vadose zone may play a role in transport, where the fractures are open and the site either received large volumes of water, mobilizing contaminants, or produced gaseous by-products that were transported via vapor-transport. Soils and tuff on the mesa tops or sediments in the canyon bottoms may be sites where contaminants can be retained, and serve as secondary sources that have the potential to continue to release contaminants into the environment. Within the canyons, contaminants in the sediment can be transported downstream by surface water flow, and may impact alluvial ground water (Figure 3). In locations where an intermediate ground water zone underlies the alluvial ground water, contaminants may be transported between the two zones. From all of the above-mentioned sources and pathways, there is the potential that contaminants can be transported to the deeper regional aquifer.

The specific concerns regarding characterization of the regional aquifer beneath the Laboratory have been summarized by the New Mexico Environment Department in correspondence dated August 17, 1995 as follows:

> "Basic geology, hydrogeology, and pathways for contaminant transport have not been adequately addressed to date. At present, the following fundamental hydrogeologic issues/questions remain unresolved at LANL:
>
> • Individual zones of saturation beneath LANL have not been adequately delineated, and the 'hydraulic interconnection' between these is not understood. A facility-wide description of the hydrogeologic characteristics affecting ground-water flow beneath the facility cannot be made without adequate delineation of the perched-intermediate aquifer(s) beneath LANL.
>
> • The recharge area(s) for the main and perched-intermediate aquifers have not been identified. It is unknown at this time if any significant quantity of water is recharging the main aquifer through fracture-fault zones which occur on the Pajarito Plateau. Characterization of these site-wide fault zones as potential pathways for aqueous migration is not complete. It is unknown what effect, if any, these zones may have on the direction of ground-water flow and hydraulic gradient of the main and perched-intermediate aquifers.
>
> • The ground water flow direction(s) of the main aquifer and perched-intermediate aquifer(s), as influenced by pumping of production wells is unknown.
>
> • Aquifer characteristics cannot be determined without additional monitoring wells installed within specific intervals of the various aquifers beneath the facility. Locations of wells designed for aquifer testing cannot be addressed adequately without the delineation of individual zones of saturation beneath LANL."

In addition to characterization and contamination issues, the water quantity available for beneficial use in the regional aquifer is also a concern. Long-term projections of water availability and potability in the aquifer cannot be made at present, due to a lack of detailed data. Water level declines due to municipal pumping may exceed 2.4 feet per year at some locations. The total usable quantity (and quality) of stored water in the regional aquifer, as well as its rate of replenishment (i.e. recharge), have not been quantified. In addition, water quality in the Guaje and former Los Alamos well fields, as well as at San Ildefonso Pueblo located on the east side of the Laboratory, has unacceptably high arsenic levels. These high natural levels are suspected to be caused by poorer quality water being drawn into wells from deeper portions of the aquifer. Without additional data, future water management decisions regarding the development and production of potable water from the regional aquifer, will be seriously compromised.

Basic understanding of the hydrogeology of the vadose zone and the regional aquifer is somewhat incomplete at this time. Without a basic understanding of the hydrogeologic and geochemical processes operating beneath the Pajarito Plateau, the Laboratory cannot adequately implement long-term ground water protection monitoring nor plan for long-term water supply production. The Laboratory has the scientific and technical resources to address these needs, and currently operates multiple programs (e.g. Environmental Surveillance, Environmental Restoration), to address these needs. In order to unify its efforts, the Laboratory proposes this strategy to serve as the basis for development of its Hydrogeologic Workplan. This effort will be guided by the implementation of a Data Quality Objective (DQO) process in order to establish the data needs, the method(s) of fulfilling those needs, and a cost-effective, technical peer-reviewed, prioritized and phased technical approach to collecting the data.

STRATEGY

The goal of this strategy is to describe a dynamic approach to protecting the ground water resource from unacceptable impacts resulting from the Laboratory activities described above. As previously stated, the details of implementing this strategy will be documented in the Hydrogeologic Workplan, which is scheduled for completion in September 1996.

Fundamental to this strategic approach is the utilization and development of four major sources of monitoring and characterization information at the Laboratory. The first source encompasses all existing hydrogeologic and geochemical information, accumulated from past studies and the Laboratory's existing ground and surface water monitoring network. The second source is the ER Project's characterization and assessment of PRS's on a site-specific basis, including investigations of the canyons that contain ephemeral and intermittent streams that flow toward the Rio Grande, which will provide information regarding the Laboratory's vadose zone. A third source of information will be the proposed installation of regional aquifer wells that will be used to characterize and define the Laboratory's basic hydrogeologic setting by providing lithologic, geochemical, and hydrologic information (e.g. data from borehole core samples, geophysical logs, aquifer tests, water quality analyses, and information regarding depth to and flow direction of the regional aquifer. The fourth source involves the installation of regional aquifer wells downgradient from large geographic areas of the Laboratory which have historically hosted major Laboratory operations and activities, i.e. large aggregates of PRSs, which will provide long-term water quality monitoring.

Each of these four sources will provide monitoring and characterization information critical to the protection of the ground water resource. By using the DQO process, the Laboratory is able to ensure cost-effectiveness by articulating the technical decisions that must be made and posing technical questions that must be answered to make those decisions. By examining the existing data (referenced in the first source above), the Laboratory is able to determine whether sufficient data exists to preclude further expenditures for new data. When existing data is lacking, the DQO process identifies the new data needs and the data collection design proposed to obtain it. In the final DQO process steps, the new data needs and data collection designs are re-evaluated to optimize the technical value and cost-effectiveness of the proposed data collection designs. The final DQO process steps include writing decison rules that describe what actions will result from obtaining the new data. The DQO process sets priorities for monitoring and characterization activities, based on decision criteria, and establishes the rationale for the phasing of activities, especially the prioritized and phased installation of wells, for inclusion in the Workplan.

Both the Laboratory's Environmental Surveillance Program, and the ER Project are integral components of this strategy. As previously mentioned the ER Project will investigate PRSs to assess their risks to human health and the environment. This assessment is performed through the following steps in the RCRA Facility Investigation (RFI) process: 1) collect and evaluate available data; 2) plan and conduct additional investigations; 3) assess risks to human health and the environment; 4) propose a remedy, if necessary and 5) implement the remedy, if necessary. In this process, an investigation can end at any step that a remedy, if needed, becomes obvious or when there is no need for further action. These ER Project investigations are primarily site-specific, but may cover large geographical areas (e.g. the canyons).

The ER RFI process will be followed under this strategy, and integration of the strategy and the ER Project will be enhanced by: 1) ER's collection of hydrogeologic and geochemical data and its storage in a central database; 2) ER's application of available tools and techniques to investigate ground water occurrence, hydrodynamic behavior, and assess potential risks from contaminants, with the development of new technologies, if necessary; and 3) ER's development of monitoring systems for PRSs, and areas of hydrologic importance (e.g. the canyons) where monitoring is necessary. Regarding Laboratory-wide ground water protection activities, the ER Project will support Laboratory activities where they benefit ER. The ER Project will gain hydrogeologic and geochemical characterization information from the

Laboratory's installation of regional aquifer wells, which will help design alluvial, perched intermediate, and regional aquifer monitoring systems for ER sites that require monitoring of those ground waters.

This strategy is intended to protect ground water to sustain uses which the water can support, by applying regulatory standards for ground water quality appropriate to protecting the particular beneficial use. The selected standards will establish a baseline for monitoring, so as to determine whether the standards are, or are likely to be, exceeded as a result of Laboratory activities. Ground water from the regional aquifer serves many beneficial uses (e.g. potable water supply, irrigation, livestock and wildlife watering, etc.). In general, this strategy seeks to place the highest priority on the protection of the regional aquifer for its beneficial use as a source of drinking water. The regional aquifer also contributes flow via springs and seeps into New Mexico surface waters e.g. the Rio Grande, which also has incumbent beneficial uses and water quality standards, as designated by the New Mexico Water Quality Control Commission (WQCC). Every effort has been made to integrate this ground water protection strategy with the Laboratory's surface water protection strategy.Therefore, this strategy will also apply appropriate surface water quality standards to those relevant surface waters influenced by ground water discharge, so as to determine whether the standards are, or are likely to be, exceeded as a result of Laboratory activities.

RCRA concentration limits, as provided for under 40 CFR 264.94 will be established, as they apply to ground water, and surface water influenced by ground water discharge. These concentration limits will be established based on either background levels of a constituent, or if applicable, from the constituent limit appearing in Table 1 of 40 CFR 264.94 (a) (2). Background levels will be determined from various sources e.g. historical data, existing or new wells. If neither of these methods of establishing a constituent limit is appropriate, the Laboratory may propose an Alternative Concentration Limit (ACL) to NMED, and if established by the NMED, such a limit will be applied. In proposing ACLs, the Laboratory intends to use the maximum concentration limits (MCLs) contained in the following regulations and standards, as appropriate, for the specific water use to be protected: National Primary Drinking Water Regulations, (40 CFR 141); National Secondary Drinking Water Regulations, (40 CFR 143); New Mexico Environmental Improvement Board (NMEIB), Drinking Water Regulations, (20 NMAC 7.1); WQCC Ground Water Standards, (20 NMAC 6.2, Subpart III, 3103); WQCC Standards for Interstate and Intrastate Streams (20 NMAC 6.1, Subpart I; WQCC Abatement Standards and Requirements (20 NMAC 6.2, Subpart IV, 4103); San Ildefonso Pueblo (proposed) Water Quality Standards; and Cochiti Pueblo Water Quality Standards.

The intent of this strategy is to select the most protective standards from various applicable regulatory standards, based on ground water uses in each of the three ground water zones, and apply those standards for monitoring and risk assessment. The strategy for application of regulatory standards to the three ground water zones is further described in the following pages.

<u>Uppermost Subsurface Water Quality (Vadose Zone)</u>

The strategic goal for protecting the subsurface water in the vadose zone is to prevent contamination from new sources and characterize and/or respond to contamination entering this water from existing sources. Ground water in the canyon bottoms and other subsurface water in the vadose zone, that may become ground water or serve as a source of surface water, or be utilized by vegetation occurs at the Laboratory. The primary PRSs that potentially impact this water are those located near the canyons (disposal areas and outfalls) and in the canyon bottoms. The ER Project will assess the presence and extent of releases from these PRSs. This strategy compliments the work of the ER Project by providing guidance that will result in supplementing the contaminant distribution data with hydrogeologic and geochemical characterization data necessary to complete the risk assessment. The risk assessment will evaluate surface water and ground water pathways.

If this subsurface water is ground water, it will be designated as the "upper most aquifer" pursuant to RCRA. This ground water will be considered to be capable of supplying sufficient quantities to support the beneficial uses of supplying drinking water, wildlife and livestock water , and irrigation water, and will be protected with standards applicable to those uses, as well as applicable RCRA constituent limits. Furthermore, such ground water could serve as inflow to surface waters via springs, seeps, and base flow, and therefore provide beneficial uses in surface water, evoking beneficial uses and standards to protect those uses for surface water, as designated by the WQCC. Additionally, this water may serve as a contaminant pathway to other ground water or surface water, and thus must be protected to promote human health and prevent unacceptable ecological risks.

Because this uppermost subsurface water occurs in the vadose zone, the strategic approach will rely primarily on the ER project, which is being implemented chiefly in the vadose zone, and by relying on the ER RFI process, which is iterative and based on risk to human health and the environment. Existing hydrogeolgic and geochemical data will be assembled, and data needs will be identified. Characterization activities to reduce uncertainties to acceptable levels, based on the potential use of the water, will be planned and implemented. Assessment of the risks by various pathways will be employed to determine any necessary remediation, including monitoring. This strategy will employ monitoring as close to the source as possible to provide a warning should the contaminants migrate at rates faster than expected.

Within this uppermost subsurface water zone, the canyons at the Laboratory represent a situation where there are legacy and current operational water quality issues. The legacy issues are within the scope of the ER Project. There is essentially no cost-effective way to differentiate between legacy and current operational contaminants. Thus, regarding the canyons, ER will characterize, assess, and complete corrective actions, including monitoring, as necessary, and then convey any monitoring installations to the Laboratory's Environmental Surveillance Program for continuing monitoring of operational impacts. These monitoring systems for the uppermost subsurface water will be based on risk assessment, hydrogeologic characterization, current contamination, if any, and selected corrective measures, if needed. When hydrogeologic factors (e.g. porosity, moisture content, lithology, etc.) demonstrate favorable conditions, vadose zone monitoring will be the preferred activity under this strategy. Moreover, innovative technologies will be considered in comparison to conventional monitoring methods and techniques.

Remedial activities will be based on risk posed by any pathways. Thus, constituent limits applied to hydrogeologic media on Laboratory property will meet relevant risk criteria. RCRA concentration limits will be established based on either background levels of a constituent, or if applicable, from the constituent limit appearing in Table 1 of 40 CFR 264.94 (a) (2). If neither of these methods of establishing a constituent limit is appropriate, the Laboratory may propose an Alternative Concentration Limit (ACL) to NMED, and if established by the NMED, such a limit will be applied. In proposing ACLs, the Laboratory intends to use the maximum concentration limits (MCLs) contained in the following regulations and standards, as appropriate, for the specific water use to be protected: National Primary and Secondary Drinking Water Standards; NMEIB Drinking Water Regulations; WQCC Ground Water Standards; WQCC Abatement Standards or Alternative Abatement Standards; WQCC Standards for Interstate and Intrastate Streams; proposed San Ildefonso Water Quality Standards; and Cochiti Pueblo Water Quality Standards.

<u>Ground Water Quality: Intermediate Perched Ground Water (Vadose Zone)</u>

This ground water is probably limited in extent, which limits its beneficial use, particularly as a drinking water supply, due to extremely small yields. However, water in the intermediate zone may be hydraulically connected with alluvial ground water, may potentially commingle with the underlying regional aquifer, and may also contribute to surface water via springs or seeps. Therefore, this ground water should not exceed water quality standards to such a degree that, it would result in water quality standards being exceeded in any other water, especially the regional aquifer. Should this intermediate ground water represent a usable source of drinking water in its own right, standards appropriate to that use will be applied. This ground water will be protected to promote human health and prevent unacceptable ecological risks.

As with the alluvial ground water, the main thrust of this strategy depends on remediation of PRSs that present an unacceptable risk to the intermediate ground water. The strategic approach will rely primarily on the ER RFI process of collecting existing data, planning and implementing necessary characterization, assessing the risks, and completing any necessary corrective actions, including monitoring. This approach will consider those sites where a potential source or known contamination exists. Hydrologic connection to other ground water and surface water is a key consideration in this approach. The location and characterization of intermediate zones may offer opportunities for utilizing indirect methods of investigation, such as geophysical techniques. Nevertheless, chemical characterization will require direct examination of the waters of these intermediate saturated zones.

RCRA concentration limits will be established based on either background levels of a constituent, or if applicable, from the constituent limit appearing in Table 1 of 40 CFR 264.94 (a) (2). If neither of these methods of establishing a constituent limit is appropriate, the Laboratory may propose an Alternative Concentration Limit (ACL) to NMED, and if established by the NMED, such a limit will be applied. In proposing ACLs, the Laboratory intends to use the maximum concentration limits (MCLs) contained in the following regulations and standards, as appropriate, for the specific water use to be protected: National Primary and Secondary Drinking Water Standards; NMEIB Drinking Water Regulations; WQCC Ground Water Standards; WQCC Abatement Standards or Alternative Abatement Standards; WQCC Standards for Interstate and Intrastate Streams; proposed San Ildefonso Water Quality Standards; and Cochiti Pueblo Water Quality Standards.

<u>Ground Water Quality in the Regional Aquifer</u>

The strategic goal for water in the regional aquifer is to maintain its use as a drinking water supply. Furthermore, this ground water serves as a water source for the Rio Grande, and therefore should be protected for all of the applicable beneficial uses in surface water, as designated by the WQCC. Strategically, a very high priority will be placed on protecting this ground water to promote human health and prevent unacceptable ecological risks.

The focus of this strategy is on early detection and remediation of releases of contaminants before they reach the regional aquifer. This strategy also emphasizes the long-term assurance of ground water protection provided by monitoring of the regional aquifer, and shallower ground water zones. As described in the previous two sections, the ER Project is focused on detection and remediation of releases from legacy sites. To support the ER Project, as well as provide the Laboratory with a long term regional monitoring network, characterization of the regional aquifer will be performed as a priority, so as to describe the hydrogeologic setting beneath the Laboratory, and guide installation of a monitoring system, capable of monitoring the regional aquifer to detect any impacts of current and future operations at the Laboratory. Ultimately, monitoring wells in all three ground water zones will be used to confirm that the standards applicable to the uses of the regional aquifer are met, and provide assurance that a system is in place to detect deterioration in water quality over the long-term.

RCRA concentration limits will be established based on either background levels of a constituent, or if applicable, from the constituent limit appearing in Table 1 of 40 CFR 264.94 (a) (2). If neither of these methods of establishing a constituent limit is appropriate, the Laboratory may propose an Alternative Concentration Limit (ACL) to NMED, and if established by the NMED, such a limit will be applied. In proposing ACLs, the Laboratory intends to use the maximum concentration limits (MCLs) contained in the following regulations and standards, as appropriate, for the specific water use to be protected: National Primary and Secondary Drinking Water Standards; NMEIB Drinking Water Regulations; WQCC Ground Water Standards; WQCC Abatement Standards or Alternative Abatement Standards; WQCC Standards for Interstate and Intrastate Streams; proposed San Ildefonso Water Quality Standards; and Cochiti Pueblo Water Quality Standards.

Water Quantity in the Regional Aquifer

The Laboratory must determine that ground water of adequate quality and in adequate quantity is available for long term withdrawal from the Lower Espanola Basin. Water quantity relates to factors which affect continued availability of a good quality water supply for both Los Alamos users and for other users in the southern portion of the Espanola Basin. Some of these factors include: how increases in water supply pumping by Los Alamos, Santa Fe, Espanola, and the Pueblos will affect each of the other users; how such pumping will affect overall water quality for each of the other users; and how such pumping will affect other aspects of the hydrologic system such as water levels in the Rio Grande and the movement of chemical constituents in the regional aquifer.

The strategy for addressing water quantity issues will focus on numerical simulation (modeling) of aquifer response to ground water withdrawal. Forecasts will be prepared by applying various ground water withdrawal scenarios. Development of the ground water model(s) will necessitate the acquisition of hydrogeologic information to address uncertainties. This approach includes the construction of several deep wells in the regional aquifer to allow characterization of aquifer characteristics e.g. saturated thickness, transmissivity, specific capacity, etc., as well as ground water quality at depth. Future Laboratory activities will rely on a dependable water supply of good quality. Without the development of adequate forecasts, the quantity and quality of available ground water resources cannot be determined.

REFERENCES

NMWQCC. October, 1995. New Mexico Water Quality Control Commission Regulations. 20 NMAC 6.2.

USEPA. 1986b. Permit Guidance Manual on Unsaturated Zone Monitoring for Hazardous Waste Land Treatment Units. EPA 530-SW-86-040.

APPENDIX 4

Data Quality Objective (DQO) Process Outputs

Decision	Questions	Existing Data	New Data	Decision Rule for New Data	Data Collection Design
Are there sources of sufficient magnitude to cause contamination of groundwater?	What are the contaminants that could have been released from sources?	Pueblo: Nitrate, Pu; Los Alamos: ^{90}Sr, NO_3, ^{3}H, ^{137}Cs (in groundwater now) Legacy Sources: Los Alamos: ^{90}Sr, NO_3, ^{3}H, ^{137}Cs, ^{241}Am, Pu, metals, PAHs Sandia: Sewage & Power Plant, Cooling Tower NPDES discharges. LAMPF historical discharges, Los Alamos County Landfill, lead from Firing Range, PCB cleanup by refueling facility; Preliminary estimates of volume are available. Present Sources: NPDES outfalls, Stormwater outfalls.	Stormwater quality data	If contaminants other than those currently identified are detected in the stormwater, then add those contaminants to the list of Potential Contaminants of Concern (PCOC)	• ER: Legacy sources. Information from ER work • ER/ESH-18: Present sources - Stormwater data from developed areas
Are the alluvial sediments and uppermost subsurface water (USSW) from various present and legacy sources at contaminant concentrations ([cont.]) > regulatory limit or risk level?	What are the concentrations of these contaminants in sediments and USSW?	Concentration of contaminants in alluvial water Concentration of contaminants in sediments Background alluvial water quality in LA Canyon and provisional data for the Guaje pumice bed Background in sediments in LA, Pueblo and Sandia Canyons Surveillance data from stations near State Road 4 and annual water quality data from 3 Sandia Canyon Stations	Water quality in upper and lower Los Alamos Canyon	If contaminants other than those currently identified are detected in Los Alamos Canyon, then add those contaminants to the list of PCOCs	• ER: lower Los Alamos Canyon: five Type 1 wells to sample for water quality • ER: upper Los Alamos Canyon two Type 1 alluvial wells, one above confluence with DP Canyon, one below confluence.

Aggregate 1: Los Alamos, Sandia, and Pueblo Canyons

Decision	Questions	Existing Data	New Data	Decision Rule for New Data	Data Collection Design
	Are there occurrences of water in Los Alamos Canyon, Pueblo Canyon and Sandia Canyon?	Multiple surface water gaging stations in Los Alamos Canyon; one surface water gaging station in Sandia Canyon; and one gaging station in Pueblo Canyon. Alluvial water - greater than 50 gpd in Los Alamos Canyon and Lower Pueblo Canyon	• Extent of saturation in lower Los Alamos Canyon • Upper Pueblo Canyon - presence of alluvial water • Upper and middle Sandia Canyon presence of alluvial water	If there is saturation in the alluvium, then determine which standards apply	• ER: measure water levels in the alluvial wells in upper and lower Los Alamos Canyon (7 wells) and one Type 1 well in Guaje Canyon near confluence with Los Alamos Canyon • ER: measure water levels in alluvial wells in Pueblo Canyon: - One Type 1 well above confluence w/Acid Canyon - One Type 1 well west of Diamond Drive - Three Type 1 alluvial wells between sewage treatment plant and Acid Canyon - One Type 1 alluvial well downstream of sewage treatment plant • ER: 3 transects: - 4 Type 1 wells near LLAO-2 in lower Los Alamos Canyon - 3 Type 1 wells near LAO-4.5 in Los Alamos Canyon - 4 Type 1 wells near APO-1 in Pueblo Canyon • ER: Water level measurements from 3 Type 1 alluvial wells in Sandia Canyon

Decision	Questions	Existing Data	New Data	Decision Rule for New Data	Data Collection Design
	What are the regulatory standards that apply to the alluvial water in Los Alamos, Pueblo, and Sandia canyons?	Los Alamos Canyon has "groundwater" Surface water in Sandia, Pueblo, and Los Alamos canyons	Yield of alluvial zone in upper Pueblo Canyon and Sandia Canyon	If the average yield from alluvium in Sandia and upper Pueblo Canyons in ≥ 50 gpd then the water quality will be compared to WQCC ground-water standards and 20NMAC 4.1	ER: placing the ten Type 1 wells in Pueblo Canyon to determine occurrence of groundwater ER: placing the three Type 1 wells in Sandia Canyon to determine the occurrence of groundwater.
Is the intermediate perched groundwater underlying the alluvial sediments and USSW at [cont.] > regulatory limit or risk level?	Is there an intermediate perched water body in Los Alamos, Pueblo, and Sandia canyons?	Identified 3 perched zones below Los Alamos, Sandia, and Pueblo Canyon within upper 1/3 depth to the Regional Aquifer; LA Canyon has extensive perched zone in Guaje Pumice. Drillers observed perched zone in Sandia Canyon near SR 4 when drilling PM-1 municipal well.	In Los Alamos Canyon, identify perched zones between Guaje Pumice and Regional Aquifer. In Pueblo Canyon identify perched zones in Puye formation and basalts In Sandia Canyon investigate whether saturation occurs in the Guaje Pumice bed and basalts	If perched groundwater zones are encountered between the Guaje Pumice and the Regional Aquifer, then collect information to characterize the hydrologic characteristics of those zones.	ER: Wells to identify perched intermediate zones are: • Pueblo Canyon intermediate depth well (Type 5) between sewage treatment plant and Los Alamos Canyon (POI-4) (ER) • Pueblo Canyon Type 2 well midway between Test Well 2 and Test Well 4 (ER) • Pueblo Canyon Type 3 well near Otowi-1 (DP) • Pueblo Canyon, Type 2 well just north of Test Well 4 at Rendija Fault (DP)

Decision	Questions	Existing Data	New Data	Decision Rule for New Data	Data Collection Design
					• Pueblo Canyon, Type 2 well between Test Well 2 and Sewage Treatment Plant (ER) • Los Alamos Canyon Type 2 well between LADP-3 and LAOI-A1.1 (ER) • Los Alamos Canyon Type 3 well at existing H-19 site (DP) • Los Alamos Canyon Type 3 well near Otowi-4 (DP) • Los Alamos Canyon Type 3 well at State Route 4 (ER) • Sandia Canyon Type 3 well near PM-3 (DP) • Sandia Canyon Type 2 well at State Route 4 (ER) • Sandia Canyon Type 2 well in upper Sandia Canyon • Sandia Canyon Type 2 well, location is dependent on location of Type 2 well between LADP-3 and LAOI (ER)
	Does intermediate perched groundwater meet the definition of "ground-water"?	Both Los Alamos and Pueblo Canyon have sufficient water to yield a supply of 50 gpd	Yield of intermediate zone in Sandia Canyon	If the average yield from the intermediate perched zone in Sandia Canyon is $\geq$ 50 gpd then the water quality will be compared to WQCC ground-water standards and 20NMAC 4.1	In all Sandia Canyon wells, perform hydrologic tests in intermediate perched zones

Decision	Questions	Existing Data	New Data	Decision Rule for New Data	Data Collection Design
	What are the PCOCs from alluvial sediments that have been transported to the intermediate perched groundwater?	Los Alamos Canyon in Guaje Pumice detected ^3H, Cl Pueblo Canyon in Puye Fm detected Pu. In basalt, NO_3 was detected	If intermediate perched groundwater is present in Sandia Canyon, collect samples for water quality analysis.	If contaminants other than those currently identified are detected in the intermediate perched groundwater, then add those constituents to the list of PCOCs.	In all Regional Aquifer wells, sample intermediate perched groundwater and analyze for PCOCs.
	What are the regulatory standards that apply to the intermediate perched water in Los Alamos, Pueblo and Sandia canyons?	WQCC groundwater standards and 20 NMAC 4.1			
Is the Regional Aquifer, as affected by the Canyon systems, impacted by [cont.] ≥ some regulatory standards?	Have PCOCs migrated from intermediate perched zones and/or alluvial sediments/USSW to the Regional Aquifer?	Based on Test Wells 1,2,3 & 4, ^3H and ^{90}Sr and NO_3 are in the Regional Aquifer beneath Los Alamos and Pueblo Canyons	Determine if PCOCs have migrated into the Regional Aquifer beneath Sandia Canyon	If PCOCs are detected in the Regional Aquifer then evaluate remedial options along source and pathways.	ER: From the (2) Regional Aquifer wells in Sandia Canyon (middle segment), sample Regional Aquifer and analyze for PCOCs
	What are the concentrations of PCOCs in the Regional Aquifer?	Contaminant concentrations are below MCLs, except for nitrate, beneath Los Alamos Canyon	Presence of PCOCs in Regional Aquifer beneath Sandia Canyon	If the concentration of PCOCs in the Regional Aquifer exceeds standards, then evaluate remedial options for the Regional Aquifer	Analyze water samples from wells in Regional Aquifer
Are there sufficient source terms to cause contamination if moved along the pathways in 1000 years?			Definition of pathways Rates of contaminant transport Mass of contaminants available for transport Predicted contaminant concentrations in receiving media	If modeling predicts that contaminants will cause contamination of the Regional Aquifer within 1000 years, then evaluate remedial options.	Geologic, hydrologic, geochemical data from wells and other investigations as input to model.

Aggregate 1: Los Alamos, Sandia, and Pueblo Canyons

Decision	Questions	Existing Data	New Data	Decision Rule for New Data	Data Collection Design
What are the pathways for exposure to contaminants from alluvial sediments and USSW?	Does significant recharge occur from near surface to underlying groundwater bodies?	Contaminant distribution within underlying water bodies	Recharge from surface water to alluvial water Horizontal extent of saturation in the alluvium Channel geometry Saturated Zone geometry	If the combined geologic chemical, and hydrologic properties of the units below the canyon suggests recharge to underlying groundwater bodies occurs within 1000 years, further evaluate this pathway. (Based on: Proposed 40 CFR 193 guidance and DFNSB recommendation 94-2 (DOE Guidance))	ER: well transects across the alluvium; measure water level in wells. ER: Three nested peizometers in Pueblo Canyon between PO-4 and the "Y".
	Do we know the hydraulic properties of alluvium?	Slug test for K in Los Alamos Canyon	Porosity, hydraulic gradient, hydraulic conductivity	If the maximum calculated value of hydraulic properties suggests fluid movement downward through the alluvium occurs in 1000 years, then further evaluate this pathway	ER Program: In-situ testing of well transects
	What are the retardation factors of the alluvial sediments?		Kds for ^{90}Sr, ^{137}Cs, U, Pu, Am, Np; water chemistry; long-term water level trends	If the site-specific minimum retardation factors suggest that contaminants are not significantly retarded in the alluvium over a period of 1000 years, then further evaluate this pathway	ER: Undisturbed samples of alluvium from Type 1 wells Water Samples from alluvial wells
	Do we understand groundwater movement from alluvial water to intermediate perched zones?	Limited Cores from LAPD-3, LAOIA-1.1 where moisture characteristic curves, porosity and bulk density, mineralogy, hydraulic conductivity have been measured.	Core samples for hydraulic properties, geochemistry, saturated hydraulic conductivity, moisture characteristics, porosity, thickness, bulk density, stratigraphic information, lithology, character of perching zone.	If the combined hydraulic properties and geochemistry suggest that alluvial ground-water moves downward to intermediate perched zones within 1000 years, then further investigate this pathway.	ER: As proposed in ER work plan, core will be collected from Type 2 wells and tested for hydraulic properties and geochemistry for assessment analyses.

Decision	Questions	Existing Data	New Data	Decision Rule for New Data	Data Collection Design
	Groundwater movement from intermediate perched zone to Regional Aquifer?	Increased static head at TW-1	Core samples for hydraulic properties, geochemistry	If the combined hydraulic properties and geochemistry suggest that water from perched zones moves downward to the Regional Aquifer within 1000 years, then further evaluate this pathway way	Core from Type 2 wells to measure properties Perform tracer test between sewage treatment plant and TW-1
	Are fractures and faults Important contaminant transport pathways for liquids in the canyons?	Initial data available from LAOIA-1.1 suggest that other features (e.g., stratigraphy) dominate transport direction and rate.	Identification of faults and hydrologic characteristics of fault zones.	If measured fracture responses and models of fracture flow predicts that recharge occurs through fractures to Regional Aquifer bodies within 1000 years, further evaluate this pathway	To be determined by literature search, expert consultation, and more specific data collection described in ER work plan and sampling analysis plan Core from Pueblo Canyon Type 2 well just north of TW-4 at Rendija Fault will be used to evaluate fault and fracture characteristics.

Aggregate 1: TA-21, -53, and -73 Mesas

Decision	Questions	Existing Data	New Data	Decision Rule for New Data	Data Collection Design
Are the soils/tuff or uppermost subsurface water from various present and legacy sources at contaminant concentrations > some regulatory limit or risk level?	What are the contaminants?	TA-21: Areas A,B,T, & V Radionuclides are ^{239}Pu, ^{241}Am, ^{3}H-Curie Inventory MDA A = 11Ci MDA B = 7 Ci MDA T = 4014 Ci MDA V = 3.1 Ci (existing data on inventory) Existing data for TA73 airport landfill; methane, VOCs. TA53 data on existing sources is available from ER and ESH	ER investigation to determine if hazardous components are also present Core samples and/or trenching	If the contaminants other than those currently identified are detected as a result of ER or other investigations, then add those to the list of PCOCs.	ER: Planned work to investigate sources.
	What are the concentrations?	Limited information on non-radioactive contaminants	Analyses of core collected from sources	If contaminants are detected above Screening Action Levels (SALs) and background, then further investigate their presence in the groundwater pathway.	ER: Planned work to investigate sources.
	What are the concentrations of contaminants in the future?	No changes expected.	No data needs.		
	Are there occurrences of water at this site?	Surface stormwater during storm events. DP Spring	Stormwater quality	If contaminants other than those currently identified are detected in stormwater on the mesa top, then add those constituents to the list of PCOCs.	ER/ESH: sample stormwater runoff at natural collection areas within the developed portions of TA-21, -53, -73.
	What are the regulatory standards that apply?	In the unsaturated zone, the WQCC Abatement regs. & 20NMAC 4.1 may apply			

Decision	Questions	Existing Data	New Data	Decision Rule for New Data	Data Collection Design
Is the Regional Aquifer or an underlying intermediate perched zone, as potentially affected by a present or legacy source, predicted to be impacted by [cont.] > regulatory standard or risk level using a conservative model?	What model will be used?	A screening model such as RESRAD or MULTIMED.	Outputs of screening model	If the screening model, using conservative scenarios, suggest that underlying groundwater bodies would not be contaminated above a regulatory standard or risk limit by the identified present or legacy sources, then do not further evaluate pathways.	Outputs of modeling scenarios
	What data are needed for the model?	Preliminary data is available from the literature, archival information, ESH, WM, and ER data	No new data needed		
What are the pathways for exposure to contaminants from soils/tuff and water in the USSW?	What is the recharge? (groundwater movement further downward from the site)				
	• Are the hydrological and chemical properties of the underlying geological strata known?	Cores and neutron tube measurements near TA-21 show higher moisture in soil/tuff in near surface (10-15ft) than deeper.	Chemical data on Bandelier: (list from Scenario 2), surface area, microbial populations, redox potential. Geological, chemical and hydrologic parameters of underlying units.	If the combined geologic, chemical, and hydrologic properties of the units below the mesa suggest recharge to underlying groundwater bodies occurs within 1000 years further evaluate this pathway.	• TA-53 lagoon seepage into subsurface with water balance measurements. • Outcrop testing will be developed for testing of non-recovery zones (Cerro Toledo) in TA-21, TA-73, and TA-53 • Collect core from Type 2 wells in canyon
	• Are fractures and faults and important contaminant transport pathways for liquids?	FRACTURES: Data and modeling for MDA-G Evidence of water in fractures is the presence of soils w/clays iron oxide, and calcium carbonate in some fractures Fracture mapping of outcrops at TA-21 and Pueblo Canyon area		If measured fracture responses and models of fracture flow predicts that recharge occurs through fractures to underlying groundwater bodies within 1000 years, further evaluate this pathway	• Fracture mapping of outcrops at TA-53 and TA-73

Decision	Questions	Existing Data	New Data	Decision Rule for New Data	Data Collection Design
		Cores beneath TA-53 lagoons with ^{3}H measurements and moisture measurements to a depth ~100 ft.	Response of fractures: fracture density, apertures, filling characteristics both chemical and hydrological, length and connection		• Map fractures in cores that are collected from boreholes that are placed for other reasons.
			Model of fracture flow of both liquid and gas including fracture-matrix interactions		
		FAULTS: Existing fault maps	FAULTS: Identify faults by comparing fracture density and surface mapping.	If faults in critical zones are identified and testing and/or modeling of those fault zones predict recharge to underlying groundwater bodies occurs within 1000 years then further evaluate this pathway.	ER: Characterization Studies: • Fracture mapping of outcrops to identify fault zones
			Detailed mapping to identify offsets in stratigraphic units (e.g., surge beds)		• Detailed stratigraphic mapping where faults in critical zones (critical zone = areas with contaminant sources).
			Hydrologic characteristics of fault zones		• In-situ testing and monitoring in boreholes in faults in critical zones (air permeability if possible)

Decision	Questions	Existing Data	New Data	Decision Rule for New Data	Data Collection Design
	• Can we estimate recharge?	Area G testing including steady-state moisture profile and hydrologic parameters; water balance Moisture measurements from MDA-B Pilot Study	Steady-State moisture profile, hydrologic parameters, water balance (tuff and deeper units); environmental tracers (in tuff) at TA-21, TA-53, TA-73	If estimates of recharge predict that water would move from near the surface of the mesa to the Regional Aquifer (or intervening groundwater body) within 1000 years, then further evaluate this pathway	ER: Characterization studies: Core samples from boreholes to measure steady-state moisture profile and hydrologic parameters and environmental tracers • Water balance measurements of mesa; measurements include runoff and infiltration • Drainage study in outcrops of non-recovery zones (Puye and Cerro Toledo)
	Does significant vapor phase transport occur?	Core and downhole sampling from TA-73 landfill detected methane and VOCs	Vapor diffusion coefficients, liquid-vapor partitioning relationships and constant; retardation of vapor phase, transformation of contaminants, stratigraphy, lithology, mineralogy, vapor density vs concentration relationship, temperature distribution, fraction of organic carbon, barometric pressure, air permeability versus water content for each geologic unit, porosity, in-situ water content and/or pressure head	For sources with significant vapor - producing contaminants, if the vapor diffusion characteristics underlying that source suggest that vapor phase transport has or could occur within 1000 years then further evaluate this pathway.	ER: Characterization Studies in areas where there is vapor generation (TA-73 landfill and MDA-B): collect core samples for analysis and in-situ testing of borehole.

Decision	Questions	Existing Data	New Data	Decision Rule for New Data	Data Collection Design
	• Are fractures and faults important contaminant transport pathways for vapors?	TA-54 studies of vapor movement TA-73 studies of vapor movement Fracture mapping of TA-21 and Pueblo Canyon	Same as faults and fractures for liquid	For sources with significant vapor-producing contaminants, if measurements and modeling suggest that fractures and faults contribute to vapor phase transport, then further evaluate this pathway.	Same as faults and fractures for liquid
	Is there a lateral component of liquid flow?				
	• Is there visual evidence?	Presence of DP Spring Flow out of pumice bed (Cerro Toledo) below DP spring Surveillance data analysis of spring samples	Identify location of springs Determine if anthropogenic contaminants (Appendix VIII, HE, fission products) are present and if naturally occurring constituents are above expected distribution (concentration guideline) Perform trend analysis of surveillance data	If anthropogenic contaminants and/or naturally-occurring contaminants above the concentration guideline are detected in springs/seeps, conduct further investigations to establish source spring/ seep connection	• Analyze existing data and/or sample springs and other groundwater discharge areas to establish concentration guideline of naturally-occurring constituents • For springs with anthropogenic contaminants or naturally-occurring constituents above concentration guideline delineate seep/spring source area relative to contamination source, install boreholes to investigate source areas, hydraulic properties, in-situ water content, conductivity of layers above and below seep/spring zone, stratigraphy, porosity, chemical signature of seep/spring water, temperature, electrical conductivity, discharge measurement, tracer studies

Decision	Questions	Existing Data	New Data	Decision Rule for New Data	Data Collection Design
	• Are hydraulic contrasts between adjacent stratigraphic layers sufficient to cause lateral direction of flow	In tuff: hydraulic conductivity vs water content/pressure potential for each layer, and porosity for each layer.	In deeper layers: hydraulic conductivity vs water content/pressure potential for each layer, moisture characteristics for each layer and porosity for each layer	If the hydraulic contrasts between units deeper than the tuff is greater than 2 orders of magnitude, then further evaluate this pathway.	In source areas, collect core samples for testing and complete in-situ tests for each layer below the tuff.
Based on the cumulative data from Aggregate 1 characterization, and resulting refined conceptual model, are there indications of impact from Laboratory activities that would impair beneficial use, and require further action?	What is the Regional Aquifer water quality? • What is the upgradient Regional Aquifer water quality?	Water quality information from production wells and test wells; because regional flow direction is unknown, whether this is upgradient is unknown Water quality information from production wells and test wells, not zone-specific	Water quality in upgradient direction(s) Flow direction in Regional Aquifer Water Quality from areas that have not been impacted by Lab activities Geologic zone-specific water quality Connection between near - surface contamination and underlying groundwater bodies	If the water quality of the upgradient limit of the aggregate is statistically different from the downgradient limit of the aggregate, then evaluate remedial options	Install Regional Aquifer wells: • DP: 1 Type 2 well 4 Type 3 wells • ER: 5 Type 2 wells 1 Type 3 well 1 Type 5 well (for locations see Aggregate 1 details for canyons and mesas)
	What concentration of contaminants would constitute impairment of beneficial use?	WQCC groundwater standards and 20NMAC 4.1			

Aggregate 1: TA-21, -53, and -73 Mesas

Decision	Questions	Existing Data	New Data	Decision Rule for New Data	Data Collection Design
	Which areas show the highest levels of contamination (e.g., upward trends), requiring monitoring?	Based on ER investigations: Los Alamos Canyon Pueblo Canyon TA-21 TA-53	Fate-and transport of contaminants through the ground-water system	If contamination sources are present and pathways from those sources to groundwater would cause contamination of the groundwater above regulatory standards and/or risk limits, then implement remedial actions and monitor the groundwater quality to verify adequacy for beneficial use.	Modeling of groundwater flow system, based on data collected in mesa and canyons of Aggregate 1.

Aggregate 2: Cañada del Buey and Pajarito Canyons

Decision	Questions	Existing Data	New Data	Decision Rule for New Data	Data Collection Design
Are there sources of sufficient magnitude to cause contamination of groundwater?	What are the contaminants that could have been released from sources?	Legacy Sources: Same list as TA-54 mesa top plus HE, DU, Be, Ba Present Sources: Pajarito Canyon NPDES Outfall	Stormwater quality data Contaminants in sediments in both canyons	If contaminants other than those currently identified are found in stormwater or during ER investigations, then add those contaminants to the list of PCOCs.	• Legacy Sources: Information from ER work • ER/ESH: Present Sources: stormwater data from developed areas
Are the alluvial sediments and uppermost subsurface water (USSW) from various present and legacy sources at contaminant concentrations ([cont.]) > regulatory limit or risk level?	What are the concentrations of these contaminants in sediments and USSW?	Concentration of contaminants in alluvial water in Pajarito Canyon Partial information on concentrations of contaminants in sediments from ER and ESH data	Contaminants in sediments in Cañada del Buey and Pajarito Canyons Background water quality in both canyons Background for sediments in Cañada del Buey and Pajarito Canyons	If contaminants are detected above SALs and background, then further investigate their presence in the groundwater pathway.	ER plans to install: • 12 Type 1 alluvial wells in Pajarito Canyon • One Type 1 well in Three Mile Canyon Sediment sampling in Pajarito Canyon and Cañada del Buey
	Are there occurrences of water in Pajarito Canyon and Cañada del Buey?	Surface water gauging stations in both canyons Alluvial water - greater than 50 gpd in middle reach of Pajarito Canyon, this is considered groundwater No alluvial groundwater in Cañada del Buey Canyon, but does have USSW.	Nature of upper Pajarito Canyon alluvial water Water quality in all channel segments for alluvial ground-water	If there is saturation in the alluvium of upper Pajarito Canyon, then determine which Standards apply.	ER Placing wells in alluvium in Pajarito Canyon
		Surface water in both Pajarito and Cañada del Buey	Water levels and yield of alluvial zone in upper Pajarito Canyon	If the average yields from alluvium in upper Pajarito Canyon is $\geq$ 50 gpd, then the water quality will be compared to WQCC groundwater standards and 20 NMAC 4.1	ER placing 12 Type 1 wells in Pajarito Canyon to determine occurrence of groundwater and yield of water bearing zones

Decision	Questions	Existing Data	New Data	Decision Rule for New Data	Data Collection Design
	What are the regulatory standards that apply to the alluvial water in Pajarito and Cañada del Buey canyons?	WQCC Surface Water Standards, WQCC Abatement Regs. and 20 NMAC 4.1			
Is the intermediate perched groundwater underlying the alluvial sediments and USSW at [cont.] > regulatory limit or risk level?	Is there an intermediate perched water body in Pajarito and/or Cañada del Buey Canyons?	No information available	Identify perched zones beneath Pajarito and Cañada del Buey canyons.	If perched groundwater is encountered between the base of the alluvium and the Regional Aquifer, then collect information to characterize the hydrologic characteristics of those zones.	ER will install: • One Type 2 well in Two Mile Canyon; • One Type 2 well in upper reach of Pajarito Canyon above confluence with Two Mile Canyon; • One Type 2 well in middle reach of Pajarito Canyon above TA-18; • One Type 2 well in Lower Pajarito Canyon in association with MDA-G. DP: Monitoring well (Type 3) in association with PM-2 will also be used to collect data on intermediate zone.
	Does intermediate perched groundwater meet the definition of "groundwater"?	No information available	Yield of intermediate perched groundwater.	If the intermediate perched groundwater yields $\geq$ 50 gpd, then the water quality will be compared to WQCC groundwater standards and 20 NMAC 4.1.	Wells to expected depth of Regional Aquifer will identify intermediate perched water. If perched water is encountered, estimate yield.

Decision	Questions	Existing Data	New Data	Decision Rule for New Data	Data Collection Design
	What are the PCOCs from alluvial sediments that have been transported to the intermediate perched groundwater?	See list from TA-54 Area G & L that includes DU, BE, BA.	If intermediate perched groundwater is present in Pajarito Canyon, collect samples for water quality analysis	If contaminants other than those currently identified are detected in the intermediate perched groundwater, then add those constituents to the list of PCOCs.	ER placing 4 wells in Pajarito Canyon that will identify intermediate perched water.
	What are the regulatory standards that apply to the intermediate perched water in Cañada del Buey and Pajarito Canyons	No information available	Presence and yield of intermediate perched groundwater.	If the average yield from the intermediate perched zone in Pajarito Canyon is $\geq$ 50 gpd then the water quality will be compared to WQCC groundwater standards and 20 NMAC 4.1	Wells to identify intermediate perched water. If perched water is encountered, estimate yield.
Is the Regional Aquifer, as affected by the canyon systems, impacted by [cont.] $\geq$ some regulatory standards?	Have PCOCs migrated from intermediate perched zones and/or alluvial sediments/USSW to the Regional Aquifer?	A organic vapor plume has been documented at a depth of 500 feet below land surface at TA-54	Water quality in Regional Aquifer with respect to PCOCs.	If PCOCs are detected in the Regional Aquifer then evaluate remedial options along source and pathways	Five wells to Regional Aquifer depth to collect core and samples of water. Collect samples and analyze for PCOCs in the five Regional Aquifer wells.
	What are the concentrations of PCOCs in the Regional Aquifer?	No existing data	Water quality data for the Regional Aquifer	If the concentration of PCOCs in the Regional Aquifer exceeds standards, then evaluate further actions.	Collect samples and analyze for PCOCs in the 5 Regional Aquifer wells
Are there sufficient source terms to cause contamination if moved along the pathways in 1000 years.			Definition of pathways Rates of contaminant transport Mass of contaminants available for transport Predicted contaminant concentration in receiving media	If modeling predicts that contaminants will cause contamination of Regional Aquifer within 1000 years, then evaluate remedial options	Geologic, hydrologic, and geochemical data from wells and other investigations as input to model.

Aggregate 2: Cañada del Buey and Pajarito Canyons

Decision	Questions	Existing Data	New Data	Decision Rule for New Data	Data Collection Design
What are the pathways for exposure to contaminants from alluvial sediments and USSW?	Does significant recharge occur from near surface to underlying groundwater bodies?	Limited information on Cañada del Buey. No information on Pajarito Canyon.	Recharge from surface water to alluvial water, horizontal extent of saturation in the alluvium, channel geometry	If the combined geologic, chemical, and hydrologic properties of the units below the canyon suggests recharge to underlying groundwater bodies within 1000 years, further evaluate this pathway.	ER Program: Well transects across the alluvium in the midsection of Pajarito Canyon
	Do we know the hydraulic properties of alluvium?	Unknown	Porosity, hydraulic gradient, hydraulic conductivity	If the maximum calculated value of hydraulic properties suggests fluid movement downward through the alluvium occurs, then further evaluate this pathway.	ER Program: In-situ testing of well transects
	What are the retardation factors of the alluvial sediments?	Unknown	Kds for ^{90}Sr, ^{132}Cs, U, Pu, Am, Np; water chemistry particularly for HE, DU, Ba, Be, U	If the site-specific minimum retardation factors suggest that contaminants are not significantly retarded in the alluvium over a period of 1000 years, then further evaluate this pathway.	Core samples from Type 1 wells; water samples from Type 1 wells.
	Are fractures and faults important contaminant transport pathways for liquids in the canyons?	Extent of fracturing and faulting is unknown.	Investigation of role of faults and fractures.	If measured fault and fracture responses and models of fault and fracture flow predict that recharge occurs through fractures to Regional Aquifer bodies within 1000 years, further evaluate this pathway.	To be determined by literature search, expert consultation, and more specific data collection as described in ER work plan and sampling analysis plan.
	Do we understand ground-water movement from alluvial water to intermediate perched zones?	Unknown	Core samples for hydraulic properties, geochemistry, FOC.	If the combined hydraulic properties and geochemistry suggest that alluvial ground-water moves downward to intermediate perched zones, then further investigate this pathway.	Five wells to Regional Aquifer to collect data on intermediate perched water and perching layers.

Decision	Questions	Existing Data	New Data	Decision Rule for New Data	Data Collection Design
	Groundwater movement from intermediate perched zones to Regional Aquifer?	Unknown	Core samples for hydraulic properties, geochemistry	If the combined hydraulic properties and geochemistry suggest that water from perched zones moves downward to the Regional Aquifer, then further evaluate this pathway.	Five wells to Regional Aquifer.

Decision	Questions	Existing Data	New Data	Decision Rule for New Data	Data Collection Design
Are the soils/tuff or USSW from various present and legacy sources at contaminant concentrations > some regulatory limit or risk level?	What are the contaminants?	From archival data; waste records; ER investigations; the contaminants are: Pu, Am, Np, Sr, Cs, C-14, ^{3}H, TCA, TCE	ER investigation to determine hazardous and radioactive components. Core samples and/or trenching.	If contaminants other than those currently identified are detected during investigations, then add those contaminants to the PCOC list.	ER drilling, trenching, and sampling around sites to investigate source terms in the vadose zone.
	What are the concentrations of contaminants?	Waste records indicate radionuclides placed in shafts and pits.	Concentration of contaminants	If contaminants are detected above SALs, then further investigate their presence in the pathway.	ER drilling, trenching, and sampling around sites to investigate source terms in the vadose zone.
	Are there occurrences of water at this site?	Surface stormwater data is available	Presence of subsurface water above the Regional Aquifer, only if intermediate perched zones are encountered in the canyons.	If significant intermediate perched zones are encountered beneath the canyons, then investigate beneath the mesa	Possible ER boreholes
	What are the regulatory standards that apply?	Subsurface saturation above Regional Aquifer is not expected. Seismic hazard borehole west of TA-54, Area L indicated presence of intermediate zone. Recent ER drilling beneath Area L has not confirmed intermediate water. In the unsaturated Zone the WQCC abatement regs. & 20 NMAC 4.1.			
Is the Regional Aquifer or an underlying intermediate perched zone, as potentially affected by a present or legacy source, predicted to be impacted by [cont.] > regulatory standard or risk level using a conservative model?	What model will be used? What data are needed for the model?	A screening model such as RESRAD or MULTIMED Preliminary data is available from the literature, archival data, ESH, WM, and ER work. TA-54 Area G, data is available from Performance Assessment	Outputs of screening model.	If the screening model, using conservative scenarios suggest that underlying groundwater bodies would not be contaminated above a regulatory standard or risk limit by the identified present or legacy sources, then do not further evaluate pathways.	Run the model(s)

Decision	Questions	Existing Data	New Data	Decision Rule for New Data	Data Collection Design
What are the pathways for exposure to contaminants from soils/tuff and water in the USSW?	What is the recharge? (groundwater movement further downward from the site)				
	• Are the hydrological and chemical properties of the underlying geological strata known?	Cores and neutron tube measurements near TA-54 show higher moisture in soil/tuff in near surface (10-15 ft) than deeper. Cores of Bandelier Tuff for geological properties. TA-54 in-situ air permeability sampling. MDA-G Performance Assessment	Data on Bandelier: moisture characteristics, conductivity, in-situ water content, pressure potential, porosity, bulk density, particle density, hydrodynamic dispersion, retardation coefficient, pH, CEC, water chemistry, fracture of organic carbon, liquid diffusion coefficient, gas diffusion coefficient, stratigraphy, mineralogy, lithology, isotopes, trace element chemistry, surface area, microbial populations, redox potential. Geological, chemical, and hydrologic parameters of underlying units underlying the Bandelier Tuff.	If the combined geologic hydrologic, and chemical properties of the units below the mesa suggests recharge could occur to underlying groundwater bodies within 1000 years, then further evaluate this pathway.	• Water balance measurement to distinguish run-off from infiltration in TA-54 • Core from boreholes and in-situ testing of non-recovery zones in boreholes (Cerro Toledo, Puye) in TA-54 • ER/WM will drill one borehole to Regional Aquifer depth in Pajarito Canyon

Decision	**Questions**	**Existing Data**	**New Data**	**Decision Rule for New Data**	**Data Collection Design**
	• Are fractures and faults and important contaminant transport pathways for liquids?	FRACTURES: Data and modeling for MDA-G. Presence of water indicated by soils w/clays, iron oxides and calcium carbonate observed in some fractures. Limited fracture mapping from Pit 39. Cores beneath pits with full suite & ^{3}H measurements and moisture measurements. Horizontal core holes drilled under waste pits at MDA-G.	FRACTURES: Response of fractures: fracture density, apertures, filling characteristics both chemical and hydrological, length and connection. Model of fracture flow of both liquid and gas including fracture matrix interactions.	If measured fracture responses and models of fracture flow predict recharge occurs through fractures to underlying groundwater bodies within 1000 years, further evaluate this pathway.	• Fracture mapping of outcrops at TA-54. • Map fractures in cores that are collected from boreholes that are placed for other reasons. • Map fractures in open pits.
			Fracture mapping of outcrops at TA-54.		
		FAULTS: Existing fault maps. Numerous small faults observed at TA-54.	FAULTS: Identify faults by comparing fracture density and surface mapping. Detailed mapping to identify offsets in stratigraphic units (e.g., surge beds). Hydrologic characteristics of fault zones.	If faults are identified in critical zones and the testing and/or modeling of those fault zones suggests that recharge to underlying water bodies occurs within 1000 years, then further evaluate this pathway.	• Fracture mapping of outcrops to identify fault zones. • Detailed stratigraphic mapping where faults in critical zones (critical zone = areas with contaminant sources). • In-situ testing and monitoring in boreholes in faults in critical zones (air permeability if possible).

Decision	Questions	Existing Data	New Data	Decision Rule for New Data	Data Collection Design
	• Can we estimate recharge?	Area G testing including steady-state moisture profile and hydrologic parameters; water balance.	Steady-state moisture profile, hydrologic parameters. Water balance (in tuff) and environmental tracers at TA-54 of tuff and deeper units.	If estimates of recharge predict that water would move from near the surface of the mesa to the Regional Aquifer (or intervening groundwater body) within 1000 years, then further evaluate this pathway.	• Core samples from boreholes to measure steady-state moisture profile and hydrologic parameters and environmental tracers. • Water balance measurements of mesa; including runoff and infiltration. • Drainage study in outcrops of non-recovery zones (Puye and Cerro Toledo).
	Does significant vapor phase transport occur?	Core and downhole sampling from TA-54, MDA L & G have indicated > 500 ft. vertical movement.	Vapor diffusion coefficients, liquid-vapor partitioning relationships and constant; retardation of vapor phase, transformation of contaminants, stratigraphy, lithology, mineralogy, vapor density vs. concentration relationship, temperature distribution, fraction of organic carbon, barometric pressure, air permeability versus water content for each geologic unit, porosity, in-situ water content and/or pressure head are needed for both Bandelier tuff and underlying units.	For sources with significant vapor-producing contaminants, if vapor diffusion characteristics underlying that source suggest that vapor phase transport has or could occur within 1000 years, then further evaluate this pathway.	One Type 2 well will be installed at MDA-L (ER); while drilling this well, core samples will be collected for analysis and in-situ testing of the borehole will be conducted.

Decision	Questions	Existing Data	New Data	Decision Rule for New Data	Data Collection Design
	• Are fractures and faults important contaminant transport pathways for vapors?	TA-54 studies of vapor movement	Same as for faults and fractures for liquid	For sources with significant vapor-producing contaminants, if measurements and modeling suggest that fractures and faults contribution to vapor phase transport, then further evaluate this pathway.	Same as for faults and fractures for liquid
	Is there a lateral component of liquid flow?				
	• Is there visual evidence?	No evidence of seeps or springs			
	• Are hydraulic contrasts between adjacent stratigraphic layers sufficient to cause lateral direction of flow?	In tuff: hydraulic conductivity vs. water content/pressure potential for each layer, and porosity for each layer.	In deeper layers, starting with Guaje Pumice hydraulic conductivity vs. water content/ pressure potential for each layer, moisture characteristics for each layer and porosity for each layer	If the hydraulic contrast between units deeper that the tuff is greater than 2 orders of magnitude, then further evaluate this pathway	In source areas, collect core samples for testing and complete in-situ tests for each layer below the tuff.
Based on the cumulative data from Aggregate 2 characterization, and resulting refined conceptual model, are there indications of impacts from Laboratory activities that would impair beneficial use, and require further action	What is the regional aquifer water quality?				

Decision	Questions	Existing Data	New Data	Decision Rule for New Data	Data Collection Design
	• What is the upgradient regional aquifer water quality?	Water quality information from production wells and test wells; because Regional Aquifer flow direction is unknown, upgradient direction is unknown.	• Water quality upgradient of Lab activities • Regional Aquifer flow direction(s)	If the water quality of the upgradient limit of the aggregate is statistically different from the downgradient limit of the aggregate, then evaluate remedial options	• Water quality from Type 3 well associated with PM-2.
		Water quality information from production wells and Test Wells, but not zone specific	• Water quality from areas not impacted by Lab activities • Geologic zone-specific water quality		• Rely on Regional Aquifer Control wells installed by DP for determination of potentiometric surface and flow direction(s) in Regional Aquifer. • Collect water quality samples from upgradient and Regional Aquifer Control wells at multiple water-bearing zones.
	What concentration of contaminants would constitute impairment of beneficial use?	WQCC groundwater standards and 20 NMAC 4.1			
	Which areas show the highest levels of contamination (e.g., upward trends), requiring monitoring?	Based on ER investigation: TA-54 Area L & G	Connection between near surface contamination and underlying ground-water bodies Determine or predict fate and transport of contaminants through the ground-water system	If contamination sources are present and pathways from those sources to groundwater would cause contamination of the groundwater above regulatory standards and/or risk limits, them implement remedial actions and monitor groundwater quality to verify adequacy for beneficial use.	• Collect data specified in Aggregate 2 if screening level is exceeded • Determine or predict fate and transport of contaminants through the groundwater system

Decision	Questions	Existing Data	New Data	Decision Rule for New Data	Data Collection Design
Are the soils/tuff or USSW from various present and legacy sources at contaminant concentrations > some regulatory limit or risk level?	What are the contaminants?	TA-49, Area AB, radionuclides are ^{239}Pu, ^{241}Am, U, Pb, Be	Hazardous contaminants present at TA-49	If contaminants other than those currently identified are detected during ER investigations, these will be added to the list of PCOCs.	ER investigation report being prepared. ER investigation will determine hazardous constituents.
	What are the concentrations of contaminants?	TA-49 data on existing sources are available.			
	What are the concentration of contaminants in the future?	Estimated inventory 90,000 kg Pb, 11 kg Be, 2500 Ci radionuclides	No data needs.		
	Are there occurrences of water at this site?	Subsurface is generally unsaturated; however there is high water content beneath asphalt pad and water in borehole in asphalt pad Surface water during storm events.	Need stormwater data.	If contaminants other than those currently identified are detected in stormwater, then add those to list of PCOCs.	Collect stormwater run-off from mesa top; analyze for water chemistry.
	What are the regulatory standards that apply?	For unsaturated zones, the WQCC abatement regs. & 20 NMAC 4.1.			
Is the Regional Aquifer or an underlying intermediate perched zone, as potentially affected by a present or legacy source, predicted to be impacted by [cont.] > regulatory standard or risk level using a conservative model?	What model will be used?	A screening model such as RESRAD or MULTIMED.	Outputs of screening model	If the screening model, using conservative scenarios, suggests that underlying groundwater bodies would not be contaminated above a regulatory standard or risk limit by the identified legacy or present sources, then do not further evaluate pathways.	Run the model(s)
	What data are needed for the model?	Preliminary data is available from the literature, archival data, ESH and ER investigations.	No data needs		

Decision	Questions	Existing Data	New Data	Decision Rule for New Data	Data Collection Design
What are the pathways for exposure to contaminants from soils/tuff and water in the USSW?	What is the recharge? (groundwater movement further downward from the site)	Cores and neutron probe measurements near TA-49 show higher moisture in soil/tuff in near surface than deeper (0 - 30 ft.).			• Water balance measurements to distinguish run-off from infiltration in TA-49.
	• Are the hydrological and chemical properties of the underlying geological strata known?	Cores of Bandelier Tuff for geological and hydrological properties at TA-49.	Chemical data on Bandelier: moisture characteristics, conductivity, in-situ water content and pressure potential, porosity, bulk density, particle density, hydrodynamic dispersion, retardation coefficient, pH, CEC, water chemistry, fraction of organic carbon, liquid and gas diffusion coefficient, stratigraphy, mineralogy, lithology, isotopes, trace element chemistry, surface area, redox potential. Geological chemical and hydrologic parameters of underlying units.	If combined geologic, chemical, and hydrologic properties of the units below the mesa suggest recharge to underlying groundwater bodies occurs within 1000 years, then further evaluate this pathway.	• Core from boreholes and in-situ testing of non-recovery zones in the boreholes (Cerro Toledo, Puye) in TA-49. ER will install: • One Type 2 well in the mesa at TA-49 (deepen existing 700-ft deep borehole) • One Type 2 well in Water Canyon near junction of Water Canyon and Canyon de Valle (in Aggregate 6).
	• Are fractures and faults and important contaminant transport pathways for liquids?	FRACTURES: Data and modeling for MDA-G, however TA-49 receives more precipitation than does MDA-G.	FRACTURES: Response of fractures: fracture density, apertures, filling characteristics both chemical and hydrological, length and connection.	If measured fracture responses and models of fracture flow predicts that recharge occurs through fractures to underlying groundwater bodies within 1000 years, further evaluate this pathway.	• Fracture mapping of outcrops at TA-49 • Map fractures in cores that are collected from boreholes that are placed for other reasons.

Decision	Questions	Existing Data	New Data	Decision Rule for New Data	Data Collection Design
			Model of fracture flow of both liquid and gas including fracture matrix interactions. Fracture mapping of outcrops.		
		FAULTS: Existing fault maps	FAULTS: Identify faults by comparing fracture density and surface mapping. Detail mapping to identify offsets in stratigraphic units (e.g., surge beds). Hydrologic characteristics of fault zones.	If faults in critical zones are identified and testing and/or modeling of those fault zones predict recharge to underlying groundwater bodies within 1000 years, then further evaluate this pathway.	• Fracture mapping of outcrops to identify fault zones. • Detailed stratigraphic mapping where faults in critical zones (critical zone = areas with contaminant sources). • In-situ testing and monitoring in boreholes in faults in critical zones (air permeability).
	• Can we estimate recharge?	Area G testing including steady-state moisture profile and hydrologic parameters; water balance Moisture profile from one borehole Data from Environmental Surveillance reports and Purtymun & Stoker (1987)	Steady-state moisture profile, hydrologic parameters, water balance (in tuff and deeper units) environmental tracers (in tuff) at TA-49.	If estimates of recharge predict that water would move from the near surface of the mesa to the Regional Aquifer (or intervening groundwater body) within 1000 years, then further evaluate this pathway.	• Core samples from boreholes to measure steady-state moisture profile and hydrologic parameters and environmental tracers. • Water balance measurements on mesa, including infiltration.
	Does significant vapor phase transport occur?	As a contaminant transport mechanism vapor phase transport is not applicable due to the PCOCs.			

Decision	Questions	Existing Data	New Data	Decision Rule for New Data	Data Collection Design
	Are fractures and faults important contaminant transport pathways for vapors?	As a contaminant transport mechanism vapor phase transport is not applicable due to the PCOCs.			
	Is there a lateral component of liquid flow?				
	• Is there visual evidence?	No springs or saturation in boreholes.			
	Are hydraulic contrasts between adjacent stratigraphic layers sufficient to cause lateral direction of flow?	Unknown	Install borehole and collect core samples and in-situ-tests.	If the hydraulic contrast between units deeper that the tuff is greater than 2 orders of magnitude, then further evaluate this pathway.	In source area, collect core samples for testing and complete in-situ tests for each layer below the tuff.
Based on the cumulative data from Aggregate 3 characterization, and resulting refined conceptual model, are there indications of impacts from Laboratory activities that would impair beneficial use, and require further action?	What is the Regional Aquifer water quality?				
	• What is the upgradient Regional Aquifer water quality?	Water quality information from test wells, but none upgradient. Water quality information from production well and test wells; but it is not zone-specific.	Water quality in upgradient and downgradient direction(s). Flow direction in the Regional Aquifer. Water quality from areas not impacted by Lab activities.	If the water quality of the upgradient limit of the aggregate is statistically different from the downgradient limit of the aggregate, then evaluate remedial options.	• Rely on Regional Aquifer wells installed for determination of potentiometric surface and flow direction(s) in Regional Aquifer. • Collect water samples from (1) ER Type 2 well downgradient at TA-49 and (1) Type 2 well in Water Canyon.

Decision	Questions	Existing Data	New Data	Decision Rule for New Data	Data Collection Design
			Zone specific water quality. Connection between near-surface contamination and underlying groundwater bodies.		• Type 3 well to be installed by DP on east side of S-Site (near MDA-P) to provide upgradient water quality (Aggregate 6)
	What concentration of contaminants would constitute impairment of beneficial use?	WQCC groundwater standards and 20 NMAC 4.1.			
	Which areas show the highest levels of contamination (e.g., upward trends), requiring monitoring?	Based on current understanding: MDA-AB	Determine or predict fate and transport of contaminants through the groundwater system.	If contamination sources are present and pathways from the sources to groundwater would cause contamination of the groundwater above regulatory standards and/or risk limits, then implement remedial actions and monitor the groundwater quality to verify adequacy for beneficial use.	Use all data collected for characterization of Aggregate 3.

Decision	Questions	Existing Data	New Data	Decision Rule for New Data	Data Collection Design
Are there legacy and/or present sources of sufficient magnitude to cause contamination of groundwater?	What are the contaminants that could have been released from sources?	Legacy Sources: Based on archival data, ESH and ER work, expected contaminants are: high explosives, depleted uranium, mercury, lead, beryllium, barium chromium, thallium, cadmium, uranium, solvents, PCBs. Present Sources: NPDES outfall-contact cooling water. Stream gage present on Ancho Canyon, some stormwater runoff collection and analysis from stream.		If contaminants other than those currently identified are detected in outfall sampling or ER work, then add those contaminants to the list of PCOCs.	• Legacy Sources: information for ER work • ER/ESH-18: continued NPDES sampling and sampling of stormwater
Are the alluvial sediments and uppermost subsurface water (USSW) from various present and legacy sources at contaminant concentrations ([cont.]) > regulatory limit or risk level?	What are the concentrations of these contaminants in sediments and USSW?	Concentration of contaminants in sediments. Background in sediments in Ancho Canyon	Role of stormwater in sediment transport in the drainage channel. Water quality in saturated zone beneath MDA-Y at a depth of 15 ft. is not known, but will not be sampled because the overlying sediments do not contain contaminants. Concentration of contaminants in Indio and Chaquehui canyons.	If contaminants are detected above SALs and background then further investigate their presence in the groundwater pathway.	• ESH-18: Measurement of stream flow resulting from storms, grab samples of run-off from stream, analysis of samples. • ER Program plans to sample sediments in Indio and Chaquehui canyons. • ER Canyons work plan includes three Type 1 alluvial wells: - North branch of Ancho Canyon near confluence of two main branches - South branch of Ancho Canyon near confluence of two branches - Near PAAC-1

Decision	Questions	Existing Data	New Data	Decision Rule for New Data	Data Collection Design
	Are there occurrences of water in Ancho, Indio, and Chaquehui canyons?	Ephemeral surface water in channel; stream gage present 1 mile below TA-39 fence in Ancho Canyon. Encountered a saturated zone in the alluvium near MDA-Y, but whether this is a permanent alluvial water body is unknown. Subsequent drilling has not detected any further saturated conditions. Ancho Spring occurs about 2 miles downstream of TA-39. Occurrence of alluvial water in Indio and Chaquehui canyons unknown.	Presence and extent of alluvial water Quality of alluvial water	If there is saturation in the alluvium, then determine which standards apply.	ER: Measure water levels in alluvial wells and collect water quality samples.
	What are the regulatory standards that apply to the alluvial water in Ancho, Indio, and Chaquehui canyons?	WQCC Abatement regulations and 20 NMAC 4.1		If the average yield from alluvium is >50 gpd, then the water quality will be compared to WQCC ground-water standards and 20 NMAC 4.1.	• ER: If alluvial water is detected in wells, estimate yield.
Is the intermediate perched groundwater underlying the alluvial sediments and USSW at [cont.] > regulatory limit or risk level?	Is there an intermediate perched water body in Ancho, Indio, or Chaquehui canyons?	Unknown, however presence of Ancho Spring suggests an intermediate zone is present throughout some length of Ancho Canyon, but not necessarily beneath TA-39.	Identify perched zone(s) below Ancho, Indio, and Chaquehui canyons. Geochemical characteristic, and isotopic analyses of Ancho Spring water.	If perched groundwater is encountered between the base of the alluvium and the Regional Aquifer, then collect information to characterize the hydrologic characteristics of those zones.	ER Canyon Work Plan: sample spring water for: geochemical parameters and isotopic analysis. DP will install: • Type 3 well to Regional Aquifer to identify perched water located close as possible to Ancho Spring. • Type 2 well in north branch of Ancho Canyon

Decision	Questions	Existing Data	New Data	Decision Rule for New Data	Data Collection Design
	Does intermediate perched groundwater meet the definition of "groundwater"?	If the source of water for Ancho Spring is intermediate perched groundwater, then based on observation that Ancho Spring supplies significant flow to stream in Ancho Canyon it is likely to be "groundwater."			
	What are the PCOCs from alluvial sediments that have been transported to the intermediate perched groundwater?	Total suite of PCOCs unknown, but depleted uranium has been detected in Ancho Spring water, as well as high explosives in 1995 surveillance sample. It is unknown whether it was transported via groundwater or is from sediment in the surface water.	Filtered water quality from Ancho Spring Evaluate transport mechanism Water quality of perched water	If COCs are present in spring water, then conduct investigations to identify source spring connection.	ER Canyon Work Plan: • Filter sample of Ancho Spring water and analyze for PCOCs. • Collect samples from Type 3 well in perched water near Ancho Spring and analyze for PCOCs.
	What are the regulatory standards that apply to the intermediate perched water in Ancho Canyon?	WQCC groundwater standards WQCC Abatement Regulations and 20 NMAC 4.1. WQCC Stream Standards apply to surface water at Ancho Spring.			
Is the Regional Aquifer, as affected by the canyon systems, impacted by [cont.] ≥ some regulatory standards?	Have PCOCs migrated from intermediate perched zones and/or alluvial sediments/USSW to the Regional Aquifer?	No data, but presence of depleted uranium and HE in Ancho Spring raises possibility of contamination of Regional Aquifer.	Depending on perched water quality and extent, water quality of Regional Aquifer.	If contaminants are present in Ancho Spring and/or perched groundwater, then conduct investigations of Regional Aquifer water quality	DP: Type 3 well near Ancho Canyon Spring and Type 2 well in north branch of Ancho Canyon. Use Regional Aquifer wells for determination of potentiometric surface and flow direction(s) in Regional Aquifer.
	What are the concentrations of PCOCs in the Regional Aquifer?	No data.	Water quality of Regional Aquifer	If contaminants are detected in the Regional Aquifer above MCLs, WQCC groundwater standards, and 20 NMAC 4.1, then evaluate further actions.	ER/ESH will collect water samples from Regional Aquifer well and analyze for PCOCs.

Decision	Questions	Existing Data	New Data	Decision Rule for New Data	Data Collection Design
Are there sufficient source terms to cause contamination if moved along the pathways in 1000 years.			Definition of pathways Rates of contaminant transport Mass of contaminants available for transport Predicted contaminant concentrations in receiving media	If modeling predicts that contaminants will cause contamination of the Regional Aquifer within 1000 years, then evaluate remedial options.	Geologic, hydrologic, and geochemical data from wells and other investigations as input to model.
What are the pathways for exposure to contaminants from alluvial sediments and USSW?	Does significant recharge occur from near surface to underlying groundwater bodies?	Unknown	Recharge from surface water to subsurface water Extent of saturation in the alluvium	If the combined geologic, chemical, and hydrologic properties of the units below the canyon suggest recharge to underlying ground water bodies occurs within 1000 years, further evaluate this pathway.	ER: Install 3 Type 1 wells (described in Decision 1) and measure head.
	Do we know the hydraulic properties of alluvium?	Estimates from descriptions of alluvial material.	Porosity, hydraulic gradient, hydraulic conductivity	If the maximum calculated value of hydraulic properties suggest fluid movement downward through the alluvium occurs, then further evaluate this pathway.	ER: In-situ water content, permeameter, and grain size analysis of cuttings from the wells.
	What are the retardation factors of the alluvial sediments?	No data.	Kds for COCs, water chemistry	If the site-specific minimum retardation factors suggest that contaminants are not significantly retarded in the alluvium over a period of 1000 years, then further evaluate this pathway.	ER: Samples from 3 Type 1 wells if pathways and contaminants are significant.

Decision	Questions	Existing Data	New Data	Decision Rule for New Data	Data Collection Design
	Are fractures and faults important contaminant transport pathways for liquids in the canyons?	Existing faults maps	Investigation of role of faults and fractures.	If measured fault and fracture responses and models of fracture flow predicts that recharge occurs through faults and fractures to Regional Aquifer bodies within 1000 years, further evaluate this pathway.	To be determined by literature search, expert consultation, and more specific data collection. Described in ER Work Plan and Sampling Analysis Plan.
	Do we understand ground-water movement from alluvial water to intermediate perched zones?	No data.	Hydraulic properties and geochemistry	If the combined hydraulic properties and geochemistry suggest that alluvial groundwater moves downward to intermediate perched zones, then further investigate this pathway.	ER: Collect core for hydraulic properties from 3 Type 1 alluvial wells and two Regional Aquifer wells. Analyze geochemistry of core and water.
	Groundwater movement from intermediate perched zones to Regional Aquifer?	Unknown.	Hydraulic properties, geochemistry, water quality	If the combined hydraulic properties and geochemistry suggest that water from intermediate perched zones moves downward to the Regional Aquifer, then further evaluate this pathway.	ESH: Core samples from the two Regional Aquifer wells to measure hydraulic properties, geochemistry and water quality.

Aggregate 4: TA-33 Mesa

Decision	Questions	Existing Data	New Data	Decision Rule for New Data	Data Collection Design
Are the soils/tuff or uppermost subsurface water from various present and legacy sources at contaminant concentrations > some regulatory limit or risk level?	What are the contaminants?	TA-33: Based on archival information expected contaminants are ^{3}H, beryllium, High Explosives (HE), plutonium, depleted uranium, lead, ^{60}Co and polonium.	ER investigation to determine contaminants. Core samples and/or trenching Stormwater quality	If contaminants other than those currently identified are detected as a result of stormwater analyses and/or ER investigations, then add those contaminants to PCOC list.	• ER: Drilling around sites to investigate source terms in the vadose zone • ER/ESH-18: collect stormwater data and analyze for water chemistry
	What are concentrations?	Concentrations known from ER Phase I and II data	None		
	What are the concentrations of contaminants in the future?	Some ER data available. Both CEARP and ER work encountered ^{3}H in 10^{5} nanocurie/liter concentrations to a depth of 200 ft.	Predicted concentrations in future time frames	If the concentration of contaminant are expected to change in the future, continue to investigate their presence in pathway.	ER: Perform Phase II investigations
	Are the occurrences of water at this site?	Surface water during storm events	Delineation of high moisture zone.	If the high moisture zone is saturated, then evaluate which regulatory standards apply.	ER work plans describe further delineation of high moisture zone.
		High moisture zone encountered at tuff/basalt interface in ER boreholes east of the tritium facility in MDA-K.			
	What are the regulatory standards that apply?	For the unsaturated zone, the WQCC Abatement regulations and may apply 20 NMAC 4.1	None		

Decision	Questions	Existing Data	New Data	Decision Rule for New Data	Data Collection Design
Is the Regional Aquifer or an underlying intermediate perched zone, as potentially affected by a present or legacy source, predicted to be impacted by contaminant concentrations > some regulatory standard or risk level using a conservative model?	What data are needed for the model? • What model will be used?	A screening model such as RESRAD or MULTIMED. Preliminary data is available from the ER Phase 2 findings. Based on available data, the sources at TA-33 will not contribute significant contamination to groundwater.	Outputs of screening model None	If the screening model, using conservative scenarios, suggest that underlying groundwater bodies would not be contaminated above a regulatory standard or risk limit by the identified present or legacy sources, then do not further evaluate pathways.	Run the model(s)
Based on the cumulative data from Aggregate 4 characterization and resulting refined conceptual model, are there indications of impacts from Laboratory activities that would impair beneficial use, and require further action?	What is the Regional Aquifer water quality? • What is the upgradient Regional Aquifer water quality? What concentration of contaminants would constitute impairment of beneficial use?	Water Quality information from production wells and Test Wells; because Regional Aquifer flow direction is unknown, upgradient direction is unknown. Water quality information from production wells and test wells; but it is not zone-specific. WQCC groundwater standards and 20 NMAC 4.1.	Regional Aquifer upgradient and background water quality to be determined; flow direction(s) in Regional Aquifer.		ER: TA-33 Work Plan • TA-33 vadose zone monitoring for tritium • ER Canyons work plan 3 Type I alluvial wells. • Hydrogeologic work plan: DP: Regional Aquifer Type 3 well near Ancho Spring. Use Regional Aquifer wells installed for determination of potentiometric surface and flow directions in Regional Aquifer.
	Which areas show the highest levels of contamination (e.g., upward trends), requiring monitoring?	Based on ER and Surveillance Data: • TA-33-tritium • Ancho Canyon - Ancho Spring	Determine or predict fate and transport of contaminants through the groundwater system.	If contamination sources are present and pathways from the sources to groundwater would cause contamination of the groundwater above regulatory standards and/or risk limits, then implement remedial actions and monitor the groundwater quality to verify adequacy for beneficial use.	

Decision	Questions	Existing Data	New Data	Decision Rule for New Data	Data Collection Design
Are there legacy and/or present sources of sufficient magnitude to cause contamination of groundwater?	What are the contaminants that could have been released from sources?	Legacy Sources: Based on archival data, knowledge of process and ER sampling data: HE, barium, depleted uranium beryllium, VOCs, silver, copper Present Sources: • NPDES Outfalls • Potential contaminants from new facilities (e.g., DAHRT) • Stormwater outfalls	Stormwater quality data	If contaminants other than those currently identified are detected in stormwater, then add those contaminants to the list of PCOCs.	ER: Legacy sources: information from ER work. ER/ESH-18: stormwater data from developed areas.
Are the alluvial sediments and uppermost subsurface water (USSW) from various present and legacy sources at contaminant concentrations ([cont.]) > regulatory limit or risk level?	What are the concentrations of these contaminants in sediments and USSW?	Sampling of stream flow near MDA-P resulted in detection of barium Concentration of contaminants in alluvial water	Concentration of contaminants in alluvial water Concentration of contaminants in sediments Background alluvial water quality in Canon del Valle Background in sediments in Canon del Valle	If contaminants are detected above SALs and background, then further investigate their presence in the groundwater pathway.	ER Canyons Work Plan includes ER placing Type 1 wells in alluvium in Canon del Valle • Near MDA-P • Near confluence with Water Canyon • West of TA-16 near State Route 501 Sampling of up- and down-gradient alluvial water at 3 Type 1 alluvial wells Sediment sampling in canyon
	Are there occurrences of water in Canon del Valle?	Surface water gages are present. Saturated alluvium near MDA-P. Perched intermediate water indicated by results in SHB-3.			

Decision	Questions	Existing Data	New Data	Decision Rule for New Data	Data Collection Design
	What are the regulatory standards that apply to the alluvial water in Canon de Valle?	Presence of alluvial saturation. Surface water.	Yield of alluvial zone in Canon de Valle	If the average yield from alluvium in Canon de Valle is > 50 gpd, then the water quality will be compared to WQCC groundwater standards and 20 NMAC 4.1	ER placing 3 Type 1 wells in alluvium
Is the intermediate perched groundwater underlying the alluvial sediments and USSW at [cont.] > regulatory limit or risk level?	Is there an intermediate perched water body in Canon de Valle?	Maybe present based on water in SHB-3	Confirm presence of perched zone(s)	If perched groundwater zones are encountered between the base of the alluvium and the Regional Aquifer, then collect information to characterize the hydrologic characteristics of the zone(s).	ER Program will potentially identify upper perched zones in mesa-top boreholes to depth of 200 ft. consistent with elevation of springs. DP: Type 3 Regional Aquifer well east of TA-16 (near MDA-P) will identify perched zones.
	Does intermediate perched groundwater meet the definition of "groundwater"?	No existing data	Yield of intermediate perched zone	If the average yield from intermediate perched groundwater zones is ≥ 50 gpd, then the water quality will be compared to WQCC groundwater standards and 20 NMAC 4.1	ER: estimate yield from permeability evaluation in well near MDA-P.
	What are the PCOCs from alluvial sediments that have been transported to the intermediate perched groundwater?	Barium has been detected in surface water/alluvial water. HE has been detected in springs.	Quality of intermediate perched water	If contaminants other than those currently identified are detected in the intermediate perched groundwater, then add these constituents to the list of PCOCs.	ER Permeability evaluation in well near MDA-P.
	What are the regulatory standards that apply to the intermediate perched water in Canon de Valle?	Perched water may be present: Unknown whether it is "groundwater"			

Aggregate 5. Canon del Valle Canyon

Decision	Questions	Existing Data	New Data	Decision Rule for New Data	Data Collection Design
Is the Regional Aquifer, as affected by the canyon systems, impacted by [cont.] ≥ some regulatory standards?	Have PCOCs migrated from intermediate perched zones and/or alluvial sediments/USSW to the Regional Aquifer?	No existing data, however HE is present in springs	Water quality in the Regional Aquifer	If PCOCs are detected in the Regional Aquifer then evaluate remedial options of sources and along pathways.	DP: Hydrogeologic work plan: two wells to Regional Aquifer near Canon de Valle: • West of TA-16 (Type 2) • East of TA-16 near MDA-P (Type 3) Sample water and analyze for PCOCs
	What are the concentrations of PCOCs in the Regional Aquifer?	No data	Water quality in the Regional Aquifer	If the concentration of PCOCs in the Regional Aquifer exceeds standards, then evaluate further actions.	Sample water and analyze for PCOCs in the two Regional Aquifer wells
Are there sufficient source terms to cause contamination if moved along the pathways in 1000 years.			Definition of pathways Rates of contaminant transport Mass of contaminants available for transport Predicted contaminant concentrations in receiving media	If modeling predicts that contaminants will cause contamination of the Regional Aquifer within 1000 years, then evaluate remedial options.	Geologic, hydrologic, and geochemical data from wells and other investigations as input to model.
What are the pathways for exposure to contaminants from alluvial sediments and USSW?	Does significant recharge occur from near surface to underlying groundwater bodies?	Presence of alluvial system in Canon del Valle that is recharged by surface water.	Magnitude of recharge from surface water to alluvial water Channel geometry	If the maximum calculated infiltration is greater than 1 cm/yr., then infiltration will be considered and investigated as a pathway.	ER Program: Install 3 Type 1 alluvial wells Mapping of alluvium
	Do we know the hydraulic properties of alluvium?	No existing data	Porosity, hydraulic gradient, hydraulic conductivity	If the maximum calculated value of hydraulic properties suggests fluid movement downward through the alluvium occurs, then further evaluate this pathway.	ER Program: In-situ testing of the 3 Type 1 alluvial wells and/or testing of the core.

Decision	Questions	Existing Data	New Data	Decision Rule for New Data	Data Collection Design
	What are the retardation factors of the alluvial sediments?	No existing data	Kds for HE, barium, beryllium, and depleted uranium or other PCOCs water chemistry	If the site-specific minimum retardation factors suggest that contaminants are not significantly retarded in the alluvium over a period or 1000 years, then further evaluate this pathway.	ER: Core samples from the 3 Type 1 alluvial wells ER: Water samples from the Type 1 alluvial wells
	Are fractures and faults important contaminant transport pathways for liquids in the canyons?	Existing fault maps	Investigation of role of faults and fractures	If measured fault and fracture responses and models of fault and fracture flow predicts that recharge occurs through faults and fractures to Regional Aquifer within 1000 years, further evaluate this pathway.	To be determined by literature search, expert consultation, and more specific data collections as described in ER Work Plan and Sampling Analysis Plan.
	Do we understand ground-water movement from alluvial water to intermediate perched zones?	No existing data.	Core samples for hydraulic properties, geochemistry.	If the combined hydraulic properties and geochemistry suggest that alluvial groundwater moves downward to intermediate perched zones, then further investigate this pathway.	ER Program: Collect core from alluvial wells and Regional Aquifer well; analyze for hydraulic properties and geochemistry.

Aggregate 5: ..est Side Mesas (TA -8, -9, -14, -16)

Decision	Questions	Existing Data	New Data	Decision Rule for New Data	Data Collection Design
Are the soils/tuff or uppermost subsurface water from various present and legacy sources at contaminant concentrations > some regulatory limit or risk level?	What are the contaminants?	Legacy Sources: Based on archival data, knowledge of process, ESH and ER sampling data: HE, barium, depleted uranium, beryllium, VOCS, silver, and copper Present sources: NPDES outfalls	ER investigation data.	If contaminants other than those currently identified are detected during ER investigations, then add those to the list of PCOCs	Legacy Sources: Continued ER investigations
	What are concentrations?	Data for some sites are in ER RFI reports and ESH annual surveillance reports	Contaminant concentrations.	If contaminants are detected in concentrations above SALs and background, then further investigate their presence in pathways.	ER continued investigations
	What are the concentrations of contaminants in the further?	TA-16 is an operational site and activities will continue. Assume MDA-P will be clean-closed. ER investigation defined.	No data needs.		
	Are the occurrences of water at this site?	Surface water during storm events. Multiple springs assumed to come from perched zone at TA-16 and TA-9. NPDES outfalls on top of mesa. Perched zone identified in seismic hazard borehole (SHB-3)	Presence of intermediate zones	If perched groundwater zones are encountered between the surface and the Regional Aquifer, then collect in formation to characterize the hydrologic characteristics and water quality of these zones.	ER: 4 boreholes to 200 ft. depth; estimate yield DP: Install three wells to the Regional Aquifer based on projected surface of the Regional Aquifer from site-wide well network. Intermediate perched zones will be identified and sampled. The wells are: • Type 2 west of TA-16 • Type 3 east of TA-16 near MDA-P • Type 2 in Water Canyon near State Route 501 (Aggregate 6)

Aggregate 5: West Side Mesas (TA -8, -9, -14, -16)

Decision	Questions	Existing Data	New Data	Decision Rule for New Data	Data Collection Design
	What are the regulatory standards that apply?	In the unsaturated zone the WQCC Abatement regulations and 20 NMAC 4.1	Perched groundwater yield	If perched intermediate zone(s) yield greater than 50 gpd, then the perched groundwater will be compared to the WQCC groundwater standards and 20 NMAC 4.1	Estimate yield of perched zone from data collected in the three Regional Aquifer wells.
Is the Regional Aquifer or an underlying intermediate perched zone, as potentially affected by a present or legacy source, predicted to be impacted by contaminant concentrations > some regulatory standard or risk level using a conservative model?	What model will be used? What data are needed for the model?	A screening model such as RESRAD or MULTIMED. Preliminary data is available from the literature, archival data, ESH data and ER investigations.	Outputs of screening model.	If the screening model using conservative scenarios suggest that underlying groundwater bodies would not be contaminated above a regulatory standard or risk limit by the identified present of legacy sources, then do not further evaluate pathways.	Run the model(s)
What are the pathways for exposure to contaminants from soils/tuff and water in the uppermost subsurface waters?	What is the recharge (groundwater movement further downward from the site)?	Based on measurements at MDA-P and core from boreholes, significant infiltration does occur. Very limited existing data from boreholes	Contribution from anthropogenic sources (e.g., outfalls)	If the combined geologic, chemical, and hydrologic properties of the units below the mesa suggest recharge to underlying groundwater bodies occurs within 1000 years, the further evaluate this pathway.	• ER: Water balance measurements to distinguish run-off from infiltration in TA-16 • Ongoing Ponderosa Pine pilot study. • ER: Core from boreholes and in-situ testing in non-recovery zones of boreholes (Cerro Toledo, Puye) in TA-16: • boreholes to depth of 50 ft. to investigate spring discharge.

Aggregate 5: West Side Mesas (TA -8, -9, -14, -16)

Decision	Questions	Existing Data	New Data	Decision Rule for New Data	Data Collection Design
					• 4 boreholes to depth of 200 ft. to investigate intermediate perched groundwater. DP: 3 wells to Regional Aquifer: • Type 2 well west of TA-16 • Type 3 well east of TA-16 near MDA-P • Type 2 well in Water Canyon near State Route 501 (Aggregate 6)
	Are the hydrological and chemical properties of the underlying geological strata known?	Limited data from MDA-P	Hydrologic & Chemical data on Bandelier: moisture characteristic, conductivity, in-situ water content and pressure potential, porosity, bulk density, particle density, hydrodynamic dispersion, retardation coefficient, pH, CEC, water chemistry, fraction of organic carbon, liquid and gas diffusion coefficients, stratigraphy, mineralogy, lithology, isotopes, trace element chemistry, surface area, microbial populations, redox potential. Geological chemical and hydrologic parameters of underlying units.		

Decision	Questions	Existing Data	New Data	Decision Rule for New Data	Data Collection Design
	Are fractures and faults important contaminant transport pathways for liquids?	FRACTURES: Soils w/clays, iron oxide, and calcium carbonate are present in some fractures suggest water was present. Springs emerging from fractured zones in Bandelier Tuff at TA-16.	FRACTURES: Response of fractures: fracture density, apertures, filling characteristics both chemical and hydrological, length and connection. Model of fracture flow of both liquid and gas including fracture matrix interactions.	If measured fracture responses and models of fracture flow predicts that recharge occur through fractures to underlying groundwater bodies within 1000 years, then further evaluate this pathway.	• ER: characterization studies - fracture mapping of outcrops at TA-16. • Map fractures in cores that are collected from boreholes that are placed for other reasons. • Mapping of fractures during excavation of MDA-P.
		FAULTS: Existing fault maps Parjarito Fault Zone has been mapped to the west of TA-16, and may go through TA-16.	FAULTS: Identify faults by comparing fracture density and surface mapping. Detailed mapping to identify offsets in stratigraphic units (e.g., surge beds). Hydrologic characteristics of fault zones.	If faults are identified in critical zones and the testing and/or modeling of those fault zones suggest that recharge to underlying water bodies occurs within 1000 years, then further evaluate this pathway.	• Fracture mapping of outcrops to identify fault zones • Detailed stratigraphic mapping where faults in critical zones (critical zone = areas with contaminant sources). • In-situ testing and monitoring in boreholes in faults in critical zones (air permeability)

Decision	Questions	Existing Data	New Data	Decision Rule for New Data	Data Collection Design
	Can we estimate recharge?	Limited data from Ponderosa Pine Pilot Study Limited data on soil moisture from MDA-P	Steady-state moisture profile, hydrologic parameters. Water balance (in tuff) and environmental tracers at TA-16 of tuff and deeper units.	If estimates of recharge predict that water would move from near the surface of the mesa to the Regional Aquifer (or intervening groundwater bodies) within 1000 years, then further evaluate this pathway.	• Core samples from boreholes to measure steady-state moisture profile, hydrologic parameters, and environmental tracers • Water balance of the mesa. • Geophysical studies in boreholes or on surface, if geophysics are effective.
	Does significant vapor phase transport occur?	No significant vapor plumes have been identified and process knowledge does not suggest presence of significant VOCs.	Identify PCOCs at site.	If significant vapor plumes are detected, then further investigate.	ER RFI field investigation.
	Are fractures and faults important contaminant transport pathways for vapors?	No significant vapor expected; will be reviewed based on ER findings.			
	Is there a lateral component of liquid flow?				
	• Is there visual evidence?	Presence of multiple springs from tuff at TA-16 and TA-9. Presence of episodic seeps at TA-9. HE present in springs Interflow between soil horizons at Ponderosa Pine pilot study.	Identify location of springs within Aggregate. Determine if anthropogenic contaminants (Appendix VIII, HE, fission products) are present and if naturally occurring constituents are above expected distribution (concentration guideline)	If anthropogenic contaminants and/or naturally-occurring contaminants above the concentration guideline are detected in springs/seeps, then conduct further investigations to establish source-spring/seep connection.	• ER TA-16 Work Plan has 10-15 boreholes to investigate source areas, data collection to include hydraulic properties, in-situ water content, conductivity of layers above and below seep/spring zone, stratigraphy, porosity, chemical signature of seep/spring water temperature, discharge measurement, and tracer studies.

Decision	Questions	Existing Data	New Data	Decision Rule for New Data	Data Collection Design
			For springs with anthropogenic contaminants establish source/spring connection.		• In source areas, collect core samples for testing and conduct in-situ tests for each layer below the tuff.
	The hydraulic contrasts between adjacent stratigraphic layers sufficient to cause lateral direction of flow?	Soil zone potential Springs suggest potential in tuff	Hydraulic conductivity vs. water content/pressure potential for each layer, moisture characteristics for each layer and porosity for each layer	If the hydraulic contrasts between units is greater than 2 orders of magnitude, then further evaluate this pathway.	Collect data from the four 200-ft. core holes and three Regional Aquifer wells
Based on the cumulative data from Aggregate 5 characterization and resulting refined conceptual model, are there indications of impacts from Laboratory activities that would impair beneficial use, and require further action?	What is the Regional Aquifer water quality? • What is the upgradient Regional Aquifer water quality?	Unknown. Water quality information from production wells and test wells.	Water quality in Regional Aquifer upgradient of Aggregate 5. Background Regional Aquifer water quality	If the water quality of the upgradient limit of the aggregate is statistically different from the downgradient limit of the aggregate, then evaluate remedial options.	Collect samples from: • Three Regional Aquifer wells • Upgradient water quality in alluvial system: - one alluvial well in Water Canyon at confluence with Canon del Valle - One alluvial well in Canon del Valle west of State Road 502.
	What concentration of contaminants would constitute impairment of beneficial use?	WQCC groundwater standards			

Decision	Questions	Existing Data	New Data	Decision Rule for New Data	Data Collection Design
	Which areas show the highest levels of contamination (e.g., upward trends), requiring monitoring:	Based on ER investigations: • TA-16 and TA-9 • Canon del Valle	Connection between near surface contamination and underlying groundwater bodies. Determine or predict fate and transport of contaminants through the groundwater system.	If contamination sources are present and pathways from those sources to groundwater would cause contamination of the groundwater above regulatory standards and/or risk limits, then implement remedial actions and monitor the groundwater quality to verify adequacy for beneficial use.	• Water samples from the Type 3 well downgradient from MDA-P in TA-16 • Sample and analyze springwater • Monitoring the 50 ft. and 200 ft. wells in TA-16

Decision	Questions	Existing Data	New Data	Decision Rule for New Data	Data Collection Design
Are there legacy and/or present sources of sufficient magnitude to cause contamination of groundwater?	What are the contaminants that could have been released from sources?	Legacy Sources: from Environmental Surveillance and archival data: HE, barium, beryllium, VOCs, heavy metals Present Sources: • Existing firing site operations • NPDES outfalls • Stormwater outfalls	Stormwater quality data	If contaminants other than those currently identified are detected in the stormwater, then add those contaminants to the list of PCOCs.	ER: Information on Legacy Sources from ER work. ER/ESH-18: stormwater data from developed areas
Are the alluvial sediments and uppermost subsurface water (USSW) from various present and legacy sources at contaminant concentrations ([cont.]) > regulatory limit or risk level?	What are the concentrations of these contaminants in sediments and USSW?	Portrillo canyon sampling of sediments, stormwater, soil moisture, over 5000 samples Water Canyon has 3 alluvial wells that are dry Alluvial wells are present in Fence Canyon at State Route 4 and at the hydrologic sink	Concentration of contaminants in alluvial water Concentration of contaminants in sediments in Water and Fence Canyons Background alluvial water quality in the canyons Background in sediments in the canyons	If contaminants are present at concentrations exceeding SALs and background, then further investigate their presence in the groundwater pathway.	ER Program canyon work plan: • Sample sediment to establish background • Sample sediments in Fence and Water Canyons to measure concentrations of PCOCs • If alluvial water is present, it will be sampled and analyzed for PCOCs
	Are there occurrences of water in Water, Portrillo and Fence Canyon?	Surface water is ephemeral; gaging stations on Water Canyon, and at State Route 4. Alluvial water has not been detected in any of the canyons, but may be present in segments of the canyons that do not have wells.	Presence of alluvial water in Portrillo and Water canyons	If there is saturation in the alluvium, then determine which standards apply.	ER Program will place: • Two Type 1 alluvial wells in Portrillo Canyon • One Type 1 well in Water Canyon downstream of confluence with Canon del Valle

Aggregate 6: Water, Portrillo, and Fence Canyons

Decision	Questions	Existing Data	New Data	Decision Rule for New Data	Data Collection Design
	What are the regulatory standards that apply to the alluvial water in Water, Portrillo, and Fence canyons?	WQCC Abatement regulations WQCC Surface Water Standards			
Is the intermediate perched groundwater underlying the alluvial sediments and USSW at [cont.] > regulatory limit or risk level?	Is there an intermediate perched water body in Water, Portrillo, and Fence canyons?	No existing data; however, in Portrillo Canyon near the hydrologic sink there may be a perched zone; the volume of water in Water Canyon suggests a perched zone may be present.	Identify perched zones in Portrillo and Water canyons. No perched zones expected beneath Fence Canyon.	If perched groundwater zones are encountered between the base of the alluvium and the Regional Aquifer, then collect information to characterize the hydrologic characteristics of those zones.	ER: Wells to identify perched intermediate zones are planned by ER Program: • One Type 2 well near confluence of Water Canyon and Canon del Valle • One Type 2 well at the hydrologic sink near State Road 4 in Portrillo Canyon. DP: Wells to identify perched water: • One Type 3 well in Water Canyon at State Route 501 • One Type 4 well near alluvial well WCO-1 in Water Canyon • One Type 2 well near confluence of Portrillo and Water canyons
	Does intermediate perched groundwater meet the definition of "groundwater"?	No existing data	Yield of perched water, if present	If the average yield of the intermediate perched zones is $\geq$ 50 gpd, then compare the water quality to WQCC groundwater standards and 20 NMAC 4.1.	ER: Estimate permeability of intermediate zones in wells.

Decision	Questions	Existing Data	New Data	Decision Rule for New Data	Data Collection Design
	What are the PCOCs from alluvial sediments that have been transported to the intermediate perched groundwater?	In Portrillo Canyon, HE, barium, beryllium, uranium, heavy metals, have been detected Similar PCOCs would be expected in Water and Fence canyons	Concentration of contaminants in sediments of Water and Fence canyons	If contaminants are detected in the perched intermediate zones, then further investigate this pathway.	ER: Water quality intermediate perched water in all wells.
	What are the regulatory standards that apply to the intermediate perched water in Water, Portrillo and Fence canyons?	No data to indicate presence of perched water.	Yield of perched zones, if present	If the average yield of intermediate perched zone(s) is > 50 gpd, then water quality will be compared to WQCC groundwater standards and 20 NMAC 4.1.	ER: Estimate yield from all wells.
Is the Regional Aquifer, as affected by the canyon systems, impacted by [cont.] ≥ some regulatory standards?	Have PCOCs migrated from intermediate perched zones and/or alluvial sediments/USSW to the Regional Aquifer?	No existing data	Regional Aquifer water quality	If PCOCs are detected in the Regional Aquifer, then evaluate remedial options for sources and along pathways.	The five Regional Aquifer wells will be used to determine Regional Aquifer water quality
	What are the concentrations of PCOCs in the Regional Aquifer?	No existing data	Regional Aquifer water quality	If the concentration of PCOCs in the Regional Aquifer exceeds standards then evaluate further actions.	ER: Water quality from the five Regional Aquifer wells.
Are there sufficient source terms to cause contamination if moved along the pathways in 1000 years.			Definition of pathways Rates of contaminant transport Mass of contaminants available for transport Predicted contaminant concentrations in receiving media	If modeling predicts that contaminants will cause contamination of Regional Aquifer within 1000 years, then evaluate remedial options.	Geologic, hydrologic, and geochemical data from wells and other investigations as input to model.

Decision	Questions	Existing Data	New Data	Decision Rule for New Data	Data Collection Design
What are the pathways for exposure to contaminants from alluvial sediments and USSW?	Does significant recharge occur from near surface to underlying groundwater bodies?	Active surface water channels	Recharge from surface water to alluvial water Horizontal extent of saturation in the alluvium Channel geometry	If maximum calculated value of infiltration is greater than 1 cm/yr., then infiltration will be considered and investigated as a pathway.	ER Program: Type 1 alluvial wells in Water, Fence and Portrillo canyons will be used to determine recharge
	Do we know the hydraulic properties of alluvium?	No existing data	Porosity, hydraulic gradient, hydraulic conductivity	If the maximum calculated value of hydraulic properties suggests fluid movement downward through the alluvium occurs, then further evaluate this pathway.	ER Program: In-situ testing of alluvial wells ER: Core samples from alluvial wells ER: Water samples from alluvial wells
	What are the retardation factors of the alluvial sediments?		Kds for PCOCs Water Chemistry	If site-specific minimum retardation factors suggest that contaminants are not significantly retarded in the alluvium over a period of 1000 years, then further evaluate this pathway.	ER: Water samples from alluvial wells
	Are fractures and faults important contaminant transport pathways for liquids in the canyons?	FRACTURES: Existing faults maps	Investigation of role of faults and fractures	If measured fault and fracture responses and models of fault and fracture flow predicts that recharge occurs through faults and fractures to Regional Aquifer bodies within 1000 years, further evaluate this pathway.	To be determined by literature search, expert consultation, more specific data collection as described in ER Work Plan and Sampling Analysis Plan.

Decision	Questions	Existing Data	New Data	Decision Rule for New Data	Data Collection Design
	Do we understand ground-water movement from alluvial water to intermediate perched zones?	No existing data.	Core samples for hydraulic properties, geochemistry.	If the combined hydraulic properties and geochemistry suggest that alluvial groundwater moves downward to intermediate perched zones then further investigate this pathway.	Proposed in ER Work Plan: alluvial and Regional Aquifer wells will have core samples for analyses.
	Groundwater movement from intermediate perched zone to Regional Aquifer?	No existing data.	Core samples for hydraulic properties, geochemistry.	If the combined hydraulic properties and geochemistry suggest that water from perched zone moves downward to the Regional Aquifer, then further evaluate this pathway.	The five wells to the Regional Aquifer will have cored segments for testing.

Aggregate 6: ı A-6, -15, -36, and -37 Mesas

Decision	Questions	Existing Data	New Data	Decision Rule for New Data	Data Collection Design
Are the soils/tuff or uppermost subsurface water from various present and legacy sources at contaminant concentrations > some regulatory limit or risk level?	What are the contaminants?	Based on archival data: HE, depleted uranium, barium, beryllium, metals, solvents ER firing site soil sampling RCRA sampling around active firing sites			
	What are concentrations?	Not completely defined.	Concentrations of contaminants	If the concentration of contaminants exceeds SALs and background, then further investigate their presence in the pathway.	ER Program will investigate some terms in the vadose zone.
	What are the concentrations of contaminants in the further?	Some TA's are operational and may change future contaminant concentrations.			
	Are the occurrences of water at this site?	Surface water associated with storm events.			
	What are the regulatory standards that apply?	In the unsaturated zone, the WQCC Abatement regulations and 20 NMAC 4.1			

Decision	Questions	Existing Data	New Data	Decision Rule for New Data	Data Collection Design
Is the Regional Aquifer or an underlying intermediate perched zone, as potentially affected by a present or legacy source, predicted to be impacted by contaminant concentrations > some regulatory standard or risk level using a conservative model?	What model will be used? What data are needed for the model?	A screening model such as RESRAD or MULTIMED. Preliminary data is available from the ER and RCRA investigation; the sources are not sufficient to cause contamination of underlying groundwater bodies.		If the screening model, using conservative scenarios, suggests that underlying groundwater bodies would not be contaminated above a regulatory standard or risk limit by the identified present or legacy sources, then to not further evaluate pathways.	Run the model(s)
Based on cumulative data from Aggregate 6 characterization, and resulting refined conceptual model, are there indications of impacts from Laboratory activities that would impair beneficial use, and require action.	What is the Regional Aquifer water quality? • What is the upgradient Regional Aquifer water quality? What concentrations of contaminants would constitute impairment of beneficial use? Which areas show the highest levels of contamination (e.g., upward trends), requiring monitoring?	Water quality information from production wells and test wells Water quality information from production wells and test wells WQCC groundwater standards and 20 NMAC 4.1	Water quality in Regional Aquifer upgradient of Aggregate Water quality in Regional Aquifer from areas not effected by Lab activities	If the water quality of the upgradient limit of the aggregate is statistically different from the downgradient limit of the aggregate, then evaluate remedial options.	Collect hydrostatigraphic unit information, thickness of aquifer, and aquifer parameters in wells proposed for aggregate characterization and regional control.

Aggregate 7: Mortandad and Ten Site Canyons

Decision	Questions	Existing Data	New Data	Decision Rule for New Data	Data Collection Design
Are there legacy and/or present sources of sufficient magnitude to cause contamination of groundwater?	What are the contaminants that could have been released from sources?	Legacy Sources: Mortandad: Nitrate, Pu, ^{90}SR, NO_3, ^{3}H, ^{137}Cs, ^{241}Am (in groundwater now); Ten Site: SC, metals from sources, PAHs, ^{238}Pu, $^{239/240}$ Pu Preliminary estimates of volume are available Present Sources: NPDES outfalls, stormwater outfalls.	Stormwater quality data	If contaminants other than those identified are detected in the stormwater, then add those contaminants to the list of Potential Contaminants of Concern (PCOC)	• ER Legacy Sources: information from ER work • ER/ESH-18 Present Sources: Stormwater data from developed areas
Are the alluvial sediments and uppermost subsurface water (USSW) from various present and legacy sources at contaminant concentrations ([cont.]) > regulatory limit or risk level?	What are the concentrations of these contaminants in sediments and USSW?	Concentration of contaminants in alluvial water. Concentration of contaminants in sediments. Need background water quality in similar canyon e.g., Los Alamos Canyon since Mortandad and Ten Site headwater in TA-3/TA-35 respectively.	Baseline sediments in upper headwater of canyons.		ER will collect data during RFI investigations. ER will provide pre-Laboratory background sediment data from canyon (e.g., Indio Canyon data because Indio Canyon drains entirely in the Bandelier Tuff as does Mortandad Canyon).
	Are there occurrences of water in Mortandad and Ten Site canyons?	Surface water gaging station Mortandad Canyon. Alluvial water (greater than 50 gpd) present in Mortandad Canyon.	Ten Site Canyon - presence of alluvial water Water quality in Ten Site Canyon	If there is saturation in the alluvium, then determine which standards apply	Ten Site Canyon: (ER) Type 1 alluvial well to sample for water quality.
	What are the regulatory standards that apply to the alluvial water in Mortandad and Ten Site canyons?	Mortandad Canyon has "groundwater" Surface water in Mortandad ephemeral water in Ten Site.	Yield of alluvial zone in both canyons	If the average yield from alluvium in both canyons $\geq$ 50 gpd then the water quality will be compared to WQCC groundwater standards and 20 NMAC 4.1	ER placing One Type 1 well in Ten Site Canyon to determine occurrence of groundwater, yield, and water quality.

Decision	Questions	Existing Data	New Data	Decision Rule for New Data	Data Collection Design
Is the intermediate perched groundwater underlying the alluvial sediments and USSW at [cont.] > regulatory limit or risk level?	Is there an intermediate perched water body in Mortandad and Ten Site canyons?	Unknown	Identify whether intermediate perched water exists.	If perched groundwater zones are encountered, then collect information to characterize the hydrologic characteristics of those zones.	ER: Two Regional Aquifer wells to identify perched intermediate zones are planned by ER Program: - Mortandad Canyon one Type 2 well below Radioactive Liquid Wastewater Treatment Plant outfall - One Type 2 well immediately east of sediment traps.
	Does intermediate perched groundwater meet the definition of "groundwater"?	Unknown	Collect information on yield	If the intermediate perched groundwater yields ≥ 50 gpd then the water quality will be compared to WQCC groundwater standards and 20 NMAC 4.1	Wells to Regional Aquifer will identify intermediate perched water. If perched water is encountered estimate yield.
	What are the PCOCs from alluvial sediments that have been transported to the intermediate perched groundwater?	Unknown	PCOC concentrations in the intermediate perched groundwater.	If contaminants are detected in the perched intermediate zones, then further investigate this pathway.	Sample perched water if encountered and analyze for PCOCs.
	What are the regulatory standards that apply to the intermediate perched water in Los Alamos and Pueblo canyons?	WQCC Groundwater Standards and 20 NMAC 4.1			
Is the Regional Aquifer, as affected by the canyon systems, impacted by [cont.] ≥ some regulatory standards?	Have PCOCs migrated from intermediate perched zones and/or alluvial sediments/USSW to the Regional Aquifer?	Based on Test Well TW-8, ^{3}H is in the Regional Aquifer	Confirm presence of ^{3}H in Regional Aquifer. Identify presence of other contaminants in the Regional Aquifer	If PCOCs are detected in the Regional Aquifer, then evaluate remedial options along source and pathways	Sample Regional Aquifer water in the two Type 2 wells and analyze for PCOCs. DP: Install one Type 3 well near PM-5 water supply well toward Mortandad Canyon.

Aggregate 7: Mortandad and Ten Site Canyons

Decision	Questions	Existing Data	New Data	Decision Rule for New Data	Data Collection Design
	What are the concentrations of PCOCs in the Regional Aquifer?	Contaminant concentrations are below MCLs	Confirm concentrations of PCOC.	If the concentration of PCOCs in the Regional Aquifer exceeds standards, then evaluate further actions.	Compare analytical results to standards.
Are there sufficient source terms to cause contamination if moved along the pathways in 1000 years.			Definition of pathways Rates of contaminant transport Mass of contaminants available for transport Predicted contaminant concentrations in receiving media	If modeling predicts that contaminants will cause contamination of the Regional Aquifer within 1000 years, then evaluate remedial options.	Geologic, hydrologic, and geochemical data from wells and other investigations as input to model.
What are the pathways for exposure to contaminants from alluvial sediments and USSW?	Does significant recharge occur from near surface to underlying groundwater bodies?	Contaminant distribution within underlying water bodies	Recharge from surface water to alluvial water. Horizontal extent of saturation in the alluvium. Channel geometry.	If the maximum calculated infiltration is greater than 1 cm/yr., then infiltration will be considered and investigated as a pathway	ER: Will use existing wells in the alluvium.
	Do we know the hydraulic properties of alluvium?	Slug test for K	Porosity, hydraulic gradient, hydraulic conductivity.	If the maximum calculated value of hydraulic properties suggests fluid movement downward through the alluvium occurs, then further evaluate this pathway	ER Program: In-situ testing of existing wells and perform pumping tests on wells

Decision	Questions	Existing Data	New Data	Decision Rule for New Data	Data Collection Design
	What are the retardation factors of the alluvial sediments?		Kds for ^{90}Sr, ^{137}Cs, U, Pu, Am, Np; water chemistry.	If the site-specific minimum retardation factors suggest that contaminants are not significantly retarded in the alluvium over a period of 1000 yrs., then further evaluate this pathway.	Water samples from alluvial wells
	Are fractures and faults important contaminant transport pathways for liquids in the canyons?	Existing fault maps	Investigation of role of faults and fractures	If measured fault and fracture responses and models of fault and fracture flow predicts that recharge occurs through faults and fractures to Regional Aquifer bodies within 1000 years, further evaluate this pathway.	To be determined by literature search, expert consultation, more specific data collection as described in ER Work Plan and Sampling Analysis Plan.
	Do we understand ground-water movement from alluvial water to intermediate perched zones?	Limited cores from MCM Series measured: moisture characteristic curves, porosity and bulk density, hydraulic conductivity on upper Bandelier Tuff	Core samples for hydraulic properties, geochemistry for lower Bandelier Tuff, Guaje, and lower units	If the combined hydraulic properties and geochemistry suggest that alluvial groundwater moves downward to intermediate perches zones, then further investigate this pathway	Will perform core tests and in-situ tests from intermediate zones in ER wells.
	Groundwater movement from intermediate perched zone to Regional Aquifer?		Core samples for hydraulic properties, geochemistry	If the combined hydraulic properties and geochemistry suggest that water from perched zones moves downward to the Regional Aquifer, then further elevate this pathway	ER: The 2 wells to Regional Aquifer.

Aggregate 7: ıA-50, -35 & -55 MDA-C Mesas

Decision	Questions	Existing Data	New Data	Decision Rule for New Data	Data Collection Design
Are the soils/tuff or uppermost subsurface water from various present and legacy sources at contaminant concentrations > some regulatory limit or risk level?	What are the contaminants?	Mesa Areas: radionuclides including: ^{241}Am, ^{3}H, ^{239}Pu, ^{238}Pu, heavy metals, organic (existing data on inventory) Angle drilling beneath MDA-C	ER investigation to determine if hazardous components are also present Core samples and/or trenching	If the contaminants other than those currently identified are detected as a result of ER or other investigations, then add those to the list of PCOCs.	ER: Drilling around sites to investigate source terms in the vadose zone.
	What are concentrations?	Limited information on non-radioactive contaminants. Phase I investigation at TA-35.	Analyses of cored collected from sources	If contaminants are detected above Screening Action Levels (SALs) and background, then further investigate their presence in the groundwater pathway.	ER: Planned ER work to investigate sources.
	What are the concentrations of contaminants in the further?	Don't know of any other sites.	No data needs		
	Are the occurrences of water at this site?	Surface stormwater during storm events.	Need stormwater data for MDA-C	If contaminants other than those currently identified are detected in stormwater on the mesa top, then add those constituents to the list of PCOCs.	ER/ESH-18: Collect samples of stormwater from points on the mesas where stormwater collects; analyze samples.
	What are the regulatory standards that apply?	In the unsaturated zone the WQCC Abatement regulations and 20 NMAC 4.1 may apply			

Decision	Questions	Existing Data	New Data	Decision Rule for New Data	Data Collection Design
Is the Regional Aquifer or an underlying intermediate perched zone, as potentially affected by a present or legacy source, predicted to be impacted by contaminant concentrations > some regulatory standard or risk level using a conservative model?	What model will be used?	A screening model such as RESRAD or MULTIMED.			
	What data are needed for the model?	Preliminary data is available from the literature, archival information and ER Data.		If the screening model, using conservative scenarios, suggest that underlying groundwater bodies would not be contaminated above a regulatory standard or risk limit by the identified present or legacy sources, then do not further evaluate pathways.	Run the model(s)
What are the pathways for exposure to contaminants from soils/tuff and water in the uppermost subsurface waters?	Does significant infiltration occur into the mesa?	Limited.	Magnitude of infiltration	If maximum calculated infiltration is greater than 1 cm/yr., then further evaluate this pathway.	• ER water balance measurements to distinguish run-off from infiltration in TA-50, TA-35 and MDA-C.
	What is the recharge? (groundwater movement further downward from the site)				

Aggregate 7: ı A-50, -35 & -55 MDA-C Mesas

Decision	Questions	Existing Data	New Data	Decision Rule for New Data	Data Collection Design
	Are the hydrological and chemical properties of the underlying geological strata known?	Limited cores of Bandelier Tuff for geological and hydrological properties TA-50, TA-35, MDA-C	Chemical data on Bandelier; moisture characteristic, conductivity, in-situ water content and pressure potential, porosity, bulk density, particle density, hydrodynamic dispersion, retardation coefficient, pH, CEC, water chemistry, fraction of organic carbon, liquid and gas diffusion coefficient, stratigraphy, lithology, mineralogy, isotopes, trace element chemistry. Geological, chemical and hydrologic parameters of underlying units	If the combined geologic, chemical, and hydrologic properties of the units below the mesa suggest recharge to underlying groundwater bodies occurs within 1000 years, further evaluate this pathway.	Core from boreholes and in-situ testing of non-recovery zones in boreholes (Cerro Toledo, Puye) in TA-50, TA-35, and MDA-C.
	Are fractures and faults important contaminant transport pathways for liquids?	FRACTURES: Data and modeling for MDA-G Evidence of water in fractures is the presence of soils w/clays, iron oxide, and calcium carbonate in some fractures Fracture mapping of trenching and outcrops at TA-55 and experimental data.	Response of fractures: fracture density, apertures, filling characteristics both chemical and hydrological, length and connection.		

Decision	Questions	Existing Data	New Data	Decision Rule for New Data	Data Collection Design
		Cores beneath TA-50, TA-35, TA-50 pipeline, and MDA-C measurements and moisture measurements to a depth ~ 100 ft.	Model of fracture flow of both liquid and gas including fracture matrix interactions.	If measured fracture responses and models of fracture flow predicts that recharge occurs through fractures to underlying groundwater bodies within 1000 years, further evaluate this pathway.	Fracture mapping of outcrops at TA-50, TA-55, TA-35, and MDA-C Map fractures in cores that are collected from boreholes that are placed for other reasons.
		FAULTS: Existing fault maps	FAULTS: Identify faults by comparing fracture density and surface mapping. Detailed mapping to identify offsets in stratigraphic units (e.g., surge beds) Hydrologic characteristics of fault zones	If faults in critical zones are identified and testing and/or modeling of those fault zones predict recharge to underlying groundwater bodies occurs within 1000 years, then further evaluate this pathway.	ER: Characterization Studies Fracture mapping of outcrops to identify fault zones. Detailed stratigraphic mapping where faults in critical zones (critical zone = areas with contaminant sources). In-situ testing and monitoring in boreholes in faults in critical zones (air permeability if possible)

Decision	Questions	Existing Data	New Data	Decision Rule for New Data	Data Collection Design
	Can we estimate recharge?	Area G testing including steady-state moisture profile and hydrologic parameters; water balance	Steady-state moisture profile, hydrologic parameters, water balance (tuff and deeper units); environmental tracers (in tuff) at TA-50, TA-55, TA-35 and MDA-C	If estimates of recharge predict that water would move from near the surface of the mesa to the Regional Aquifer (or intervening groundwater body) within 1000 years, then further evaluate this pathway.	ER: Characterization studies: Core samples from boreholes to measure steady-state moisture profile and hydrologic parameters and environmental tracers. • Water balance measurements in tuff. • Drainage study in outcrops of non-recovery zones (Puye and Cerro Toledo)
	Does significant vapor phase transport occur?	Core and downhole sampling from TA-73 landfill detected methane and VOCs.	Vapor diffusion coefficients, liquid-vapor partitioning relationships and constant; retardation of vapor phase, transformation of contaminants, stratigraphy, lithology, mineralogy, vapor density vs concentration relationship, temperature distribution, fraction of organic carbon, barometric pressure, air permeability versus water content for each geologic unit, porosity, in-situ water content and/or pressure head	For sources with significant vapor-producing contaminants, if the vapor diffusion characteristics underlying that source suggest that vapor phase transport has or could occur within 1000 years then further evaluate this pathway using RESRAD.	ER: Characterization Studies in areas where there is vapor generation (TA-73 landfill and MDA-C and TA-50): collect core samples for analysis and in-situ testing of borehole.

Decision	Questions	Existing Data	New Data	Decision Rule for New Data	Data Collection Design
	Are fractures and faults important contaminant transport pathways for vapors?	TA-54 studies of vapor movement TA-73 studies of vapor movement Fracture mapping of TA-21 and Pueblo Canyon TA-50 MDA-C studies of vapor movement	Same as faults and fractures for liquid	For sources with significant vapor-producing contaminants, if measurements and modeling suggest that fractures and faults contribute to vapor phase transport, then further evaluate this pathway.	Same as faults and fractures for liquid
	Is there a lateral component of liquid flow?				
	• Is there visual evidence?	No visual evidence	Perform recon of canyons for presence of springs If springs are present, determine if anthropogenic contaminants (Appendix VIII, HE, fission products) are present and if naturally occurring constituents are above expected distribution (concentration guideline)	If anthropogenic contaminants and/or naturally-occurring contaminants above the concentration guidelines are detected in springs/seeps, conduct further investigations to establish source-spring/seep connection.	Analyze existing data and/or sample springs and other groundwater discharge areas to establish concentration guideline for naturally-occurring constituents For springs with anthropogenic contaminants or above concentration guideline for naturally-occurring constituents: delineate seep/spring source areas, hydraulic properties, in-situ water content, conductivity of layers above and below see/spring zone, stratigraphy, porosity, chemical signature of see/spring water temperature, electrical conductivity, discharge measurement, tracer studies
	Are hydraulic contrasts between adjacent stratigraphic layers sufficient to cause lateral direction of flow?	In tuff have: hydraulic conductivity vs water content/pressure potential for each layer, and porosity for each layer.	In deeper layers: hydraulic conductivity vs water content/pressure potential for each layer, moisture characteristics for each layer and porosity for each layer	If the hydraulic contrasts between units deeper than the tuff is greater than 2 orders of magnitude then further evaluate this pathway.	In source areas, collect core samples for testing and complete in-situ tests for each layer below the tuff.

Decision	Questions	Existing Data	New Data	Decision Rule for New Data	Data Collection Design
Based on the cumulative data from Aggregate 7 characterization and resulting refined conceptual model, are there indications of impacts from Laboratory activities that would impair beneficial use, and require further action?	What is the Regional Aquifer water quality? • What is the upgradient Regional Aquifer water quality?	Water quality information from production wells and test wells; because regional flow direction is unknown, whether this is upgradient is unknown	Water quality in upgradient direction(s) Flow direction in Regional Aquifer	If the quality of the water with respect to contaminants from Laboratory operations is statistically different up-gradient than down-gradient, then evaluate remedial options	In Mortandad Canyon, three Regional Aquifer wells: • Type 3 well near PM-5 water supply well toward Mortandad Canyon (DP) • Type 2 well below Radioactive Liquid Waste Water Treatment Plant outfall (ER) • Type 2 well east (ER) of sediment traps
		Water quality information from production wells and Test Wells, not zone-specific	Water quality from areas that have not been impacted by Laboratory activities Zone-specific water quality		Characterize the water quality and pumping effects of PM-4 and PM-5 using the DP Type 3 well located near PM-5.
	What concentration of contaminants would constitute impairment of beneficial use?	WQCC groundwater standards and 20 NMAC 4.1			
	Which areas show the highest levels of contamination (e.g., upward trends), requiring monitoring:	Based on ESH-18 investigation: Mortandad Canyon	Connection between near- surface contamination and underlying groundwater bodies Fate-and transport of contaminants through the groundwater system	If contaminants sources are present and pathways from those sources to ground water would cause contamination of the groundwater above regulatory standards and/or risk limits, then implement remedial actions and monitor the groundwater quality to verify adequacy for beneficial use.	Data collected in Aggregate 7 characterization.

Decision	Questions	Existing Data	New Data	Decision Rule for New Data	Data Collection Design
Are there legacy and /or present sources of sufficient magnitude to cause contamination of groundwater?	What are the contaminants that could have been released from sources?	Legacy Sources: In Bayo Canyon DU and Pb. Preliminary estimates of volume may be obtained through ER/RFI. Bayo Canyon in the former TA-10 area has been remediated under Formerly Used Sites Remedial Action Program (FUSRAP). Present Sources: Some data on stormwater runoff is available.	Stormwater quality data	If contaminants other than those currently identified are detected in the stormwater, then add those contaminants to the list of PCOCs.	• Legacy Sources: FUSRAP reports, and information for ER work • Present Sources: Stormwater data from developed areas
Are the alluvial sediments and uppermost subsurface water (USSW) from various present and legacy sources at contaminant concentrations ([cont.]) > regulatory limit or risk level?	What are the concentrations of these contaminants in sediments and USSW?	Background water quality in Guaje Canyon Background in sediments in Guaje Canyon	Concentration of contaminants in sediments.	If contaminants are detected above SALs and background, then further investigate their presence in the groundwater pathway.	ER plans to collect sediment samples.
	Are there occurrences of water in Bayo, Guaje, Barrancas, and Rendija Canyons?	Surface water is present due to precipitation runoff. No alluvial water present in Bayo Canyon near TA-10 based on ER investigations.	Runoff data for Bayo Canyon	If there is saturation in the alluvium, then determine which standards apply.	• 1 Type 1 alluvial well will be installed by ER at the confluence of Guaje and Los Alamos canyons (Aggregate 1). • Stormwater monitoring in Bayo Canyon by ER/ESH-18

Decision	Questions	Existing Data	New Data	Decision Rule for New Data	Data Collection Design
	What are the regulatory standards that apply to the USSW in the Canyons?	WQCC Surface Water Standards, WQCC Abatement Regs. and 20 NMAC 4.1 may apply.			
Is the intermediate perched groundwater underlying the alluvial sediments and USSW at [cont.] > regulatory limit or risk level?	Is there an intermediate perched water body in Bayo, Guaje, Rendija and Barrancas canyons?	Unknown	Results of sediment surveys will determine the need to investigate the perched intermediate groundwater zone	If the contaminants are present in sediments above SALs, then conduct further investigations to determine the presence and quality of intermediate perched aquifer.	ER work plan describes sediment sampling.
	Does intermediate perched groundwater meet the definition of "groundwater"?	Unknown, but not expected to.			
	What are the PCOCs from alluvial sediments that have been transported to the intermediate perched groundwater?	Intermediate perched groundwater not expected to be present.			
	What are the regulatory standards that apply to the intermediate perched water?	WQCC Abatement regulations and 20 NMAC 4.1.			

Decision	Questions	Existing Data	New Data	Decision Rule for New Data	Data Collection Design
Is the Regional Aquifer, as affected by the Canyon systems, impacted by [cont.] $\geq$ some regulatory standards?	Have PCOCs migrated from intermediate perched zones and/or alluvial sediments/USSW to the Regional Aquifer?	Previous remediation efforts removed most source materials	Presence of mobile contaminants in sediments.	If PCOCs are detected in sediments above SALs and background, then further evaluate their presence in this pathway.	ER RFI work plan proposed sediment sampling
	What are the concentrations of PCOCs in the Regional Aquifer?	Previous remediation efforts removed most source materials.			
Are there sufficient source terms to cause contamination if moved along the pathways in 1000 years?	Based on previous remedial action, sufficient source terms are not present.				

Aggregate 9: Regional Aquifer Control - Water Supply and Operational Contamination

Decision	Questions	Existing Data	New Data	Decision Rule for New Data	Data Collection Design
Is groundwater of adequate quantity and quality available for long-term withdrawal to supply Laboratory operations and Los Alamos County within the historical water supply system operations area?				If the withdrawal scenarios from modeling the Lower Espanola Basin suggest that demand by the Laboratory and Los Alamos County will exceed supply of adequate quality water, then the Laboratory's Master Plan will be revised to include water management options.	
	How much water is available from beneath the Laboratory and Los Alamos County?	Geometry of Aquifer - Regional Aquifer is bounded on west by Jemez Mountains, on the east there is some discharge to the Rio Grande; from existing water production wells, some hydrologic properties in the portion of the Regional Aquifer penetrated by the wells; geophysical work has indicated the depth of sediments; composite hydraulic head from existing water production wells and hydraulic head of top of Regional Aquifer from test wells.	Geometry of Aquifer - • Along western boundary determine vertical gradient; hydraulic head; seasonal water level response. • Along northern boundary refine hydrostratigraphic units, hydraulic head, gradient; identify Chaquehui formation in the area west of existing well field.	Same as above.	• Western Boundary: 3 DP wells along western boundary of Laboratory - One Type 2 well west of TA-16 (Aggregate 5) - One Type 3 well up above skating rink in Los Alamos Canyon, replacing H-19 (Aggregate 1) - One Type 3 well in Water Canyon at State Route 501 (Aggregate 6)

Decision	Questions	Existing Data	New Data	Decision Rule for New Data	Data Collection Design
		<u>Geometry of Aquifer (cont)</u> USGS data on eastern boundary or Regional Aquifer Buckman water production field provides data on Eastern boundary EES drilling and geothermal exploration by UNOCAL are available for Jemez Mountains (Valle Grande) on western boundary. Have currently penetrated approximately one-half of Regional Aquifer	• Along southern boundary - hydrostratigraphic units, thickness of aquifer, aquifer parameters. • Along eastern boundary gradient within the Regional Aquifer, hydrostratigraphic units, hydraulic head, vertical gradients. • Top of Aquifer, the potentiometric surface	Same as above.	• <u>Northern Boundary</u>: 2 DP wells along northern boundary - One Type 2 well north of Test Well 4 (Aggregate 1) - One Type 4 well North of Barrancas Mesa or Rendija Canyon near Sportsman Club; if this well encounters the Chaquehui formation continue drilling until the bottom of the Chaquehui is reached. Geophysics to identify extent of Chaquehui
		Northern boundary characteristics known from Guaje well field	<u>Geometry of Aquifer (cont)</u> Bottom of Aquifer, the water quality deep within the Regional Aquifer and the thickness of Chaquehui.	Same as above	• <u>Southern Boundary</u>: Geophysics to identify extent of Chaquehui 3 Regional Aquifer wells: - One Type 2 well at TA-49 (Aggregate 3) - One Type 2 well in north branch of Ancho Canyon (Aggregate 4) - One Type 3 well near Ancho Spring (Aggregate 4)

Aggregate 9: Regional Aquifer Control - Water Supply and Operational Contamination

Decision	Questions	Existing Data	New Data	Decision Rule for New Data	Data Collection Design
				Same as above	• <u>Eastern Boundary</u>: 3 DP wells to define discharge, potentiometric surface vertical gradients, head, etc. - One Type 2 well at confluence located at Portrillo Canyon and Water Canyon (Aggregate 6) - One Type 3 well located near Ancho Spring (Aggregate 4) - One Type 3 well in White Rock, south of Cañada del Buey • Top of Aquifer - Measure water level in all wells installed at Laboratory in the Regional Aquifer • Bottom of Aquifer - As pumps are removed from existing water production wells for maintenance, conduct water chemistry sampling in selected deep zones - Sample and analyze water chemistry from all wells drilled to the Regional Aquifer

Decision	**Questions**	**Existing Data**	**New Data**	**Decision Rule for New Data**	**Data Collection Design**
		<u>Identify the Producing Zones</u> - Geologic logs from water supply wells - 2 spinner logs, one from Los Alamos well field and one from Guaje well field; these suggest vertical variability of water in flow to the wells - Borehole geophysical logs in water production wells and Test Wells 1 and 49 - Definition of the Chaquehui Formation as a producing zone based on geologic and geophysical logs and major water chemistry - Other producing zones (i.e., Puye and Tschicoma) have been identified based on specific capacity pumping tests in production wells	<u>Identify the Producing Zones</u> • Hydraulic conductivity from individual water producing zones. • Additional spinner logs from the Chaquehui Formation • Piezometic head from the individual water production zones. • Geometry of high permeability zones in the upper Santa Fe Group and Puye Formation	Same as above	This data will be obtained from the wells proposed for defining the geometry of the aquifer

Decision	Questions	Existing Data	New Data	Decision Rule for New Data	Data Collection Design
		Collect Aquifer Parameters - Composite hydraulic conductivities for long-well-screened production - Transmisivity data from production and test wells	Collect Aquifer Parameters • Storage coefficient and distribution of storage coefficient across the plateau • Grain size distribution • Porosity	Same as above	Same as above
		Determine Hydraulic Head in Water Producing Zones - Non-pumping water levels in production wells based on composite averages	Determine Hydraulic Head in Water Producing Zones - Hydraulic head data with better spatial coverage laterally across the Laboratory, and also specific to individual producing zones.	Same as above	Same as above

Decision	Questions	Existing Data	New Data	Decision Rule for New Data	Data Collection Design
		<u>Determine recharge, boundary conditions, sources and sinks</u> - Some information on mesa top infiltration. - Stream gage information on up-gradient and down-gradient sites on major Laboratory canyons.	<u>Determine recharge, boundary conditions, sources and sinks</u> • Hydraulic property and gradient information from the northwest portion of the Laboratory and the western portion of the Laboratory		• In-situ testing and textural analysis of aquifer materials • Aquifer performance tests; borehole geophysics • Surface geophysics • In-situ tests e.g., drill stem tests • Textural analysis of aquifer materials
			• Hydraulic properties and gradients along the eastern and south boundaries of the Laboratory	Same as above	• Seepage run on the Rio Grande - Seepage Runs - Infiltration studies - Evapotranspiration Studies - Seepage run on the Rio Grande
		- Records of Laboratory pumpage - Access to pumpage records from major regional water users e.g., City of Santa Fe - Well drawdowns from production wells	• Seepage loss measurements from Otowi Bridge to Frijoles Creek	Same as above	

Aggregate 9: Regional Aquifer Control - Water Supply and Operational Contamination

Decision	Questions	Existing Data	New Data	Decision Rule for New Data	Data Collection Design
		<u>Determine Water Balance</u> - Existing data on well pumpage - Some evaportranspiration data	<u>Determine Water Balance</u> • Seepage loss information in all watersheds via measurement or calculation	Same as above	
		- Limited seepage loss information (Mortandad, Los Alamos, Pueblo Canyons) - Diversion of surface flows for irrigation - Precipitation data	• Evapotranspiration data • GW inflow from the north and west (same information as above under recharge) • Seepage loss measurements from Otowi Bridge to Frijoles Creek	Same as above	
	How good is the quality of available water:	• The water quality standards are: - NM drinking water regulations - WQCC groundwater standards - DOE DCG for radioactive constituents		If the withdrawal scenarios from modeling the lower Espanola basin suggests that demand by the Laboratory and Los Alamos County will exceed supply of adequate quality water, then the Laboratory's Master Plan will be revised to include water management options.	

Decision	Questions	Existing Data	New Data	Decision Rule for New Data	Data Collection Design
		• Horizontal water quality distribution - Samples from water production wells, test wells, and springs; geographic area limited	• Horizontal water quality distribution - Western 1/3 of Lab - Eastern 1/3 of Lab	Same as above	• Regional boundary wells and wells within Aggregates will be used to collect samples, filter and analyze for water quality • As water production well pumps are removed for maintenance, collect samples in isolated water producing zones.
		• Vertical water quality distribution - LA-6 and PM-3 have 6 different zones that were samples over the length of the well screen	• Vertical water quality distribution - Depth-specific water-quality profiles in identified water producing zones		• Collect samples and data from multiple completion wells. • Sample regional boundary multiple-completion wells from water-producing zones
			- Water quality from below the current water production horizon		• Drill and install 2 DP wells to approximately 1000 ft. below the current water production horizon (in Chaquehui Formation): - Type 3, Pajarito Canyon area (Aggregate 2) - Type 4, Pueblo Canyon, Rendija Canyon near Sportsmen's Club (Aggregate 1)
			- Review water quality trends from current data		Review current water quality data for trends

Aggregate 9: Regional Aquifer Control - Water Supply and Operational Contamination

Decision	Questions	Existing Data	New Data	Decision Rule for New Data	Data Collection Design
	How much water is needed?	Utility department records of well pumpage (total for Lab and County) • Forecasts of water use for Laboratory projects in the SWEIS • County master plan • Existing water rights	• Projections of Los Alamos County water use	Same as above	• Interview County government representatives about County projections
	How does water withdrawal impact the hydraulics and quality of the aquifer system?	• USGS model of Espanola Basin using MODFLOW Code; but the layers are based on equal depth, not on hydrostratigraphic layers. (Could be refined to use hydrostratigraphic units.)	• Improvement in accuracy that would come from revising USGS model to hydrostratigraphic layers	Same as above	• Interview USGS authors regarding existing model • Form a modeling Committee to evaluate the existing model and compare to other available codes
		• Scenarios for model simulations have been based on: - Historical pumpage - Patterns of pumpage	• Prediction scenarios for model simulations would add: - Effect of pumping in Buckman Field and other users in the Espanola Basis	Same as above	• Interview USGS and Santa Fe City representative for Projections of Santa Fe pumping • Data collected from regional boundary wells and within Aggregates will be used to refine physical parameters

Decision	Questions	Existing Data	New Data	Decision Rule for New Data	Data Collection Design
		Assumed demand for water (range of pumping conditions)	- Refine physical parameters that the model is based on wells installed for ER and other programs - Sensitivity analysis to identify most sensitive physical parameters - Calibration and validation of model simulations	Same as above	• Use ER data maintained in the FIMAD to build 3-dimensional pictures of geologic and hydrologic parameters

APPENDIX 5

Criteria for Scheduling Well Installation

CRITERIA FOR SCHEDULING WELL INSTALLATION

(No. of Points) Explanation of Criteria

(5) Reduce Hydrologic Setting Uncertainty

This criterion evaluates how much knowledge about the hydrologic setting will be gained with the installation of a particular well. Factors that are considered include how much is already known about the area from previous wells, the potential to encountered an intermediate perched zone(s), and proximity to ambiguous features such as the apparent high groundwater level in Test Well 1.

(4) Reduce Stratigraphic and Structural Uncertainty

Points assigned are based on a consideration of how much additional knowledge of the stratigraphy and structure of the area will be gained with the installation of a particular well. Factors used in making this assessment are how much is already known about the area from wells, boreholes, mapping, and other methods, and the potential presence of stratigraphic or structural features that may control the presence and flow of groundwater, such as faults or interfingered basalts.

(4) Contaminant Detection for Water Supply System

This criterion is based on placement of the well between contaminant sources and a water supply well in order to provide detection of approaching contaminants. The primary factor that is considered is location of the well with respect to both a water supply well and the anticipated movement of contaminants from sources.

(4) Assessment of Nature and Extent of Potential Contamination in Groundwater

This criterion reflects whether a well is placed to encounter suspected contamination. Although the water encountered by all of the wells will be analyzed and will add to the knowledge of contaminant distribution, some wells will be located with the primary purpose of detecting contamination. Other wells have special value because they define upgradient water quality for an aggregate.

(3) Future Water Supply

This is an evaluation of whether a well will provide information related to the potential for additional groundwater supply development. This potential is based principally on determining the extent of the high-permeability Miocene trough that is most productive in current water supply wells.

(2) Control of Timing and Construction of Other Wells

This criterion is an indication of which wells must be installed before other wells, because the information from the first well is important to either location, construction or interpreting results from the succeeding wells. Examples are the wells with fully-cored boreholes, which will serve as reference wells, and therefore must be installed before other boreholes, so that the reference stratigraphy can be used.

(2) Budget and Programmatic Constraints

A judgment of how important the purpose or resulting data from each well is to the funding program.

(1) Operational Efficiency

Indicates the savings related to logistics if a particular well is installed in the same mobilization as one or more other wells. Scheduling efficiencies could result in saving program funds.

R-1 Northern Regional Well

Criteria	Assigned Points	Rationale
Reduce hydrologic setting uncertainty	5	No information is currently available in this area; boundary well, reference well, background
Reduce stratigraphic and structural uncertainty	4	No information is currently available for this area
Contaminant detection for water supply system	0	Not related to water supply
Assessment of nature and extent of potential contamination in groundwater	1	Upgradient to aggregate 1
Future water supply	3	northern extension of high-permeability zone
Controls timing and construction of other wells	0	Installation contingent on groundwater modeling to evaluate data need
Budget and programmatic constraints	2	Provides lots of information to constrain hydrologic setting
Operational efficiency - scheduling	0	Not located near other wells or activities
R-1 Total	**15**	

R-2 Pueblo Canyon at Acid Canyon

Criteria	Assigned Points	Rationale
Reduce hydrologic setting uncertainty	4	Potential for intermediate perched zone discovery; information on effect of Rendija Canyon fault on hydrology
Reduce stratigraphic and structural uncertainty	3	Information on nature of Rendija Canyon fault zone and displacement; information on deeper stratigraphy; stratigraphy affecting perched zones
Contaminant detection for water supply system	1	Possible information on Acid Canyon contamination affecting Otowi 1 and 4
Assessment of nature and extent of potential contamination in groundwater	4	Information on extent of contamination below TA-45 Acid Canyon outfall
Future water supply	0	Not in area of potential development
Controls timing and construction of other wells	2	Affects placement of R3 and R4
Budget and programmatic constraints	2	Needed for FY 98 Completion of LA/Pueblo Canyon RFI Workplan
Operational efficiency - scheduling	1	Install in sequence with other wells in canyon
R-2 Total	**17**	

R-3 Upper Pueblo Canyon between Test Well 2 and Test Well 4

Criteria	Assigned Points	Rationale
Reduce hydrologic setting uncertainty	3	Intermediate perched zone information needed; information on regional aquifer in high-permeability Miocene trough
Reduce stratigraphic and structural uncertainty	2	Information on pre-Bandelier stratigraphy; stratigraphy affecting intermediate perched zones
Contaminant detection for water supply system	0	Not near current wells; some information on Acid Canyon contamination affecting Otowi 1 and 4
Assessment of nature and extent of potential contamination in groundwater	4	Identify presence of Acid Canyon and sewage outfall contaminant plumes
Future water supply	1	Could define edge of high-permeability Miocene trough
Controls timing and construction of other wells	2	Depends on R2, could affect R4
Budget and programmatic constraints	2	Needed for FY 98 Completion of LA/Pueblo Canyon RFI Workplan
Operational efficiency - scheduling	1	Install in sequence with other wells in canyon
R-3 Total	**15**	

R-4 Pueblo Canyon below Test Well 2

Criteria	Assigned Points	Rationale
Reduce hydrologic setting uncertainty	2	Intermediate perched zone information needed
Reduce stratigraphic and structural uncertainty	2	Stratigraphy affecting perched zones
Contaminant detection for water supply system	1	Not near current wells; some information on Acid Canyon contamination affecting Otowi 1 and 4; affects contaminant detection well R-5 near Otowi 1
Assessment of nature and extent of potential contamination in groundwater	4	Identify presence of Acid Canyon and sewage outfall contaminant plumes
Future water supply	0	Other information already exists in area
Controls timing and construction of other wells	1	Affects placement of R-5
Budget and programmatic constraints	2	Needed for FY 98 Completion of LA/Pueblo Canyon RFI Workplan
Operational efficiency - scheduling	1	Install in sequence with other wells in canyon
R-4 Total	**13**	

R-5 Water supply contaminant detection well near Otowi 1 in Lower Pueblo Canyon

Criteria	Assigned Points	Rationale
Reduce hydrologic setting uncertainty	4	Close to Otowi-1, POI-4, and TW-1; will help define vertical extent and constrain lateral extent of intermediate perched zones, evaluate high water level in Otowi-1
Reduce stratigraphic and structural uncertainty	3	Area of facies changes and interfingering of basalt that requires wells close together to evaluate; investigate fault or other structural features controlling the high-permeability zone
Contaminant detection for water supply system	4	Purpose of the well is to provide contaminant detection of contamination approaching a water supply well
Assessment of nature and extent of potential contamination in groundwater	3	Location based on Otowi-1, not on location of contaminant plumes or sources; however, contaminants from sewage effluent have been detected in POI-4, TW-1, TW-1A, and Basalt Spring.
Future water supply	2	Potential to constrain the eastern edge of the high-permeability zone
Controls timing and construction of other wells	0	Location of this well should be finalized after results from R-4 provide information of the location of groundwater contaminant plumes
Budget and programmatic constraints	2	Protecting the water supply is a high programmatic priority
Operational efficiency - scheduling	1	Logistics would be easier if all Pueblo Canyon wells were installed with one mobilization
R-5 Total	**19**	

R-6 Upper Los Alamos Canyon near H-19

Criteria	Assigned Points	Rationale
Reduce hydrologic setting uncertainty	4	New information on intermediate perched zones; water levels in regional aquifer
Reduce stratigraphic and structural uncertainty	4	Could penetrate Pajarito fault depending on location; confirm earlier stratigraphic picks and expand structural picture; may want to deepen to reach Totavi Lentil
Contaminant detection for water supply system	0	Upgradient of water supply wells and contaminant sources
Assessment of nature and extent of potential contamination in groundwater	1	Will provide background information for intermediate perched zone and regional aquifer groundwater
Future water supply	0	Not within potential area of development
Controls timing and construction of other wells	0	Will not be installed soon enough to affect R-7 and R-2
Budget and programmatic constraints	2	Needed for FY 98 Completion of LA/Pueblo Canyon RFI Workplan
Operational efficiency - scheduling	1	Install in sequence with other wells in canyon
R-6 Total	**12**	

R-7 Upper Los Alamos Canyon south of TA-21

Criteria	Assigned Points	Rationale
Reduce hydrologic setting uncertainty	4	Vertical extent of intermediate perched zones
Reduce stratigraphic and structural uncertainty	3	Stratigraphy deeper than the Bandelier
Contaminant detection for water supply system	2	Located between TA-2 and Otowi-4 on a potential contaminant transport pathway, but not proximal to Otowi-4
Assessment of nature and extent of potential contamination in groundwater	4	Located within contaminated alluvial and intermediate perched zone groundwater and close to a contamination source
Future water supply	1	Potential to constrain the western edge of the high-permeability zone
Controls timing and construction of other wells	1	Should be installed before R-8 to provide hydraulic parameters necessary for placement of R-8
Budget and programmatic constraints	2	Necessary to meet ER Project goal of completing LA/Pueblo Canyon RFI Workplan by end of FY98
Operational efficiency - scheduling	1	Logistics would be easier if all LA Canyon wells were installed with one mobilization
R-7 Total	**18**	

R-8 Water supply contaminant detection well for Otowi 4 in Los Alamos Canyon

Criteria	Assigned Points	Rationale
Reduce hydrologic setting uncertainty	2	Close to Otowi-4, LADP-3, and TW-3; will help define vertical extent and constrain lateral extent of intermediate perched zones
Reduce stratigraphic and structural uncertainty	2	Close to Otowi-4, LADP-3, and TW-3; stratigraphy deeper than the Bandelier
Contaminant detection for water supply system	4	Purpose of the well is to provide detection of contaminants approaching a water supply well
Assessment of nature and extent of potential contamination in groundwater	2	Location based on Otowi-4, not on location of contaminant plumes or sources; however, it is close to DP Canyon , a potential contaminant source
Future water supply	0	Otowi-4 provides all information necessary for future water supply
Controls timing and construction of other wells	0	Should be installed after R-7 to get hydraulic parameters necessary for placement of R-8
Budget and programmatic constraints	2	Protecting the water supply is a high programmatic priority
Operational efficiency - scheduling	1	Logistics would be easier if all LA Canyon wells were installed with one mobilization
R-8 Total	**13**	

R-9 Boundary well in Los Alamos Canyon

Criteria	Assigned Points	Rationale
Reduce hydrologic setting uncertainty	4	Provide information on intermediate perched zones; groundwater mound at TW-1; hydraulic information on drawdown due to pumping PM-1 and Otowi 1
Reduce stratigraphic and structural uncertainty	3	Information on boundary of high-permeability Miocene trough and intermediate perched zone facies changes
Contaminant detection for water supply system	1	Down gradient of water supply wells but possibly in zone of influence of two wells
Assessment of nature and extent of potential contamination in groundwater	4	Down gradient from Aggregate 1; on boundary of Laboratory
Future water supply	0	Near existing wells
Controls timing and construction of other wells	0	Will be installed after other wells
Budget and programmatic constraints	2	Needed for FY 98 Completion of LA/Pueblo Canyon RFI Workplan
Operational efficiency - scheduling	1	Install in sequence with other wells in canyon
R-1 Total	**15**	

R-10 Upper Sandia Canyon

Criteria	Assigned Points	Rationale
Reduce hydrologic setting uncertainty	3	Information on intermediate perched zones related to possible southerly flow along Guaje Pumice; water losses related to Laboratory sewage outfall
Reduce stratigraphic and structural uncertainty	2	Information on pre-Bandelier paleo valley structure
Contaminant detection for water supply system	1	Could trace pathways of Laboratory sewage outfall
Assessment of nature and extent of potential contamination in groundwater	4	Potential detection of Aggregate 1 and Laboratory sewage outfall contamination
Future water supply	0	Near other information
Controls timing and construction of other wells	0	Will be installed in any case; not strongly tied to other wells
Budget and programmatic constraints	2	Needed for FY 98 Completion of LA/Pueblo Canyon RFI Workplan
Operational efficiency - scheduling	1	Install in sequence with other wells in canyon
R-9 Total	**13**	

R-11 Water supply contaminant detection well for PM-3 in Sandia Canyon

Criteria	Assigned Points	Rationale
Reduce hydrologic setting uncertainty	2	Close to PM-3; will help define presence and vertical extent of intermediate perched zones
Reduce stratigraphic and structural uncertainty	2	Close to PM-3, which provides structural and stratigraphic information
Contaminant detection for water supply system	4	Purpose of the well is to provide detection of contaminants approaching a water supply well
Assessment of nature and extent of potential contamination in groundwater	1	Location based on PM-3, no current information on presence of contaminants. Potential to detect contaminants from Sandia Canyon
Future water supply	0	PM-3 is in a highly productive zone; this well will not add to that knowledge
Controls timing and construction of other wells	0	The location of other wells are not dependent on this well
Budget and programmatic constraints	2	Protecting the water supply is a high programmatic priority
Operational efficiency - scheduling	1	Logistics would be easier if all Sandia Canyon wells were installed with one mobilization
R-11 Total	**12**	

R-12 Sandia Canyon boundary well

Criteria	Assigned Points	Rationale
Reduce hydrologic setting uncertainty	4	Provides information on intermediate perched zones found in PM-1; a Laboratory boundary well; may show influence of PM-1 pumping; will provide information on regional aquifer groundwater levels related to original vs. post-completion levels
Reduce stratigraphic and structural uncertainty	3	Near existing information but will provide core information for reference purposes
Contaminant detection for water supply system	4	Near PM-1; may detect contaminants arriving via possible southerly flow path from Los Alamos Canyon
Assessment of nature and extent of potential contamination in groundwater	4	Could be down gradient from Aggregate 1
Future water supply	0	Near existing well
Controls timing and construction of other wells	2	Could affect locations of holes R-11, R-9
Budget and programmatic constraints	2	Needed for FY 98 Completion of LA/Pueblo Canyon RFI Workplan
Operational efficiency - scheduling	1	Install in sequence with other wells in canyon
R-12 Total	**20**	

R-13 Mortandad Canyon below TA-50 outfall

Criteria	Assigned Points	Rationale
Reduce hydrologic setting uncertainty	3	Provide information on intermediate perched zones and water loss mechanisms below TA-50 outfall
Reduce stratigraphic and structural uncertainty	2	Close to other information but provides data on paleo valley and additional deep stratigraphy
Contaminant detection for water supply system	1	Additional information relating to contaminant detection near PM-5
Assessment of nature and extent of potential contamination in groundwater	4	Provides data on pathways and extent of TA-50 discharge contamination
Future water supply	0	In area of other deep wells
Controls timing and construction of other wells	0	Will be installed in any case; does not directly affect other wells
Budget and programmatic constraints	2	Needed for FY 99 Completion of Mortandad Canyon RFI Workplan
Operational efficiency - scheduling	1	Install in sequence with other wells in canyon
R-13 Total	**13**	

R-14 Water supply contaminant detection well for PM-5 near Mortandad Canyon

Criteria	Assigned Points	Rationale
Reduce hydrologic setting uncertainty	2	Close to PM-5 and TW-8; will help define presence and vertical extent of intermediate perched zones
Reduce stratigraphic and structural uncertainty	1	Close to PM-5, which provides structural and stratigraphic information; will provide some information on the axis of the paleo valley on top of the Puye Formation
Contaminant detection for water supply system	4	Purpose of the well is to provide detection of contaminants approaching a water supply well
Assessment of nature and extent of potential contamination in groundwater	1	Location based on PM-5, potential to detect contaminants from Mortandad Canyon where contaminants have been detected in TW-8
Future water supply	0	PM-4 and PM-5 are in a highly productive zone, this well will not add to that knowledge
Controls timing and construction of other wells	2	Findings could affect installation of other Mortandad Canyon wells
Budget and programmatic constraints	2	Protecting the water supply is a high programmatic priority
Operational efficiency - scheduling	1	Logistics would be easier if R-13 and R-15 were installed with one mobilization
R-14 Total	**13**	

R-15 Mortandad Canyon below Ten Site Canyon

Criteria	Assigned Points	Rationale
Reduce hydrologic setting uncertainty	4	Provides intermediate perched zone information; may show influence of PM-5 pumping
Reduce stratigraphic and structural uncertainty	2	Provides structural and stratigraphic information supplementing nearby wells
Contaminant detection for water supply system	2	Could be upgradient of PM-3
Assessment of nature and extent of potential contamination in groundwater	4	May identify down gradient extent of TA-50 discharge contamination
Future water supply	0	Information exists in area
Controls timing and construction of other wells	0	Will be installed in any case to identify possible contamination
Budget and programmatic constraints	2	Needed for FY 99 Completion of Mortandad Canyon RFI Workplan
Operational efficiency - scheduling	1	Install in sequence with other wells in canyon
R-15 Total	**15**	

R-16 Cañada del Buey east of White Rock

Criteria	Assigned Points	Rationale
Reduce hydrologic setting uncertainty	5	Provides information on intermediate perched zones, hydrologic setting and source of White Rock Canyon springs, discharge to Rio Grande, and regional aquifer groundwater levels; a boundary well
Reduce stratigraphic and structural uncertainty	4	Borehole provides reference core information in an area with little deep stratigraphic control
Contaminant detection for water supply system	0	Not near wells
Assessment of nature and extent of potential contamination in groundwater	1	Down gradient of Mortandad Canyon and Cañada del Buey
Future water supply	0	Not in area of water supply expansion
Controls timing and construction of other wells	1	Not closely related to other holes but provides information for stratigraphic interpretation
Budget and programmatic constraints	0	Not closely related to other holes
Operational efficiency - scheduling	0	Not closely related to other holes
R-16 Total	**11**	

R-17 Two Mile Canyon

Criteria	Assigned Points	Rationale
Reduce hydrologic setting uncertainty	3	Provides intermediate perched zone and regional aquifer groundwater level information beneath a tributary to Pajarito Canyon, in an otherwise unknown area; will be supplemented by other new wells
Reduce stratigraphic and structural uncertainty	3	Provides stratigraphic data in a current data gap; will be relatively near R-18
Contaminant detection for water supply system	1	Upgradient of PM wells
Assessment of nature and extent of potential contamination in groundwater	4	Upgradient of Mortandad Canyon; may detect contamination from HE sites and TA-3
Future water supply	0	Not in area of water supply development
Controls timing and construction of other wells	1	May supply information for R-19; installed after R-18
Budget and programmatic constraints	1	Needed for FY 00 Completion of Pajarito Canyon RFI Workplan
Operational efficiency - scheduling	0	Not near other wells; difficult mobilization
R-17 Total	**13**	

R-18 Pajarito Canyon above Two Mile Canyon

Criteria	Assigned Points	Rationale
Reduce hydrologic setting uncertainty	5	Provides intermediate perched zone and regional aquifer groundwater level and flow direction data in an area not influenced by the Pajarito fault zone
Reduce stratigraphic and structural uncertainty	4	Located in a data gap; could provide deep fault zone information
Contaminant detection for water supply system	1	Upgradient of PM wells
Assessment of nature and extent of potential contamination in groundwater	4	Detection of contamination from TA-16 and firing sites in Aggregate 5
Future water supply	0	Could delineate western edge of high-permeability Miocene trough if deep enough
Controls timing and construction of other wells	2	May provide information affecting placement of R-19, R-17
Budget and programmatic constraints	1	Needed for FY 00 Completion of Pajarito Canyon RFI Workplan
Operational efficiency - scheduling	0	Not near other wells; difficult mobilization
R-18 Total	**17**	

R-19 Pajarito Canyon above TA-18

Criteria	Assigned Points	Rationale
Reduce hydrologic setting uncertainty	3	Provides intermediate perched zone and regional aquifer groundwater level information
Reduce stratigraphic and structural uncertainty	3	Information on basalt facies distribution in area remote from other wells
Contaminant detection for water supply system	1	Possibly upgradient from PM-2, PM-4
Assessment of nature and extent of potential contamination in groundwater	4	Detection of possible HE from TA-6 and TA-9 firing sites and HE machining processes
Future water supply	0	Near other wells
Controls timing and construction of other wells	0	Installed after R-17, R-18
Budget and programmatic constraints	1	Needed for FY 00 Completion of Pajarito Canyon RFI Workplan
Operational efficiency - scheduling	1	Can be installed with R-20, R-22
R-19 Total	**13**	

R-20 Water supply contaminant detection well near PM-2 in Pajarito Canyon

Criteria	Assigned Points	Rationale
Reduce hydrologic setting uncertainty	3	Close to PM-2; will help define presence and vertical extent of intermediate perched zones; support Area G Performance Assessment
Reduce stratigraphic and structural uncertainty	2	Close to PM-3, which provides structural and stratigraphic information
Contaminant detection for water supply system	4	Purpose of the well is to provide detection of contaminants approaching a water supply well
Assessment of nature and extent of potential contamination in groundwater	1	Location based on PM-2, no current information on presence of contaminants. Potential to detect contaminants from TA-18
Future water supply	0	PM-2 is in a highly productive zone, this well will not add to that knowledge
Controls timing and construction of other wells	0	The location of other wells are not dependent on this well
Budget and programmatic constraints	2	Protecting the water supply is a high programmatic priority
Operational efficiency - scheduling	1	Logistics would be easier if R-19, R-20, and R-22 were installed with one mobilization
R-20 Total	**13**	

R-21 MDA L

Criteria	Assigned Points	Rationale
Reduce hydrologic setting uncertainty	3	Mesa top well; possible intermediate perched zone and groundwater level information; other information nearby; useful for MDA G performance assessment
Reduce stratigraphic and structural uncertainty	2	Near other wells; some pre-Bandelier information on structure, dip, basalt facies
Contaminant detection for water supply system	0	No wells down gradient
Assessment of nature and extent of potential contamination in groundwater	4	Identify extent of VOC plume from MDA L
Future water supply	0	Near other wells
Controls timing and construction of other wells	0	Well will be installed regardless of other wells
Budget and programmatic constraints	2	Need for ongoing FU 5 RFI characterization
Operational efficiency - scheduling	0	No nearby wells
R-21 Total	**11**	

R-22 Pajarito Canyon below MDA G

Criteria	**Assigned Points**	**Rationale**
Reduce hydrologic setting uncertainty	5	Intermediate perched zone and regional aquifer groundwater level information; a boundary well; down gradient from MDA G; reference core information will support MDA G performance assessment
Reduce stratigraphic and structural uncertainty	4	Fills data gap below Bandelier; supplies MDA G performance assessment information on stratigraphy; could detect edge of high-permeability Miocene trough
Contaminant detection for water supply system	0	Not near wells
Assessment of nature and extent of potential contamination in groundwater	4	Down gradient of MDA G, MDA L, TA-18 contaminant sources
Future water supply	1	Not in expansion area but could define edge of high-permeability Miocene trough
Controls timing and construction of other wells	2	Core could affect other nearby wells and MDA G performance assessment
Budget and programmatic constraints	1	Needed for FY 00 Completion of Pajarito Canyon RFI Workplan
Operational efficiency - scheduling	1	Install along with R-19, R-20
R-22 Total	**18**	

R-23 Potrillo Canyon

Criteria	Assigned Points	Rationale
Reduce hydrologic setting uncertainty	4	May define water loss in discharge sink; possible intermediate perched zones; pathway identification for HE
Reduce stratigraphic and structural uncertainty	3	Data gap filled in part by R-22; extends information on basalts; gives structure at discharge sink
Contaminant detection for water supply system	0	Not near wells
Assessment of nature and extent of potential contamination in groundwater	4	Trace impact of HE and firing site sources
Future water supply	1	Could define edge of high-permeability Miocene trough
Controls timing and construction of other wells	0	Well will be drilled regardless of other wells
Budget and programmatic constraints	0	Later on ER Project schedule
Operational efficiency - scheduling	0	Later on ER Project schedule
R-23 Total	**12**	

R-24 Within Pajarito Fault zone

Criteria	Assigned Points	Rationale
Reduce hydrologic setting uncertainty	5	Provides boundary, fault zone, and water level information; possible perched zones
Reduce stratigraphic and structural uncertainty	4	Information on fault zone characteristics and structure
Contaminant detection for water supply system	0	Not near wells
Assessment of nature and extent of potential contamination in groundwater	1	Background water quality information upgradient of Aggregate 5
Future water supply	0	Not in area of potential production
Controls timing and construction of other wells	0	Not affected by other wells
Budget and programmatic constraints	0	None
Operational efficiency - scheduling	1	Drill with R-26
R-24 Total	**11**	

R-25 Cañon de Valle at MDA P

Criteria	**Assigned Points**	**Rationale**
Reduce hydrologic setting uncertainty	5	Will help resolve uncertainties of water levels and intermediate perched zones raised by drilling of SHB-3; information on infiltration from Cañon de Valle
Reduce stratigraphic and structural uncertainty	4	Data gap below top of Puye formation
Contaminant detection for water supply system	0	Could provide evidence of HE contamination and pathways, but not near wells
Assessment of nature and extent of potential contamination in groundwater	4	Could provide evidence of HE contamination and pathways near MDA P, HE wastewater outfalls, and infiltration from Cañon de Valle; upgradient water quality information for other aggregates
Future water supply	2	Provides information on water quality (HE movement) and stratigraphy upgradient of possible water supply expansion area
Controls timing and construction of other wells	2	Install early- information has big impact on Laboratory operational decisions and other installations
Budget and programmatic constraints	2	Early installation provides better mesh with ER schedule; defining intermediate perched zones and giving basis for shallow drilling
Operational efficiency - scheduling	1	Coincide with other ER installations in area
R-25 Total	**20**	

R-26 Down thrown of Pajarito Fault zone in Water Canyon

Criteria	Assigned Points	Rationale
Reduce hydrologic setting uncertainty	5	Provides boundary, fault zone, and water level information; possible intermediate perched zones
Reduce stratigraphic and structural uncertainty	4	Information on fault zone characteristics and structure; more stratigraphic and less structural information than R-24
Contaminant detection for water supply system	0	Not near wells
Assessment of nature and extent of potential contamination in groundwater	1	Background groundwater quality information upgradient of Aggregate 5
Future water supply	0	Not in area of potential production
Controls timing and construction of other wells	0	Not affected by other wells
Budget and programmatic constraints	0	None
Operational efficiency - scheduling	1	Install with R-24
R-26 Total	**11**	

R-27 Water Canyon at Cañon de Valle

Criteria	Assigned Points	Rationale
Reduce hydrologic setting uncertainty	4	Provides intermediate perched zone information for two wet canyons; water level information; down gradient of HE area
Reduce stratigraphic and structural uncertainty	2	Near existing information at TA-49; could get additional deep structure information
Contaminant detection for water supply system	0	No wells nearby
Assessment of nature and extent of potential contamination in groundwater	4	Provides water quality information down gradient of Aggregate 5; upgradient of Aggregate 3; could detect HE contamination
Future water supply	1	Helps define extent of high-permeability Miocene trough
Controls timing and construction of other wells	2	Controls TA-49 well R-30
Budget and programmatic constraints	2	Information on HE contamination could affect decisions on Laboratory operations and other area installations
Operational efficiency - scheduling	0	Not near other wells
R-27 Total	**15**	

R-28 Mid Water Canyon

Criteria	Assigned Points	Rationale
Reduce hydrologic setting uncertainty	3	Potential to find intermediate perched zones in wet canyon; regional aquifer groundwater levels
Reduce stratigraphic and structural uncertainty	4	Constraints on high-permeability Miocene trough; cores allow reevaluation of nearby well stratigraphy in deeper units
Contaminant detection for water supply system	0	Not near water supply wells
Assessment of nature and extent of potential contamination in groundwater	4	Evaluate contaminant movement from nearby HE sources
Future water supply	3	Information on deeper stratigraphy related to future water supply potential; also water quality and HE contamination
Controls timing and construction of other wells	2	Data supports nearby wells
Budget and programmatic constraints	2	Needed for OBOD characterization; HE contaminant pathway information could affect other installations
Operational efficiency - scheduling	0	Not near other wells; remote access
R-28 Total	**18**	

R-29 Lower Water Canyon at Potrillo Canyon

Criteria	Assigned Points	Rationale
Reduce hydrologic setting uncertainty	5	Provides information on intermediate perched, regional aquifer water levels, hydrologic setting of White Rock Canyon springs; a boundary well
Reduce stratigraphic and structural uncertainty	4	Fills in lack of stratigraphic and structural information at deeper levels
Contaminant detection for water supply system	0	Not near wells
Assessment of nature and extent of potential contamination in groundwater	2	Could define edge of HE contamination near boundary; not as high a priority as Ancho Canyon as no present contaminant detections
Future water supply	0	Not in expected area of development
Controls timing and construction of other wells	0	Doesn't relate closely to other wells
Budget and programmatic constraints	0	Doesn't relate closely to other wells
Operational efficiency - scheduling	0	Doesn't relate closely to other wells
R-29 Total	**11**	

R-30 TA-49 Mesa top well

Criteria	Assigned Points	Rationale
Reduce hydrologic setting uncertainty	3	Will provide hydrologic properties and may show existence of perched horizons; assess possible HE contaminant pathways
Reduce stratigraphic and structural uncertainty	1	Will supplement nearby existing wells
Contaminant detection for water supply system	0	No wells nearby
Assessment of nature and extent of potential contamination in groundwater	4	Will assess presence and pathways for possible HE contamination, as well as other potential contaminants from hydronuclear testing (Be, U)
Future water supply	0	Other nearby information exists
Controls timing and construction of other wells	0	Doesn't drive other wells
Budget and programmatic constraints	2	Regulatory concerns make this a high priority
Operational efficiency - scheduling	0	No related wells
R-30 Total	**10**	

R-31 Ancho Canyon down gradient of Aggregate 8 OBOD sites

Criteria	Assigned Points	Rationale
Reduce hydrologic setting uncertainty	5	Provides data in an unknown area including possibility of perched horizons
Reduce stratigraphic and structural uncertainty	4	Provides data in a current information gap
Contaminant detection for water supply system	0	Not near wells
Assessment of nature and extent of potential contamination in groundwater	4	Could define extent of HE contamination from OBOD sites
Future water supply	2	Could define edge of high-permeability Miocene trough
Controls timing and construction of other wells	0	Will be installed regardless of other findings to define HE contamination and hydrologic issues
Budget and programmatic constraints	2	HE contamination information will affect Laboratory operational decisions and other installations
Operational efficiency - scheduling	1	Could be installed with R-32
R-31 Total	**18**	

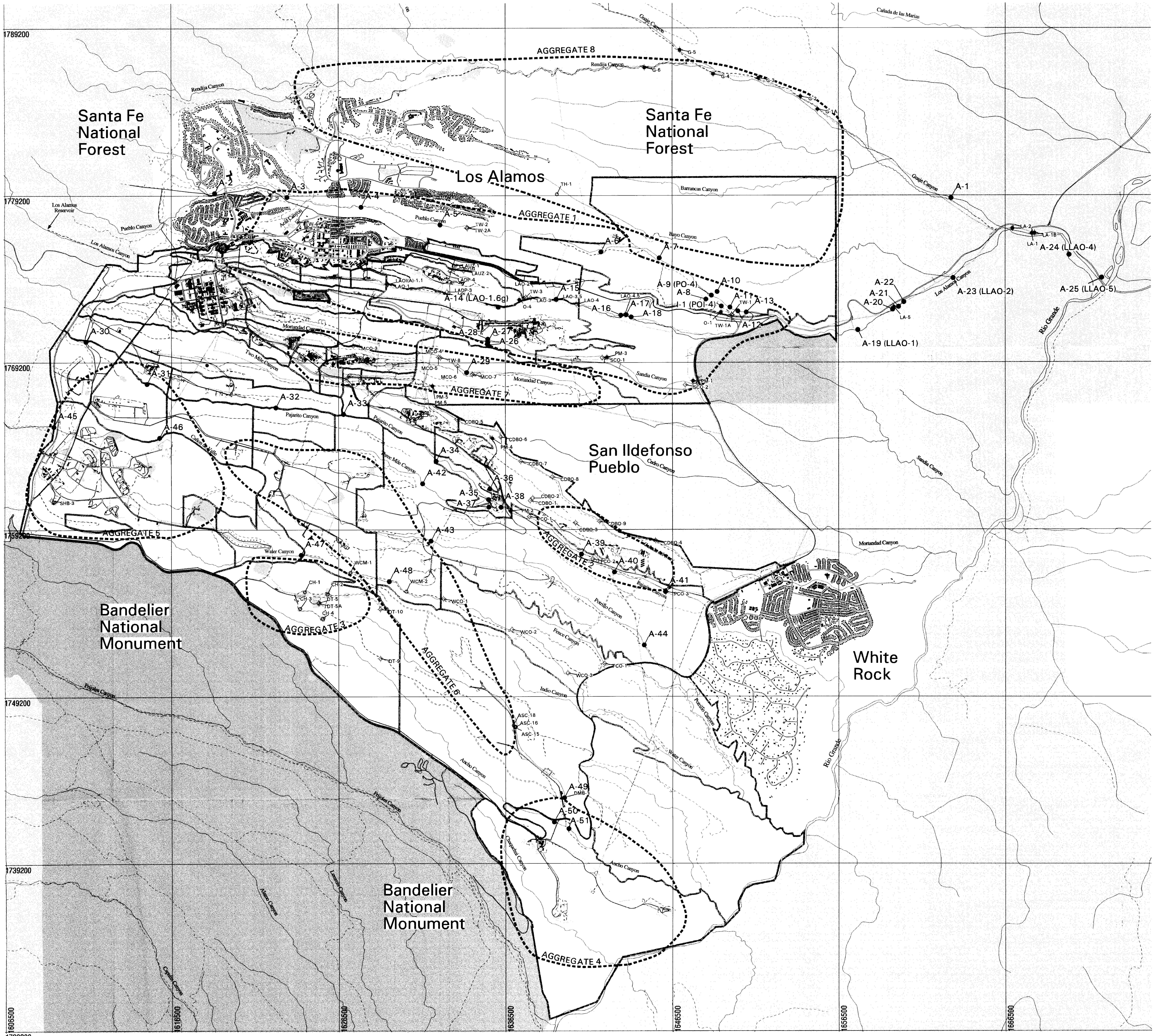
R-32 Ancho Canyon above Ancho Spring

Criteria	Assigned Points	Rationale
Reduce hydrologic setting uncertainty	5	Source of information relating to regional aquifer discharge area and setting of White Rock Canyon springs, regional aquifer groundwater levels, and possible HE contamination pathways
Reduce stratigraphic and structural uncertainty	4	Fills gap in deep stratigraphic information
Contaminant detection for water supply system	0	Not near wells
Assessment of nature and extent of potential contamination in groundwater	4	Near HE sources; could define pathways and extent of contamination; boundary well near pueblos
Future water supply	0	Not in area of expected development
Controls timing and construction of other wells	2	Reference well in relatively unknown area; information could affect placement of other wells
Budget and programmatic constraints	2	HE contamination information will affect Laboratory operational decisions and other installations
Operational efficiency - scheduling	1	Could be installed with R-31
R-32 Total	**18**	

APPENDIX 6

FIMAD Maps for Proposed Well Locations

GROUND WATER MONITOR WELL PROJECT



Proposed Alluvial and Intermediate Wells

LEGEND

- Dirt Road
- Dirt Road/Trail
- Drainage
- Electric Line, >13.2 kV
- Electric Line, <13.2 kV
- Gas Line
- LANL Boundary
- Paved Road
- Technical Area Boundary
- Well Aggregate Area
- Potential Release Site
- Structure

- Bandelier National Monument
- Los Alamos National Laboratory
- San Ildefonso Pueblo
- Santa Fe National Forest

EXISTING WELLS

- Borehole or Corehole
- Monitor Well
- Water Supply Well

PROPOSED ALLUVIAL AND INTERMEDIATE WELLS

- Alluvial Well
- Intermediate Well

FACILITY for INFORMATION, MANAGEMENT, ANALYSIS and DISPLAY
EARTH & ENVIRONMENTAL SCIENCES DIVISION (EES-5)
LOS ALAMOS NATIONAL LABORATORY, Los Alamos, New Mexico

Produced by: Doug Walther
Date: May 12, 1998 FIMAD Plot ID: G106454

N

State Plane Coordinate System, New Mexico Central Zone.
1983 North American Datum

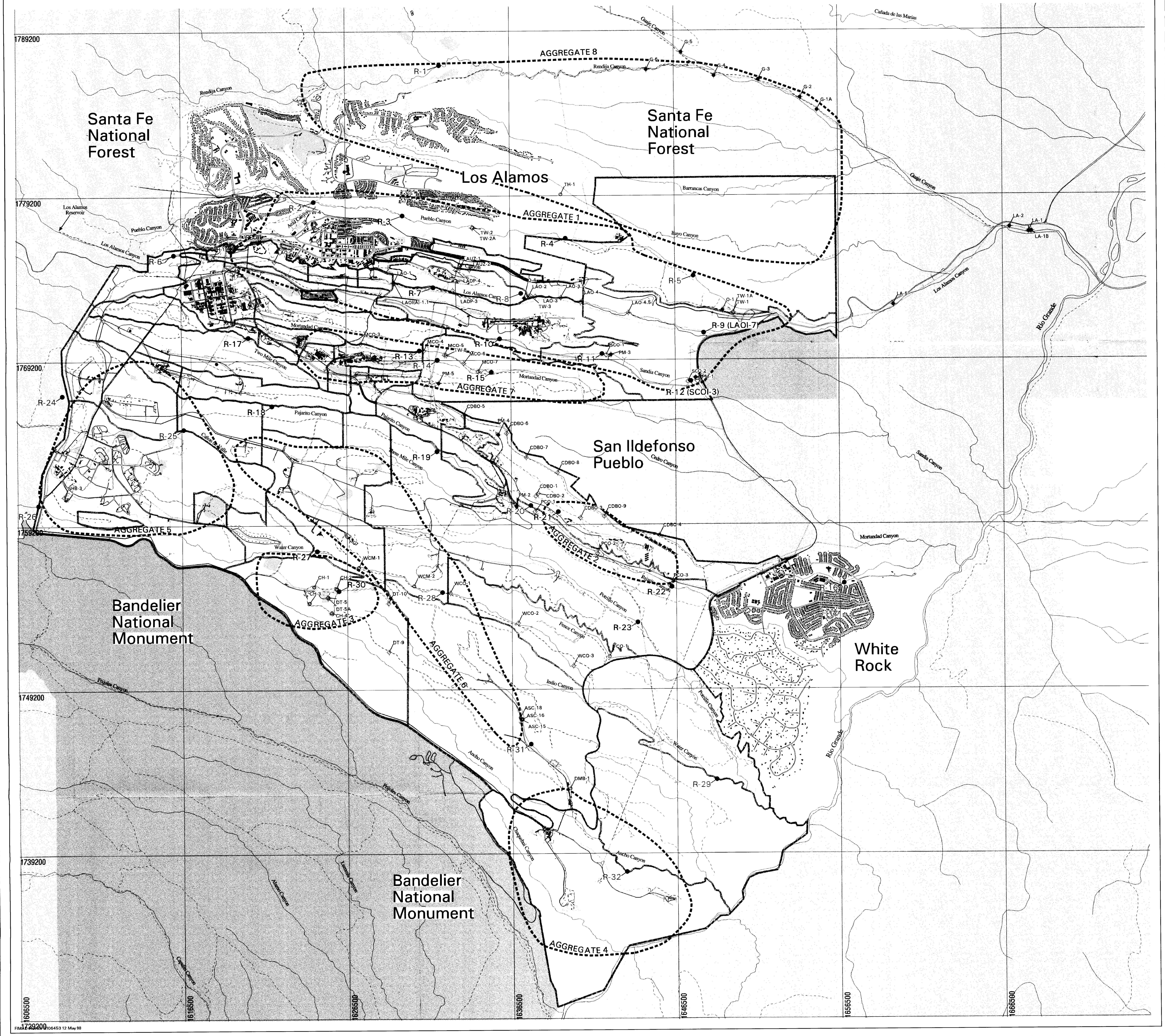
Grid provides NM State Plane coordinates in feet.
Grid interval, in feet: 10000
Feet per inch on map = 2500

SCALE 1:30000

0 762 1524 2286 3048
METERS
0 2500 5000 7500 10000
FEET

NOTICE: The information on this map is provisional. Feature locations are dependent on scale and symbology and their accuracy may not have been confirmed. Los Alamos National Laboratory boundary is based on legal description established in 1995. Contour data are from a September 1991 aerial survey. All other data are from various sources and are part of the FIMAD repository.

GROUND WATER MONITOR WELL PROJECT



Proposed Regional Wells

LEGEND

- Dirt Road
- Dirt Road/Trail
- Drainage
- Electric Line, >13.2 kV
- Electric Line, <13.2 kV
- Gas Line
- LANL Boundary
- Paved Road
- Technical Area Boundary
- Well Aggregate Area
- Potential Release Site
- Structure

- Bandelier National Monument
- Los Alamos National Laboratory
- San Ildefonso Pueblo
- Santa Fe National Forest

EXISTING WELLS

- Borehole or Corehole
- Monitor Well
- Water Supply Well

PROPOSED REGIONAL WELLS

- NWT/MWIP Well
- EM/ER Well

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EARTH & ENVIRONMENTAL SCIENCES DIVISION (EES-5)

LOS ALAMOS NATIONAL LABORATORY, Los Alamos, New Mexico

Produced by: Doug Walther

Date: May 12, 1998

FIMAD Plot ID: G106453

State Plane Coordinate System, New Mexico Central Zone.
1983 North American Datum

Grid provides NM State Plane coordinates in feet.
Grid interval, in feet: 10000
Feet per inch on map = 2500

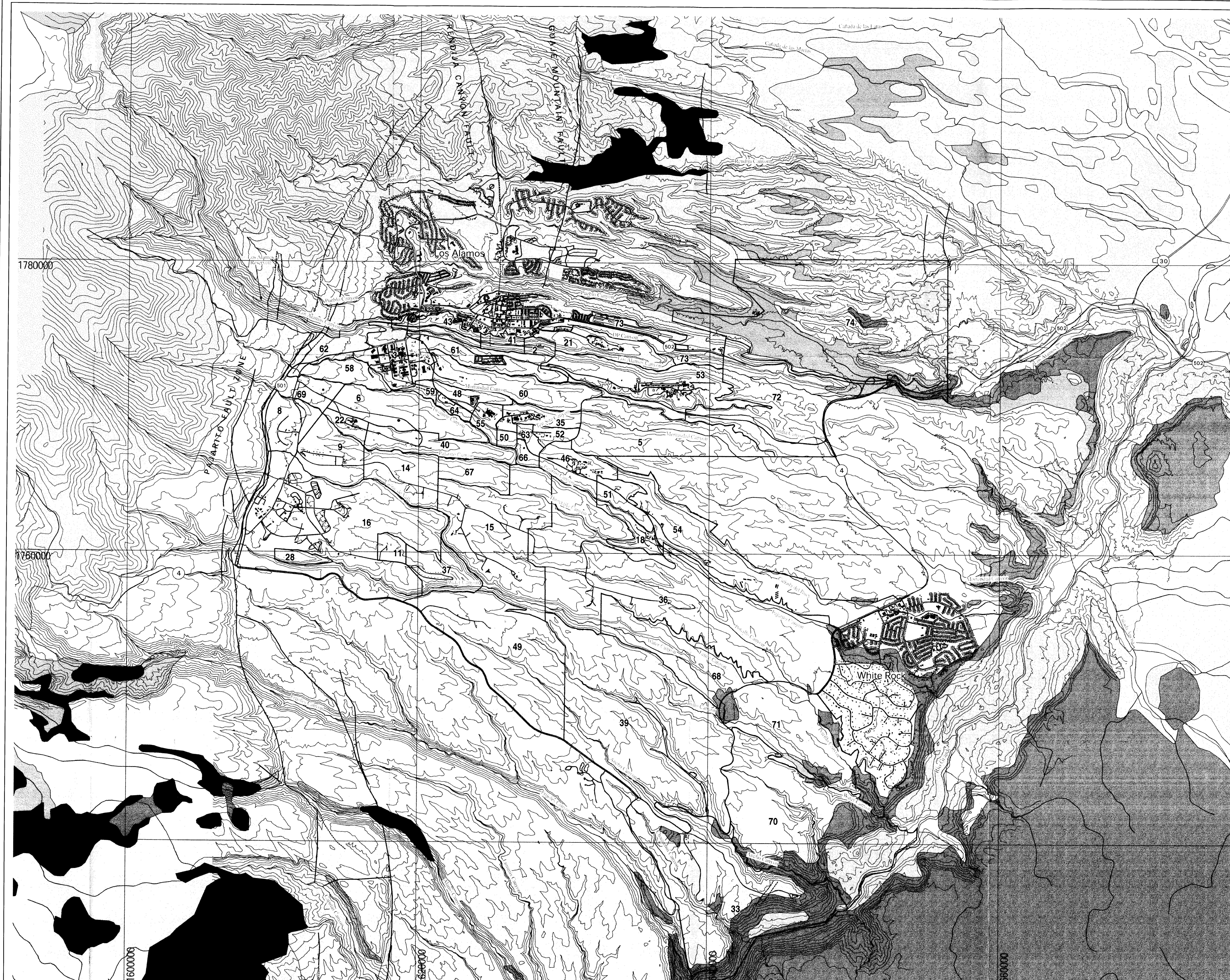
SCALE 1:30000

0 762 1524 2286 3048
METERS

0 2500 5000 7500 10000
FEET

NOTICE: The information on this map is provisional. Feature locations are dependent on scale and symbology and their accuracy may not have been confirmed. Los Alamos National Laboratory boundary is based on legal description established in 1995. Contour data are from a September 1991 aerial survey. All other data are from various sources and are part of the FIMAD repository.

Geologic Map of the Pajarito Plateau



- Contour, 100-ft
- Drainage
- Paved Road
- Technical Area Boundary
- Permanent Structure

- Qal - ALLUVIUM (0-100(?) ft)
- Qf - FAN DEPOSITS (0-100(?) ft)
- Ql - LANDSLIDE DEPOSITS (0-150(?) ft).
- Qg - TERRACE GRAVELS

CERRO TOLEDO RHYOLITE

- Qctt - Rhyolite tuffs and tuff breccias (0-200+ ft).

BANDELIER TUFF (30-900+ ft)

- Qbt - TSHIREGE MEMBER of Bandelier Tuff (50-900+ ft).
- Qbo - OTOWI MEMBER of Bandelier Tuff (0-600+ ft).
- QTb - BASALTIC LAVAS AND TUFFS OF CERROS DEL RIO. (0-1,000 ft).

CERRO RUBIO QUARTZ LATITE

- Qcrv - Volcanic dome of red to gray biotite-hornblende quartz latite.

- QTp - PUYE FORMATION (50-700 ft).

- Tt - TSCHICOMA FORMATION (0-3,000+ ft).

BEARHEAD RHYOLITE (0-2,000+ ft).

- Tbi - Volcanic domes and shallow intrusions.

PALIZA CANYON FORMATION

- Tpd - Mainly thick massive flows and dome-flows (0-800 ft).
- Tpa - Mainly hypersthene-augite andesites. (0-2,000+ ft).

- Tsf - SANTA FE FORMATION AS USED BY H.T.U. SMITH (1938), DENNY (1940), AND GALUSHA (1966) (0-5,000+ ft).
- Apparent Fault
- Approximate Fault

Geology taken from R. L. Smith, R. A. Bailey, and C. S. Ross, U.S. Geological Survey Miscellaneous Geological Investigation Map I-571 (1970)

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LOS ALAMOS NATIONAL LABORATORY, Los Alamos, New Mexico

Produced by: Marcia Jones
Date: April 27, 1998 FIMAD Plot ID: 106429

State Plane Coordinate System, New Mexico Central Zone.
1983 North American Datum

Grid provides NM State Plane coordinates in feet.
Grid interval, in feet: 20000
Feet per inch on map = 2500

SCALE 1:30000

0 762 1524 2286 3048 METERS

0 2500 5000 7500 10000 FEET

NOTICE: The information on this map is provisional. Feature locations are dependent on scale and symbology and their accuracy may not have been confirmed. Los Alamos National Laboratory boundary is based on legal description established in 1995. Contour data are from a September 1991 aerial survey. All other data are from various sources and are part of the FIMAD repository.