LANL 06d

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HYDROGEOLOGIC EVALUATION OF LOS ALAMOS NATIONAL LABORATORY

Teri D. Davis
Susan Hoines
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Hazardous and Radioactive Materials Bureau
New Mexico Environment Department

July 1996

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ACRONYMS

AOC	Area of contamination
CA	Corrective Action
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CFR	Code of Federal Regulations
CMI	Corrective Measures Implementation
CMS	Corrective Measures Study
DOE	Department of Energy
DOE OB	Department of Energy Oversight Bureau
EES	Earth and Environmental Science
EPA	Environmental Protection Agency
ER	Environmental Restoration
ES	Environmental Surveillance
ESH	Environment, Safety and Health Management
FIMAD	Facility for Information Management, Analysis, and Display
gpd	gallons per day
gpm	gallons per minute
GWMP	Groundwater Monitoring Plan
GWPMPP	Groundwater Protection Management Program
HRMB	Hazardous and Radioactive Materials Bureau
HWA	Hazardous Waste Act
HSWA	Hazardous and Solid Waste Amendment
IWP	Installation Work Plan
LANL	Los Alamos National Laboratory
MCL	Maximum Contaminant Level
MDA	Material Disposal Area
NM	New Mexico
NMAC	New Mexico Annotated Code
NMSA	New Mexico Statutes Annotated
NMED	New Mexico Environment Department
OU	Operable Unit
pCi/L	pico-Curies per liter
ppm	parts per million
PRS	Potential Release Site
RCRA	Resource Conservation and Recovery Act
RFA	RCRA Facility Assessment
RFI	RCRA Facility Investigation
S/cm	Siemens per centimeter
SDWA	Safe Drinking Water Act
SR	State Road
SWMU	Solid Waste Management Unit
SWSP	Site-Wide Study Plan
TA	Technical Area
TDS	Total Dissolved Solids
TSD	Treatment, Storage, or Disposal [Facility]
USGS	United States Geological Survey
WQA	Water Quality Act
WQCC	Water Quality Control Commission

I. EXECUTIVE SUMMARY

Los Alamos National Laboratory (LANL) has over 2,000 potential release sites covering an area of 43 square miles. LANL's current ground-water monitoring system is inadequate, and fundamental issues regarding the facility's site-wide geology, hydrogeology, and modes of contaminant transport have not been adequately addressed to date. As a result, insufficient information exists to determine the nature, rate, extent of any contamination in ground water, and subsequent risk to human health and the environment.

This report summarizes the current knowledge of the hydrogeologic system at LANL, revises LANL's conceptual model of the hydrogeologic setting, and identifies additional investigations necessary to comply with the ground-water regulatory requirements of RCRA/HSWA. Revision of LANL's conceptual model of the hydrogeologic setting included a total of four modes of ground-water occurrence beneath the Pajarito Plateau: perched water within volcanic rocks (Tschicoma Formation and Tshirege Member of the Bandelier Tuff); shallow perched "alluvial" ground water in canyon bottoms; intermediate perched water; and the regional or "main" aquifer.

In addition to the identification of four modes of ground-water occurrence, NMED made the following conclusions concerning the hydrogeologic setting at LANL: drainage patterns of the Pajarito Plateau have shifted over geologic time, and one dominant drainage (which connects present-day separate canyon systems and cuts present-day mesa tops) is recurrent; intermediate perched ground water movement may be significantly influenced by paleodrainages; shallow perched and intermediate perched ground water systems may be co-located beneath canyon bottoms; a two-mile radius of effect from production wells may impact the direction of ground-water flow within the regional aquifer; and White Rock Canyon springs may represent discharge points for both the regional aquifer and intermediate perched ground water.

As a result of this evaluation, NMED recommends that LANL develop a site-wide hydrogeologic workplan for approval by the administrative authority as part of the RCRA ground-water monitoring requirements of 40 CFR 264/265 Subpart F and the HSWA Module of LANL's RCRA permit. This workplan would aid in determining the effect of past, current, and future laboratory operations on the ground-water regime, and in evaluating the impact on human health and the environment.

II. INTRODUCTION

Department of Energy (**DOE**)/Los Alamos National Laboratory (**LANL**) has over 2,000 radioactive and hazardous waste potential release sites (**PRSs**) covering an area of 43 square miles. The pathways for releases from any of these units have not been adequately characterized. Fundamental characterization questions remain which prevent the evaluation of risk to ground water. Currently, insufficient information exists to determine the nature, rate, extent of any contamination in ground water, and subsequent impact to human health and the environment.

Fundamental environmental setting questions remain and need resolution prior to the design of a comprehensive ground-water monitoring system. Sampling plans for phase I assessments of release determination from Solid Waste Management Units (**SWMU**) have been developed prior to an adequate environmental setting characterization. Integrating the objectives of a site-wide characterization (such as the need to delineate aquifer extent, determine directions of ground-water flow, and aquifer characteristics) is essential to better understand the environmental framework for specific sites.

LANL's Environmental Restoration (**ER**) program began in 1988 to address releases from SWMUs and Areas of Concern (**AOC**) which constitute the above-mentioned PRSs. The ER program is subject to the Resource Conservation and Recovery Act (**RCRA**) Corrective Action (**CA**) process which is divided into three stages: RCRA Facility Investigation (**RFI**), Corrective Measures Study (**CMS**), and Corrective Measures Implementation (**CMI**).

Given that LANL is currently conducting many Phase 2 RFIs, the New Mexico Environment Department (**NMED**)/Hazardous and Radioactive Materials Bureau (**HRMB**) is concerned with identifying and assuring closure of site-wide issues. As stated within LANL's June 15, 1995 Draft Site-Wide Study Plan (**SWSP**), "the remaining portion of the remediation decisions cannot be reached in an informed manner without significant additions to our [site-wide environmental setting] knowledge base."

LANL's current ground-water monitoring system has been determined by numerous independent sources to be inadequate (NMED, 1993; Stephens et al., 1993; DOE, 1991; LANL, August 1991; Environmental Protection Agency (**EPA**), 1993). Since both DOE and the State are facing increased workloads and decreasing resources, the need to focus on the most important and urgent environmental issues is paramount. This report summarizes the current knowledge of the hydrogeologic system at LANL and identifies additional investigatory activities which NMED has determined necessary to develop an adequate site-wide ground-water detection monitoring system.

Since the drafting of this report, DOE/LANL has committed to the development of a Site-Wide Hydrogeologic Workplan to be submitted to NMED in October 1996 and the continued funding for implementation of the workplan. NMED commends DOE/LANL for recent progress that has been made towards meeting the RCRA-regulatory requirements concerning site-wide hydrogeology and strongly encourages future progress.

A. Scope of Work

As a part of an EPA/NMED RCRA work grant negotiation for Fiscal Year 1995-1996, the HRMB committed to conducting a hydrogeologic evaluation of LANL. The scope of the hydrogeologic evaluation includes the following elements:

1. NMED shall review the available literature concerning the ground-water monitoring at LANL to evaluate specific hydrogeologic requirements outlined in LANL's Hazardous and Solid Waste Amendment (**HSWA**) Module VIII and the ground-water monitoring requirements of RCRA. NMED shall summarize the current status of knowledge pertaining to the main aquifer, perched-intermediate aquifer(s), and the alluvial aquifers as determined by the literature search.

2. NMED shall recommend work required by LANL to meet the hydrogeologic requirements outlined in the HSWA Module VIII. NMED shall recommend to EPA how the work should be conducted in order to characterize the facility-wide hydrogeology. The recommendations shall include numbers and locations of wells to be installed and depths to be monitored, as well as any tests to be preformed by LANL. Ground-water monitoring requirements shall also be included in the recommendation to EPA.

New Mexico received authorization for RCRA Corrective Action in January 1996 and thus will be ultimately responsible for assuring the requirements under the HSWA Module VIII are met.

B. Statuatory and Regulatory Drivers

1. Resource Conservation and Recovery Act (RCRA)

New Mexico statuatory authority to implement Subtitle C of RCRA is under Article 4 of Chapter 74 of New Mexico Statutes Annotated (**NMSA**) 1978, the New Mexico Hazardous Waste Act (**HWA**). The New Mexico (**NM**) HWA is implemented by the 20 New Mexico Annotated Code (**NMAC**). Ground-water monitoring is required at all permitted hazardous waste treatment, storage, and disposal (**TSD**) facilities under 40 Code of Federal Regulations (**CFR**) Part 264.90 (a) (1) except as provided in 264.90(b). Ground-water monitoring requirements for all non-regulated units are specified in the Permit and Subpart S (264.101 (b)). All SWMU must comply with the requirements in Section 264.101, Corrective Action for Solid Waste Management Units. Permitted regulated units (waste piles, landfills, surface impoundments, and land treatment units), must comply with Sections 264.91 through 264.100 (Subpart F) in lieu of Section 264.101(Subpart S) for the purposes of detecting, characterizing, and responding to releases to the uppermost aquifer. Other RCRA SWMUs, such as container storage, tank treatment, incinerator, tank storage, and miscellaneous units, are subject to permit conditions, as well as Subpart S requirements for ground water monitoring. The ground-water monitoring regulations under Section 264.91-264.100 may also apply to miscellaneous units.

LANL has proposed several waivers to the ground-water monitoring requirements under 40 CFR Part 265.90 for the following RCRA-regulated units:

Technical Area (**TA**)-54, Area 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)

RCRA Sections 264.91-264.100 require, the Permittee (i.e., LANL) to verify that no potential for liquid migration from a regulated unit to the uppermost aquifer will occur during the active life of the unit plus thirty years. Based on the inadequate demonstration that no migration would occur, NMED denied LANL's request for a ground water monitoring waiver on May 30, 1995.

Ground-water monitoring program plans are required at the sites listed above for LANL to be in compliance with 20 NMAC Subpart VI, 40 CFR 265 Subpart F regulations. In light of DOE\LANL budgetary constraints, NMED required LANL to develop a comprehensive ground-water monitoring program plan which addresses both site-specific and site-wide ground-water monitoring objectives. An understanding of the upper-most aquifer beneath regulated units is required in 40 CFR Parts [264, 265, and 270]. At present, individual zones of saturation beneath LANL have not been delineated and the hydraulic connection between these zones is not understood. A site-wide ground-water monitoring program plan would incorporate the needs of RCRA ground-water monitoring requirements to ensure the required hydrogeologic information is available and adequate.

2. Hazardous and Solid Waste Amendments (HSWA) Module VIII

A comprehensive, facility-specific, site-wide hydrogeologic characterization is required of LANL by Module VIII of the RCRA Operating Permit (Section P, Task III: Facility Investigation, A. Environmental Setting, 1. Hydrogeology). Module VIII requires the Permittee to collect information that supplements and verifies existing information on the hydrogeologic conditions at the facility. Specific requirements outlined in Module VIII require the Permittee to "conduct a program to evaluate hydrogeologic conditions at the facility." Refer to Appendix A of this document for specific projects stipulated in the Permit.

3. Other

DOE Order 5400.1, General Environmental Protection Program (Chapter IV, Section 5.b, p. 9) requires the development and implementation of a Groundwater Protection Management Program (**GWPMPP**). DOE Order 5400.1 also requires the development of a Groundwater Monitoring Plan (**GWMP**) as a specific element of the GWPMPP. The GWPMPP (Chapter III, Section 4.a, p.2) includes the following: "1) documentation of the groundwater regime with respect to quantity and quality; 2) design and implementation of a groundwater monitoring program to support resource management and comply with applicable environmental laws and regulations; 3) a management program for groundwater protection and

remediation, including specific Safe Drinking Water Act (**SDWA**), RCRA, and Comprehensive Environmental Response, Compensation, and Liability Act (**CERCLA**) actions... LANL may use in whole or in part those technical documents, plans, and permits associated with compliance with SDWA, RCRA, and CERCLA to satisfy this requirements."

NMED has previously voiced concerns over the lack of integration between various DOE/LANL programs implemented to affect an adequate ground-water monitoring plan (NMED, August 17, 1995):

> "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."

An additional regulatory driver to RCRA/HSWA which DOE must consider with regards to site-wide ground-water monitoring is the NM Water Quality Act (**WQA**). The WQA is implemented by the NM Water Quality Control Commission (**WQCC**) regulations which require all active discharges to ground water to have an NMED-approved Ground Water Discharge Plan. Considerable information pertaining to a facility's site-wide hydrogeology is required within a Ground Water Discharge Plan.

C. Issues

The lack of knowledge surrounding these fundamental hydrogeologic issues does not allow for compliance with the regulatory requirements of a site-wide hydrogeologic characterization as outlined within Section P, Task III of the HSWA Module (see Appendix A). At present, the following fundamental hydrogeologic issues remain unresolved at LANL (reference to the HSWA module requirement is made following each issue bullet):

- Individual zones of saturation beneath LANL have not been adequately delineated. LANL has inaccurate and incomplete knowledge concerning the geometries and boundary conditions of the zones of saturation beneath the facility. As a result, the "hydraulic interconnection" between these multiple zones of saturation is not fully understood. A facility-wide description of the hydrogeologic characteristics affecting ground-water flow beneath the facility cannot be made without adequate delineation of the intermediate perched aquifer(s) beneath LANL. [Task III (A) (1)(a)(d)(e)(f)]

- Recharge area(s) for the main and intermediate perched 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 incomplete. It is unknown what effect, if any, these zones may have on the direction of ground-water flow and hydraulic gradient of the regional and intermediate perched aquifers. [Task III (A) (1)(a)(b)(c)(e ii, iii)(h)]

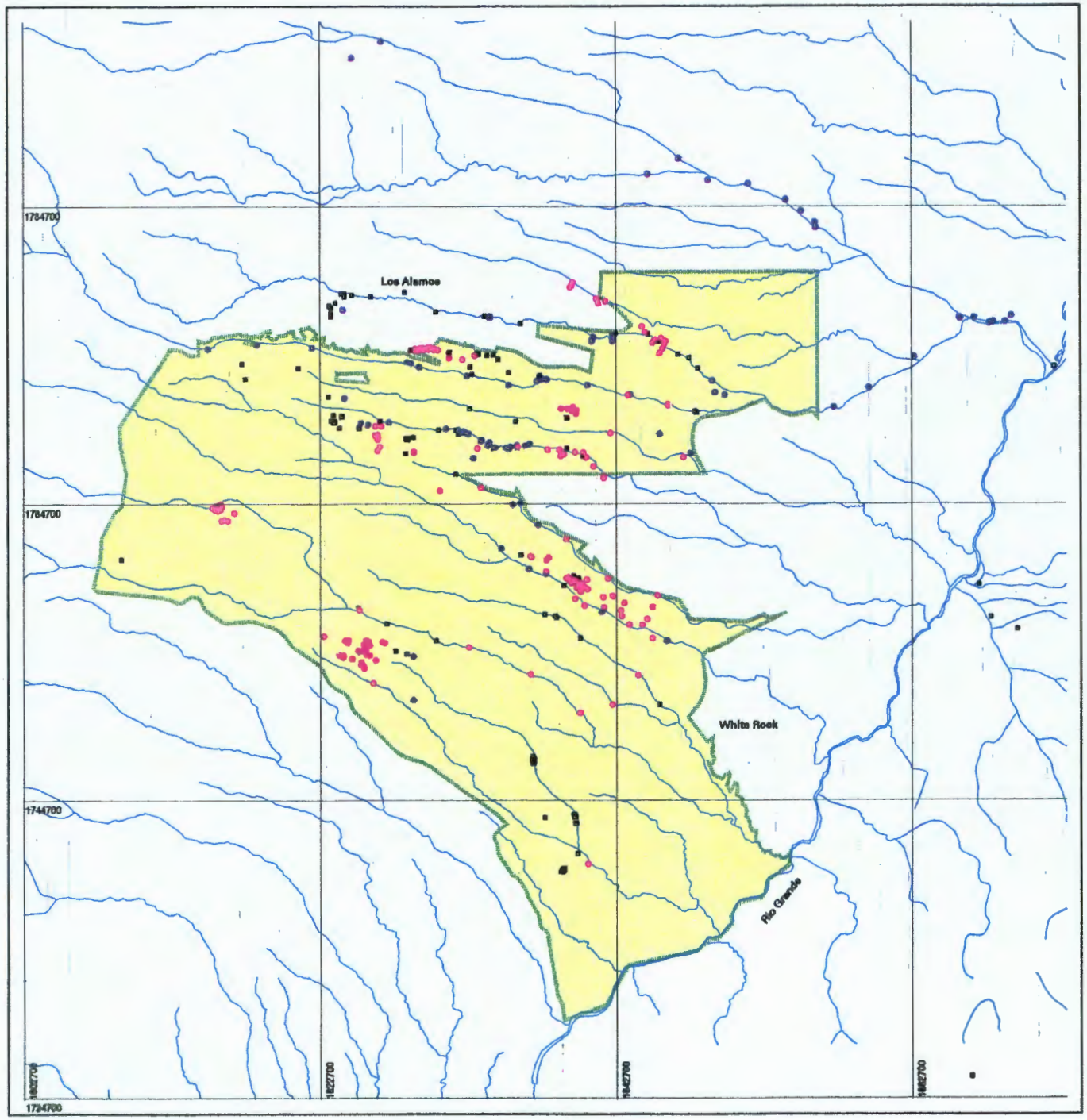
- Ground-water flow direction(s) of the regional aquifer and intermediate perched aquifer(s), as influenced by pumping of production wells, is(are) unknown. [Task III (A) (1)(a)(b)(f)(g)]

- Aquifer characteristics cannot be determined without the installation of additional monitoring wells within specific intervals of the various aquifers beneath the facility. Locations of wells designed for aquifer testing cannot be addressed adequately without resolving the first bullet. [Task III (A) (1)(a)(d)(e iii)(f)]

D. Approach and Data Sources

NMED reviewed ground-water monitoring literature concerning LANL obtained from the following sources: LANL Earth and Environmental Science (**EES**)-1 Group, LANL Environment, Safety, and Health Management (**ESH**)-18 Group, Facility for Information Management, Analysis, and Display (**FIMAD**), ER Records processing facility, ER Reading Room, NMED DOE Oversight Bureau (**DOE OB**), State Engineers Office, United States Geological Survey (**USGS**), EPA Region 6 facility correspondence, and personal communications with LANL employees, San Ildefonso representatives, and other DOE personnel. Site visits were conducted to ascertain field conditions at various locations across LANL. Field observations were integrated with the information obtained from the literature to gain a general understanding of the site which is reflected in the status report and the ensuing recommendations. Water-level elevations for existing wells, slug test data from selected existing wells, and PRS information was obtained from SWMU reports, the ER Program's Site Ranking System, RCRA Facility Assessment (**RFA**), RFI associated reports and workplans, and other LANL-generated documents.

A summary of all known drill holes across the Pajarito Plateau having penetrations greater than one foot is shown in Figure 1 and Plate 1. These data represent the current information available from the FIMAD database, which includes all information provided by Purtymun (1995), as well as, additional borehole penetrations drilled since the Purtymun (1995) compilation. Figure and Plate 1 also include borehole penetrations which NMED found in other source documentation and supplied to FIMAD for reference and possible future verification. Appendix B1 provides a key for the map designations in Plate 1 and the total



Drill Hole Penetrations at LANL

Explanation

- Boundary, LANL
- Drainage
- Dry Penetration (see note)
- Saturated Penetration (see note)
- Penetration, Unknown if Dry or Saturated

FIGURE 1

Not all penetrations may be represented and some duplicates exist. The existence of saturation was estimated from available information and should not be considered definitive

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
1 inch = 10000 feet

METERS

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 1996. Other boundary, structure, and utility data are from Los Alamos National Laboratory Engineering Division and Los Alamos County Utility and Engineering Departments. Contour data are from Los Alamos National Laboratory Environmental Restoration Project aerial survey, September 1991.

University of California
Los Alamos National Laboratory
Earth and Environmental Sciences Division

FIMAD Facility for Information Management, Analysis, and Display
FIMAD is the electronic data repository for the Environmental Restoration Project at Los Alamos National Laboratory.

Produced by: Doug Walther

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depth for each penetration. These data provide the basis for understanding the available subsurface information at LANL.

NMED made a comparison of original well logs (geologists' logs, drillers' logs, and geophysical logs) between the USGS Record of Wells (John et al., 1966), the FIMAD database, and the Purtymun report (1995). The USGS Record of Wells (John et al., 1966) commonly references Griggs (1955; 1964) as its source of data. Differences noted between the various data sources include stratigraphic nomenclature, ground level elevations, geologic contact elevations, logging interpretations of geologic strata, and undifferentiated units. The stratigraphic nomenclature and correlation utilized in this report follows the system proposed within LANL's 1993 Installation Workplan (**IWP**). Additional well log information was obtained from personal communications with LANL geologists who either logged the wells or were responsible for the accuracy of the logged data. All data were then compiled and assessed for constancy among the various sources; obvious and explainable discrepancies led to a measure of confidence in the data as indicated in the Level of Confidence column found in the tables of Appendix B2.

NMED constructed five paleotopographic surfaces using the compiled well log data: the Totavi Formation, the pre-Bandelier, the Guaje Pumice Bed, the Otowi Member, and the Tsankawi Pumice Bed. Paleotopographic maps were constructed to provide insight into the locations of potential subsurface paleodrainages. Identifying paleodrainages can be useful in siting optimum locations for future drill holes. Paleodrainages are likely locations of paleofill, and thus, potential subsurface zones of higher permeability. When considering the occurrence of intermediate perched ground water, paleodrainages may indicate preferential paths of ground-water flow. It should be noted, however, that stratigraphic contacts from outcrop data were not available for inclusion in this report.

NMED constructed four ground-water occurrence maps using available data: perched ground water within the volcanic rocks of the Tshirege Member and the Tschicoma Formation; intermediate perched ground water; shallow perched "alluvial" ground water; and the regional aquifer. These occurrences were either contoured or plotted noting the top elevation of the individual mode of ground-water occurrence and the geologic stratum associated with either the intercept or discharge point. Data were plotted according to the FIMAD database coordinates which were generally obtained from Purtymun (1995). These maps were used to identify additional data gaps and needs.

NMED constructed a water level map of the regional aquifer using a contour interval of 100 feet and 1993 water level data (LANL, 1994). The water level map gives a visual interpretation of the hydraulic gradient across the Plateau and provides a reference for comparison with the top of the main aquifer. The difference between the top of the regional aquifer and the water level may indicate general areas across the plateau where semi-confined or confined aquifer conditions exist. The comparison of the regional water level map to various paleotopographic surfaces, other modes of ground-water occurrence, and a geologic

map with indicated fault-fracture zones allows for possible inferences regarding influences on the direction of ground-water flow within the regional aquifer.

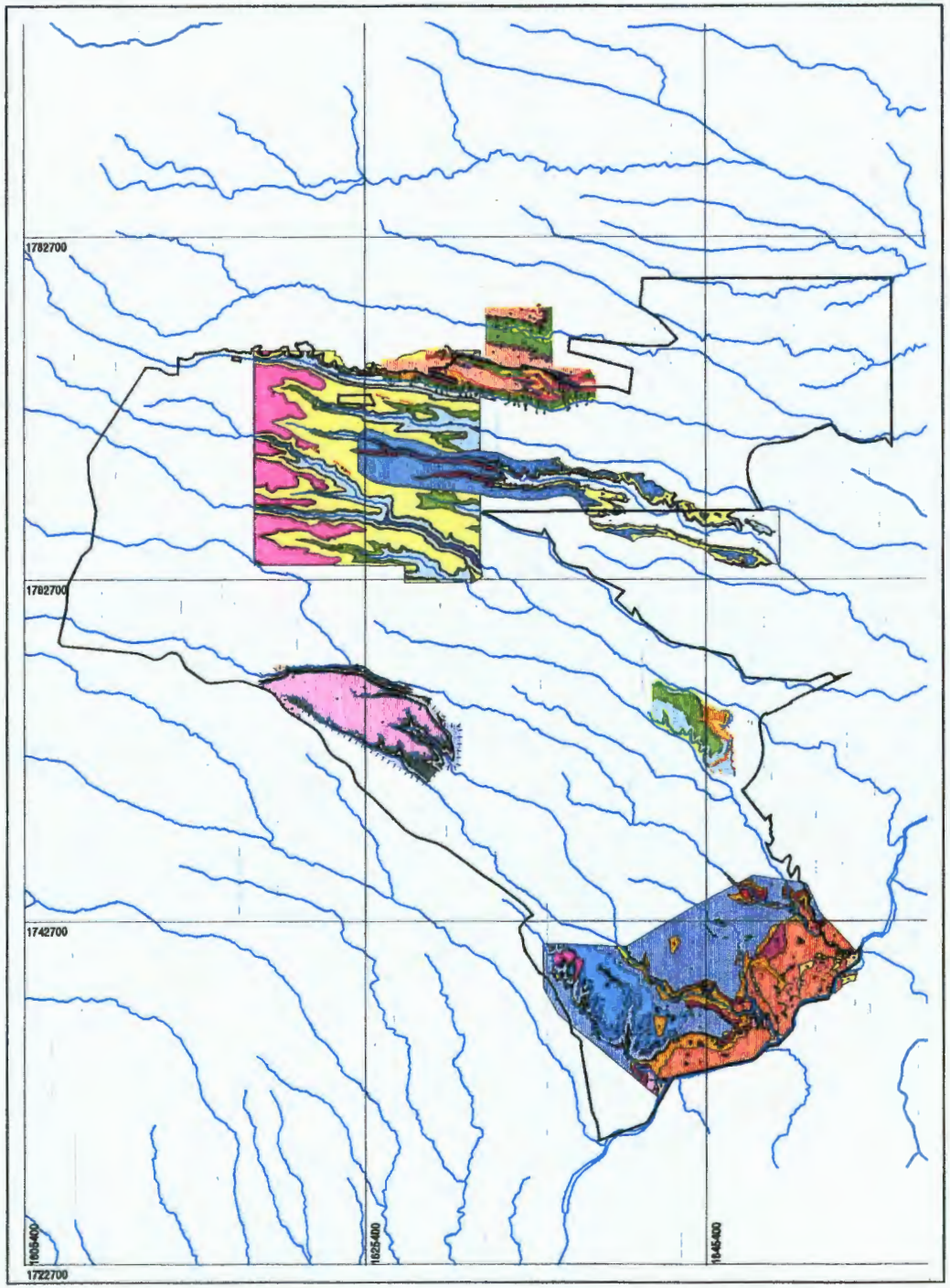
NMED's review of ground-water chemistry data led to the construction of a map which shows known and suspected releases to ground water. This map used all known exceedances of SDWA Maximum Contaminant Levels (**MCLs**), as well as, data which indicated other water quality concerns for all ground-water Environmental Surveillance (**ES**) stations regardless of time. This map was used to gain a plateau-wide perspective of the contaminant problems which may exist. Surface water releases, which were not included in this report, are identified as a data gap later in this report.

A PRS map, showing the spatial relationship between the above data and PRS locations, was reviewed for this report. The PRSs are divided into HSWA SWMUs, AOCs, Material Disposal Areas (**MDAs**), and RCRA-regulated units. NMED evaluated the MDAs, RCRA units, and other miscellaneous PRSs for the potential for release to ground water. Additionally, the need for long-term ground-water monitoring at PRSs was considered.

A geologic map, including known and suspected fault-fracture zones across the Pajarito Plateau, was prepared by LANL (Figure 2 and Plate 2). This map was compared to available well logs and schematic cross-sections, and utilized to identify potential pathways of contaminant transport. Information obtained from this map was used for this report even though the current geologic map of the Pajarito Plateau is incomplete.

Scoping calculations, which resulted in general observations regarding aquifer type and radii of effect from production wells, were performed on available aquifer characteristics data. A modification of the Jacob equation was used to estimate transmissivity from specific capacity data (Driscoll, 1989). A further estimate of transmissivity was made from by using the pumping rate and drawdown data from a production well (Stallman, 1971). By the distance-drawdown modification to the Jacob approximation, an estimate of the radius of cone of depression for specific pumping conditions was made using reasonable estimates of transmissivity assuming equilibrium conditions (Jacob, 1946).

This NMED report identifies specific data gaps designed to assist LANL in complying with the ground-water regulatory requirements of RCRA/HSWA. The recommendations contained within this report combine the available data and known data gaps with the regulatory requirements of RCRA/HSWA. These recommendations are for ground-water investigations which can be further subdivided into intrusive and non-intrusive activities. Recommendations for ground-water investigations are based on the nature of the various modes of ground-water occurrence, the presence of paleodrainages, current and historic release information, the known and inferred presence of fault-fracture zones, pathways for preferential flow coupled with the location of the PRSs, and the regulatory requirements.



LANL Surfical Geology

EXPLANATION

MORTANDAD CANYON GEOLOGY

- Qal
- Qbo
- Qbt1a
- Qbt1b
- Qbt2
- Qbt2a
- Qbt2b
- Qbt3

NORTH-CENTRAL GEOLOGY

- Unit 4 Sandy tuff with small pumice fragments
- Nonwelded slope-forming interval
- Unit 3 Poorly-welded cliff-forming tuff of Pajarito Mesa surface
- Nonwelded slope-forming interval
- Unit 2 Moderately- to densely-welded cliff-forming unit of Twomile Canyon.
- Unit 1v Poorly-welded, vapor-phase altered. Unit 1g Nonwelded glassy tuff.
- Undifferentiated reworked tuffs, Cerro Toledo strtal, and Otowi Member in Los Alamos Canyon
- Zones of intense fracturing
  Source: Vaniman, D. and Wohletz, K. Los Alamos National Laboratory Memorandum EES-1-91-90-17.

TA-49 GEOLOGY

- Qal Alluvium; mapped only in Water Canyon
- Qbt6 Unit 6; light-pinkish-gray to brownish- pink, moderately welded, rhyolite tuff; cliff-forming unit. Locally includes 2-6 feet of water-laid pumice at top. Covered by thin clayey soil on flat upland areas
- Qbt4 Unit 4; gray, friable to moderately welded, pumiceous, rhyolite tuff; cliff- forming unit
- Qbt3 Unit 3; light-gray, friable, pumiceous, rhyolite tuff; slope-forming unit
- Qbt2 Unit 2; light-purplish-gray, welded, rhyolite tuff; cliff-forming unit
- Qbt1 B Unit 1B; light-gray to light-pink, pumiceous, rhyolite tuff containing numerous rock fragments; slope-forming unit

TA-21 GEOLOGY

- Qf Artificial fill and disturbed soils on mesa tops.
- Qmt Mesa top soils; soils developed in weathered Bandelier Tuff, loess, and alluvium on mesa tops; includes small bedrock outcrops.
- Qts Talus and Colluvium; slope wash and rock fall from local sources; includes small landslides, small alluvial fans, and small patches of alluvium on canyon sides.
- Qal Alluvium; stream deposits of gravel, sand, silt, and clay in valley bottoms.
- Qcal Terrace Gravel; older alluvium that lies along margin of DP Canyon.

—— Tshirege Member, Bandelier Tuff ——

- Qbt-3 Unit 3; cliff-forming, nonwelded to partially welded ignimbrite; combined with nonwelded Unit in east side of map area.
- Qbt-nw Slope-forming, nonwelded unit; jagged contact lines show approximate eastern limit of unit, combined with Unit 3 in east side of map area.
- Qbt-2 Unit 2; cliff-forming, partially to moderately welded ignimbrite.
- Qbt-1 Unit 1; nonwelded to partially welded ignimbrite; vapor-phase notch occurs in this unit and vapor-phase alteration is widespread above this feature; Tsankawi pumice fall at base of Unit 1.
- Qct Cerro Toledo interval; equivalent in time to Cerro Toledo Rhyolite; pumice fall deposits interbedded with Puye-like fluvial gravel, cobble, and boulder deposits.
- Qbo Otowi Member, Bandelier Tuff; slope-forming nonwelded ignimbrite; undivided.

TA-39 GEOLOGY

- artificial fill
- Qa3 Alluvial deposits (Holocene and Pleistocene)
- Qa2 Alluvial and lacustrine deposits (late Pleistocene)
- Qf3 Alluvial fan deposit (Holocene and late Pleistocene)
- Qf2 Alluvial fan deposit (late Pleistocene)
- Qf1 Alluvial fan deposit (middle Pleistocene)
- Qt Talus deposit (Holocene and late Pleistocene)
- Qc Colluvial deposits (middle Pleistocene to Holocene)
- Qls Landslide deposit (Pleistocene)
- Qlsa Alluvial and Colluvial deposits on landslides (Pleistocene)
- Tpl Puye Formation, fanglomerate facies (Pliocene)
- Tpt Puye Formation, ancestral Rio Grande facies (Pliocene)
- Tsfu Santa Fe Group, undivided (middle Miocene to early(?) Pliocene)
- Qeo El Cajete pumice (late Pleistocene)
- Qbt-1 Bandelier Tuff, Tshirege member, Unit 1 (early Pleistocene)
- Qbt-2 Bandelier Tuff, Tshirege member, Unit 2 (early Pleistocene)
- Qbt-3 Bandelier Tuff, Tshirege member, Unit 3 (early Pleistocene)
- Qbt Bandelier Tuff, Tshirege member, undivided (early Pleistocene)
- Qbo Bandelier Tuff, Otowi member (early Pleistocene)
- Tco Cinder cone deposit (Pliocene)
- Tcm Phreatomagmatic deposit (Pliocene)
- Tcb3 Basalt flows (late Pliocene)
- Tcba Basaltic andesite and related flows (Pliocene)
- Tcbm Basalt flows and interlayered Phreatomagmatic deposits (Pliocene)
- Tcb2 Basalt flows (Pliocene)
- Tcb1 Basaltic flows (Pliocene)
- Tcbu Basalt flows, undivided (Pliocene)

TA-36 GEOLOGY

- Unit 2u (undifferentiated)
- Unit 2w
- Unit 1u (Upper)
- Unit 1u (Lower)
- Unit 1w
- Alluvium

- Boundary, LANL
- Drainage
- Fault, locations are estimated assembled from multiple sources

University of California
Los Alamos National Laboratory
Earth and Environmental Sciences Division
FIMAD
Produced by: Doug Walker
Date: May 20, 1996
FIMAD Plot ID: 0104250

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: 20000
1 inch = 10000 feet

METERS

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. Other boundary, structure, and utility data are from Los Alamos National Laboratory Engineering Division and Los Alamos County Utility and Engineering Departments. Contour data are from Los Alamos National Laboratory Environmental Restoration Project aerial survey, September 1991.

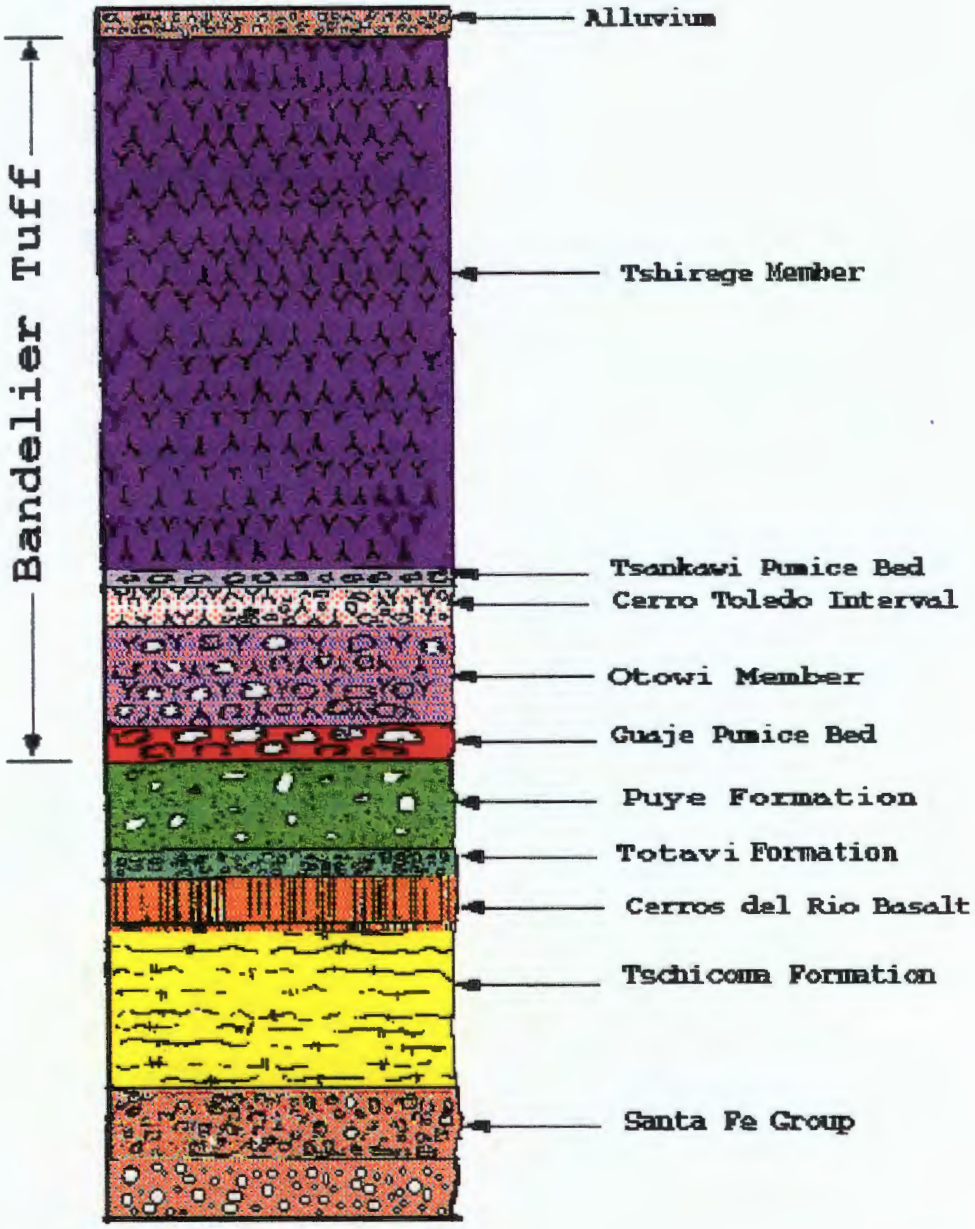
FIGURE 2

III. GEOLOGIC SETTING

The following information, which NMED concurs with, was taken directly from LANL's 1993 IWP, Section 2.6.1 Geology and is graphically represented in Figure 3.

> "The Laboratory is situated on the Pajarito Plateau on the east flank of the Jemez Mountains and on the west side of the Rio Grande valley. The Jemez Mountains are part of the Jemez volcanic field, which consists of some 432 cubic miles of volcanic rocks erupted from numerous vents, including a giant, multi-stage caldera (Gardner, et al., 1986, 0310). The Jemez volcanic field occurs at the intersection of the Jemez lineament, a northeast-trending alignment of volcanic fields, and the Rio Grande rift, a major north-trending zone of extensional tectonics (Aldrich, 1986, 0554).
>
> "Two major volcanic eruptions in the Jemez Mountains that occurred about 1.5 and 1.13 million years ago produced widespread and voluminous ash flow sheets: the Otowi and Tshirege members of the Bandelier Tuff (Smith and Bailey, 1966, 0377; Spell, et al., 1990, 0607). The morphology of the Pajarito Plateau is dominated by a gently eastward-sloping surface, formed on top of the Bandelier Tuff, which is dissected by numerous steep-sided canyons. The Otowi and Tshirege Members of the Bandelier Tuff were erupted concomitantly with the collapse of the Toledo and Valles calderas, respectively. Following formation of the calderas, volcanism continued with the extrusion of domes along ring fractures. The latest eruption in the Jemez Mountains occurred about 130,000 years ago, producing the El Cajete pumice and Banco Bonito rhyolite flow (Gardner, et al.,1986, 0310; Self, et al., 1988, 0500). Vestiges of volcanic activity continue today, as evidenced by solfataric and hot spring activity both within and outside of the Valles caldera (Goff, et al., 1989, 0774). Studies of P-wave arrival time delays suggest the presence of partially molten rock beneath the Valles caldera, possibly the remnants of the cooling Bandelier magma chamber (Roberts, et al., 1991, 0775).
>
> "The Pajarito Plateau is in the western part of the Española basin of the Rio Grande rift, a major tectonic feature of the western United States. The Española basin lacks distinct major faults on its eastern margin, but faults of major vertical offset may exist within Precambrian rocks of the Sangre de Cristo uplift (Vernon and Riecker, 1989, 0558; Biehler, et al., 1991, 0528). The western margin is characterized by a prominent zone of major faults, which cuts Miocene to Quaternary rocks of the Jemez volcanic field (Smith, et al., 1970, 0776; Gardner and Gaff, 1984, 0719; Goff, et al., 1990, 0557). These border faults exerted strong control on the location and development of the volcanic field (Gardner and Goff, 1984, 0719; Gardner, et al., 1986, 0310).

FIGURE 3



Generalized Stratigraphic Column-- Pajarito Plateau

"Rocks formed before the rift developed are exposed around the margins of and underlie the Española basin. These rocks consist of Mississippian to Permian marine limestones, sandstones, and shales; Mesozoic marine to terrestrial sandstones and shales; and Eocene sandstones, shales, and freshwater limestones. Precambrian rocks—predominantly quartzite, granitic gneiss and schist, and greenstone are exposed in the cores of the flanking Sangre de Cristo, Nacimiento, and Brazos uplifts (Kelley, 1978, 0641). The earliest sediments deposited in the Tertiary Española basin are those of the Abiquiu, Picuris, and Los Piños formations, which consist of tuffaceous sandstones and volcaniclastic conglomerates derived largely from volcanic highlands to the north and northeast. These units range in age from about 28 to 17 million years old (Baldridge, et al., 1980, 0527; May 1984, 0536; Ingersoll, et al., 1990, 0533).

2.6.1.2 Stratigraphic Units

"Beneath a veneer of soils and alluvial deposits, the mesas of the Pajarito Plateau are immediately underlain by the Bandelier Tuff of Pleistocene age, which is exposed in the canyon walls and is penetrated by numerous drill holes. Beneath the Bandelier Tuff, a sequence of interstratified sedimentary and volcanic rocks of Miocene to Pleistocene age occur, which have been penetrated by water supply wells and which have been studied where they outcrop in canyons on the margins of the Pajarito Plateau. These rock units include volcanic rocks of the Paliza Canyon Formation, Tschicoma Formation, and the Cerros del Rio volcanic field, and sedimentary deposits of the Puye Formation, the Totavi Formation, the Cochiti Formation, and the Santa Fe Group. These units are briefly discussed below.

2.6.1.2.1 Santa Fe Group

"The Santa Fe Group of Miocene and early Pliocene age (formed 18 to 4.5 million years ago) is a thick series of terrestrial conglomerates, sandstones, and mudstones, with minor limestones, evaporites, volcanic tuffs, and intercalated basalts. These rocks are the most extensive units filling the Rio Grande rift, and most production from water wells at Los Alamos is from the Santa Fe Group (Griggs and Hem, 1964, 0313; Purtymun, 1984, 0196). Sedimentary rocks usually dominate the Santa Fe Group, although basalts constitute up to 45% of the section penetrated by water supply wells at the Laboratory (Purtymun, et al., 1984, 0713). In the Española basin and underlying the northern part of Los Alamos County, the Santa Fe Group is subdivided into two formations (Tesuque and Chamita formations) and several members, which reflects the diversity of the coalesced alluvial fans deposited in the Española basin (Galusha and Thick, 1971, 0108; Ingersoll, et al., 1990, 0533). Early investigators inferred that all Santa Fe Group rocks exposed

around the flanks of the Pajarito Plateau and intersected by water wells beneath the plateau belonged to the Tesuque Formation (Griggs and Hem, 1964, 0313; Cooper, et al., 1965, 0495), although more recent investigations suggest that some of the upper Santa Fe Group in the vicinity of Los Alamos is instead Chamita Formation (Turbeville, et al., 1989, 0221).

2.6.1.2.2 Keres Group

"Two formations of the Keres Group (Bailey, et al., 1969, 0019; and Gardner, et al., 1986, 0310 discuss formational relations in the Keres Group) may be important in the pre-Bandelier Tuff subsurface in the southern parts of the Laboratory. These are the Paliza Canyon and Cochiti formations, each about 13 million to about 6 or 7 million years old. The St. Peter's Dome area lies about 3 miles from the southern boundary of the Laboratory and was a major center of Keres Group volcanism (Goff, et al., 1990, 0557). Large volumes of Paliza Canyon andesite were erupted from the St. Peter's dome center and spread to the east and north. It appears that some of the volcanic units encountered in wells at TA-49 (Weir and Purtymun, 1962, 0228) may be Paliza Canyon lavas that have been misidentified as Tschicoma and Cerros del Rio units, as discussed below.

"Beneath the southern Pajarito Plateau, sedimentary deposits of the Cochiti Formation compose the Miocene basin fill and are therefore laterally equivalent to the sedimentary rocks of part of the Santa Fe Group and possibly also to those of the Puye Formation (Section 2.6.1.2.3) to the north (Gardner, et al., 1986, 0310). The Cochiti Formation consists dominantly of basin fill gravels derived from the volcanic centers of the southern and central Jemez Mountains volcanic field. The transition between the Cochiti, Santa Fe, and Puye formations probably occurs somewhere beneath Los Alamos County, but it is very poorly defined.

2.6.1.2.3 Tschicoma Formation

"The Tschicoma Formation consists of a sequence of dacitic domes and lavas that were erupted from vents in the central to northeastern Jemez Mountains between about 7 and 3 million years ago, (Gardner, et al., 1986, 0310). These volcanic rocks outcrop extensively in the mountains immediately west of the Laboratory and are reported in the subsurface beneath the western and southern part of the Laboratory (Weir and Purtymun, 1962, 0228; Griggs 1964 and Hem, 0313; Dransfield and Gardner, 1985, 0082).

2.6.1.2.4 Puye Formation

"The Puye Formation consists of a Pliocene-to-Pleistocene fanglomerate that was shed eastward from Tschicoma volcanic centers in the northeastern Jemez volcanic field between about 4 and 1.7 million years ago. Earlier workers (e.g., Griggs, 1964; Hem, 0313) included the Totavi Lentil, now considered a separate formation (Section 2.6.1.2.5), as part of the Puye Formation. Most of the Puye conglomerates contain cobbles of dacitic to andesitic composition in a volcanic sand matrix. The beds include stream flow deposits, debris flow deposits, volcanic ash and block flow deposits, and ash fall and pumice fall deposits (Waresback and Turbeville, 1990, 0543). The Puye Formation is best exposed north of the Laboratory, but lithologically similar rocks have been penetrated in drill holes as far south as Frijoles Mesa (Weir and Purtymun, 1962, 0228; Dransfield and Gardner, 1985, 0082). Under parts of the Laboratory, the Puye Formation is interstratified with basalts of the Cerros del Rio volcanic field. In Los Alamos water supply wells, the top of the main aquifer is usually within the Puye Formation.

2.6.1.2.5 Totavi Formation

"Immediately beneath the fanglomerates of the Puye Formation, unconformably overlying the Santa Fe Group, is a section of poorly consolidated fluvial gravels, which Griggs originally named the Totavi Lentil of the Puye Formation (Griggs and Hem, 1964, 0313). The gravels contain clasts that differ lithologically from those in the Puye, including abundant well-rounded cobbles and boulders of quartzite, granite, and pegmatite that record a source area distant from the Jemez Mountains; this unit probably represents axial channel gravels of an ancestral Rio Grande. Recently, Waresback and Turbeville (1990, 0543) redefined these fluvial gravels as a separate formation, the Totavi Formation, which also includes lacustrine sediments that are complexly interstratified with the upper Puye Formation ("old alluvium" of Griggs and Hem, 1964, 0313). In some water supply wells beneath the Laboratory, the Totavi was reported between the Santa Fe and the Puye, occurring at lower elevations in the eastern wells (Cooper, et al., 1965, 0495; Purtymun, et al., 1983, 0712; Purtymun, et al. 1984, 0713). The presence of the Totavi at these levels suggests that Rio Grande river gravels were deposited on erosional surfaces, a setting analogous to Quaternary terraces of the Rio Grande in the Española basin described by Dethier, et al. (1988, 0773) before deposition of the Puye fans, which unconformably overlie older formations.

2.6.1.2.6 Cerros del Rio Basalts

"Basaltic flows, breccias, and scoria of the Cerros del Rio occur in the subsurface beneath much of the Pajarito Plateau (Dransfield and Gardner, 1985, 0082) and outcrop in the east and southeast parts of Los Alamos County (Griggs, 1964 and Hem, 0313). These volcanic rocks are associated with the Pliocene-to-Pleistocene Cerros del Rio basalt field, east of the Rio Grande, and rocks from this field have been dated at 4.6 to 2.0 million years old (Gardner, et al., 1986, 0310). The youngest lava flows in this area occurred between the two Bandelier Tuff eruptions, 1.5 and 1.13 million years ago ("basaltic andesite of Tank Nineteen" described by Smith, et al., 1970, 0776). Part of this volcanic field is also known as basaltic rocks of Chino Mesa (Griggs and Hem, 1964, 0313). The top of the main aquifer beneath the Laboratory is locally within this section of basaltic rocks.

2.6.1.2.7 Otowi Member, Bandelier Tuff

"The Otowi Member of the Bandelier Tuff underlies the Tshirege Member in the subsurface beneath much of the Pajarito Plateau and outcrops in many of the canyons (Griggs and Hem, 1964, 0313). The Otowi Member is mostly a nonwelded ash flow tuff (ignimbrite) that was erupted from the Jemez Mountains 1.5 million years ago (Spell, et al., 1990, 0607). It is highly porous and poorly indurated and is composed of multiple flow units. Where it outcrops, cooling joints are typically absent because of relatively low emplacement temperatures and the lack of induration. The Guaje Pumice Bed generally occurs at the base of the Otowi Member and consists of sorted pumice fragments that average 0.8 to 1.6 inches in size (Crowe, et al., 1978, 0041).

2.6.1.2.8 Cerro Toledo Rhyolite and Interbedded Sediments

"An interbedded sequence of rhyolitic tuffs and sediments commonly occurs between the Otowi and Tshirege members of the Bandelier Tuff. The rhyolitic tuffs were erupted between 1.5 and 1.2 million years ago, predominantly from the Cerro Toledo domes in the northeastern Jemez Mountains (Heiken, et al., 1986, 0316). Beneath the Pajarito Plateau, the sediments are epiclastic sands and sandy gravels that lithologically resemble Puye Formation fanglomerates. At the Laboratory, deposits in this interval have sometimes been referred to as "Tsankawi pumice" or "Tsankawi member." These units may play an important role in the migration of water in the subsurface beneath the Laboratory (Stoker, et al., 1991, 0715).

2.6.1.2.9 Tshirege Member, Bandelier Tuff

"The most widespread rock unit on the Pajarito Plateau is the Tshirege Member of the Bandelier Tuff (Griggs and Hem, 1964, 0313), which was erupted from the Valles caldera in the Jemez Mountains about 1.13 million years ago (Spell, et al., 1990, 0607). The Tshirege Member is composed of multiple flow units of crystal-rich ash flow tuff (ignimbrite) and displays significant variations in welding and alteration, both in a single stratigraphic section and with varying distance from the caldera. Individual units tend to be more welded and thicker to the west. Flow units are locally separated by volcanic surge deposits of well-sorted, fine-grained, cross-bedded crystal and pumice fragments. Vapor phase alteration, caused by post emplacement cooling and migration of entrained magmatic gases, occurs in much of this unit. The base of the Tshirege Member is often marked by 1.5 to 10 feet of bedded, unconsolidated, pumice-rich ash fall tuff of the Tsankawi Pumice Bed (Bailey, et al., 1969, 0019; Crowe, et al., 1978, 0041). The Tsankawi Pumice Bed is generally poorly recognized in drill bit cuttings because rotary drills commonly grind the soft materials into dust.

"The Tshirege Member has been subdivided into a sequence of mappable units based on either erosional characteristics (Weir and Purtymun, 1962, 0228; Baltz, et al., 1963, 0024; Purtymun and Kennedy, 1971, 0200) or on primary cooling units (Crowe, et al., 1978, 0041). These units have been correlated over large distances on the Pajarito Plateau. However, the boundaries between the units are not always distinct in the field and can be difficult to recognize in drill holes, causing investigators to place the contacts between units at different locations. Furthermore, in the absence of geologic mapping in the intervening areas, the validity of the correlations is uncertain.

"Stratigraphic features in the tuff, such as volcanic surge deposits, may locally provide a preferential migration pathway for moisture and contaminants in the subsurface (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 joint 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 nonwelded tuff. Hydraulic conductivities are generally greatest in the fractured, welded parts of ash flow tuffs and least in the nonwelded parts (Crowe, et al., 1978, 0041).

2.6.1.2.10 Post-Bandelier Units

"Stratigraphically overlying the Bandelier Tuff are discontinuous Quaternary alluvial units that occur as thin deposits (typically less than 15 feet thick) on mesa tops and as deposits in canyons. Alluvial fans consisting mostly of dacite debris are being shed over the Bandelier Tuff at the western boundary of the Laboratory. Well-sorted to poorly sorted sandy and gravelly alluvium occurs in the major drainages of the Pajarito Plateau, ranging up to at least 70 feet thick in some drill holes (Baltz, et al., 1963, 0024). Additional, older alluvium occurs on stream terraces on the sides of the canyons, which can be buried by colluvial deposits from the canyon walls. The distribution of alluvial deposits on the mesas has not been mapped, but these deposits are most widespread on the western part of the Pajarito Plateau. Post Bandelier alluvial units represent a range of ages from 1.1 million years ago to the present. Generally, alluvial units on the surface of the mesas are probably oldest, becoming inactive as drainages were incised into the plateau. Those units lowest in the drainages grade into the active alluvium along canyon bottoms.

"The alluvial sediments in the canyon bottoms probably record a complex history of erosion and deposition, in part related to regional climatic changes. In Cabra Canyon, immediately north of Los Alamos, several cycles of erosion and deposition of sediment occurred over the last 6,000 years, during which most of the previously stored sediment was eroded (Gardner, et al., 1990, 0639). Similar cycles of erosion and deposition have been documented in many parts of the southwestern United States, and the older alluvial units in the vicinity of Los Alamos may also record the effects of regional climatic changes (Dethier, et al., 1988, 0773).

"The mesas of the Pajarito Plateau are also covered in part by deposits of the El Cajete pumice, erupted from El Cajete crater in the Jemez Mountains. Deposits of pumice on the mesas have not been mapped, but at the Laboratory they are generally most common to the south, and the axis of the volcanic dispersal plume is south of Los Alamos County. Available data suggest that the El Cajete pumice is 130,000 to 170,000 years old (Self, et al., 1988, 0500).

2.6.1.4 Geologic Structure

"As mentioned earlier, 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, in preparation, 0720). The fault system is made up of over

65 miles 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, 0110).

"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 mile 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 feet 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 feet 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, 0639). 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, 0639). 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 feet) zones of intense brecciation and fracturing superimposed on the network of cooling joints in the Bandelier Tuff (Vaniman and Wohletz, 1990, 0541). 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 ground-water migration than do cooling joints.

"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 on the plateau, they have shown that fracture abundances and apertures increase in the Bandelier Tuff over fault projections, which indicates the 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 (Rogers, 1977, 0216), that suggest additional unmapped fault zones. Unfortunately, detailed fracture studies on the Pajarito Plateau are few."

IV. REGIONAL HYDROGEOLOGIC CONCEPTUAL MODEL

A. LANL's Conceptual Model

The key elements of LANL's conceptualization of the regional hydrogeologic system, previously summarized by NMED in the *Initial Assessment of LANL's Ground Water Monitoring Program*, (1993b) are as follows:

- Ground water occurs in the three following situations:
  - perched water in alluvium in canyons,
  - perched water in basalts and sedimentary units of the Puye Formation, and
  - beneath the regional water table in the regional or "main" aquifer.

- The alluvium on canyon floors is recharged by surface-water runoff.

- The main aquifer consists of the Tesuque Formation and the lower parts of the overlying and inter-tonguing Tschicoma Formation (in the western part of the Pajarito Plateau), and the Tesuque Formation and overlying Puye Formation (in the central and eastern parts of the Pajarito Plateau).

- The main aquifer is separated from the shallow alluvial and other perched aquifers by 250 to 620 feet of unsaturated tuff and sediments.

- There is little or no recharge of the main aquifer from the mesas, the shallow alluvium, or other perched ground water.

- The main aquifer is recharged in the Valles Caldera, west of LANL.

- Ground water in the main aquifer flows easterly until discharging to the Rio Grande.

Since the drafting of NMED's 1993 report, LANL's conceptual model has changed slightly to include other possible recharge areas for the main aquifer. Increased consideration has been given to the Pajarito fault zone, canyon bottoms containing ground water, and other perched ground water.

B. Modes of Ground-Water Occurrence

It is conceptualized by NMED that four modes of ground-water occurrence beneath the Pajarito Plateau can be identified as follows:

- Perched water within volcanic rocks (Tschicoma Formation and Tshirege Member of the Bandelier Tuff) of the western portion of the Pajarito Plateau;

- Shallow perched "alluvial" ground water in alluvium of the canyon bottoms dissecting the Pajarito Plateau;

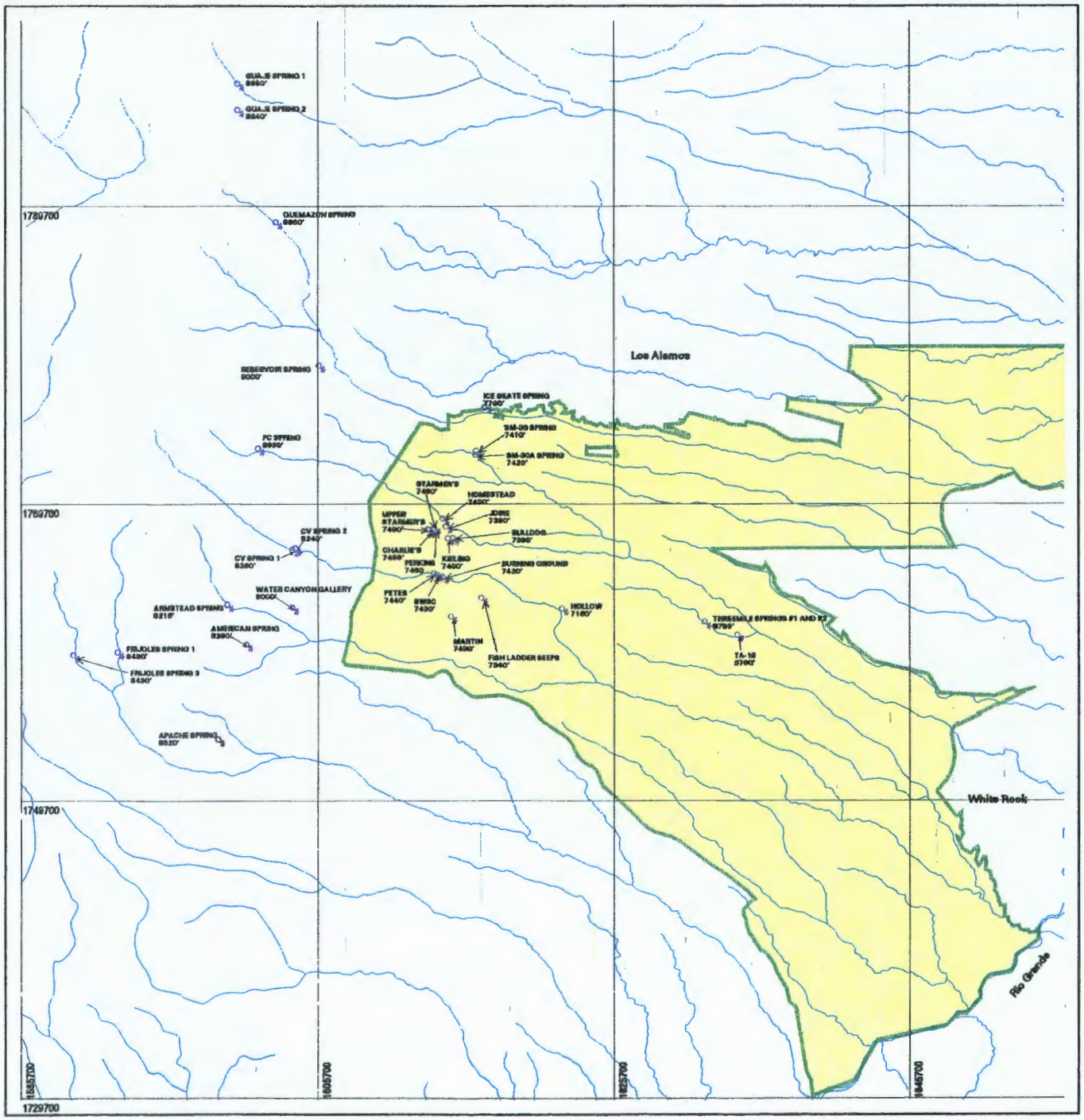
- Intermediate perched water within the basalts, sedimentary units of the Puye Formation, and within intervals of the Otowi Member of the Bandelier Tuff (including the Guaje Pumice Bed); and

- Regional or "main" aquifer occurs beneath LANL within the Puye Formation, Totavi Formation, and Santa Fe Group primarily, and to a lesser extent, within the Tschicoma Formation and basalts.

LANL's 1993 conceptual model proposed three modes of ground-water occurrence (i.e. last three bullets above). NMED recognizes the perched water within the volcanics as an additional and distinct mode of ground-water occurrence. The following sections discuss the current status of knowledge, as understood by NMED, for each individual mode of ground-water occurrence.

1. Perched Ground Water within Volcanic Rocks

Perched ground water within the Tschicoma Formation and the Tshirege Member of the Bandelier Tuff is indicated by the presence of numerous springs discharging predominantly along the western boundary of LANL (Figure 4 and Plate 3). Table 1 summarizes the known springs with their elevations, possible geologic occurrence, and estimated flow rates. This mode of ground-water occurrence supports baseflow in the upper reaches of the Guaje, Los Alamos, Pajarito, Cañon de Valle, and Water Canyons, and has been implicitly recognized by various investigators (Griggs, 1955; John et al., 1966).



Perched Ground Water - Tschicoma Formation and Tshirege Member

Explanation

- Boundary, LANL
- Drainage
- Spring
  SWSC (Spring Id)
  7405' (Approximate elevation)

FIGURE 4

DATA SOURCE: Modified Preliminary Data from NMED DOE Oversight Bureau (1995). Additional data from Purtymun, 1995, LA-1283-MS

This map contains preliminary and unverified data

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: 20000
1 inch = 10000 feet

METERS

FEET

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Date: May 07, 1996 FIMAD Plot ID: G104460

Table 1 Shallow Perched Ground Water (Springs) within Volcanics

SPRING	ELEVATION [ft]	GEOLOGIC OCCURRENCE[1]	FLOW[2] [gpm]	DATA SOURCE[3]
GC Spring 1	8,850	Qbt[4]?/QTtl[5]	25	Purtymun 1995
GC Spring 2	8,840	Qbt?/QTtl	40	Purtymun 1995
Quemazon Spring	8,660	Qal[6]/QTtl?	15	Purtymun 1995
Reservoir Spring	8,000	Qal/QTtl?	20	Purtymun 1995
PC Springs	8,660	Qal/QTtl?	25	Purtymun 1995
CV Spring 1	8,260	Qal/QTtl?	4	Purtymun 1995
CV Spring 2	8,240	Qal/Qbt	4	Purtymun 1995
Water Canyon Gallery	8,000	Qbt	90	Purtymun 1995
Armstead Spring	8,216	QTtl	2	Purtymun 1995
American Spring	8,280	Qbt	5	Purtymun 1995
Frijoles Spring 1	8,430	Qbt	100	Purtymun 1995
Frijoles Spring 2	8,430	Qbt	110	Purtymun 1995
Apache Spring	8,320	Qbt	<1	Purtymun 1995
Ice Skate Spring	7,700	Qbt	-	Blake 1995
SM-30 Seep	7,420	Qal?/Qbt	<1	DOE OB 1995
SM-30A Seep	7,410	Qal?/Qbt	<1	DOE OB 1995
Josie Spring	7,380	Qbt	3-5	DOE OB 1995
Homestead Spring	7,450	Qbt	5-10	Purtymun 1995/
Starmers Spring	7,460	Qbt	15-20	DOE OB 1995
Upper Starmers	7,490	Qbt	-	DOE OB 1995
Perkins Spring	7,460	Qbt	-	DOE OB 1995
Kieling	7,400	Qbt	5-8	DOE OB 1995
Bulldog Spring	7,390	Qbt	15-20	DOE OB 1995
Peter Seep	7,440	Qbt	5-8	DOE OB 1995
SWSC	7,430	Qbt	3-5	DOE OB 1995
Burning Ground	7,420	Qbt	10-15	DOE OB 1995
Martin Spring	7,430	Qbt	1-2	DOE OB 1995
Fish Ladder Seeps	7,340	Qal/Qbt?	<1	DOE OB 1995
Hollow Spring	7,160	Qal/Qbt?	-	DOE OB 1995
Threemile Springs	6,795	Qal/Qbt?	30	DOE OB 1995
TA-18 Spring	6,760	Qbt	6	DOE OB 1995

1. The geologic occurrence was inferred by spring location superimposed on a geologic map of the Los Alamos area (Griggs, 1964).
2. The flow values reported are estimates and do not reflect seasonal variations.
3. The DOE OB 1995 data are preliminary.
4. Qbt - Quaternary Bandelier Tuff
5. QTtl- Quaternary/Tertiary Tschicoma Formation
6. Qal - Quaternary alluvium

The perched ground water within the dacitic flows of the Tschicoma Formation appears to occur in much the same manner as the perched ground water within the Tshirege Member of the Bandelier Tuff. Preferential flow through fractures (cooling and tectonic) and higher permeability zones (e.g., surge beds and unit contacts) of recent water probably dominates the flow patterns of this generalized type of ground-water occurrence. Dual porosity (fracture flow and matrix flow) may account for movement of ground water through this mode of ground-water occurrence. Dual fracture flow (near-vertical cooling joints and horizontal cooling joints along bedding planes) through the Tschicoma Formation and the more densely welded Unit 4 of the Tshirege Member of the Bandelier Tuff may grossly describe the fracture flow regime. Matrix flow may be accounted through permeable surge beds and unit contacts. If the conceptual model is applicable for these perched water bodies within the Bandelier Tuff, then inferences can be made concerning the geometries of these zones of saturation. Each spring discharge point may not represent a connected ground-water system, but rather discrete bodies of water which migrate through the volcanic rocks based on the geometries of the preferential flow paths.

Springs appear to discharge along two, and perhaps three, apparent north-south oriented lineaments as inferred from Figure 4 and Plate 3. When topography is superimposed on the spring locations, an apparent correlation between the spring locations and an abrupt change in contour is observed on topographic maps, aerial photographs, and shaded relief maps. Springs discharging from the westernmost lineament (located west of the major Pajarito fault system) range in elevation from 8,660 to 8,000 feet. The elevations for those springs discharging along an apparent lineament east of the major Pajarito fault system range from 7,500 to 7,350 feet. The springs located in the central portion of the Pajarito Plateau do not correspond to either of these two groupings and have elevations ranging from approximately 6,795 to 6,750 feet.

As noted within LANL's 1995 IWP, the Frijoles fault segment along the western portion of the LANL boundary produces a major fault scarp which can be seen on topographic maps, aerial photographs, shaded relief maps, and is visible from almost anywhere on the Pajarito Plateau. Paleogeologic maps of the pre-Bandelier Tuff suggest that the pre-Bandelier stratigraphy is cut by a series of down-to-the-west normal faults beneath the Pajarito Plateau. Although the Bandelier Tuff does not appear to be displaced, intense fracture zones within the Tuff are superimposed on older structural features. These down-to-the-west buried faults, or apparent splays of the major Pajarito fault system, plus the apparent lineaments may have a significant role in the discharge of this mode of ground-water occurrence.

NMED field observations indicate that some springs appear to discharge from the Tshirege Unit 3 - Unit 4 contact along canyon walls and floors. This would suggest that ground-water movement may be controlled partially by horizontal transport along unit contacts. Unit 3 of the Tshirege Member may be acting as a partially perching layer, and thus springs discharge where the canyons intersect the cross-sectional area of these ground-water bodies. As

previously suggested, the apparent lineaments may also further influence ground-water movement.

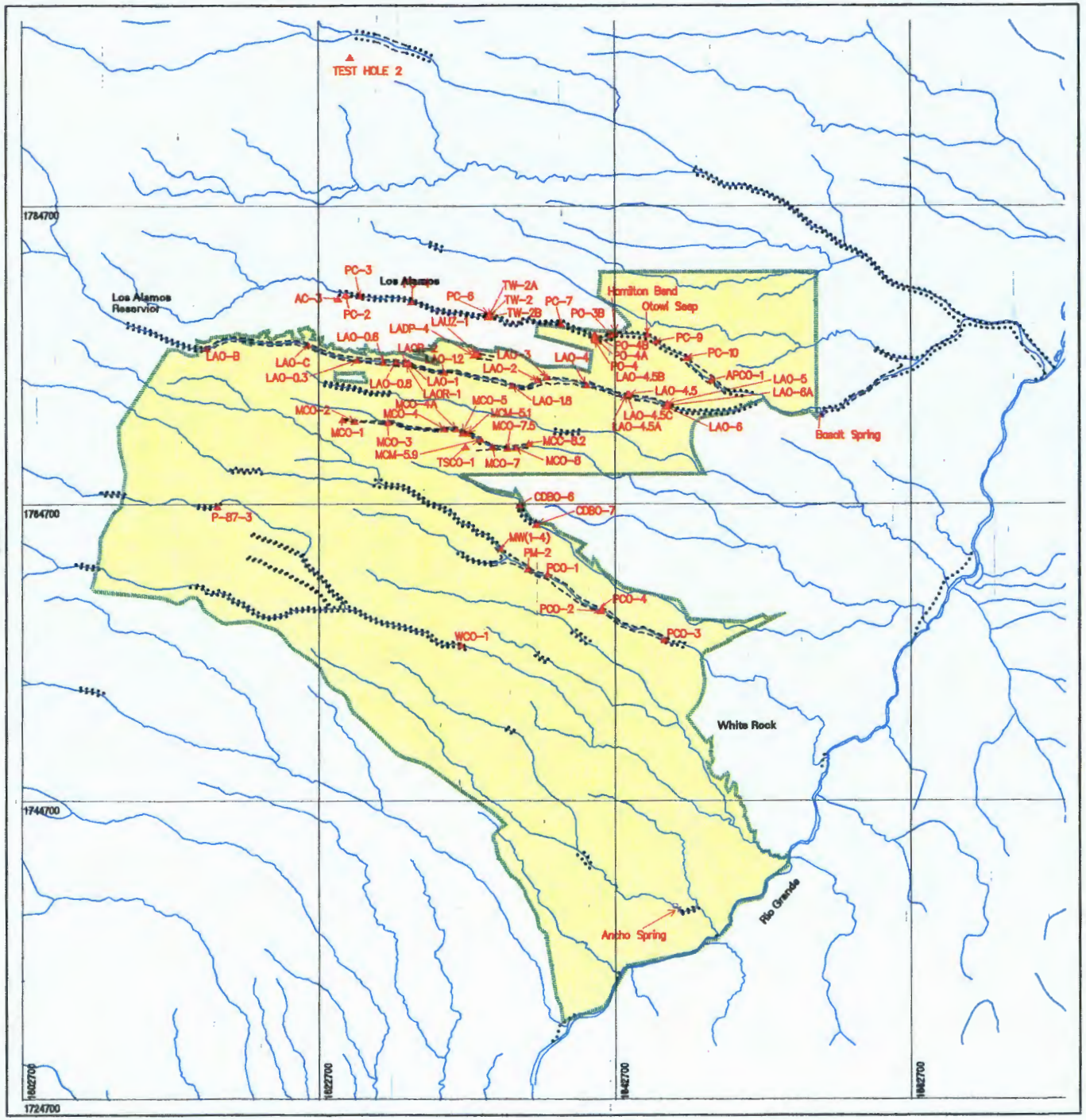
The water chemistry of these springs indicates that a source for these perched waters may be from infiltration of precipitation through canyon bottoms and fault-fracture zones of the Pajarito fault system. Measured tritium levels in these springs are similar to the tritium levels measured in precipitation. Tritium measured within precipitation occurring near LANL ranges from approximately 65 to 325 pico-curies per liter (**pCi/L**) (Adams and Goff, 1991; Blake et al., 1995). The concentrations of tritium in Apache spring, Homestead Spring, Water Canyon Gallery Spring, and Armstead Spring range from 14 to 154.2 pCi/L (Blake et al., 1995). Blake et al. (1995) state that ground water with tritium values of 16 to 65 pCi/L has a recent recharge component.

A good summary of the ground-water chemistry for the perched ground water within volcanic rocks of the western portion of the Pajarito Plateau can be found in the *Chemical Quality of Ground Water* (Griggs and Hem, 1964). This perched ground water typically has a low total dissolved solids (**TDS**) content (100 to 150 parts per million [**ppm**]) and a high silica content (60 to 75 ppm). The silica accounts for about half of the TDS and bicarbonate is the dominant cation for these springs. Specific conductance ranges from 80 to 157 micromhos at 25°C, and temperature ranges from approximately 10 to 18°C. More recent NMED data (1992 to the present) indicate a more narrow temperature range for shallow perched ground-water springs within volcanic rocks along the western portion of the Pajarito Plateau. Starmers Spring, Charlie's Spring, Homestead Spring, Armstead Spring, Apache Spring, Josie's Spring, and Perkins Spring have temperatures that range from 7 to 9.1^{o}C.

As discussed in the Releases to Ground Water section, ground-water contamination has been detected by LANL in several springs associated with this mode of ground-water occurrence. Spring discharge from this mode of ground-water occurrence most likely supports localized shallow, perched "alluvial" ground-water systems. Little is known regarding the hydraulic connection of this system with other modes of ground-water occurrence.

2. Shallow Perched "Alluvial" Ground Water within Canyon Bottoms

The known extent of shallow ground water within the canyon bottoms is depicted on Figure 5 and Plate 4. The canyons which support a known shallow perched ground water system include the following: Guaje, Pueblo, Los Alamos, Sandia, Mortandad, Cañada del Buey, Pajarito, Cañon de Valle, and Water Canyons. Perennial or ephemeral saturated conditions within the canyon bottoms are expected within various segments of numerous canyons across the Plateau. The reaches of lower Guaje Canyon; lower Bayo Canyon; mid-Pueblo Canyon; lower Los Alamos Canyon; upper and mid-portion of Sandia Canyon; a small section of upper Cañada del Buey; an upper section and mid-portion of Pajarito Canyon; and small sections of Potrillo, Fence, Cañon de Valle, Water, and Ancho Canyons are suspected to contain saturated conditions as indicated in Figure 5 and Plate 4. It is also suspected that the confluence of



Shallow Perched "Alluvial" Ground Water

Explanation

- Boundary, LANL
- Drainage
- Shallow-Perched "Alluvial" Ground Water Known Extent
- Shallow-Perched "Alluvial" Ground Water Suspect Extent
- Wells and Holes
- Spring

FIGURE 5

This map contains preliminary and unverified data.

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: 20000
1 inch = 10000 feet

METERS

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several Rio Grande tributaries supports saturated conditions which would also conform to this mode of ground-water occurrence. The vertical separation between the regional aquifer and the shallow perched ground water near the Rio Grande may be negligible. These waters most likely commingle with those in the regional aquifer, and possibly, with the intermediate perched water near the Rio Grande.

The suspected locations of alluvial ground water systems are based on canyon topography, grain size and thickness of alluvium, field observations (surface water data), and well logs which indicate the presence or absence of alluvial ground water. NMED estimated the extent of saturated conditions within canyon bottoms by compiling available information from wells which did or did not encounter ground water. Water-level elevations were not plotted due to a lack of similar temporal data. Water level in a single well has been observed to fluctuate over 3 feet on a seasonal basis. In general, however, elevations for this mode of ground-water occurrence range from 7,700 to 5,400 feet.

The geologic units of the shallow perched ground-water systems mainly include alluvium and colluvium; however, weathered tuff, basalt, Puye Formation, and Santa Fe Group geologic materials also support saturated conditions for this mode of ground-water occurrence. Geometries of the shallow perched ground water appear to be mainly wedge-like as defined by the canyon cutting into bedrock. Purtymun (1995) demonstrated the geometry of the saturated zone to be wedge-like within a transect across Mortandad Canyon. Within a transect of a canyon bottom, the horizontal extent of saturation appears to be the canyon walls. Saturation decreases towards the canyon walls while the bottom of the water-bearing zone appears to conform with the surface of the perching layer. It is assumed that the greatest flux through a transect of a canyon bottom would be controlled by the grain size distribution of the alluvial/colluvial deposition and the slope/geometry of the bedrock surface within an incised canyon.

There is no apparent direct correlation between the thickness of the alluvium and saturated conditions within a canyon bottom. Purtymun (1995) indicates through diagrammatic sections that the thickness of alluvium within selected portions of the Plateau's canyons varies unrelated to saturated thickness. For example, in Sandia Canyon, between Wells SCO-1 and SCO-2, the alluvium is up to 20 feet thick while saturated conditions do not exist. In Mortandad Canyon, the thickness of alluvium encountered in well MCO-13 was 65 feet, and dry conditions were encountered. As stated above, saturated conditions are dependent upon numerous factors, one of which is the availability of water.

The shallow perched "alluvial" aquifer typically has ground-water temperatures ranging from 2.8 to 11°C for the entire facility. TDS values vary between canyons: Pueblo Canyon ranges from 250 to 400 ppm; Los Alamos Canyon ranges from 150 to 300 ppm; Mortandad Canyon ranges from 200 to 900 ppm; and Pajarito Canyon ranges from 150 to 1,420 ppm.

Tritium levels in Pajarito and Pueblo Canyons are approximately 200 pCi/L, with an uncertainty of ± 300 pCi/L. Tritium levels in the LAO-series wells in Los Alamos Canyon

show LANL influence: measurements range from 8,600 to 31,000 pCi/L for LAO-1; 29,000 pCi/L for LAO-2; 9,177 pCi/L for LAOR-1. Tritium levels in the MCO-series wells in Mortandad Canyon show LANL influence: tritium values ranged from 111.2 to 63,000 pCi/L. Tritium values in precipitation over the Los Alamos region range from 65 to 325 pCi/L (Blake et al., 1995). Therefore, 325 pCi/L is the highest tritium value for ground water in a shallow perched alluvial aquifer that could be categorized as background. Assuming this mode of ground-water occurrence has a significant recent recharge component, recent data suggest that several canyons on LANL property have been affected by laboratory activity.

Since the drafting of this report by NMED, two summaries of the specific occurrence of perched "alluvial" ground water have been compiled by Purtymun (1995) and LANL's GWPMPP (March 6, 1995). Specific portions from LANL's 1995 IWP were directly excerpted for this report. Specific major drainages were required to be investigated within the HSWA permit: Pueblo, Los Alamos, Sandia, Guaje, Bayo, Barrancas, Rendija, Mortandad, Cañada del Buey, Cañon de Valle, Water, Potrillo, Pajarito, Twomile, Threemile, Fence, Ancho, Indio, and Chaquehui. The following sections briefly describe the specific canyon systems.

Guaje Canyon

Guaje Canyon begins on the eastern slope of Cerro Rubio (10,449 ft elevation) and includes a watershed area of approximately 26 square miles before it converges with Los Alamos Canyon near the Rio Grande. Major tributaries of Guaje Canyon include: Rendija, Barrancas, and Bayo Canyons.

It is unclear if saturated conditions were encountered in the Guaje Canyon alluvium during drilling based on the review of the Guaje test and production well logs. However, it is hypothesized that saturated conditions exist seasonally within lower Guaje Canyon as shown in the shallow perched water map (Figure 5 and Plate 4).

Guaje Canyon is crossed by at least two fault-fracture zones: the Guaje and Rendija fault zones. Two wells were drilled into the floor of Guaje Canyon between the two fault zones to investigate the presence of shallow ground water. Both wells encountered water within the alluvium near the stream level as shown in Figure 5 and Plate 4.

Pueblo Canyon

Pueblo Canyon heads (8,990 ft. elevation) on the western portion of LANL from the border of the volcanic flows of the Valles Caldera. The drainage area of Pueblo Canyon has several tributaries, including Acid and Graduate Canyons and covers an area of approximately 8.6 square miles until its convergence with Los Alamos Canyon near State Road (**SR**) 4.

The extent of the saturated alluvium in Pueblo Canyon is estimated by compiling available information from wells which encountered ground water. During 1954 through 1956, saturated conditions were encountered in a series of wells (designated with the prefixes of PC, PO, and AC) drilled in Pueblo/Acid Canyon (Weir et al., 1962; Abrahams and Purtymun, 1966). Saturated alluvium was also encountered in lower Pueblo Canyon during the drilling of well APCO-1 in 1990 (Purtymun and Stoker, 1990).

Saturated conditions are most likely discontinuous within various portions of Pueblo Canyon as evidenced by the dry conditions encountered in many of the PO-series borings. Saturated conditions vary depending upon the amount of precipitation. Sanitary effluent from the Bayo Treatment Plant contributes to the overall water balance within the stretch of canyon near Hamilton Bend.

Los Alamos Canyon

Shallow perched ground water within Los Alamos Canyon is most probably continuous throughout the canyon bottom wherever saturated conditions exist. The slope of the canyon bottom probably mirrors the slope of the water surface within the shallow perched ground water (LANL, May 1993).

Saturated conditions are expected to exist from Los Alamos reservoir to LAO-B where the presence of the alluvial aquifer has been confirmed. The shallow alluvial ground water is known to exist from LAO-B to LAO-6A. It is suspected that the shallow perched water in the middle portion of Los Alamos Canyon exists down-canyon from LAO-6A to a point possibly just west of SR-4. This is where the saturated conditions from Los Alamos Canyon merge with the shallow perched water of Pueblo Canyon. Flow in the mid to lower reaches of Los Alamos Canyon has been observed to reach a point just east of SR-4 where the thickness of alluvium decreases to less than one foot and basalts outcrop in the stream channel.

Tributaries of Los Alamos Canyon include Quemazon, DP, Pueblo, Bayo, and Guaje Canyons. Recently installed wells have confirmed the existence of shallow perched "alluvial" ground water within upper DP Canyon.

Sandia Canyon

As noted by Purtymun (1995), saturated conditions appear to exist only within the upper reach of Sandia Canyon. It is suspected that saturated conditions within the alluvium may exist throughout a small stretch in mid Sandia Canyon. The canyon is joined by a drainage from near TA-53 in which numerous outfalls discharge. The width of the canyon increases and appears to provide an area of sediment accumulation. The alluvium in this same area also appears to be underlain by the Tsankawi Pumice and Cerro Toledo Interval. No wells

currently exist in either of the above-mentioned locations to confirm or deny the existence of saturated conditions.

Mortandad Canyon

As Mortandad Canyon heads on the plateau near TA-3, it only has a total drainage area of approximately 5.9 square miles. As shown in Figure 5 and Plate 4, shallow perched ground water is known to exist from the introduction of effluent near TA-50 to a point down-canyon just west of MCO-9. Significant tributaries include Ten-site and Cedro Canyons, while Cañada del Buey converges with Mortandad Canyon near the Rio Grande. A shallow perched system is probably supported near the Rio Grande by effluent discharged into Cañada del Buey from the White Rock sewage treatment plant.

Recent low-level tritium data from TW-8 indicates that a surface connection with the regional aquifer most likely exists near Mortandad Canyon. The potential exists for intermediate depth ground water to occur within Mortandad Canyon at depths greater than 500 feet and co-located with the known shallow perched ground water.

Cañada del Buey

Shallow perched "alluvial" ground water is known to exist within a small reach of this canyon near CDBO-6 and -7. This occurrence of ground water is probably limited based on other well data within Cañada del Buey (Figure 5 and Plate 4).

Pajarito Canyon

Pajarito Canyon heads on the rim of the Valles Caldera just south-southeast of Pajarito Mountain (10,044 ft. elevation). The drainage area of Pajarito Canyon approximates 10.61 square miles and includes several principle canyons and drainage as tributaries, most notably Threemile and Twomile Canyons.

Pajarito Canyon supports numerous saturated reaches within LANL's property boundaries. Within the upper- to mid-reaches of Pajarito Canyon, several springs discharge into the canyon bottom, supporting perennial flow, and thus, shallow perched ground-water bodies. The most significant occurrence of shallow perched ground water is in the mid-stretch of Pajarito Canyon from the western boundary of TA-18 to White Rock.

Cañon de Valle

Cañon de Valle heads west of the Pajarito Fault Zone on the rim of the Valles Caldera at about 9,300 feet. Cañon de Valle is a major tributary of Water Canyon. Suspected shallow perched "alluvial" ground water is located within this canyon. Perched ground water within volcanics is known to discharge into this canyon.

Water Canyon

Water Canyon also heads on the rim of the Valles Caldera and drains a total area of approximately 19.5 square miles. Numerous springs discharge into upper Water Canyon from perched ground water within volcanic rocks along the western boundary of LANL. These springs may support shallow perched ground-water systems limited to an area just west of the boundary of LANL and SR-501. Major tributaries include Cañon de Valle, Potrillo, and Indio Canyons. As shown in Figure 5 and Plate 4, shallow perched ground water may also exist within a stretch near the confluence of Cañon de Valle and Fish Ladder tributary.

Potrillo Canyon

As noted within the RFI for Operable Unit (**OU**) 1130 (LANL, June 1993), the Potrillo Canyon "discharge sink" may act as an infiltration area for the large volume of streamflow. However, it is believed that the stream within Potrillo Canyon is mostly ephemeral in nature and probably does not support significant occurrences of shallow perched ground water (Figure 5 and Plate 4).

Ancho Canyon

Ancho Canyon heads on the plateau near TA-49 and includes a total drainage area of approximately 7 miles. Shallow perched ground water may exist near the confluence of Ancho Canyon and an unnamed canyon near TA-39. Shallow perched ground water is also suspected in lower Ancho Canyon just down-canyon of Ancho Spring. It is currently unknown if Ancho Spring discharges from the main aquifer or from some intermediate perched ground-water system. As discussed in Section E. Nature of White Rock Canyon Springs (Summary of Findings), Ancho Spring may represent an intermediate perched ground water discharge point.

Chaquehui Canyon

Chaquehui Canyon, only about 2.5 miles in length, heads along the eastern portion of the Plateau near TA-33. Numerous springs discharge into Chaquehui Canyon near the confluence

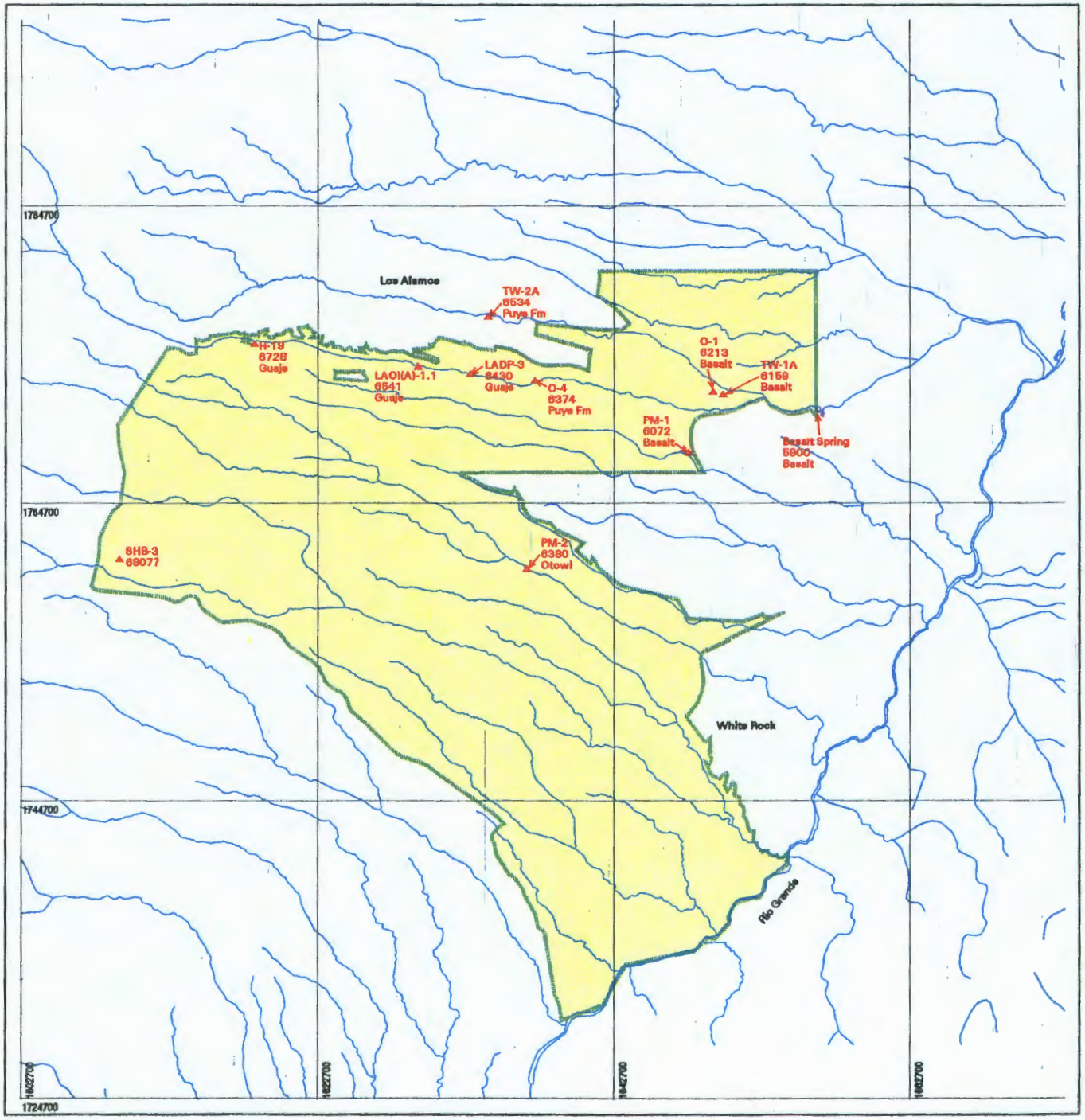
with the Rio Grande. A shallow perched ground-water system may be supported by spring discharge along the Rio Grande.

3. Intermediate Perched Ground Water

Intermediate perched ground water has been observed from well logs in Pueblo, Los Alamos, Sandia, and Pajarito Canyons as indicated in Figure 6 and Plate 5. Other intermediate perched ground water may occur beneath the Pajarito Plateau; however, few boreholes have been drilled to investigate this possibility. These intermediate-depth zones of saturation are of concern from a contaminant transport perspective because they may be hydrologically connected with shallow perched ground water and contaminant sources. Furthermore, these zones of saturation may be hydraulically connected to the main aquifer, particularly on the eastern portion of the facility boundary near the Rio Grande.

Eleven intercepts of this mode of ground-water occurrence plateau-wide are shown in Figure 6 and Plate 5. Elevations of the top of the zone of saturation and the associated geologic strata are also indicated in Figure 6 and Plate 5. The strata associated with the known intercepts of intermediate perched ground water appears to vary from the western portion of the Plateau, where the Otowi Member or the Guaje Pumice Bed is the first water encountered, to the eastern portion of the plateau, where the pre-Bandolier geology hosts the intermediate perched ground water. The known elevations of this mode of ground-water occurrence range from 6,728 feet (H-19) in Los Alamos Canyon to 5,900 feet in lower Los Alamos Canyon (Basalt Spring). Intermediate perched ground water has been found within various geologic strata across the plateau: Cerro Toledo Interval (suspected), Otowi Member of Bandelier Tuff, Guaje Pumice Bed, Puye Formation, and basalts. The depth to ground water from the land surface varies from 450 feet in the western portion of the plateau, to 112 feet in the central portion, to near land surface along the eastern side of the plateau. Saturated thicknesses vary from about 21 feet to 1 foot (the thickness and areal extent of these systems is not yet well understood).

The geometry of the intermediate perched ground water may be controlled by the flux through the system, the geographic position of canyon bottoms relative to fracture-fault zones, the geology (deposition, lithology, structure, etc.) of supporting hydrogeologic units, and the occurrence of subsurface paleodrainages (perching units). Data from wells (H-19, LAO-1.1, LADP-3, O-4, TW-2, TW-1, and PM-2) suggest a co-location of the shallow perched ground-water systems with the intermediate perched ground water toward the western and central portions of the plateau. Within the central and eastern portions of the plateau, the movement of ground water may be influenced by the presence of paleodrainages which intersect these zones of saturation. In general, the intermediate perched ground water occurs directly beneath canyon bottoms which contain alluvial ground-water systems; vertical separation averages approximately 250 feet. The horizontal extent of the perched zone, with regards to the length of saturation within a canyon bottom, depends on the volume of water available for movement.



Known Intercepts of Intermediate Perched Ground Water

Explanation

- Boundary, LANL
- Drainage
- Well
  - PM-2: Well id
  - 6380: Elevation of water bearing zone encountered while drilling or spring elevation. (ft)
  - Otowi: Geologic strata associated with top of water-bearing zone
- Spring

FIGURE 6

This map contains preliminary and unverified data.

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
1 inch = 10000 feet

METERS

FEET

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The horizontal extent of the intermediate perched ground water beneath canyon bottoms probably does not extend any appreciable distance laterally beneath the mesa tops. A comparison of ground water encountered between LADP-3, MDA-V corehole, LADP-4 to O-4, and TW-3 indicates that, on a gross scale, the horizontal extent of saturation is limited to some point near the base of the canyon walls. With exception of the paleodrainage influence, intermediate perched ground water is probably separated hydraulically from other intermediate perched ground water systems in other canyon settings.

In general, intermediate perched ground water appears to be sodium bicarbonate type ground water: low in TDS (50 to 360 ppm), high in silica (50 to 80 ppm). Specific conductance ranges from 330 to 469 Siemens per centimeter (**S/cm**), temperature ranges from 8 to 15°C, and tritium values range from 0.5 to 6,000 pCi/L. As previously discussed, the precipitation over the Los Alamos region has a tritium content typically ranging from 65 to 325 pCi/L (Blake et al., 1995). Thus, wells with tritium contents greater than 325 pCi/L may indicate laboratory influence.

Pueblo Canyon

Intermediate perched ground water in upper Pueblo Canyon (as seen at well TW-2A) occurs 112 feet below land surface and within a 3-foot interval of the upper Puye Formation. Additional ground water was encountered within a 5-foot interval approximately 50 feet below the first zone of saturation. Both the upper and lower zones of saturation were noted in the well logs to exhibit confining conditions as ground water rose from 19 to 57 feet within each well.

However, due to the uncertainty regarding the validity of drilling data, the nature of the aquifer remains questionable. This is the case for all of the TW-series wells drilled at LANL. The uncertainty associated with the TW-series data are addressed further in this report under the "Regional Aquifer" section.

Ground water occurs within the Puye Formation which consists of dacitic to andesitic composition detritus. These colluvial/fluvial intervals are interbedded with lenses of clay with some cellular white pumice traces. Approximately 653 feet separate the deeper regional aquifer from this occurrence of intermediate perched ground water. On January 6, 1953 and on May 18, 1993, the total dissolved solids were measured by NMED at approximately 56 and 99 ppm and the temperature was recorded as 11.6 and 14.5°C, respectively.

After the well completion of TW-2A in 1950, transmissivity was estimated at 50 gallons per day (**gpd**)/ft or approximately 6.67 ft^2/day. However, it is uncertain by what method transmissivity was estimated (eg. step-down data or specific capacity data, etc.) after well completion. Specific capacity was reported as 0.03 gallons per minute (**gpm**)/ft obtained after

4.5 hours of pumping (John et al., 1966). A modification of the Cooper/Jacob equation can be used to compare the reported transmissivity when the specific capacity is known (Driscoll, 1986). The empirical equation for a confined aquifer assumes typical values for the variables within the log function of the modified Jacob's equation to estimate the specific capacity:

$$Q / s = T / 2{,}000 \quad \text{(for confined conditions)} \tag{1}$$

where:

Q = discharge of the well [gpm]
s = drawdown observed in well [ft]
T = transmissivity [gpd/ft]

For TW-2A, estimates of transmissivity based on specific capacity data are close to the USGS reported value.

Although the water level recorded in TW-2A over the years has been declining (93 feet depth to ground water at drilling to 121 feet at present), saturation within the intermediate perched ground water zone presently exists. Effluent from a previous sewage treatment facility probably supported an alluvial system within this stretch of Pueblo Canyon in the past. However today, NMED speculates that an alluvial system probably does not exist within this canyon reach and, therefore, would not be co-located with this occurrence of intermediate perched ground water.

Water under pressure was also encountered approximately 210 feet below land surface within a basaltic interflow zone in lower Pueblo Canyon (TW-1A). Approximately 27 feet of head was observed in TW-1A after well completion. The thickness of the saturated unit is indeterminate from the available logs; however, water chemistry from this saturated zone indicates that it is in hydraulic connection not only with the alluvial system in Pueblo Canyon, but also with Basalt Spring in lower Los Alamos Canyon (LANL, 1992). Approximately 411 feet separates the deeper regional aquifer from this occurrence of intermediate perched ground water. On January 7, 1953 and on May 18, 1993, the total dissolved solids were measured by NMED at approximately 177 and 354 ppm at a temperature of 11.6 and 15.1°C, respectively.

After the well completion of TW-1A in 1950, transmissivity was estimated at 8,300 gpd/ft or approximately 1,107 ft^2/day. Specific capacity was reported as 0.75 gpm/ft obtained after 1,128 hours of pumping (John et al., 1966). A check on the reported transmissivity values by equation (1) indicates a discrepancy between values as:

$$T = (0.75)\,(2{,}000)$$
$$T = 1{,}500 \text{ [gpd/ft] or } 200 \text{ [ft}^2\text{/day]}$$

The thickness of the saturated unit was not well described in the well log, and therefore, the hydraulic conductivity cannot be estimated by the simplified Darcy equation (Hubbert, 1957):

$$K \bullet D = T \quad (2)$$

where:

D = saturated thickness [ft]

However, if the ground water velocity (v) between TW-1A and Basalt Spring is approximately 6,500 feet/60 days or 108.3 ft/day as determined by nitrate studies (LANL, 1994), and the hydraulic gradient (I) can be approximated:

$$I = \Delta h / z \quad (3)$$

where:

Δh = change in elevation [ft]

z = distance [ft]

$$I = (6{,}186 - 5{,}900) / 6{,}500 = 0.04 \text{ [ft/ft]}$$

then, by the simplified Darcy equation:

$$v = K \bullet I: \quad (4)$$

where:

$$K = 108.3 / 0.04 = 2{,}708.3 \text{ [ft/day]}$$

By equation (2), T = 200 [ft^2/day] (by specific capacity data), the thickness of the aquifer should approximate 0.07 feet. However, if T = 1,107 [ft^2/day], then D = 0.41 [ft]. Based on the above generalized observations, NMED estimates that the saturated thickness may be less than one foot at this locality.

Intermediate perched water was noted during the drilling of production well O-1; however, this well does not monitor this zone. Intermediate perched ground water was encountered at 183 feet below land surface within a basaltic interval (Purtymun et al., February 1993). The top of the regional aquifer was encountered 492 feet below the top of the intermediate perched ground water zone. Shallow perched ground water was also encountered above 55 feet during drilling.

Los Alamos Canyon

A shallow perched "alluvial" system is known to exist the entire length of Los Alamos Canyon, with the possible exception of a discontinuous stretch between the mid and lower portions of Los Alamos Canyon. The intermediate perched ground water within the central portion of Los Alamos Canyon appears to be continuous, while the thickness of the saturated zone appears to decrease with distance down-canyon.

In upper Los Alamos Canyon, during the drilling of H-19, an intermediate perched zone of saturation was encountered within the lower 22 feet of the Guaje Pumice Bed at 450 feet below land surface. The nature of the water encountered is unclear from the geological well logs (Griggs, 1964). Water appears to be perched upon the Tschicoma Formation.

Approximately 530 feet down canyon from H-19, during the drilling of LAO(A)-1.1, intermediate perched ground water was encountered within the lower 21 feet of the Guaje Pumice Bed. In addition, an unknown saturated thickness of perched water was encountered within the Puye Formation at 316 feet below land surface. A thin clay zone appears to separate these two zones of saturation. Approximately 280 feet separate the shallow alluvial system and this intermediate perched zone. The regional aquifer is approximately 530 feet below this zone of saturation. If the assumption is made that the perched water encountered within H-19 is hydraulically connected with the ground water encountered within the Guaje Pumice Bed near LAO(A)-1.1, then the approximate hydraulic gradient would be 0.36.

LADP-3, located approximately 180 feet down-canyon of LAO-1.1, encountered approximately 4 feet of saturation within the Guaje Pumice Bed at 321 feet below land surface. The Puye Formation was unsaturated below the Guaje Pumice Bed at this locality. If the ground water is in hydraulic connection between these two points, a steep hydraulic gradient of 0.58 exists between LAO(A)-1.1 and LADP-3. Tritium has been detected within LADP-3 at levels of 6,000 to 3,000 pCi/L and has not been detected in LAO(A)-1.1. As suggested by mixing calculations (Broxton, 1995; Longmire, 1995), a pathway from surface water to this zone of saturation exists somewhere between LAO(A)-1.1 and LADP-3.

A thin zone of saturation was encountered at 253 feet during the drilling of well O-4 within the mid-section of the upper Puye Formation. The distance below the alluvial system is approximately 225 feet while the regional aquifer lies approximately 527 feet below this intermediate zone of perched ground water. The Guaje Pumice Bed was not noted in the stratigraphic log of well O-4. Little is known about this saturated zone because the water was excluded by casing in this well, and no additional wells exist which are screened at this interval. Although both Wells O-4 and TW-3 are located approximately the same distance from the canyon wall, this zone of saturation has been logged only in TW-3. TW-3 is located on the northeast side of DP Canyon approximately 30 feet down-canyon of well O-4, while O-4 is located on the northwest side of DP Canyon.

Sandia Canyon

Perched water within Sandia Canyon was noted during the drilling of production well PM-1; however, this well does not monitor this zone. Intermediate perched ground water was encountered within a two-foot thick interval of brecciated to dense, slightly vesicular basalt (LANL, 1994). The depth to intermediate perched ground water is approximately 448 feet. Shallow perched ground water is not known to exist in this reach of Sandia Canyon as shown by drill holes SIMO and SIMO-1.

Pajarito Canyon

Within mid-Pajarito Canyon near PM-2, an occurrence of water was indicated within a 30-foot interval of "tuff.... and dark volcanic rock with much white pumice." Based on log correlation with SHB-3 (Gardner et al., 1993), previous intervals within this production well may have been misinterpreted. The saturated interval encountered within this well may be associated with the Cerro Toledo Interval and the Otowi Member of the Bandelier Tuff. Currently, no wells exist which monitor this zone of saturation, therefore little information is available. An alluvial system exists in this reach of mid-Pajarito Canyon approximately 330 feet above the intermediate perched ground water encountered during drilling of PM-2. The regional aquifer exists approximately 490 feet below this zone of saturation.

4. Regional Aquifer

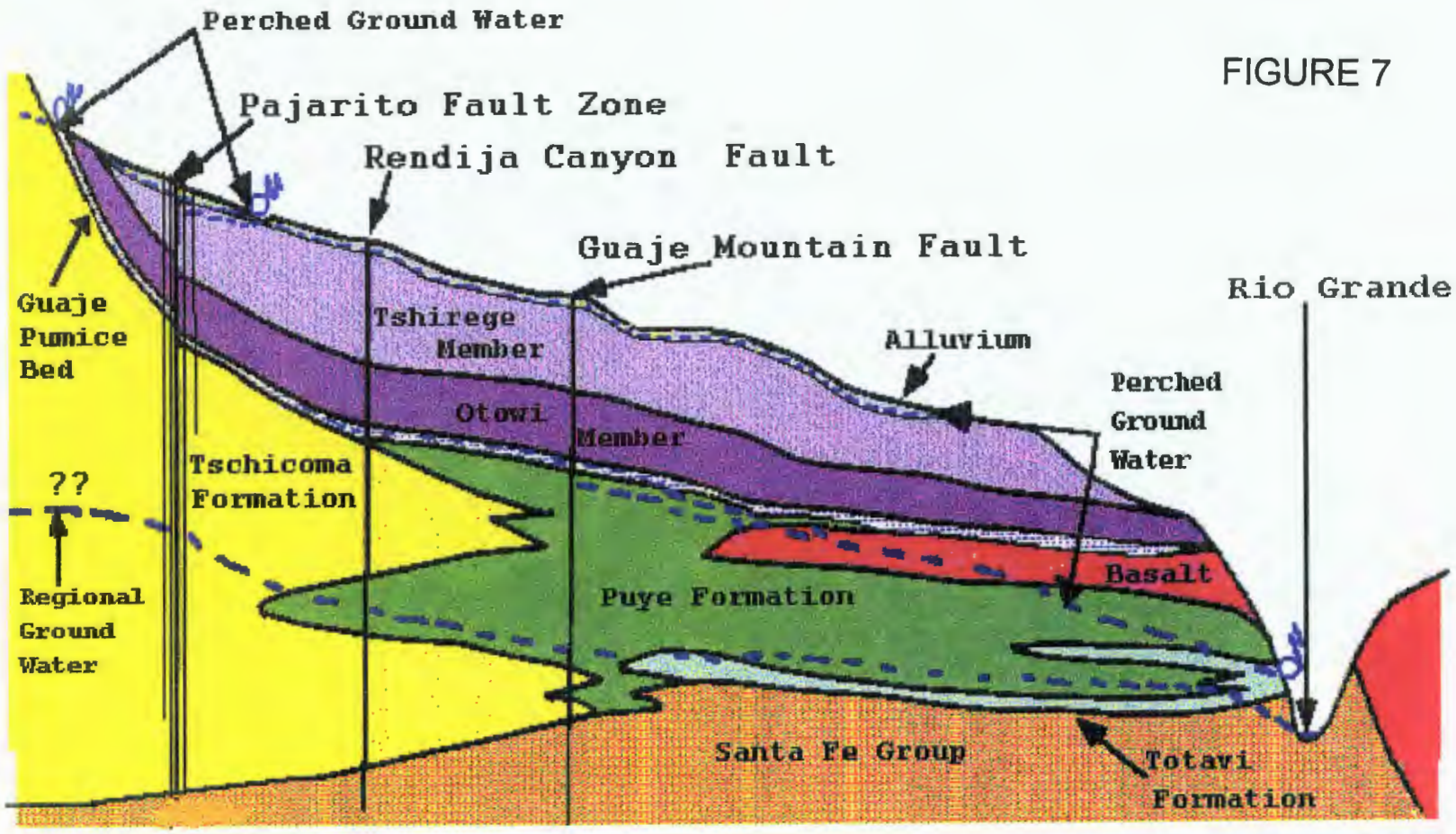
A diagrammatic cross-section through the Pajarito Plateau shows that the surface of the regional aquifer drops eastwardly from the western portion of the plateau to the Rio Grande (Figure 7). The top of the regional aquifer in the vicinity of the Los Alamos area, is believed to be represented by the surface of the Rio Grande (Griggs and Hem, 1964; Theis and Conover, 1962; Cushman, 1965). Known regional aquifer water levels vary in elevation from 6,074 feet in the west-central portion of the plateau to less than 5,400 feet near the mouth of Frijoles Canyon. The direction of ground-water flow appears to be eastwardly towards the Rio Grande as implied by generalized contours of water-levels for the regional aquifer (LANL, 1993b).

Depth to the regional aquifer varies from the eastern to western portions of the plateau and from the canyon bottoms to the mesa tops. On the eastern portion of the plateau, the depth to the regional aquifer approaches zero near the Rio Grande. In the central portion of the plateau, the depth to the regional aquifer from within a canyon bottom is approximately 600 feet. Along the western margin of LANL, the depth to the regional aquifer within the canyon bottoms is approximately 970 feet below land surface. Over 1,100 feet separate the mesa tops from the regional aquifer in the south central portion of LANL. The distance between intermediate perched ground water and the regional aquifer may approach zero as the zones of saturation commingle near the Rio Grande (Griggs, 1955). Intermediate perched ground water discharges at Basalt Spring (110 feet above the top of the regional aquifer) in Los Alamos Canyon on the eastern portion of the plateau. Approximately 530 feet separate the intermediate perched ground water from the regional aquifer in the western portion of the plateau. The following geologic strata have been associated with the top of the regional aquifer from the western portion of the plateau to the Rio Grande are shown in Figure 7: Tschicoma Formation, Puye Formation, Totavi Interval, basalts, and the Santa Fe Group.

Regional aquifer temperatures range from 19 to 30°C. Levels of calcium and sodium are similar. Most ground water in the Los Alamos region is of the calcium bicarbonate type. TDS ranges from 140 to 632.4 ppm (Blake et al., 1995). Any ground water with a tritium

Diagramatic Cross Section of the Pajarito Plateau

FIGURE 7



concentration less than or equal to 1.6 pCi/L is probably from the regional aquifer; however, some regional aquifer wells, such as TW-4, TW-8, and TW-1, have slightly higher values.

Top of Regional Aquifer

LANL has conceptualized the regional aquifer as generally unconfined except for a wedge-shaped area on the eastern portion of the plateau near Los Alamos Canyon and the Rio Grande. An inaccurate understanding of the nature of the regional aquifer can lead to misinterpretations of the head distribution within the top of the aquifer; additionally, this could lead to incorrect analysis of ground-water flow direction, aquifer characteristics, and the geologic materials associated with the top of the regional aquifer. Aquifer pressure potentials recorded across the plateau as indicated in the well logs are shown in Table 2.

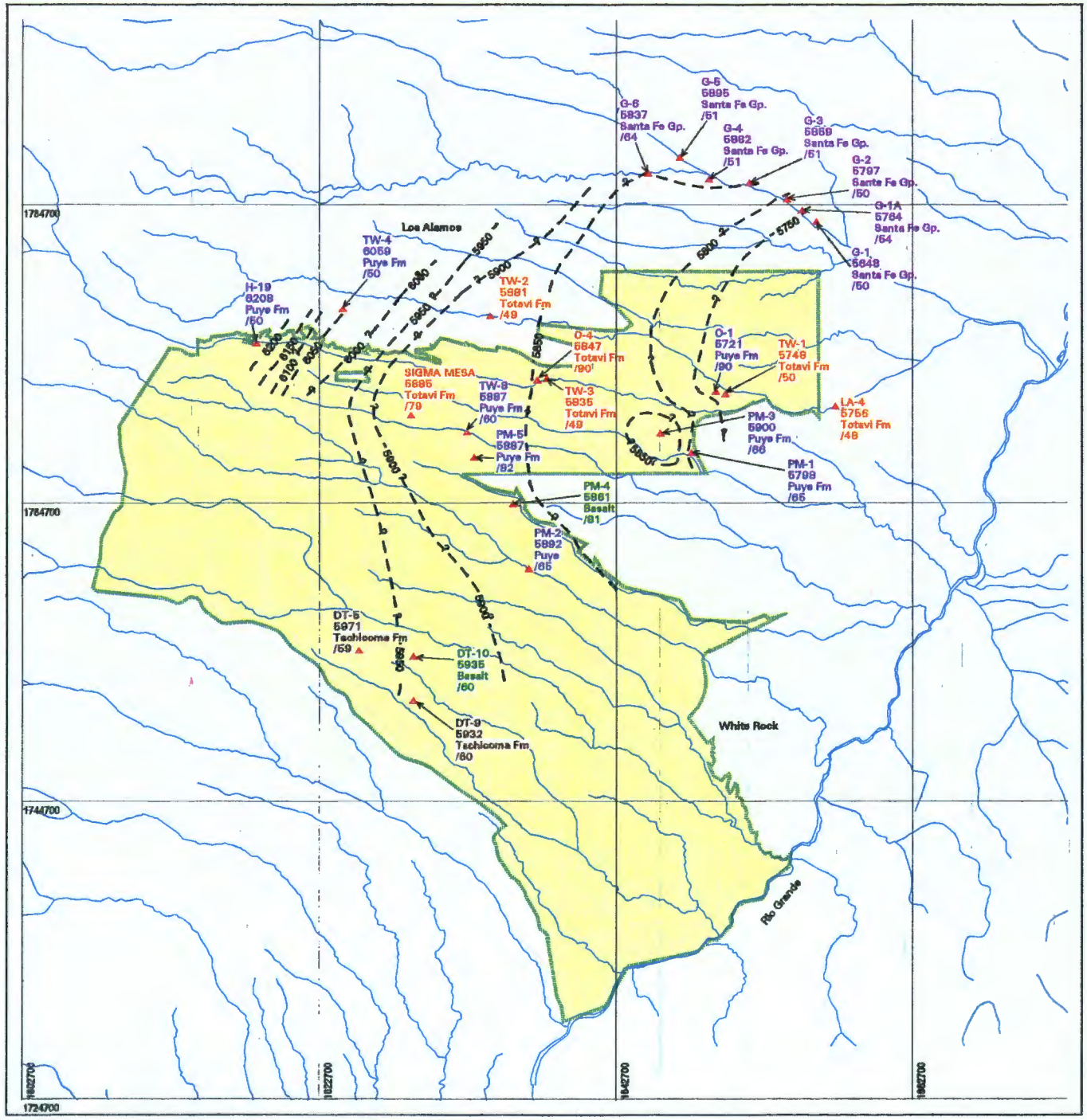
Table 2 Regional Aquifer Pressure Potential Data

WELL IDENTIFICATION	HYDRAULIC HEAD [FT][1]	ELEVATION HEAD [FT][2]	PRESSURE HEAD [FT][3]
TW-1	5,786	5,748	38
TW-2	5,887	5,881	6
TW-3	5,882	5,835	47
TW-4	6,072	6,059	13
TW-8	5,909	5,887	22

1. Hydraulic head equals the sum of the elevation head and the pressure head; equals the static water-level.
2. Elevation head equals the elevation of the first water encountered, sometimes referred to as the top of the aquifer. The reference elevation is assumed to be sea level.
3. Pressure head equals the length to which water rises in a well above the top of the aquifer.

The contours shown in Figure 8 and Plate 6 represent the regional aquifer elevations for which water was first encountered during drilling. This surface may differ from a water-level contour map if the nature of the aquifer is such that confining pressures exist. Reference to the date the well was drilled and the geologic strata at the top of the regional aquifer is made on Figure 8 and Plate 6.

Uncertainties associated with contouring the top of the regional aquifer include: 1) It is unclear from many of the existing well logs if the depth to the regional aquifer recorded in the available information refers to the static water level after drilling or the top of the encountered saturated zone associated with the regional aquifer. Only pressure head data, not



Top of Saturated Zone - Regional ("Main") Aquifer

Explanation

- Boundary, LANL
- Drainage
- Top of Main Aquifer Contour
  C.I. = 50 feet
- Geology Characterization Well
  PM-2: Well id
  5892: Elevation of water bearing zone encountered (top of main aquifer) (ft)
  Puye Fm: Geologic stratum at top of the saturated zone
  /65: Year well was drilled

Color of text indicates different lithologies
Green = Basalt
Blue = Puye Formation
Purple = Santa Fe Group
Orange = Totavi Formation
Brown = Tschicoma Formation

FIGURE 8

This map contains preliminary and unverified data.

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
1 inch = 10000 feet

METERS

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 1986. Other boundary, structure, and utility data are from Los Alamos National Laboratory Engineering Division and Los Alamos County Utility and Engineering Departments. Contour data are from Los Alamos National Laboratory Environmental Restoration Project aerial survey, September 1991.

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first water encountered, were recorded for the TW-series test wells. Even though the TW-series test wells were drilled in the early 1950's, the logs that record static water levels and the elevations for the first water encountered are available for these wells. The lack of saturated zone data and the lack of confidence in the available data lead to the possible misrepresentation of the top of the water bearing zone associated with the regional aquifer. 2) Drilling techniques have significantly improved during the timespan from 1949 to 1990 such that the elevations of the first water encounter can be more reliably ascertained. 3) Recording the top of the first water encountered relative to the static water-level elevation may not have been a drilling data objective. 4) Inherent differences exist between various geologists' stratigraphic correlations.

The elevation of the top of the regional aquifer decreases eastward from the western portion of the plateau to the Rio Grande. The slope varies from about 0.03 ft/ft on the western portion of the plateau to 0.0001 ft/ft in the central portion and to about 0.007 ft/ft in the eastern portion. Figure 7 indicates that a steeper gradient can be seen as the aquifer nears the river.

Data points significantly influencing the shape of the contour lines include Sigma Mesa, G-6, O-1, and PM-3. The top of the regional aquifer appears very steep (0.03 ft/ft) along the western portion of the plateau between wells H-19 (6,208 ft) and TW-4 (6,059 ft). The slope of the top of the regional aquifer abruptly changes to a much gentler slope from the Sigma Mesa well (5,885 ft) eastward to well TW-8 (5,887 feet). If the Sigma Mesa data point was not considered, a gradual lessening of the slope would occur from west to east. This transition may represent a change in lithology, and therefore, influence such aquifer characteristics as hydraulic conductivity, velocity, etc. This seems to fit the model described above; however, the data may also suggest that a barrier to ground-water flow exists. Utilizing the DT-series wells in the evaluation does not have a significant impact on the contour line distribution for the top of the regional aquifer. It is unknown if the top of the aquifer represents water-table conditions (pressure potential greater than or equal to atmospheric pressure) or if the top of the aquifer is controlled by confining geologic materials, therefore, discussions regarding the hydraulic gradient of the regional aquifer were not included in this analysis.

The data points in the central portion of the plateau fall generally between the 5,900- and 5,850-foot contour lines. These points include production and test well data. The slope of the contours appears fairly uniform and gradual from the central portion of the plateau towards the river with minor exception. The top of the water-bearing zone encountered in production well G-6 is at an elevation slightly less than anticipated, thereby shifting the contour lines from a north-south to an east-west trend.

Another anomaly occurs at PM-3 where the first water is encountered at an elevation of 5,900 feet which is approximately 100 feet greater than the surrounding contours. For this reason, the contour line near PM-1 was adjusted slightly to conform with the anomalous high observed at PM-3. Interestingly, perched water was encountered at an elevation of 6,070 feet within a basaltic interval of PM-1. The 170-foot vertical separation between the intermediate

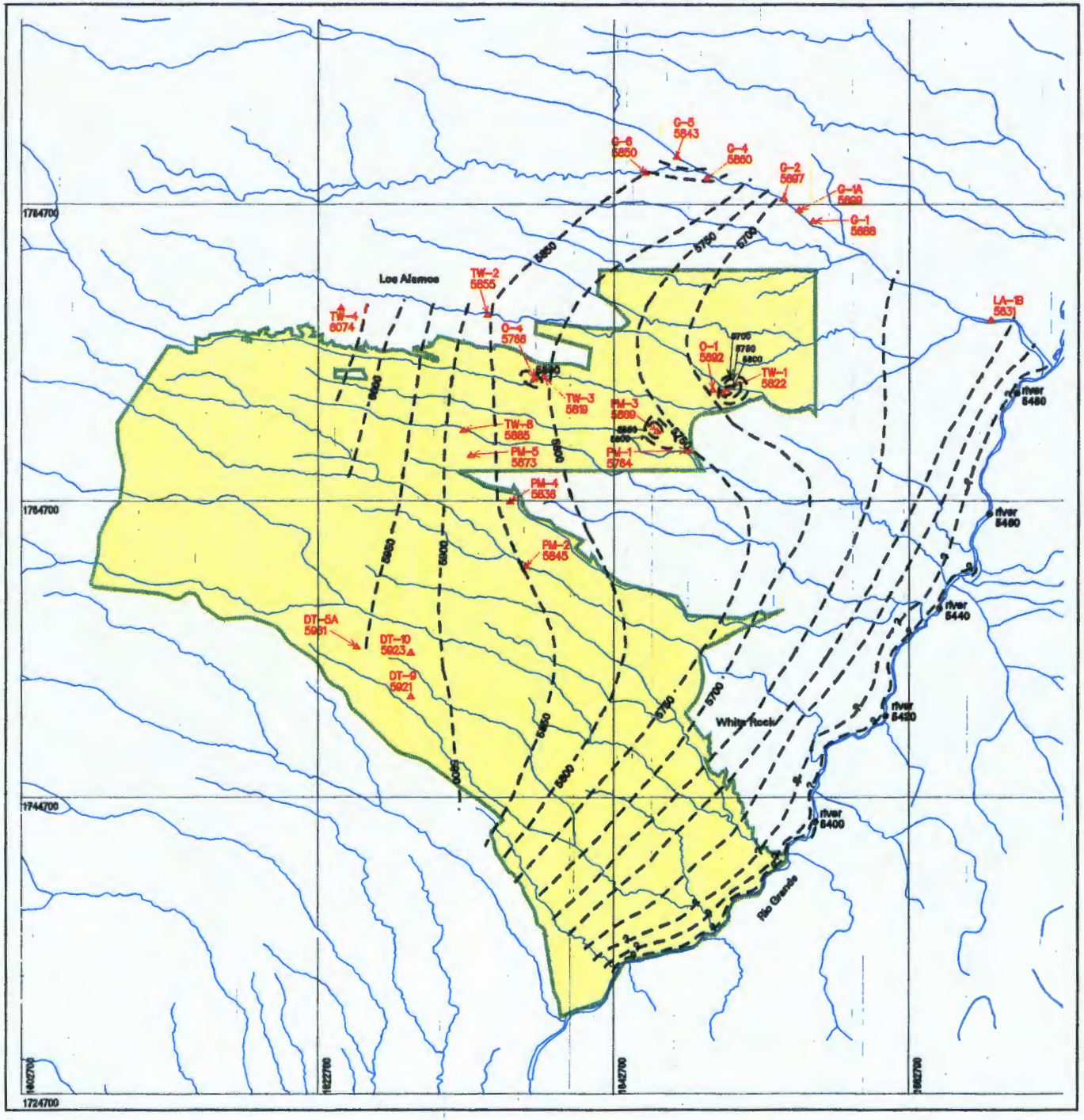
perched ground water in PM-1 and the regional aquifer in PM-3 is less than expected within the east-central portion of Plateau. Vertical separation between the regional aquifer and intermediate perched ground water decreases from the western portion of the Plateau to the eastern side: 650 feet (western portion of the Plateau), 450 feet (east-central portion of the Plateau), and 150 feet between Basalt Spring and the regional aquifer encountered in LA-4.

Another data point which departs from expected trends production well O-1. In well O-1, an elevation of 5,721 feet was observed for the top of the regional aquifer. Water was first encountered in well TW-1 at an elevation of 5,748 feet. Based on the slope of the top of the regional aquifer, TW-1 would be expected to have a lower elevation than O-1. At first this apparent minor anomaly of 27 feet difference between the two data points was thought to be explainable by the difference in well drilling dates: TW-1 was drilled during the 1950's, while O-1 was drilled in 1990. The aquifer may have been sufficiently drained to a point represented by the elevation encountered in O-1 during that 40-year time span; however, TW-1 water-level data does not support this theory since a 38-foot increase in water level was observed in TW-1. Furthermore, since the drilling of O-1 in 1990, water-levels in O-1 have decreased by 29 feet. This apparent anomaly is not understood at this time.

Water-Level Observations

A water-level map developed by LANL of the regional aquifer, using both test wells and production well data from 1993, is shown in Figure 9 and Plate 7. Data for this map were obtained from Appendix A of a December 24, 1994 LANL deliverable to EPA Region VI: Water-Level Maps for LANL. LA-1B data was obtained from Table 1 within the narrative titled "Piezometric Maps for LANL." O-4 data were obtained from LANL (1994) and water-level elevation data for the river was obtained from FIMAD data (1995).

Previous NMED correspondence with LANL suggests that the plateau-wide water-level map which was constructed from wells penetrating various zones of saturation may misrepresent the hydraulic head distribution at the top of the regional aquifer. Since Figure 9 and Plate 7 neither depict the water levels within a small vertical interval of the top of the regional aquifer nor account for potential impacts from residual effects of production well pumping (cones-of-depression which might be observed at the top of the regional aquifer), the applicability of the information is limited. Also, as discussed above, questions regarding the nature of the regional aquifer (s) raise additional questions regarding the contouring of such data. Typically, it is not accepted practice to contour water-level data from such varying screened intervals to generate water-level maps; however, general inferences can be made concerning ground-water flow if the assumption is made that no significant vertical component to flow exists within the various screened intervals of the aquifer. Contouring data of this type may indicate or identify vertical components to flow as anomalies within the system. Lack of such data prevents further understanding of the pressure regime associated with the regional aquifer (e.g. flow nets, etc.). An additional difficulty associated with understanding the pressure regime, and ultimately the direction of ground-water flow, is that



Regional "Main" Aquifer Water Levels (1993)

Explanation

- Boundary, LANL
- Drainage
- Main Aquifer Water Level
  C.I. = 50 feet
- Well
  PM-2: Well Id
  5845: Non-pumping water-level elevation (1993)

FIGURE 9

This map contains preliminary and unverified data.

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
1 inch = 10000 feet

METERS

FEET

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most of the data currently available is limited to production wells with screened intervals up to 2,000 feet in length. If significant vertical gradients exist between the elevations screened and the top of the regional aquifer, it could significantly alter the interpreted ground-water flow direction within the upper portion of the regional aquifer.

As indicated previously by NMED, the major differences between contouring TW-series wells with G-series production wells is a general shifting of contours toward the northeast. The slope of the regional aquifer water-level contours decreases towards the river to about 0.08 ft/ft. Apparent anomalies occur at wells O-4, PM-3, and O-1, and in the northeastern portion of LANL.

The water-level elevation observed in O-4 during 1993 was 5,766 feet. This elevation differs from TW-3 by approximately 53 feet as indicated by hatched contour lines in Figure 9 and Plate 7. TW-3 is located about 300 feet to the east of O-4 in, what would otherwise be considered, a downgradient direction. The top of the regional aquifer is screened by TW-3, whereas O-4 is screened over approximately 1,450 feet in the regional aquifer approximately 300 feet below the top of the aquifer. The difference observed in water levels may be due to the following: the water level data was obtained in a non-equilibrium state (i.e. the pumped well's water level had not returned to an equilibrium level prior to taking measurements); or a downward vertical flow gradient exists deeper within the aquifer. For example, the water level observed in O-4 is a summation of pressure potentials from the entire interval over which the well is screened. The water level in O-4 at the time of drilling was above TW-3's water-level elevation. This may indicate that the residual effects of pumping are influencing non-pumping water levels in O-4.

The water-level contours curve towards the east in the northeastern portion of the plateau near the Guaje Well Field. For production well G-6, the static water level has not changed significantly since the well was drilled. For production wells G-5 and G-4, water-level changes of 50 feet have occurred since drilling. Contour lines in this region appear to be influenced by pumping at the Guaje Well Field. The contour map for the top of the regional aquifer also shows a nearly 90° deflection towards the east in this general region. This may indicate a fault-fracture zone or stratigraphic control on the occurrence of ground water. Further evaluation is needed to determine why these features appeared in both the top of the saturated zone for the regional aquifer and the 1993 regional aquifer water levels contour maps (see Figures 8 and 9 and Plates 6 and 7).

The water-level elevation for PM-3 (5,869 feet) appears as an anomalous high between the 5,800- and 5,750-foot contours. Interestingly, the top of the regional aquifer contour map also shows this area as an anomalous high. PM-1 which was drilled one year earlier than PM-3 and is located 3,700 feet southeast of PM-3, encountered the top of the regional aquifer at an elevation of 5,798 feet, while PM-3 encountered the top of the regional aquifer at 5,900 feet. Additional information is needed to address the these apparent anomalies to understand if significant recharge is occurring at some of these points.

Hydraulic Conductivity

As noted by previous investigators, regions of varying hydraulic conductivity (**K**) may be inferred from lithology. Ground water from the westernmost portion of the regional aquifer moves through the Tschicoma Formation. This region may exhibit dual porosity: matrix porosity (low) and fracture porosity (high). Therefore the K for the regional aquifer within the Tschicoma Formation is expected to be of moderate range. The Puye Formation, however, exhibits moderate K values because of the variance in grain size. The area closest to the caldera would be expected to exhibit higher K values as detritus from the caldera rim consists of boulder to cobble-sized clasts. Progressively lower K values are anticipated away from the source area as the grain size decreases. However, the movement of ground water within the upper portion of the regional aquifer would be greatly influenced by the presence of paleodrainages and fracture fault zones.

The Totavi Formation is expected to exhibit relatively higher K values than any of the other lithologies associated with the regional aquifer. These axial Rio Grande deposits consist of fluvial gravels, including abundant well-rounded cobbles and boulders of various lithologies such as quartzite, pegmatite, and granites. Lacustrine units, which are included in the redefinition of the Totavi Interval (Waresback and Turbeville, 1990), are complexly interbedded with the lower Puye Formation and probably act as a localized region of decreased hydraulic conductivity. The lacustrine units may also act as local aquitards and contribute to semi-confining conditions suggested in the test wells drilled across the plateau.

The basalts of the Chino Mesa interfinger with the Puye Formation and the Santa Fe Group beneath the plateau. Typical K values of basalts with occasional cavernous porosity or breccia flow porosities is cited by Freeze and Cherry (1979) as ranging widely between 0.26 and 528 ft/day. The overall K values for the basalts are probably somewhat higher than the K for the Santa Fe Group, but much less, in general, than the K exhibited by the Totavi Interval. The Santa Fe Group consists of relatively finer-grained semi-consolidated material beneath the plateau. Because of the finer grain size, hydraulic conductivity values within the regional aquifer are probably lower within the Santa Fe Group than in within other regions of the lithology across the plateau. Hydraulic conductivity values expected for similar type lithologies in the Santa Fe Group range from 0.01 to 0.27 ft/day. From a simplistic flow model:

$$Q = K \cdot I \cdot A \qquad (5)$$

where:

Q = discharge [ft^3/day]
K = hydraulic conductivity [ft/day]
A = area of flow [ft^2]
I = hydraulic gradient [ft\ft]

with discharge (**Q**) and area (**A**) held constant, as K increases the hydraulic gradient will decrease. Thus, regions of lower K may exhibit an increase in hydraulic gradient.

Water Supply

The communities of Los Alamos, Totavi, White Rock, Bandelier National Monument, and the Los Alamos National Laboratory have obtained water from approximately 20 production wells in four well fields: Los Alamos, Guaje, Pajarito, and Otowi. The Los Alamos Well Field was taken off-line in 1992 as a cost-feasibility measure. Water supply for both municipal and industrial use in 1992 totaled 1.43 billion gallons from 11 regional aquifer production wells beneath the Pajarito Plateau. Production depths vary within the regional aquifer, but typically occur 200 to 300 feet below the top of the aquifer and include 1,500 to 2,000 feet of screen. LANL publishes a summary of the production and well-field characteristics in annual water supply reports.

The radius of effect for each production well is not well understood. The direction of ground-water flow within the regional aquifer beneath PRSs, MDAs and RCRA-regulated units as impacted by the pumping of the numerous production wells across the Plateau is unknown. This lack of information concerning cones of depression and their potential influence on the ground-water system is of utmost importance in selecting monitoring well sites for long-term detection. For those PRSs left in place as a remedial alternative, regulatory compliance including detection monitoring will require an understanding of pumping effects within the uppermost sections of the regional aquifer.

As discussed previously, a modification of the Cooper/Jacob equation can be used to estimate transmissivity (**T**) when the specific capacity is known (Driscoll, 1989):

$$Q / s = T / 2{,}000 \quad \text{(for confined conditions)} \qquad (1)$$

$$Q / s = T / 1{,}500 \quad \text{(for unconfined conditions)} \qquad (6)$$

where:

Q = discharge of the well [gpm]
s = drawdown observed in well [ft]
T = transmissivity [gpd/ft]

By the distance-drawdown modification to the Jacob approximation, an estimate of radius of cone of depression ($\mathbf{r_o}$) from a pumping well can be made using reasonable T and storage coefficient (**S**) values and assuming equilibrium conditions (Cooper and Jacob, 1946):

$$r_o^2 = (T)\,(t) / (4{,}790)\,(S) \qquad (7)$$

where:

r_o = radius of cone of depression [length]
r_w = radius of well [length]
t = time
S = storage coefficient [no dimension]

A further refinement of T can be made from Equations (1) and (6) by using the pumping rate and drawdown data from a well (Stallman, 1971):

$$T = (528)\,(Q)\,(\log (r_o/r_w)) / s \qquad (8)$$

Recalculating r_o using Equation (7) and T from Equation (8) gives a better approximation of T and, therefore, of r_o. To further check T and S, the observed drawdown in the well can be used to calculate a hypothetical pumping rate and arbitrary radius from the well at one foot to the calculated drawdown (Lohman, 1979).

O-4: A 22-day pumping test was conducted in production well O-4 in 1993 and after 11 days of pumping, the following was observed (McLin, 1993):

Q = 1,603 [gpm],
s = 42 [ft],
t = 11 days = 15,840 min,
r_w = 0.67 [ft], and assuming
S = 1.93×10^{-3} (from step-drawdown data, 1990)

Based on the above scoping calculations for radius of effect, production well O-4 has an estimated r_o equal to 11,476 feet or ~ 2.2 miles.

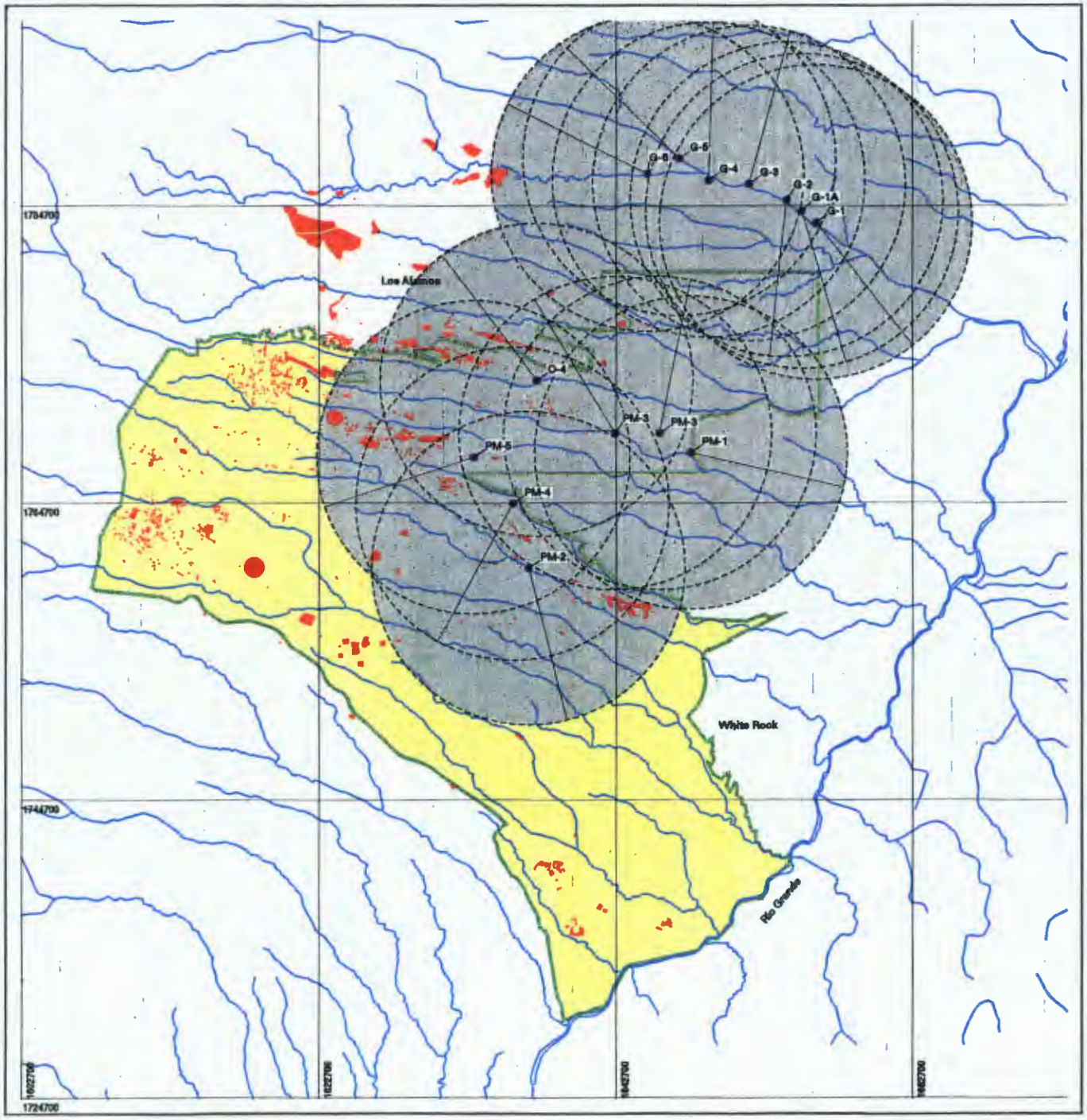
PM-3: An 11-day pumping test was conducted at PM-3 in 1993 and after 11 days of pumping the following was observed (McLin, 1993):

Q = 1,250 [gpm],
s = 32 [ft],
t = 11 days or 15,840 minutes,
r_w = 0.58 [ft], and assuming

Based on the above scoping calculations for radius of effect, production well PM-3 has an estimated r_o equal to 11,890 feet or ~2.25 miles.

After 5 days of pumping, a drawdown of approximately 2.5 feet was observed in PM-1 which is located approximately 5,000 feet from PM-3. The specific water level data was not available to adequately evaluate T and S values derived from the data; however, the drawdown in a well located this distance from the pumping well validates the theory that the cone of depression extends to a distance of at least 5,000 feet.

If the above conditions are typical for the regional aquifer and the production wells on the Pajarito Plateau, then cones of depression for the various production wells across the Plateau may be similar to those depicted in Figure 10 and Plate 8. The additive effects of overlapping cones of depression were not evaluated within this report. Whatever influence these pumping wells have on the direction of ground-water flow beneath LANL can only be hypothesized at this time. As a specific regulatory requirement within the HSWA permit, LANL must evaluate and develop a technically defensible understanding of the plateau-wide effects of pumping from production wells as it relates to PRSs.



Estimated Radius of Effect for LANL Production Wells

Explanation

- Boundary, LANL
- Drainage
- Estimated Cone of Depression (2 mile radius)
- Potential Release Site
- LANL Production Well

FIGURE 10

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: 20000
1 inch = 10000 feet

METERS

FEET

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White Rock Canyon Springs

A longitudinal section showing the relationship between the river elevation and the springs in White Rock Canyon is found in Plate 9. Straight line segments along the river were drawn from Otowi bridge to Spring 10. Spring locations were projected perpendicular along the straight line segments of the river through White Rock Canyon as shown on the Plan View of Plate 9, "White Rock Canyon Springs in Relation to the Rio Grande." The longitudinal section represents the total distance of the straight line segments shown on the Plan View. Estimated slopes of the regional aquifer were perpendicularly projected from the surface of the river to spring locations along the river. The horizontal distance from the river to each spring location was measured and multiplied by estimated slope values expected to represent the hydraulic gradient of the region near the river.

Maximum and minimum projected slope values of the regional aquifer used were 0.1 and 0.01. These values were then added to the elevation of the river at the point perpendicular to the spring location. The elevation of the projected slope (maximum and minimum) of the regional aquifer was then plotted on the longitudinal section. White Rock Canyon Springs were then plotted on the longitudinal section for comparison with the plotted maximum and minimum projected slopes expected for the regional aquifer in this region.

As noted previously, the top of the regional aquifer in the vicinity of the Los Alamos area, is believed to be represented by the surface of the Rio Grande (Griggs, 1964; Thesis, 1964; Cushman, 1965). For the purposes of this analysis, NMED assumed that the river level was equal to the top of the regional aquifer. Maximum and minimum slope values were based on observed gradients within the Los Alamos Canyon wells and derived from the extrapolation from the water-level contour map. Those springs plotted between the maximum and minimum projected points may represent regional aquifer discharge points.

From this data display, several groupings of springs are evident. Those springs plotted above the maximum projected slope of the regional aquifer (Rio Grande water level) may represent perched water discharge points.

Several studies have been conducted which investigate the hydrogeologic characteristics of the White Rock Canyon springs. However, questions surrounding the ion balance and other general water chemistry observations have lead to questionable conclusions regarding the nature of the springs in relation to the regional aquifer and to perched ground water systems. At least twenty-two springs discharge along the 11-mile stretch through White Rock Canyon. Past investigations have collectively grouped these springs as discharge points for the regional aquifer. Purtymun (1984)observed that the river gains in flow from the confluence of Los Alamos Canyon to the confluence of Frijoles Canyon. The numerous springs and seeps found

along this stretch of the river discharge an estimated 4,300 to 5,500 acre-feet per year. LANL should conduct a water balance check between the spring discharges and the river to aid in interpreting ground-water flow regimes.

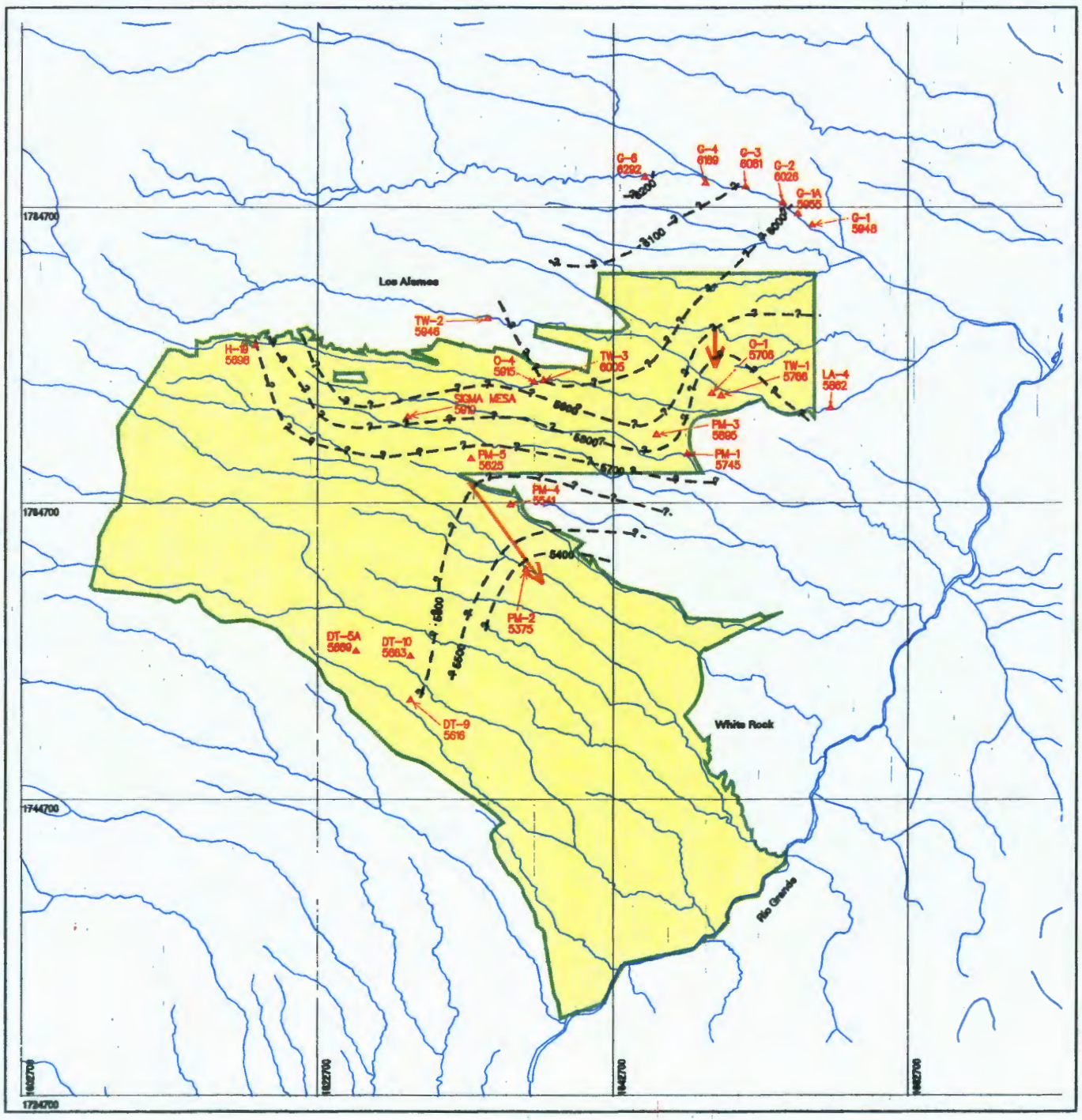
C. Paleotopographic Surfaces

This NMED evaluation did not have outcrop data available when contouring the paleotopographic surfaces. This should be taken into account when reviewing these contour map. Current drainage systems are shown on the paleotopographic maps for reference. The contact between the Puye and the Bandelier is represented by the base of the Guaje Pumice Bed for all points shown in the associated figure.

1. Totavi Formation

The depositional environment of the ancestral Rio Grande deposits across the Pajarito Plateau lends itself to a surface that is most likely discontinuous (LANL, 1993b). Figure 11 and Plate 10 show the paleotopography of the top of the Totavi Formation. Geologic logs describe the contact between the Totavi Formation and the Puye Conglomerate as laterally gradational and distinctive because of the appearance of quartzite and granite cobbles and boulders within the Totavi Formation. Uncertainties associated with stratigraphic picks for the top of the Totavi Formation include the following: inherent differences between stratigraphic position of the Totavi Formation and the Puye Conglomerate with the Santa Fe Group, the inclusion of lacustrine units into the Totavi Formation which are complexly interstratified with the Puye Conglomerate; and the potential redefinition of some portions of the Santa Fe Group to include a proposed Chaquehui Formation. Lithologic and stratigraphic similarities between the Totavi Formation and the proposed Chaquehui Formation, as well as maar deposits which include arkosic xenoliths could create difficulties discerning stratigraphic picks.

An apparent paleodrainage trends towards the south-southeast near the present-day Pueblo/Los Alamos Canyon confluence. Production wells O-1 and TW-1 control the position of this paleodrainage, although data are lacking in the southeastern portion of the plateau. Another apparent paleodrainage heads near present day Mortandad Canyon near PM-5. This centrally located paleodrainage trends southeasterly to a more southerly direction than present day canyon systems as the drainage shifts across Cañada del Buey to Pajarito Canyon near PM-2. Additional subsurface data were not available southeast of PM-2 across the Plateau. A paleotopographic high appears to occur near the vicinity of PM-3. Another apparent paleotopographic high occurs near TW-2 to O-4 and TW-3 across Pueblo and Los Alamos canyons.



Paleotopography - Totavi Formation

Explanation

- Boundary, LANL
- Drainage
- Paleodrainage
- Top of the Totavi Formation
  C.I. = 100 feet
- Well
  PM-2: Well id
  5375: Elevation of the top of the Totavi Formation

FIGURE 11

This map contains preliminary and unverified data.
Outcrop data are not included in this map

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
1 inch = 10000 feet

METERS

FEET

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2. Pre-Bandelier

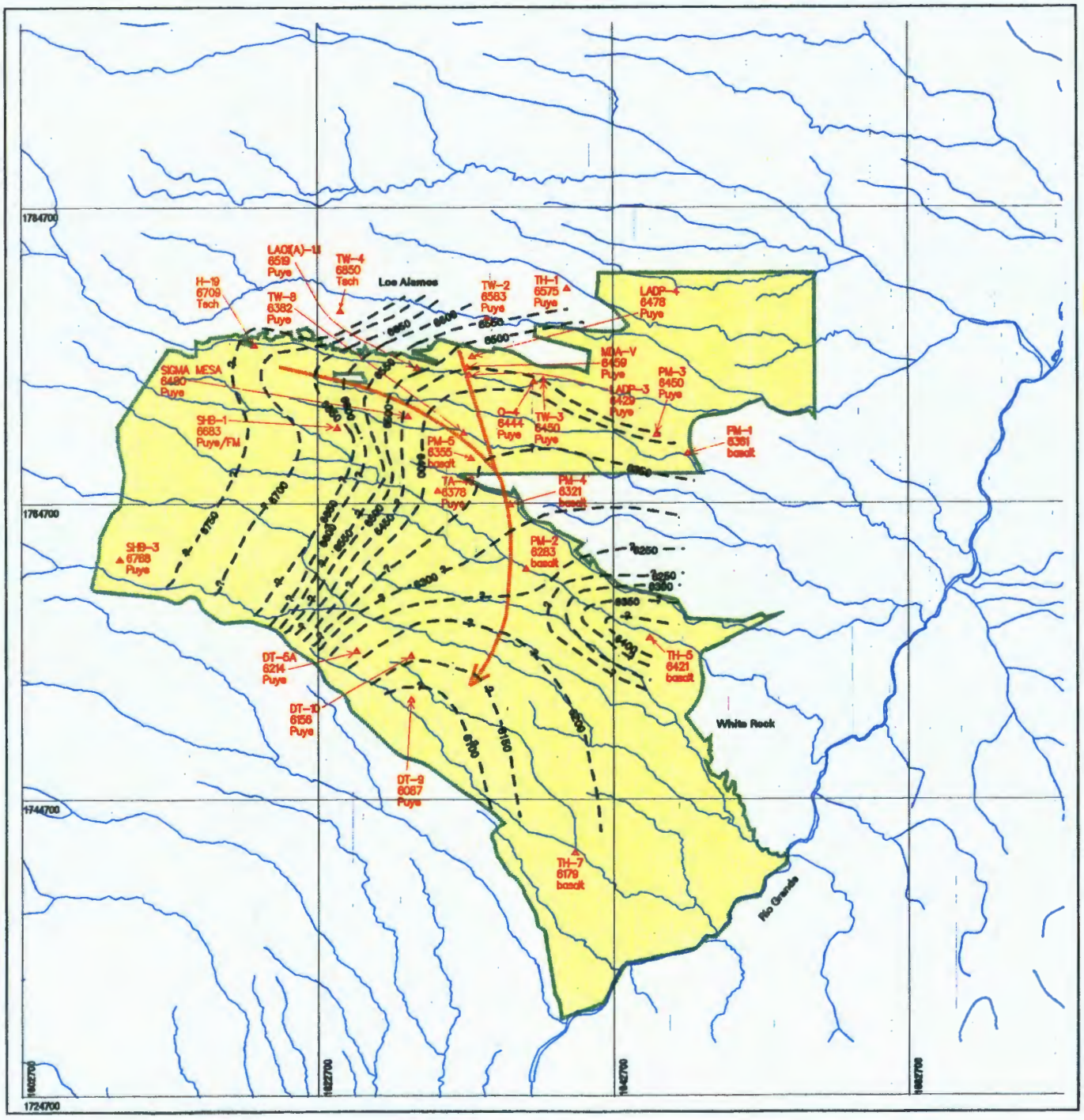
Figure 12 and Plate 11 show the paleotopography of the pre-Bandelier surface. NMED chose the base of the first Bandelier stratum noted in the available well logs for this surface. This paleotopographic contour map postulates the geometry of the surface prior to the deposition of the Bandelier Tuff. From the available well logs, this surface was represented by the base of the Guaje Pumice Bed (air-fall unit); however, field observations show that the Guaje Pumice Bed and possibly the Otowi Member may be absent locally, particularly within the southwestern portion of LANL.

The pre-Bandelier geology is characterized by the Tschicoma Formation on the western portion of the plateau, the Puye Conglomerate in the central portion, and basaltic rocks along the eastern portion of the Pajarito Plateau area. This pre-Bandelier horizon is more distinguishable than other horizons across the Pajarito Plateau because of the contrast between the Bandelier Tuff and the pre-Bandelier lithologies. The top of the pre-Bandelier, characterized by the Tschicoma Formation within the northwestern portion of LANL, is described by well logs as a dull grey, dacite flow containing phenocrysts of plagioclase and quartz with minor mafics within a fine-grained ground mass.

The Puye Formation constitutes the largest area of pre-Bandelier geology across the Pajarito Plateau. The contours of the Puye Formation appear in Figure 12 and Plate 11 like an S-shaped area across LANL. The Puye is typically described as a conglomerate or gravel in a matrix of sand, silt, and clay containing dacite, latite, or volcanic rocks. Difficulties in distinguishing between these geologic horizons could arise when the logs describe water-laid pumice abundant in an interval at greater than 80 percent. The Puye Formation may also consist of re-worked pumice at this contact, however, this description was not observed in the logs reviewed. As shown in Figure 12 and Plate 11, basaltic rocks characterize the geology of the pre-Bandelier surface along the eastern extent of LANL.

The paleotopographic map suggests the presence of two distinct paleodrainages prior to the deposition of the Bandelier Tuff. One drainage appears concurrent with the present day position of the head of Sandia Canyon. This drainage trends east-southeasterly towards PM-4 where it takes on a more south-southwesterly trend heading toward the general vicinity of the DT-series wells. Another apparent drainage in the vicinity of LADP-4 trends southeasterly and drains into the other previously noted paleodrainage near TW-8 and PM-5. This confluence may effect the trend of this drainage causing it to take a more southerly direction near PM-5. A paleo-high is apparent near TH-5 and present-day lower Pajarito Canyon. The basalts of the Cerros del Rio Field appear to affect this paleo-high and have filled a paleodrainage which is suggested on the paleosurface of the Totavi Interval (Figure 11 and Plate 10) and which drained to the southeast toward PM-2.

The pre-Bandelier paleosurface is typically 200 to 500 feet above the top of the regional aquifer. However, similar patterns between the pre-Bandelier surface and the surface of the regional aquifer appear to exist near the Sigma Mesa and PM-3 area.



Paleotopography - Pre-Bandelier Tuff

Explanation

- Boundary, LANL
- Drainage
- Paleodrainage
- Pre-Bandelier Paleotopography Contour, C.I. = 50 Feet
- Geology Characterization Well
  LADP-4: Well Id
  6459: Elevation of Pre-Bandelier Paleotopography
  Puye: Pre-Bandelier Paleogeology

FIGURE 12

This map contains preliminary and unverified data.
Outcrop data are not included in this map

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1983 North American Datum

Grid provides NM State Plane coordinates in feet.
Grid interval, in feet: 20000
1 inch = 10000 feet

METERS

FEET

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From PM-2 data, intermediate perched ground water has been noted to occur approximately 100 feet above the pre-Bandelier surface in Pajarito Canyon. Intermediate perched ground water was also encountered at one foot above the pre-Bandelier surface at LADP-3 in Los Alamos Canyon and less than 20 feet in other intercepts.

3. Guaje Pumice Bed

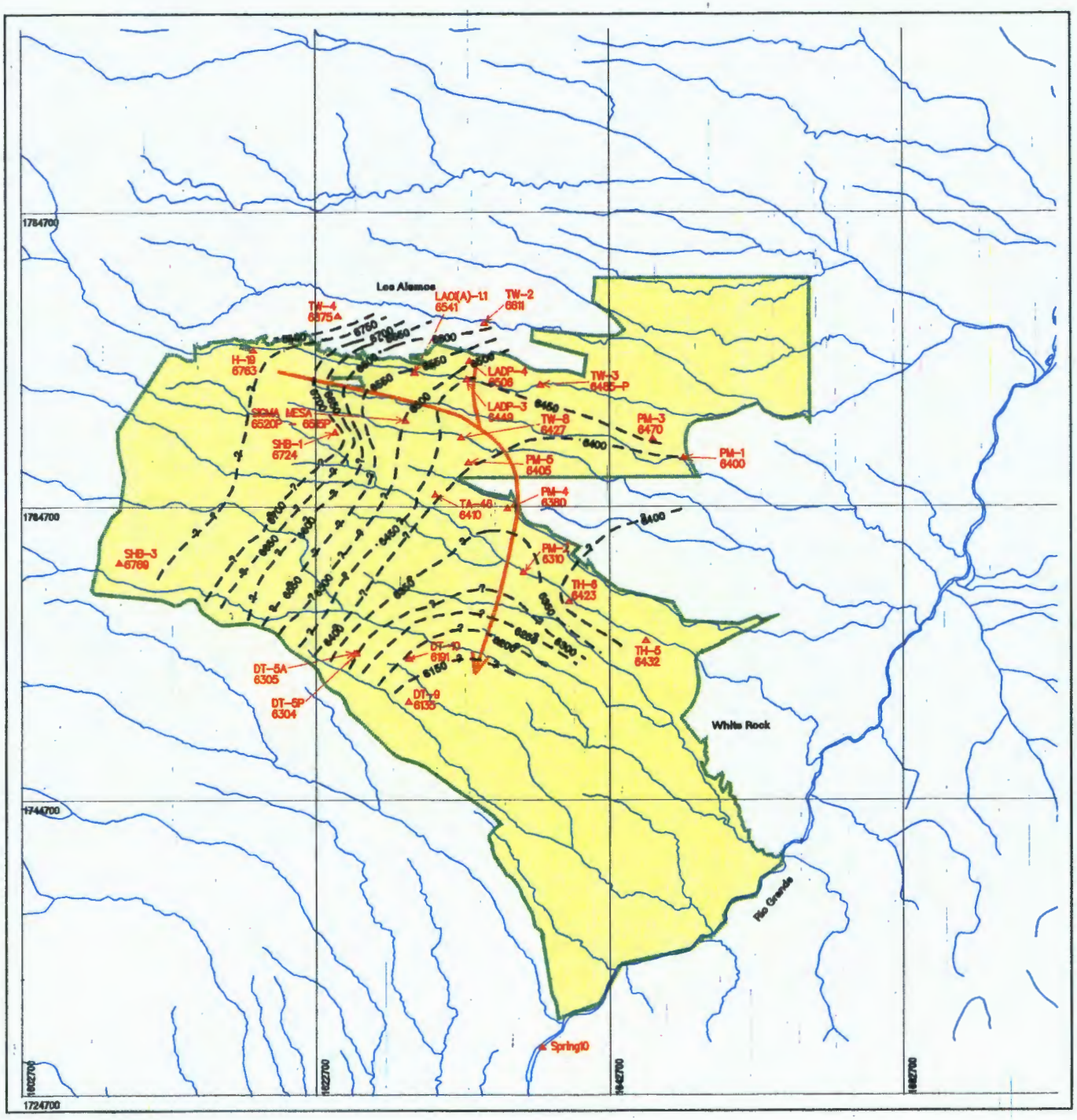
The Guaje Pumice Bed was deposited upon the pre-Bandelier topography as a blanket and is thickest within the paleodrainages of the pre-Bandelier. The top of the Guaje Pumice Bed, as shown in Figure 13 and Plate 12, shows two distinct paleodrainages similar to the pre-Bandelier paleotopography: one trending southeast from the Sigma Mesa well to TW-8 where another apparent paleodrainage converges from the north. The drainage from the northwest near Sigma Mesa is moved slightly northwards towards Los Alamos canyon in comparison with the pre-Bandelier topography. From the confluence of these two paleodrainages, the paleosurface contours flatten near PM-4 and one dominant drainage trends southward towards PM-2. In the vicinity of PM-2, the paleotopography flattens again in an area which is blanketed by a basaltic high. The southern paleodrainage apparently continues south-southwest towards the DT-series wells.

4. Otowi Member

The paleotopography of the top of the Otowi Member is shown in Figure 14 and Plate 13. The top of the Otowi Member represents an erosional surface between the deposition of ignimbrite flow deposits and the second eruption of the Valles Grande represented by the overlying Tsankawi Pumice ash-fall deposits. Based on drill holes LADP-4 and LAUZ-1, it is suspected that deeply incised canyons characterized the surface of the Otowi Member while the Cerro Toledo Interval (caldera rim detritus) was deposited eastwardly across the Otowi Member paleotopography.

In general, paleodrainages appear to be superimposed on previous drainage patterns. One dominant southeasterly trending drainage heads near SHB-1, shifting position slightly near TA-46 toward the north but trending south-southeasterly near PM-2. This paleodrainage pattern most closely resembles modern day Pajarito Canyon. A minor drainage pattern appears to be trending east-northeasterly near TW-8.

The occurrence of intermediate perched ground water in Pajarito Canyon coincides with a paleodrainage within the top of the Otowi Member. At PM-2, intermediate perched ground water occurs at 6,380 feet elevation. The common intercepts of paleodrainages among the various paleosurfaces contoured are evident at PM-2. The correlation of paleodrainages with the occurrence of this intermediate perched ground water at this location warrants further investigation. If paleodrainages influence the occurrence of intermediate perched ground



Paleotopography - Guaje Pumice Bed

Explanation

- Boundary, LANL
- Drainage
- Paleodrainage
- Top of Guaje Pumice Bed (geologic unit of the Bandelier Tuff) C.I. = 50 feet
- Geology Characterization Well
  PM-2: Well Id
  6310: Elevation of Top of Guaje Pumice Bed, (ft)

FIGURE 13

This map contains preliminary and unverified data.
Outcrop data are not included in this map

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
1 inch = 10000 feet

METERS

FEET

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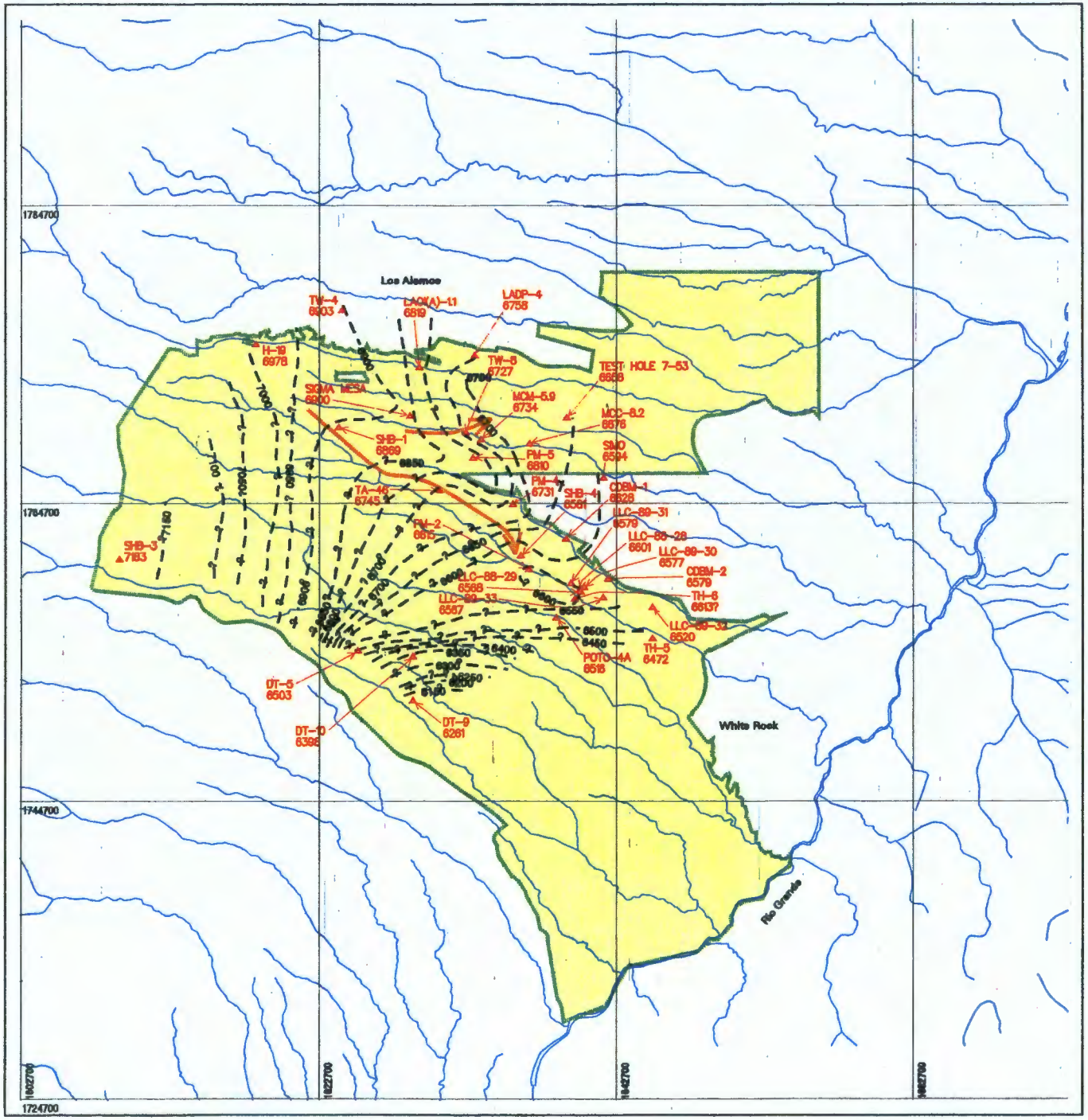

Paleotopography - Otowi Member

Explanation

- Boundary, LANL
- Drainage
- Paleodrainage
- Top of Otowi Member (geologic unit of the Bandelier Tuff) C.I. = 50 feet
- Geology Characterization Well
  PM-2: Well Id
  6610: Elevation of Top of Otowi Member, (ft)

FIGURE 14

This map contains preliminary and unverified data.
Outcrop data are not included in this map

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
1 inch = 10000 feet

METERS

FEET

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water, understanding the nature of occurrence will not only lead to fulfillment of requirements within the HSWA Permit, but also aid in siting locations for ground-water monitoring wells.

5. Tsankawi Pumice Bed

With the deposition of the Tsankawi Pumice Bed, paleodrainages of the Cerro Toledo Interval were blanketed and in-filled (Figure 15 and Plate 14). The top of the Tsankawi Pumice Bed shows a flattening of the topography similar to that of the Otowi Member (Figure 14 and Plate 13). Since the Tsankawi Pumice Bed was not always noted in the well logs, data are sparse. The Tshirege Member ash-flow was deposited on top of the Tsankawi Pumice Bed producing a fairly gentle topography. One prominent drainage appears to trend southeasterly near SHB-4 in mid-Pajarito Canyon. The location of this drainage coincides with previously contoured paleotopographic surfaces.

V. POTENTIAL RELEASE SITES - RELEASES

LANL has approximately 2,217 PRSs[1], which can be further subdivided into the following categories:

- SWMUs (total):
  - non-HSWA RCRA SWMUs: 111[2]
  (includes permitted and interim status)
    - RCRA-regulated units: 13
    - Non-regulated RCRA units: 98[3,4]
  - HSWA SWMUs: 1,099

- AOCs: 1,007

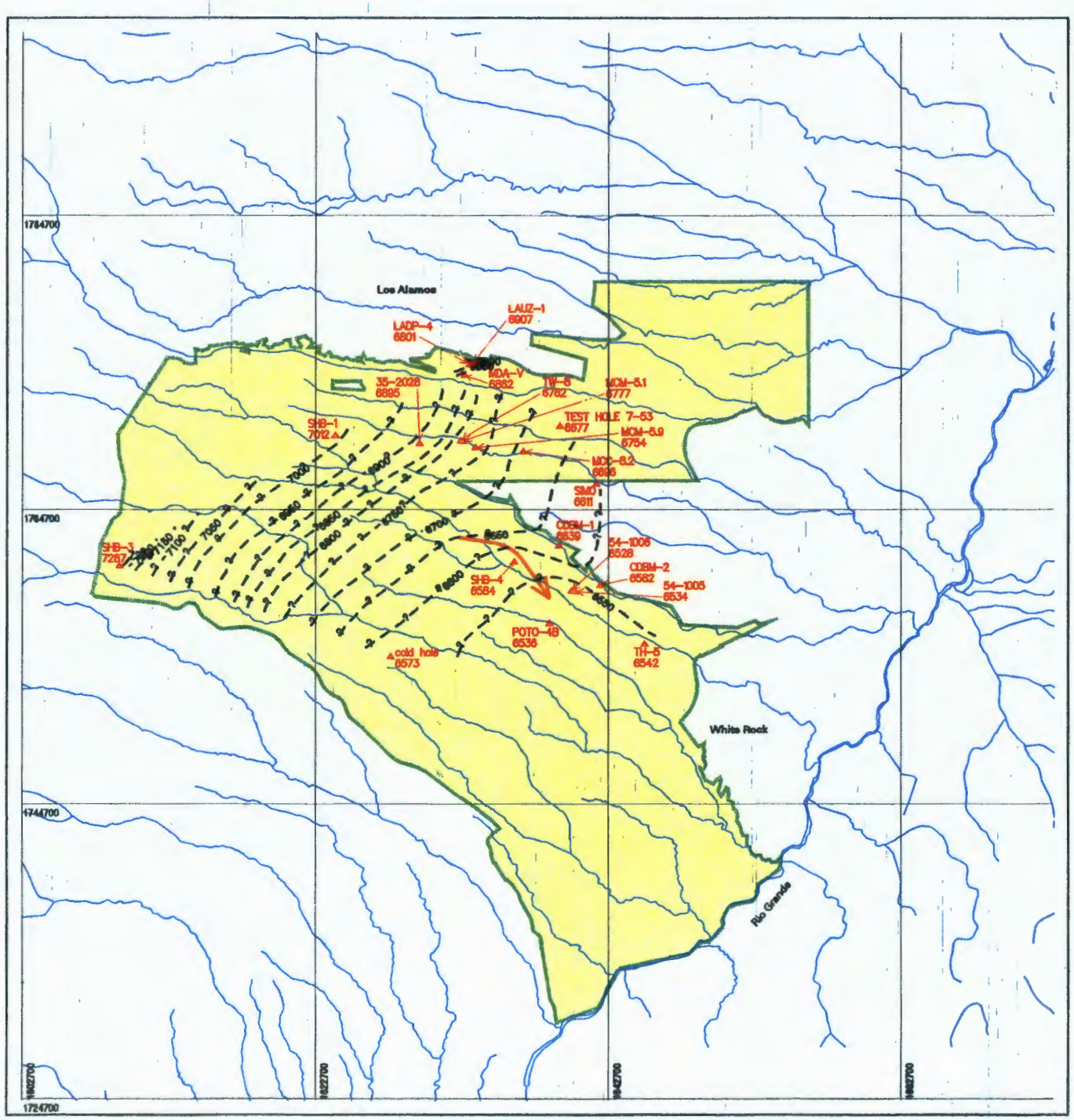
---

1 Some duplication may exist between these categories.

2 A comprehensive listing of RCRA units at TA-54 is unavailable, therefore this number is uncertain.

3 Non-regulated units are defined in 40 CFR Part 264.90 as any RCRA unit which does not include waste piiles, surface impoundments, landfills, and land treatment units.

4 RCRA Satellite accumulation, 90 day storage areas, etc. are not included in this total.



Paleotopography - Tsankawi Pumice Bed

Explanation

- Boundary, LANL
- Drainage
- Paleodrainage
- Top of Tsankawi Pumice Bed (geologic unit of the Bandelier Tuff) C.I. = 50 feet
- Geology Characterization Well
  TH-5: Well Id
  6542: Elevation of Top of Tsankawi Pumice Bed, (ft)

FIGURE 15

This map contains preliminary and unverified data.
Outcrop data are not included in this map

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: 20000
1 inch = 10000 feet

METERS

FEET

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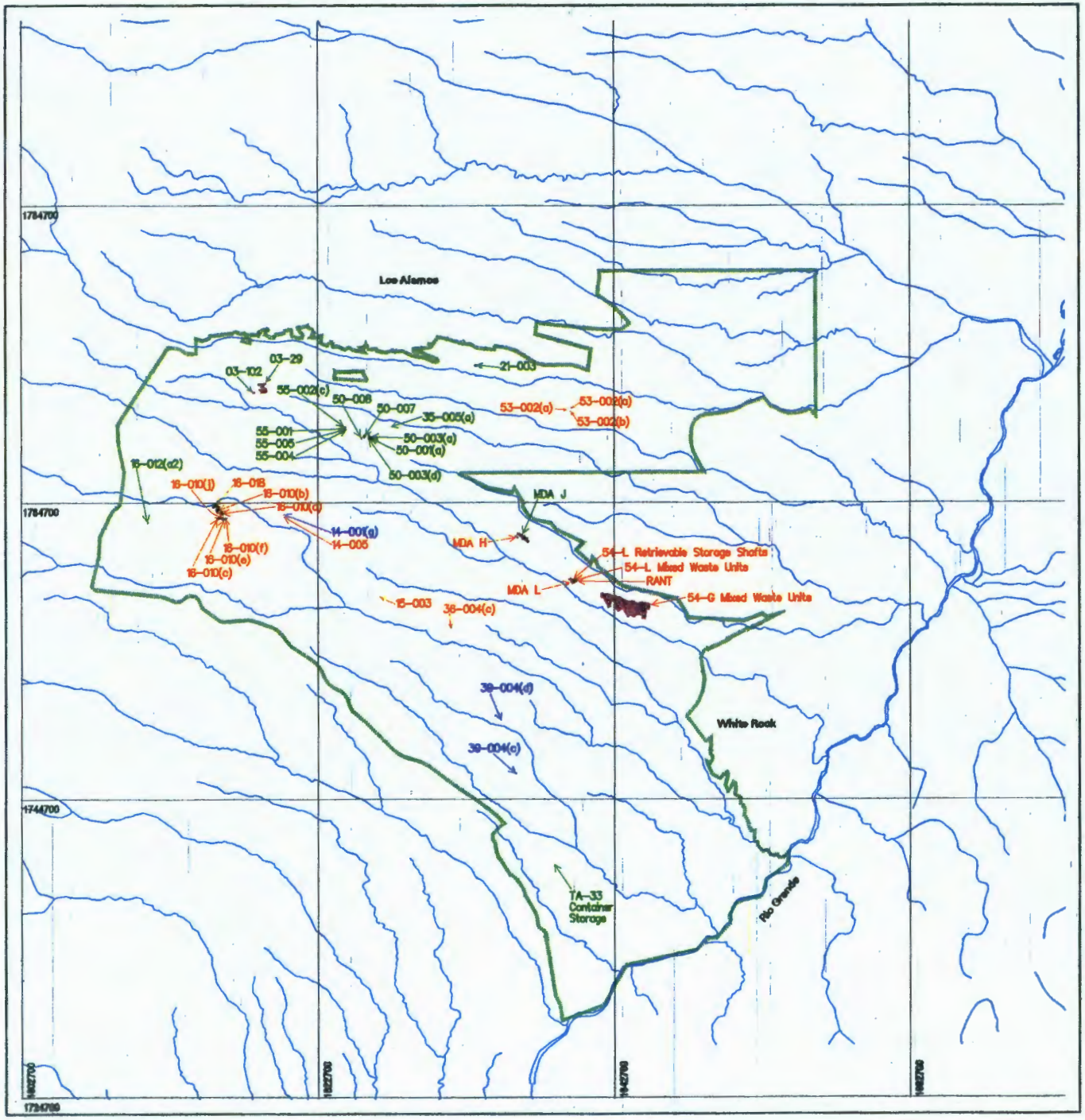
A. RCRA-Regulated Units

As discussed in Section II.B.1, regulated units (waste piles, landfills, surface impoundments, and land treatment units) and possibly certain miscellaneous units, must comply with Sections 264.91 through 264.100 (Subpart F) in lieu of Section 264.101(Subpart S) for the purposes of detecting, characterizing, and responding to releases to the uppermost aquifer. All other RCRA (non-regulated) SWMUs, such as container storage, tank treatment, incinerator, tank storage, and other miscellaneous units, are subject to permit conditions as well as Subpart S requirements for ground-water monitoring.

All non-HSWA RCRA units subject to ground-water monitoring requirements under either Subpart F or Subpart S were ranked for potential for release to ground water based on the following criteria as specified in 40 CFR Part 264.90(c): (i) The unit is an engineered structure, (ii) the unit does not receive or contain liquid waste or waste containing liquid waste, (iii) the unit is designed and operated to exclude liquid, precipitation, and other run-off and run-on, (iv) the unit has both inner and outer layers of containment enclosing the waste, (v) the unit has a leak detection system built into each containment layer, (vi) the owner will provide continuing operation and maintenance of the leak detection systems, and (vii) to a reasonable degree of certainty the unit, will not allow hazardous constituents to migrate beyond the outer containment layer prior to the end of the post-closure period. In addition, the following criteria were considered in evaluating the potential for release to ground water from a RCRA unit: distance to surface and ground water; fracture density; location relative to canyon bottom, mesa top, and mesa edge; available release information; constituents of concern and their mobility; and integrity of the unit. Table 3 summarizes the findings of the analysis of known non-HSWA RCRA units at LANL regardless of current permitted status.

Figure 16 and Plate 15 shows the location of non-HSWA RCRA units ranked for potential for release to ground water and are subject to ground-water monitoring requirements under either Subpart F or Subpart S. The figure also provides an indication of the potential for release to ground water as summarized in Table 3.

NMED compiled a sub-listing of RCRA-regulated and miscellaneous units at LANL which must meet the ground-water monitoring requirements of 20 NMAC 4.1 at 40 CFR Section 264.91 (Table 4). The term "regulated unit" is defined in 264.90 to pertain only to the following RCRA units: waste piles, landfills, surface impoundments, and land treatment units. The results of the above analysis are factored into NMED's preliminary recommendations for monitoring well placement. However, specific regulatory requirements for ground-water monitoring plans for specific units should be reviewed on a site-by-site basis. The recommendations are only a first cut at initial well placement from a site-wide monitoring perspective. Additional wells will need to be installed with well placement based on findings from the first cut.



RCRA Permitted/Interim Status Units - LANL

Explanation

- Boundary, LANL
- Drainage
- RCRA Permitted/Interim Status Unit

Red Text: RCRA (non-HSWA) units ranked high potential for release to groundwater

Blue Text: RCRA (non-HSWA) units ranked moderate potential for release to groundwater

Green Text: RCRA (non-HSWA) units ranked low potential for release to groundwater

FIGURE 16

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
1 inch = 10000 feet

METERS

FEET

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Table 3 **LANL non-HSWA RCRA Units Subject to Ground-Water Monitoring under 40 CFR Part 264.91 (Subpart F) or 270 (Subpart S)**

Low to Moderate Potential[1]	Moderate Potential[2]	Moderate to High Potential[3]
88 units (total)	3 units (total)	20 units (total)
70 container storage	3 OB/OD	4 MDAs (H, J, L, G, P)
16 tank storage/treatment		9 OB/OD
1 surface impoundment		
1 MDA (J)		5 landfills
		2 surface impoundments

1. Unless there are any dissatisfactory inspections of the units, this group does not warrant ground-water monitoring.
2. This group warrants additional investigation as to site-specific conditions and the necessity for ground-water monitoring.
3. This group warrants immediate attention as to site-specific conditions and the necessity for ground-water monitoring.

Table 4 LANL RCRA Regulated/Miscellaneous Units Subject to Ground-Water Monitoring Requirements under 40 CFR Part 264.90-100

PRS No	Unit Location	Unit Description
14-D83	TA-14	Surface impoundment (listed in RCRA Part A)
14-001(g)	TA-14	OD Firing site
14-005	TA-14	OB Burn Cage (16-BC)
15-D83	TA-15	Surface impoundment (listed in RCRA Part B)
15-003	TA-15	OD Phermex
16-018	TA-16	Landfill (undergoing closure)
16-010(b)	TA-16	OB 387 flash pad
16-010(c)	TA-16	OB 388 flash pad
16-010(d)	TA-16	OB 399 flash pad
16-010(e)	TA-16	OB 401 pressure vessel/sand filter
16-010(f)	TA-16	OB 406 pressure vessel/sand filter
16-010(j)	TA-16	OB 394 flash pad
35-005(a)	TA-35	Surface impoundment (undergoing closure)
36-004(c)	TA-36	OD
39-004(c)	TA-39	OD AC-6
39-004(d)	TA-36	OD AC-57
53-002(a)	TA-53	Surface impoundment
53-002(b)	TA-53	Surface impoundment (undergoing closure)
54-004*	TA-54	Landfill (MDA H)
54-005	TA-54	Landfill (MDA J)
54-006	TA-54	Landfill (MDA L)
54-014(b)	TA-54	Landfill (MDA G)
54-L	TA-54	5 landfills

NOTE: 14-D83 and 15-D83 were not evaluated for potential for release to ground water due to the uncertainty associated with their existence.

* Additional RCRA-regulated units exist at TA-54; however, the number of units is currently uncertain.

B. Material Disposal Areas

1. Material Disposal Area Tables

Appendix C provides an evaluation of the potential to release to ground water of 24 MDAs at LANL. As with the non-HSWA RCRA units evaluation, the following factors were considered as a qualitative approach to evaluating the potential to release to ground water: distance to surface and ground water; fracture density; location relative to canyon bottom, mesa top, and mesa edge; available release information; constituents of concern and their mobility; and integrity of the MDA. This information was obtained from LANL RFI Workplans, LANL SWMU reports, LANL Environmental Restoration Ranking System Report (1993a), and other relevant source documentation (e.g. site visits, NMED DOE OB data, site-specific geologic/hydrologic reports, etc.).

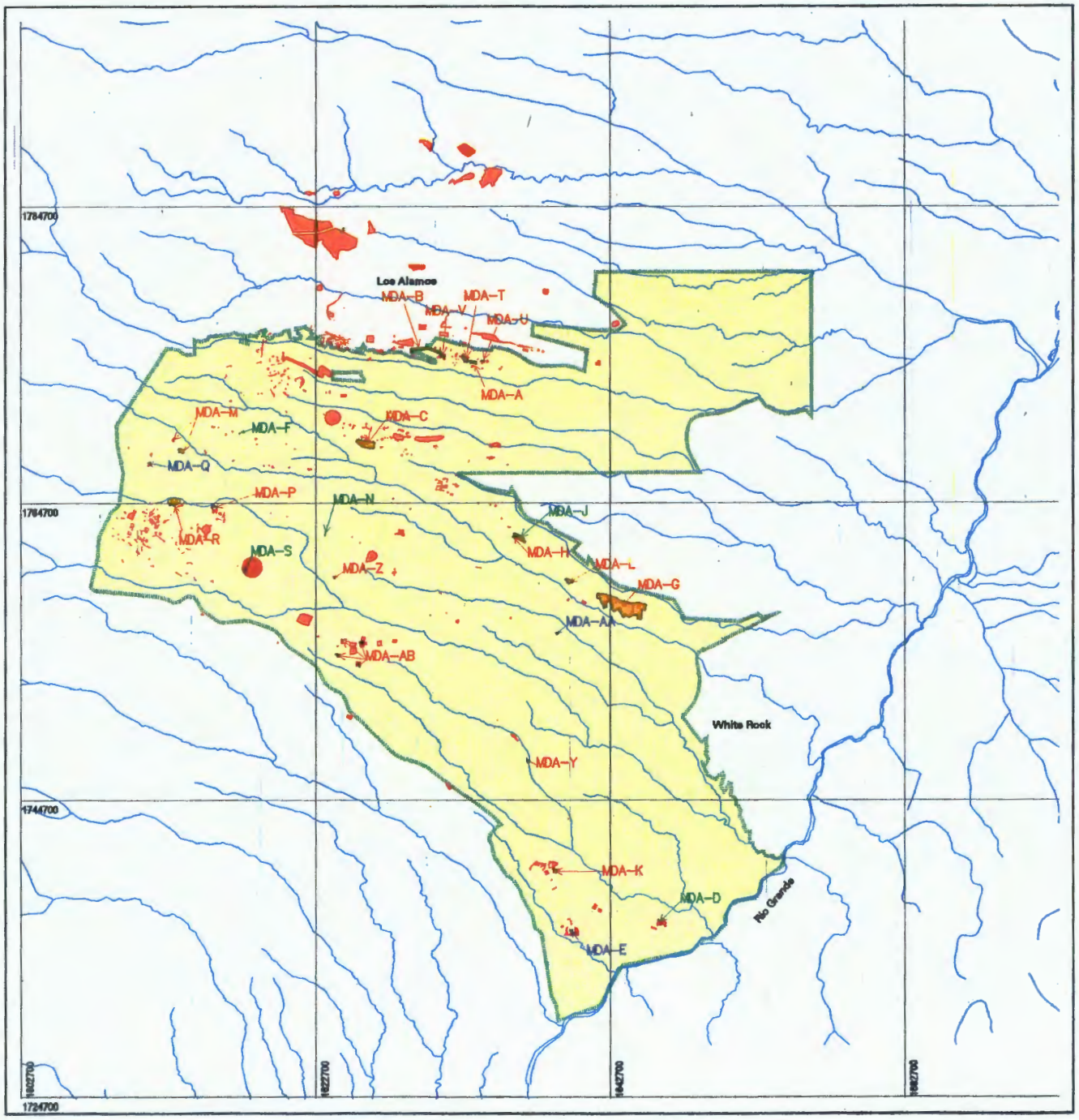
The resulting rank (Low to Moderate, Moderate, or Moderate to High) is located in the heading "Potential for Release to Ground Water" in the first row of each MDA table. A "moderate to high" potential indicates that a release to ground water has occurred or is imminent and that contamination issues should be addressed immediately. A "moderate" potential indicates a future release of hazardous constituents to the ground water is likely; although contamination may be present, these MDAs should be placed behind the "moderate to high" potential MDAs in priority. A "low to moderate" potential indicates that the threat to ground water is minimal.

As indicated on Figure 17 and Plate 16, 16 of the 24 MDAs at LANL are considered to have a "moderate to high" potential for release for ground water. Of the 8 remaining MDAs, 3 have been ranked as "moderate," and only 5 have been ranked as "low to moderate."

C. Miscellaneous Potential Release Sites

This section describes the PRSs which have affected each canyon on the Pajarito plateau. This information is based on LANL's SWMU Reports. The only PRSs considered for this section are those which managed [solid] hazardous, radioactive, or mixed wastes. Of these PRSs, only three different categories of SWMUs are discussed in this section of the report: (1) SWMUs that release or have released liquid wastes into a canyon; (2) SWMUs that have managed or are managing wastes on a canyon floor; and (3) SWMUs that have wastes which fell, spilled, or washed over a canyon rim. This compilation of SWMUs is considered to be a conservative estimate of the number of PRSs affecting each canyon.

This report will refer to ground water triggers when analytical data evaluation is discussed. Triggers are defined as a MCL, a WQCC standard, or a LANL screening action level (the lowest of the three values) for non-radiological contaminants and the DOE's



Potential Release Sites

Explanation

- Boundary, LANL
- Drainage
- Material Disposal Area
- Potential Release Site

Red Text: High to moderate potential for release to groundwater
Blue Text: Moderate potential for release to groundwater
Green Text: Low to moderate potential for release to groundwater

FIGURE 17

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
1 inch = 10000 feet

METERS

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 1968. Other boundary, structure, and utility data are from Los Alamos National Laboratory Engineering Division and Los Alamos County Utility and Engineering Departments. Contour data are from Los Alamos National Laboratory Environmental Restoration Project aerial survey, September 1991.

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Date: May 22, 1996 FIMAD Plot ID: G104300

derived concentration guide for public dose for radiological contaminants. The exceptions are the standards for gross beta, gross alpha, tritium, and strontium-90 which are MCLs.

Guaje Canyon

The G-series wells have concentrations of lead and vanadium within an order of magnitude of the lowest ground-water trigger. Well G-4 has had a sample in which a very low level of plutonium-239 was detected. According to the SWMU Reports, no SWMUs have directly discharged or spilled hazardous constituents into this canyon.

Rendija Canyon

Rendija Canyon has been affected by at least two mortar impact/firing sites. These sites could potentially have contamination resulting from buried shell residuals. No information on ground water contamination is available at this time; although it is suspected that surface transport processes may impact second or third generation drainage systems which might contain ground water.

Pueblo Canyon

Pueblo Canyon has been affected by at least one surface impoundment, two outfalls of laboratory waste, three outfalls of sanitary combined with laboratory wastes, three landfills, and two surface disposal areas.

The canyon's shallow perched "alluvial" and intermediate perched ground water are contaminated with hazardous and radioactive constituents. Based on the information provided in Appendix D, the following hazardous and radioactive constituents occur in the ground water: tritium, plutonium-239, americium-241, chromium, vanadium, lead, beryllium, uranium, cadmium, antimony, and selenium. Several ground-water quality parameters (aluminum, manganese, iron, and nitrates) also exceed WQCC standards in one or more wells.

Acid Canyon

Acid Canyon may be affected by TA-45, a plant which operated from 1951 to 1966 and discharged liquid industrial waste and radionuclide-contaminated waste into the canyon. This canyon could potentially be contaminated by hazardous and radiological constituents. No information on ground water contamination specific to this canyon is currently available.

Los Alamos Canyon

Los Alamos Canyon has been affected by at least one surface impoundment, one outfall of laboratory waste, six outfalls of sanitary combined with laboratory wastes, three landfills, one surface disposal area, one pit, one waste treatment plant, occasional releases from the Omega West reactor, TA-41, and an adjacent soil contamination.

The canyon's shallow perched "alluvial" and intermediate perched ground water are contaminated with hazardous and radioactive constituents. Releases to ground water have been documented beyond the LANL property boundary. Based on the information provided in Appendix D, the following hazardous and radioactive constituents have been found in the canyon: tritium, plutonium-238/239, strontium-90, chromium, vanadium, lead, boron, cobalt, nickel, plus gross beta and gross alpha contamination. The concentrations of these hazardous and radioactive constituents exceed triggers in one or more wells in the LAO series. Americium-241 was also detected within the canyon. Several ground-water quality parameters (aluminum, manganese, iron, nitrates and TDS) also exceed WQCC standards in one or more wells.

DP Canyon

DP Canyon has been affected by at least one pit, two waste treatment plants, and an adjacent contaminated soil site. The canyon's shallow perched "alluvial" ground water is contaminated with hazardous and radioactive constituents.

Based on the information provided in Appendix D, the following hazardous and radioactive constituents have been found in the canyon: strontium-90, benzo[a]anthracene; benzo[a]pyrene; benzo[b]fluoranthene; chrysene; 1,2-dibromo-3-chloropropane; 1,2-dibromoethane; 2,4-dinitrotoluene; 2,6-dinitrotoluene; hexachlorobenzene; 1,2,3[c,d]-indenopyrene; pentachlorophenol; vinyl chloride; gross beta; and tritium. Only gross beta exceeds the MCL in DP spring. Except for tritium, all of the hazardous and radioactive constituents listed above exceed ground water triggers in well LAUZ-1. Manganese and sodium also exceed ground water quality standards in well LAUZ-1.

Bayo Canyon

Bayo Canyon may have been affected by one outfall of sanitary combined with laboratory wastes, one firing/mortar impact site, one open burn area, one surface disposal area, one pit, and one industrial disposal system. This canyon could potentially be contaminated by hazardous organics, hazardous metals, and radiological constituents. No information on ground-water contamination is currently; however, surface transport processes may impact ground water near the confluence of Bayo and Los Alamos Canyon.

Sandia Canyon

Sandia Canyon has been affected by at least two mortar impact/firing/detonation areas, one outfall, and two operational releases to a drainageway leading to the canyon. No information on ground water contamination is currently available due to the absence of monitoring wells.

Sandia Spring, which discharges into lower Sandia Canyon, has had two instances of hazardous constituents detected equal to or slightly above ground water triggers. A sample taken in 1987 had a mercury concentration of 0.002 ppm, equal to the MCL, while a sample taken in 1990 had a lead concentration of 0.0195 ppm, exceeding the MCL of 0.015 ppm. Sandia Spring has also had two instances of manganese detected within one order of magnitude of the WQCC standards. Sandia Spring is categorized as a "suspected release to ground water" until an adequate background study verifies whether these elevated mercury and lead concentrations are naturally occurring (see further discussion in the Releases to Ground Water section of this report).

Mortandad Canyon

Mortandad Canyon has been affected by at least two surface impoundments, one firing/mortar impact site, one outfall of laboratory waste, one outfall of sanitary combined with laboratory wastes, and one soil contamination site in a natural drainage to the canyon.

Shallow perched "alluvial" ground water associated with this canyon is contaminated. Based on the information provided in Appendix D, the following hazardous and radioactive constituents have been found in the canyon: tritium, plutonium-238/239, americium-241, strontium-90, cesium-137, chromium, vanadium, lead, beryllium, selenium, plus gross beta and gross alpha. The concentrations of these hazardous and radioactive constituents exceed triggers in one or more wells in the MCO series. Several ground-water quality parameters (aluminum, manganese, fluorine, iron, nitrates and TDS) also exceed WQCC standards in one or more wells.

Ten Site Canyon

At least eight outfalls have discharged into Ten Site Canyon from operations at TA-50 and TA-35. Soil contamination areas also contribute to the contamination found within this canyon. According to the SWMU Reports, semi-volatile organic compounds, polychlorinated biphenols (**PCBs**), metals, and gamma emitters have been detected in sediment in this canyon. No information on ground-water contamination is currently available; however; surface transport processes may impact ground water near the confluence of Ten-Site and Mortandad Canyons.

Cañada del Buey

Cañada del Buey may have been affected by one surface impoundment, eight outfalls of laboratory waste, one outfall of sanitary combined with laboratory wastes, one operational release, one surface disposal, and one caisson.

This area's shallow perched "alluvial" ground water is suspected to be contaminated. Based on the information provided in Appendix D, the following hazardous constituents have been found in the canyon: lead, arsenic, barium, and beryllium. These hazardous constituents were identified in concentrations barely above triggers; however, until an adequate background study verifies if these elevated concentrations are naturally occurring, these data indicate that suspected releases to ground water have occurred (see further discussion in the Releases to Ground Water section of this report).

Pajarito Canyon

Pajarito Canyon may have been affected by one surface impoundment, four outfalls of laboratory waste, eight outfalls of sanitary combined with laboratory wastes, four firing sites/mortar impact sites, one above-ground storage tank, and nine other units of various types (pipes, underground storage tanks, soil contamination) located on the canyon floor.

Mid-Pajarito Canyon's shallow perched "alluvial" ground water has shown contamination. Based on the information provided in Appendix D, the following hazardous and radioactive constituents have been detected: 2,2-dinitrotoluene, gross beta, gross alpha, chromium, lead, barium, and cobalt. The concentrations of these hazardous and radioactive constituents exceed triggers in one or more wells in the PCO series. Several ground-water quality parameters (aluminum, manganese, iron, nitrates and TDS) also exceed WQCC standards in one or more of these wells. Concentrations above the EPA health advisory limits (20 ppm) were identified for sodium.

Within upper Pajarito Canyon, perched ground water within the Tshirege Member of the Bandelier Tuff has shown contamination. Both Homestead and Starmer's Spring have had aluminum detected above WQCC standards. Perkins Spring had a nitrate measurement above the standard. Starmer's Spring also had 2,2-dinitrotoluene measurement above ground-water triggers.

Threemile Canyon

Threemile Canyon may have been affected by one outfall of sanitary combined with laboratory wastes and four cooling water/storm drains. This canyon could potentially be contaminated by hazardous organics, hazardous metals, and radiological constituents. High explosives have been detected within Threemile Spring (NMED, December 6, 1995).

Water Canyon

Water Canyon may have been affected by one outfall of sanitary combined with laboratory wastes and thirteen industrial/storm drains. This canyon could potentially be contaminated by hazardous organics, hazardous metals, and radiological constituents.

Water Canyon Gallery Spring has had two instances of tritium detected in its sampling history. According to the 1991 Environmental Surveillance Report, Water Canyon Gallery Spring yielded a tritium sample measuring 1,000 pCi/L. Lead within Water Canyon Gallery Spring has been detected at the MCL (0.015 ppm). One sampling event detected several ground-water quality parameters (aluminum and fluorine) above WQCC standards.

Cañon de Valle

Cañon de Valle may have been affected by one landfill, one outfall, and two material disposal areas. This canyon could potentially be contaminated by hazardous and radiological constituents. Both SWSC Line Spring and Burning Ground Spring have had instances of trichloroethene detected below triggers and perchloroethene detected above WQCC standards (see Appendices D1 and D2).

Potrillo Canyon

Potrillo Canyon may have been affected by one outfall of laboratory waste, two outfalls of sanitary combined with laboratory wastes, and one material disposal area. This canyon could potentially be contaminated by hazardous organics, hazardous metals, and radiological constituents. No information on ground-water contamination specific to this canyon is currently available.

Fence Canyon

Fence Canyon may have been affected by an area of soil contamination resulting from firing range activities. This canyon could potentially be contaminated by hazardous and radiological constituents. No information on ground water contamination specific to this canyon is currently available.

Ancho Canyon

Ancho Canyon may have been affected by at least one outfall, one outfall of sanitary combined with laboratory wastes, two firing/mortar impact sites, one surface disposal area, one material disposal area, and two container storage areas on the canyon floor.

Appendix D references only one ground-water sampling point, Ancho Spring, for Ancho Canyon. Based on information in Appendix D, this canyon's ground water may be contaminated. Ancho Spring has had a vanadium concentration above ground-water triggers. Americium-241 has also been detected in Ancho Spring. Until an adequate background study verifies if these elevated concentrations are naturally occurring, these data indicate that suspected releases to ground water have occurred (see further discussion in Appendix D. Releases to Ground Water).

Chaquehui Canyon

Chaquehui Canyon may have been affected by at least one outfall of sanitary mixed with laboratory wastes, one landfill, and one outfall. Only three ground-water sampling points might be related to Chaquehui Canyon: Springs 9 and 9A and Doe Spring.

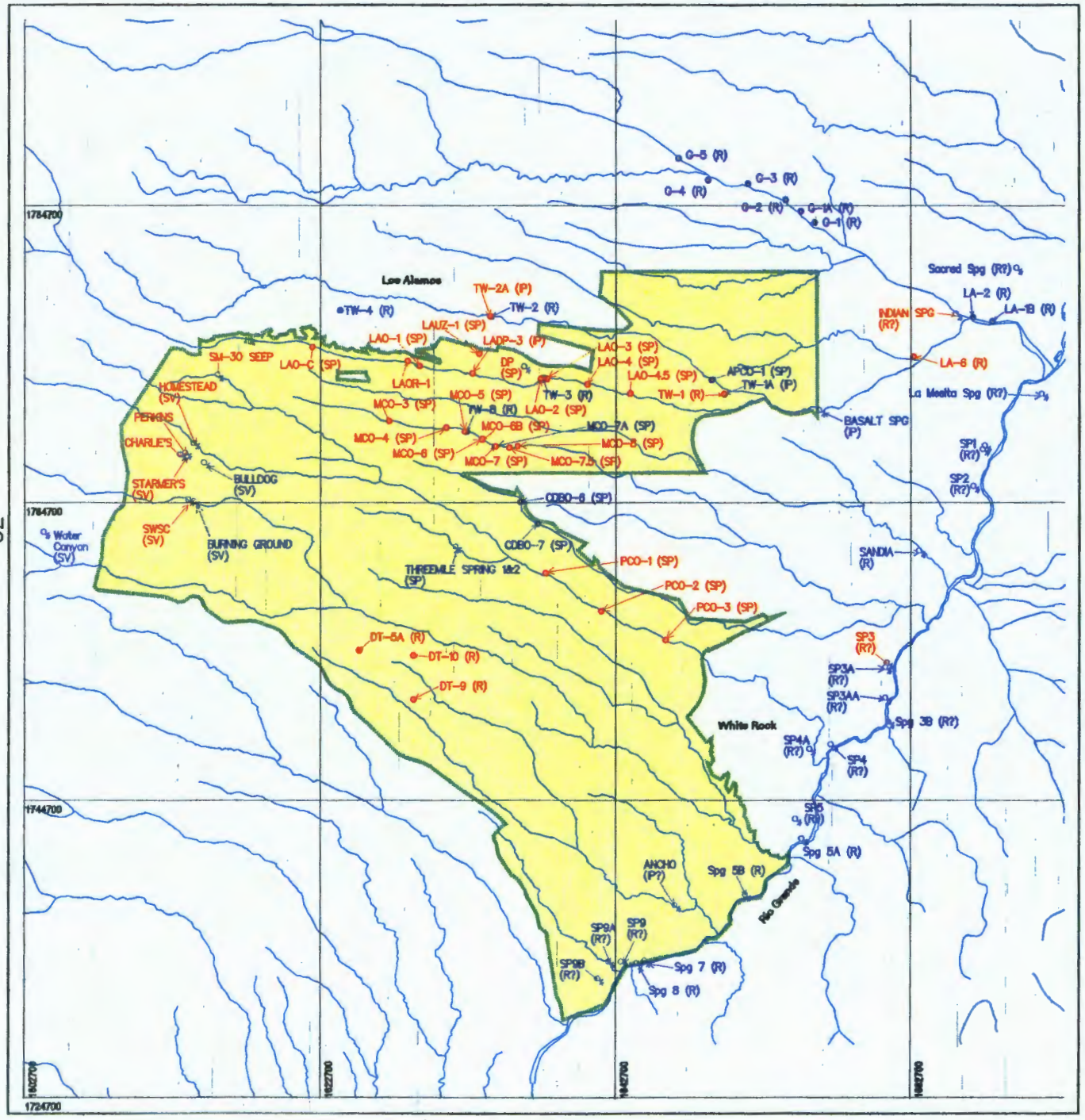
Spring 9A has had one lead measurement above ground-water triggers. Spring 9 has had one mercury measurement equal to the MCL. Springs 9 and 9A are categorized as "suspected releases to ground water" until an adequate background study verifies if the elevated lead and mercury concentrations are naturally occurring (see discussion in Appendix D. Releases to Ground Water).

D. Releases to Ground Water

1. Releases to Ground Water Map

Figure 18 and Plate 17 show known and suspected releases to ground water for LANL ground-water ES stations, regardless of time. ES stations that had at any time detected radioactive or hazardous constituents equal to or above an acceptable regulatory standard or showed suspect water quality data are indicated on the Figure 18 and Plate 17. This map provides a plateau-wide perspective of contaminant problems which may exist. Surface water releases, which were not included in this report, are identified as a data gap.

Each sampling location is color coded to indicate the type of data used (i.e. known versus suspected detection of hazardous or radiological constituents or water quality parameters). Locations marked in an orange/red color, indicate a hazardous or radioactive constituent concentration detected above a regulatory standard (except for inorganics, see below).



Known and Suspected Releases to Ground Water

Explanation

- Boundary, LANL
- Drainage
- Spring
- Known intercept of releases to ground water
- Suspected intercept of releases to ground water or questionable water quality data

(R) Regional "Main" Aquifer
(IP) Intermediate Perched Ground Water
(SV) Perched Ground Water - Tschicoma Formation and Tshirege Member
(SP) Shallow Perched "Alluvial" Ground Water

FIGURE 18

The data set used to develop this map maybe incomplete. NMED is currently unable to verify quality of the available data. The data on this map represent locations at which known or suspected releases to ground water have occurred at one or more times.

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: 20000
1 inch = 10000 feet

METERS

FEET

NOTICE: The information on this map is provisional. Feature locations are dependent on scale and cartography and their accuracy may not have been verified. Los Alamos National Laboratory boundary is based on legal description established in 1990. Other boundary, structure, and utility data are from Los Alamos National Laboratory Engineering Division and Los Alamos County Utility and Engineering Departments. Contour data are from Los Alamos National Laboratory Environmental Restoration Project aerial survey, September 1991.

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Locations with tritium concentrations above 300 pCi/L in any discrete sample are also color-coded orange/red (see justification below). Locations marked in blue, indicate a suspected release, which may fall into one or more of the following categories: (1) a tritium concentration between 10 and 300 pCi/L, (2) suspicious ground-water quality parameters, or (3) inorganic concentrations up to one order of magnitude above the standard. "Standards" for allowable concentrations came from a variety of sources: EPA proposed and promulgated MCLs, the maximum allowable concentrations mandated by the WQCC, and the DOE's derived concentration guides for public dose.

Insufficient background ground-water chemistry for each known mode of ground-water occurrence at LANL is a significant limitation. LANL has not completed an adequate background study for water chemistry as required within the HSWA module; therefore, it is uncertain whether elevated concentrations of inorganics found within the various modes of ground water at LANL are naturally occurring or anthropogenetic. It is difficult to determine if a metal concentration or non-hazardous constituent is the result of anthropogenic influence when the naturally occurring metal concentrations are not known. As a result, some locations are included on the ground-water release map (marked in blue) because these concentrations were not able to be classified as naturally occurring.

Figure 18 and Plate 17 show at least three groupings of known releases to ground water. Los Alamos, Mortandad, and Pajarito Canyons, as evinced from this map, should be the primary areas of focus for further investigation. Additionally, NMED considers those points indicated in red as high priority investigation sites.

a. Justification for Known and Suspected Release Criteria

The MCL for tritium is 20,000 pCi/L, which is much higher than the criterion used to determine a tritium "hit" (anything higher than 300 pCi/L) on the release to ground water map. Ground water containing tritium significantly above present background levels in precipitation clearly indicates young ground water, anthropogenic impacts, or contamination. The tritium content of precipitation occurring at LANL ranges from 65 to 325 pCi/L. The background tritium values for the main aquifer are less than or equal to 1.6 pCi/L. The background values from the shallow saturated zones at LANL range from 16 to 65 pCi/L (see shallow perched ground water section). For the purposes of this report, 300 pCi/L was chosen as the cutoff for a tritium "hit." NMED acknowledges this does not violate the MCL, but it indicates a strong likelihood of anthropogenic influence on the ground water at a particular location. Any ground-water samples yielding tritium concentrations between 10 to 300 pCi/L indicates that surface communication or anthropogenic influence exists.

VI. SUMMARY OF FINDINGS

A. Modes of Ground Water Occurrence

Previously, LANL recognized and integrated three modes of ground water occurrence into their conceptual ground water model:

1) Shallow perched ground water occurs within reaches of certain canyon bottoms across the Plateau. The lateral extent of these zones of saturation is limited to the confines of the canyon bottoms, and does not extend beneath the mesa tops. The location of these zones of saturation within a particular reach of a canyon is influenced by: the amount of recharge available; the current storage within a particular reach; the canyon morphology; grain size, thickness, and stratigraphy of the geologic materials present within the canyon bottoms; and possibly the presence of zones of high density fractures within the perching strata or fault zones.

2) Intermediate perched ground water appears to be co-located with alluvial ground-water systems. These intermediate perched zones occur directly below the canyon bottoms within the western and central portions of the plateau. Consequently, the horizontal extent of a perched zone across a canyon transect remains close within the confines of the canyon walls and does not extend any appreciable distance beneath the mesa tops. Within the central and eastern portions of the plateau, ground water movement may be influenced by paleodrainages intersecting the zone of saturation. Vertical separation between shallow perched and intermediate perched ground water averages approximately 250 feet.

3) The general direction of ground-water flow within the regional "main" aquifer is eastwardly toward the Rio Grande. Depth to the regional aquifer varies across the Pajarito Plateau from the western to eastern portions of the plateau (1,100 feet to near zero feet below ground level) and from the canyon bottoms to the mesa tops. Vertical separation between the regional aquifer and perched ground water systems also varies from the western to eastern portions of the plateau (800 feet to suspected hydraulic connection). The vertical separation between the regional aquifer and the shallow perched ground water near the Rio Grande may be negligible.

This report recognizes an additional mode of ground water occurrence: the perched water within volcanics along the western portion of the Plateau. Significant releases to this mode of ground water occurrence have been detected (see Modes of Ground-Water Occurrence, 1. Perched Ground Water within Volcanic Rocks).

Perched ground water within the dacitic flows of the Tschicoma Formation of the western Pajarito Plateau may occur similarly as perched water within the Tshirege Member of the Bandelier Tuff. Perched ground water within the Tschicoma Formation typically discharges at

higher elevations than the Tshirege Member perched ground water (8,200 feet versus 7,400 feet). Preferential flow of recent water through fractures (cooling and tectonic) and higher permeability zones (e.g., surge beds and unit contacts) probably dominates the flow patterns of this generalized type of ground-water occurrence.

B. Paleotopographic Observations

Similar topographic features are observed among various paleotopographic surfaces. In general, the drainage pattern development of the Pajarito Plateau has shifted over time from the south-southeast to the present day east-southeast trends. One dominant drainage system appears recurrent among the various contoured paleotopographic surfaces. The dominant paleodrainage cross cuts present-day mesa tops connecting present day separate canyon systems. Drill holes which may intersect this dominant paleodrainage are sparse and in most cases do not intercept multiple geologic horizons.

Two co-located sets of paleodrainages appear on the various contoured maps: one drainage near the present-day confluence of Pajarito and Threemile Canyons and the other between Sandia and Mortandad Canyons near TW-8. Also, a common paleotopographic high near the present day vicinity of Pajarito Canyon to White Rock has been gradually leveled and incised.

Data points used to construct all maps within this report use information from many drill holes over a 40 year span. The apparent consistency among the maps suggests a definite, but unquantified, degree of confidence in the data.

C. Occurrence of Ground Water and Paleodrainages

A tentative correlation exists between the occurrence of paleodrainages and one or more modes of ground water at LANL. The presence of paleodrainages and/or fracture-fault zones may greatly influence the movement of ground water within the upper portion of the regional aquifer. As noted above in the Pre-Bandelier Section, similar patterns between paleotopographic surfaces and the surface of the regional aquifer may exist near the Sigma Mesa and PM-3 area.

As mentioned above, the co-located paleodrainages among the various paleosurfaces contoured are evident at PM-2. The correlation of paleodrainages with the occurrence of the intermediate perched ground water at PM-2 warrants further investigation. At PM-1, intermediate perched ground water occurs approximately 100 feet below the pre-Bandelier surface in Sandia Canyon. PM-1 is in a paleotopograhic low, although data lacks to determine if this feature is equivalent to a paleodrainage.

D. Co-location of Shallow and Intermediate Perched Ground Water

Data from wells suggest a co-location of the shallow perched ground water systems with the intermediate perched ground water toward the western and central portions of the plateau. In general, intermediate perched ground water occurs directly beneath canyon bottoms with alluvial ground-water systems.

E. Nature of White Rock Canyon Springs

Contrary to LANL's conceptual model, NMED suspects White Rock Canyon Springs may represent discharge points for both the regional aquifer and intermediate perched ground water.

F. Radius of Influence from Production Wells

Scoping calculations for the regional aquifer indicate that an approximate two-mile radius of influence may exist from production wells across the plateau. The impact to the direction of ground-water flow within the regional aquifer beneath several MDAs and RCRA-regulated units may not be, as first presumed, to be downgradient. This lack of information concerning cones of depression and their potential influence on the ground-water system is of utmost importance to selecting monitoring well sites for long-term detection. For PRSs left in place as a remedial alternative, regulatory compliance, including detection monitoring, will require an understanding of pumping effects within the uppermost sections of the regional aquifer.

G. PRS Potential for Release to Ground Water

Numerous RCRA units have a high potential for release to ground water. For those units which will remain in place as result of a remedial alternative decision, long term detection monitoring will be necessary.

H. Known and Suspected Releases to Ground Water

As identified from the data indicating releases to ground water, three broad areas of ground-water contamination exist. Work currently conducted under the Pueblo/Los Alamos Canyons RFIs will better define the nature, rate, and extent of contamination within one of the three

broad areas of contamination. Additional work must focus on those areas which are contaminated. Figure 16 and Plate 15 (RCRA units) and Figure 17 and Plate 16 (MDAs) potential for release to ground water were considered for recommending monitoring well locations.

VII. LANL'S CURRENT GROUND-WATER MONITORING SYSTEM

The existing ground-water monitoring system in the Los Alamos area consists of supply wells, test wells, and springs located on site and outside of the LANL boundary (Figure 19). The 1993 Environmental Surveillance report identifies 42 ground-water monitoring wells. Of these, 21 deep wells target the main aquifer, whereas, 19 shallow wells monitor perched water in the alluvium and 2 wells monitor intermediate perched ground water. Of the 21 deep wells, 13 are water-supply wells; the remaining 8 are test wells. The supply wells used for monitoring include 7 in the Guaje Well Field, 5 in the Pajarito Well Field, and 1 in the Otowi Well Field. None of the shallow wells are water-supply wells. In addition to these wells, ground water is also monitored at approximately 33 springs that discharge primarily along the eastern edge of the plateau in White Rock Canyon.

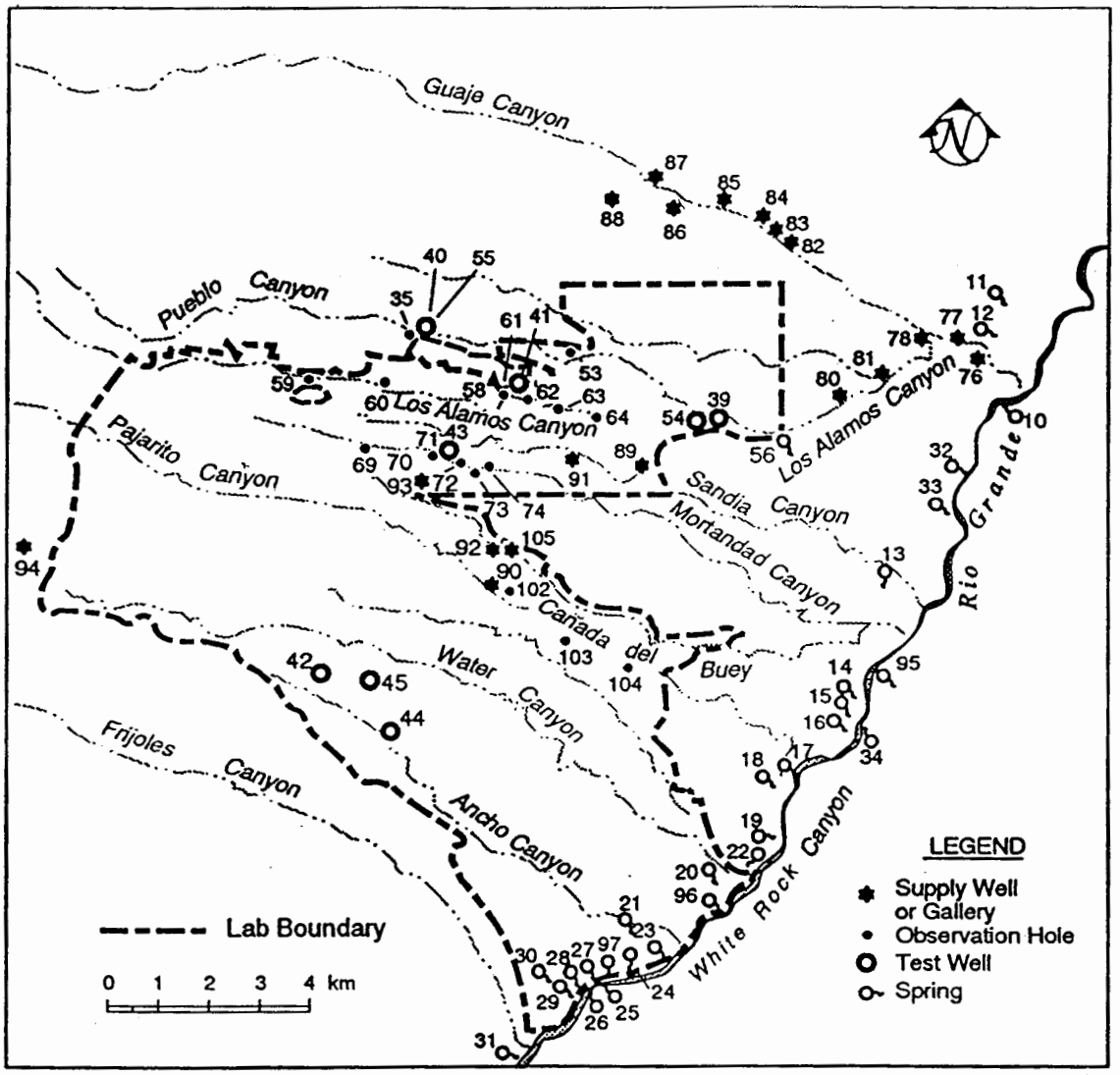
The existing monitoring system was designed for water supply investigations and development and not ground-water monitoring purposes. Due to the lack of monitoring wells in relation to PRSs, the great variation in screened intervals for the existing wells, and for other reasons identified within this report, the current monitoring system does not permit evaluation of the nature and direction of ground water flow and monitoring of the top of the regional aquifer and other modes of ground water occurrence beneath LANL. An adequate ground-water monitoring system, which assesses the potential impacts of LANL operations on the ground water regime and provides an early detection system for remaining PRSs requiring long-term ground-water monitoring, is crucial to protect one of New Mexico's most important resources.

VIII. RECOMMENDATIONS

A. General

LANL must develop a RCRA site-wide hydrogeologic workplan for approval by the administrative authority as part of the RCRA ground-water monitoring requirements of 40 CFR Subpart F and the HSWA Module of LANL's RCRA permit. Whenever possible, ground water monitoring requirements of both RCRA and HSWA should be combined to: improve understanding of site-wide hydrogeology at LANL to adequately determine the effect of past, current, and future laboratory operations on the ground-water regime, and to evaluate

FIGURE 19



LANL Ground Water Monitoring Locations (1993).

the impact to human health and the environment sufficient to satisfy regulatory requirements and DOE Orders.

The recommendations provided in this report suggest an approach to designing an adequate ground-water monitoring system and for evaluating the risk to human health and the environment for the ground-water pathway. The recommendations are divided into two subsets: non-intrusive work (spring inventories, trend analysis of water chemistry data, etc.) and intrusive work (monitoring well installation, sampling, etc.).

The non-intrusive recommendations should be addressed within LANL's site-wide hydrogeologic workplan. Existing information should be summarized and methods for closing data gaps should be proposed within the workplan.

As part of the site-wide hydrogeologic workplan, LANL should develop a site-wide GWMP which includes a summary of existing information defining the data gaps. The monitoring wells proposed within the ground water monitoring plan should be justified based on the identified data gaps. Well design and construction should follow the HSWA permit conditions and recommended EPA guidance. A sampling and analysis plan should be submitted with the GWMP and should include a proposed schedule of activities, plus reporting requirements.

NMED recommends a phased approach to the intrusive investigation (installation of monitoring wells), and estimates that at least three phases of monitoring well installation will be necessary to meet the requirements of RCRA site-specific and HSWA site-wide characterization. The dynamics of the hydrogeologic system of the Pajarito Plateau are not well understood; therefore, as the installation of monitoring wells proceeds, hydrogeologic information gained may guide the siting of subsequent ground water monitoring wells.

Table 5 represents a prioritized listing of recommended ground water monitoring wells for the initial phase of investigation. NMED's recommendations presented in this report should not be construed as final decisions regarding RCRA ground-water monitoring requirements at RCRA-regulated units.

B. Non-Intrusive Work

The following non-intrusive work recommendations should be addressed within LANL's site-wide hydrogeologic workplan:

- LANL should develop a comprehensive "penetration" map which includes all holes greater than one foot in depth across the Pajarito Plateau. Detailed information regarding diameter, total depth, date drilled, drilling method, completion records, etc. should be compiled.

- LANL should conduct a complete review of all well logs (e.g. geologic, well drillers', geophysical, etc.) and assign a level of confidence, including qualifiers, to the data for all geologic horizons of interest.

- LANL should construct structure contour maps (with an emphasis on identifying paleodrainages) of the following geologic horizons: Totavi Formation; pre-Bandelier; Guaje Pumice Bed; Otowi Member; and Tsankawi Pumice Bed. Appropriate isopach maps should also be constructed.

- LANL should compile all available water-level data (transducer data) for each mode of ground water occurrence and compare measurements to determine seasonal trends.

- LANL should submit to NMED a proposal to develop and implement (minimum of a two-year period) a quarterly water-level monitoring program within the workplan. Each quarterly data set should contain precise water-level measurements from wells within a hour time period. Water-level measurements should be provided as uncorrected data. Corrections made for atmospheric or barometric fluctuations should be provided as an additional data set. After two years, the objectives of the program should be re-evaluated.

- LANL should conduct a comprehensive plateau-wide spring inventory. At a minimum, the following data should be obtained for each spring: location (description, coordinates, and elevation); geologic units; flow rate; parameter indicators (temperature, pH, and conductivity); and date and time of the observations. This inventory should include the use of aerial photographs (infrared photography and Landsat imagery), and direct field observations (canyon walk-throughs) to identify and physically label spring/seep locations. Each individual spring should be monitored quarterly for the first two years to provide seasonal variance data.

- LANL should establish standard operating procedures for designating locations, identifying geologic units from which the spring discharges (above and below), determining flow rate, etc. The data to be collected and collection methodology should be clearly identified within a standard operating procedure.

- LANL should construct a complete plateau-wide geologic map with consistent geologic nomenclature for correlating geologic strata across the plateau. Consistent geologic nomenclature is fundamental in siting the most optimum locations for ground-water monitoring wells. This comprehensive geologic map should also include the identification of faults and high density fracture areas. Cross sections through all canyon bottoms and on a plateau-wide basis should also be constructed at a scale useful for siting ground-water monitoring wells.

- LANL should evaluate available water chemistry data to assess its validity prior to entering it into FIMAD. LANL should perform trend analyses of validated water chemistry data. The following analyses should be conducted on a plateau-wide basis: a

comparison of ES stations within specific canyons and within specific modes of ground-water occurrence; a comparison of similar water chemistry regimes; a comparison of wells with common screen intervals; and a comparison of wells within common stratigraphic horizons. Temporal considerations should be made.

- LANL should develop and implement a background water chemistry program for the individual modes of ground-water occurrence. Numerous inorganic constituents have been detected above MCLs; however, it is unknown if the observed concentrations represent background conditions or an actual release to ground water. The water chemistry background proposal should be included within the workplan.

- LANL should contour the tops of the various modes of ground-water occurrence: shallow perched "alluvial" systems, intermediate perched ground water, perched water within the volcanics, and the regional "main" aquifer. Saturated hydrogeologic units should be identified from the shallow perched ground water to the top of the regional aquifer as these units are commonly different than the stratigraphic units. This information can be utilized to identify the uppermost aquifer beneath RCRA-regulated units and address the ground-water monitoring requirements under 40 CFR Part 264/265, Subpart F and HSWA (Task III, 1.a and d) requirements.

- LANL should construct a geologic map of the top of the regional aquifer and include a proposal within the workplan to conduct stream loss and gain studies to determine the nature of stream flow within various reaches of canyons on a plateau-wide basis. Maps should be developed showing perennial and ephemeral reaches defined from the above stream loss/gain studies.

- LANL should summarize or determine the following aquifer characteristics for the various modes of ground water occurrence: transmissivity, hydraulic conductivity, hydraulic gradient, storativity, and the radii-of-effect or cones of depression resulting from production wells. The radii of effect should be depicted on all water-level contour maps of the regional aquifer. A proposal to determine aquifer characteristics should be included within the workplan which summarizes existing information.

- LANL should develop a hydrodynamic system table summarizing the current conceptual model. This table should be included within the workplan and updated within the bi-annual reports. LANL should develop a table of pressure potentials associated with the regional aquifer. This information can be integrated with current water-level data to gain an understanding of the nature of the regional aquifer and the other zones of saturation. Although not conclusive, water level data obtained under specific conditions may be used to infer hydraulic connection. Ground water flow nets should be developed and integrated into LANL's conceptual model. The use of image wells may be appropriate to further update the conceptual model.

- As implementation of the workplan proceeds, LANL should integrate the following elements into the conceptual model:

    - geological map
    - PRS map
    - known and suspected releases to ground water map
    - fault-high fracture density zone map
    - spring discharge map
    - perched water within the volcanics contour-extent map
    - shallow perched alluvial aquifer
    - structure contour of the top of the Tsankawi Pumice Bed
    - structure contour of the top of the Otowi Member
    - structure contour of the top of the Guaje Pumice Bed
    - intermediate perched ground water extent map
    - structure contour of the pre-Bandelier
    - structure contour of the top of the Totavi Formation
    - contour map overlain with the geology of the top of the regional aquifer
    - water-level contour map of top of regional aquifer including radii-of-effect
    - ground-water flow regimes as indicated by water chemistry (Stiff, Piper diagrams, etc.) for each mode of ground-water occurrence

C. Intrusive Work

Table 5, Figure 20, and Plate 18 detail well locations and rationales based on the following considerations: ground-water release data, the need to provide or collect additional data, the known occurrences of various modes of ground water, other pathway concerns (such as known areas of intensive fracturing and faulting), geologic outcropping of higher permeability geologic materials (Cerro Toledo Interval) within canyon bottoms, the locations of PRSs with high potentials for release to the ground water, aquifer characteristics as understood today, and the presence of paleodrainages.

Table 5 provides a prioritization of ground-water monitoring well installations based on a combination of the following factors: 1) concentrations of hazardous constituents detected in ground water (primary driver); 2) proximity to SWMUs which rank high for potential for release to ground water; 3) number of SWMUs which rank high for potential for release to ground water in the general vicinity of the zone of saturation to be monitored; 4) the need for long-term ground water detection monitoring at a HSWA/RCRA unit; and 5) additional site-wide characterization issues (e.g. delineation of various modes of ground water occurrence, recharge/discharge determination for various modes of ground water occurrence, parameters needed for ground water modeling and contaminant transport models, etc.).

Recommendations for monitoring well placement do not reflect background wells, which should be included in the phase 1 installation as determined from the approved water chemistry background proposal to be submitted in the Workplan. As mentioned above, site-wide characterization of fault zones, with respect to potential pathways for aqueous migration, is not complete. Background monitoring wells proposed within the workplan should also investigate known and suspected fault zones at discrete screened intervals. Characterization of potential contaminant pathways, as well as fault-fracture zone delineation and hydraulic head data, will be facilitated by the installation of background monitoring wells.

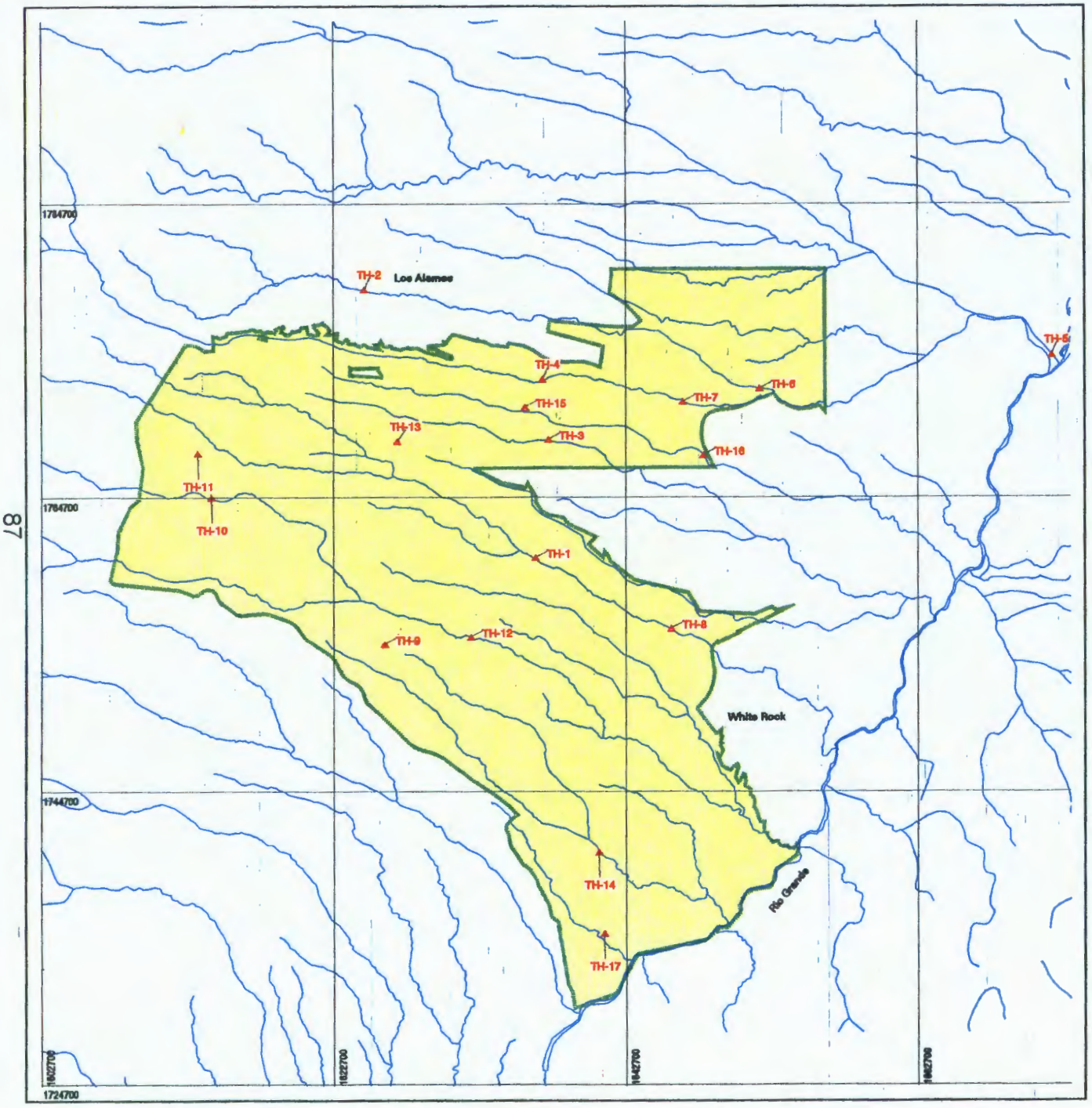
Reference to the individual mode of ground water occurrence recommended for drilling is made by the following notation: (R) Regional "Main" Aquifer; (IP) Intermediate Perched Ground Water; (SV) Perched Ground Water - Tschicoma Formation and Tshirege Member; and (SP) Shallow Perched "Alluvial" Ground Water.

Table 5 Intrusive Recommendations

TEST HOLE NUMBER	CANYON LOCATION	RATIONALE	GROUND WATER MODE
TH-1	Near the confluence of Threemile and Pajarito Canyons	Investigate known releases to shallow perched "alluvial" ground water within mid-Pajarito Canyon; monitor for potential releases from TA-18 and TA-54 HSWA/RCRA sites to shallow perched "alluvial" ground water; begin to investigate radius of influence from production well PM-2; aid in determining the optimum long-term monitoring well placement for TA-54 SWMUs which will be capped in place with in-situ stabilization as a remedial alternative; investigate the intermediate perched zone of saturation encountered at PM-2 as required within the HSWA Module; and monitor the top of the regional aquifer for constituents of concern. Clustered shallow perched "alluvial" ground water monitoring wells are recommended at this location; at least three shallow perched wells should be installed in a transect across Pajarito Canyon.	IP, R, SP
TH-2	Immediately below the confluence of Acid and Pueblo Canyons	Investigate potential releases to ground water from the HSWA Acid Canyon outfall; investigate water chemistry concerns and suspected releases of hazardous constituents to the regional aquifer as detected at TW-4; and investigate the down-thrown block of the Rendija Fault Segment.	IP, R, SP
TH-3	Mortandad Canyon near MCO-8	Investigate extent of saturation within shallow perched "alluvial" ground water in Mortandad Canyon; monitor for potential releases from TA-50, TA-35, TA-55, TA-48, TA-60, TA-5, and TA-52 HSWA/RCRA sites to the regional aquifer and potentially to shallow perched "alluvial" ground water; monitor effluent from mid-Mortandad Canyon; investigate the existence of intermediate perched ground water; begin to investigate effects of multiple cones of depression suspected from PM-series water supply wells; aid in determining optimum long-term monitoring well placement for TA-50 SWMUs which will be capped in place with in-situ stabilization as a remedial alternative; and monitor ground water at the top of the regional aquifer for constituents of concern near the laboratory boundary.	IP, R, SP
TH-4	Los Alamos Canyon immediately west of Otowi-4	Investigate known releases to shallow perched "alluvial" ground water within Los Alamos Canyon; monitor for potential releases from TA-41, TA-2, TA-01, TA-10, TA-21 HSWA sites to shallow perched "alluvial" ground water; investigate the intermediate perched zone of saturation encountered at O-4 as required within the HSWA Module; begin to investigate radius of influence from production well O-4; aid in determining optimum long-term monitoring well placement for TA-21 HSWA MDAs which will be capped in place with in-situ stabilization as a remedial alternative; and monitor the top of the regional aquifer for constituents of concern. Clustered shallow perched "alluvial" ground water monitoring wells are recommended at this location; at least three shallow perched wells should be installed in a transect across Los Alamos Canyon.	IP, R, SP
TH-5	Los Alamos Canyon near Otowi Bridge	Investigate known and suspected ground water releases detected within the regional aquifer in lower Los Alamos Canyon; investigate the existence of intermediate perched ground water; investigate the hydraulic connection between shallow perched, intermediate perched and regional aquifer ground water; monitor for constituents of concern which may be entering the Rio Grande through the ground water regime. Clustered shallow perched "alluvial" ground water monitoring wells are recommended at this location; at least three shallow perched wells should be installed in a transect across Los Alamos Canyon.	IP,R, SP

Table 5 Intrusive Recommendations			
TEST HOLE NUMBER	**CANYON LOCATION**	**RATIONALE**	**GROUND WATER MODE**
TH-6	Pueblo Canyon near TW-1	Investigate known and suspected releases to shallow perched "alluvial", intermediate perched, and regional aquifer ground water within lower Pueblo Canyon; monitor the various modes of ground water occurrence for constituents of concern near the LANL boundary. HSWA SWMUs/AOC associated with this recommended location may be described as noted in an ES Report (1992): "Most of the residual radioactivity from these historical releases is now associated with the sediments in Pueblo Canyon with an estimated total inventory of about 600 mCi of plutonium (LANL May 1981). About two-thirds (400 mCi) of this total are in the DOE-owned portion of lower Pueblo Canyon." This would suggest that additional source areas due to accumulation of sediments down-canyon need to be considered. Concentrations of constituents of concern may increase down-canyon as a result of potential "secondary" source areas. If these sediments are viewed as source areas, then it can be assumed that concentrations of constituents may increase in ground water in what might otherwise be perceived as down-canyon (downgradient) from "primary"potential source areas. Clustered shallow perched "alluvial" ground water monitoring wells are recommended at this location; at least three shallow perched wells should be installed in a transect across Pueblo Canyon.	IP, R, SP
TH-7	Los Alamos Canyon east of LAO-6	Investigate known and suspected releases to shallow perched "alluvial" ground water; investigate extent of saturation within the shallow perched "alluvial" ground water in mid-Los Alamos Canyon; investigate the extent of intermediate perched ground water within mid-Los Alamos Canyon; begin to investigate effects of multiple cones of depression suspected from O-4 and PM-series water supply wells; monitor the various modes of ground water occurrence for constituents of concern near the laboratory boundary (see TH-4 description for associated listing of HSWA sites to be monitored); possibly monitor for potential releases to ground water from RCRA units at TA-53.	IP, R, SP
TH-8	Pajarito Canyon	Investigate known and suspected releases to shallow perched "alluvial" ground water in mid-Pajarito Canyon; monitor for potential releases from TA-18 and TA-54 HSWA/RCRA sites to shallow perched "alluvial" ground water; begin to investigate radius of influence from production well PM-2; aid in determining optimum long-term monitoring well placement for TA-54 RCRA units which will require ground water monitoring under 40 CFR Part 264 Subpart F and HSWA SWMUs which will be capped in place with in-situ stabilization as a remedial alternative; investigate the intermediate perched zone of saturation encountered at PM-2 as required within the HSWA Module; and monitor the top of the regional aquifer for constituents of concern near the laboratory boundary. Clustered shallow perched "alluvial" ground water monitoring wells are recommended at this location; at least three shallow perched wells should be installed in a transect across Pajarito Canyon.	IP, R, SP
TH-9	Near TA-49	Investigate known and suspected releases to the regional "main" aquifer and aid in determining optimum long-term monitoring well placement for TA-49 HSWA MDAs which will be capped in place with in-situ stabilization as a remedial alternative.	R

Table 5 Intrusive Recommendations			
TEST HOLE NUMBER	**CANYON LOCATION**	**RATIONALE**	**GROUND WATER MODE**
TH-10	Near MDA-R	Investigate known and suspected releases to ground water within volcanics in Cañon de Valle; monitor for potential releases from TA-16 HSWA sites to shallow perched "alluvial" ground water; aid in determining optimum long-term monitoring well placement for TA-16 HSWA MDAs which will be capped in place with in-situ stabilization as a remedial alternative; and investigate the existence of intermediate perched ground water as suggested by SHB-3 data.	IP, SV,SP
TH-11	Near MDA-M	Investigate known and suspected releases to ground water within volcanics in upper Pajarito Canyon; and investigate the existence of intermediate perched ground water dependant upon what hydrogeologic information is obtained from TH-10.	P, SV
TH-12	Water Canyon near TA-36 TA-15 boundary	Investigate optimum long-term monitoring well placements for RCRA high-priority site at TA-15 which will require ground water monitoring under 40 CFR Part 264 Subpart F Monitor RCRA; and monitor for potential releases from TA-16, TA-15, TA-49, and possibly TA-11 HSWA sites to shallow perched "alluvial" ground water, regional aquifer, and possibly intermediate perched ground water.	IP, R, SP
TH-13	Near TA-50 and MDA-C	Investigate optimum long-term monitoring well placements for TA-50 HSWA SWMUs which will be capped in place with in-situ stabilization as a remedial alternative; begin to investigate effects of multiple cones of depression suspected from O-4 and PM-series water supply wells; and monitor ground water at the top of the regional aquifer for constituents of concern.	R
TH-14	Ancho Canyon near TA-39 and the MDAs within the canyon bottom	Monitor for potential releases from TA-39 and possibly TA-49 HSWA sites to various modes of ground water occurrence; and investigate the existence of intermediate perched ground water zone as required within the HSWA Module.	IP, SP, and possibly R
TH-15	Sandia Canyon near the intercept of paleodrainages within the Pre-Bandelier and Guaje Pumice Bed	Investigate extent of saturation within shallow perched "alluvial" ground water in Sandia Canyon; monitor for potential releases from TA-3, TA-61, TA-60, and TA-53 HSWA/RCRA sites to the regional aquifer and potentially to shallow perched "alluvial" ground water; investigate the existence of intermediate perched ground water; begin to investigate effects of multiple cones of depression suspected from O-4 and PM-series water supply wells; and investigate the correlation between the occurrence of ground water and the presence of paleodrainages.	IP, R, SP
TH-16	Sandia Canyon	Investigate the intermediate perched zone of saturation encountered at PM-1 as required within the HSWA Module; begin to investigate some of the issues raised regarding water-level differences observed between PM-3 and PM-1; begin to investigate effects of multiple cones of depression suspected from O-4 and PM-series water supply wells; and monitor the top of the regional aquifer for constituents of concern near the laboratory boundary.	IP, R
TH-17	Chaquehui Canyon	Investigate suspected releases to White Rock Canyon Springs near TA-33; investigate the existence of intermediate perched ground water; and monitor the top of the regional aquifer for constituents of concern near the southern most laboratory boundary.	IP possibly, R



Proposed Monitor Well Locations

Explanation

- Boundary, LANL
- Drainage
- Proposed Monitor Well

FIGURE 20

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
1 inch = 10000 feet

METERS

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 1996. Other boundary, structure, and utility data are from Los Alamos National Laboratory Engineering Division and Los Alamos County Utility and Engineering Departments. Contour data are from Los Alamos National Laboratory Environmental Restoration Project aerial survey, September 1991.

University of California
Los Alamos National Laboratory
Earth and Environmental Sciences Division
FIMAD Facility for Information Management, Analysis, and Display
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APPENDIX A

MODULE VIII OF RCRA OPERATING PERMIT

Module VIII of RCRA Operating Permit

Section P, Task III: Facility Investigation, A. Environmental Setting, 1. Hydrogeology

a. A description of the regional and facility specific geologic and hydrogeologic characteristics affecting groundwater flow beneath the facility;

b. An analysis of any topographic features that might influence the groundwater flow system.

c. An analysis of fractures within the tuff, addressing tectonic trend fractures versus cooling fractures;

d. Based on field data, tests, (gamma and neutron logging of existing and new wells, piezometer and boring) and cores, a representative and accurate classification and description of the hydrogeologic units which may be part of the migration pathways at the facility (i.e., the aquifers and any intervening saturated and unsaturated units);

e. 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:
i) Unconsolidated sand and gravel deposits,

ii) Zones of fracturing or channeling in consolidated or unconsolidated deposits, and

iii) Zones of high permeability or low permeability that might direct and restrict the flow of contaminants;

f. Based on data obtained from groundwater monitoring wells and piezometer installed upgradient and downgradient of the potential contaminant source, a representative description of water level or fluid pressure monitoring;

g. A description of manmade influences that may effect the hydrogeology of the site; and

h. Analysis of available geophysical information and remote sensing information such as infrared photography and Landsat imagery.

APPENDIX B

B1: GUIDE TO DRILL HOLES ON FIGURE 1 (DRILL HOLE PENETRATIONS AT LANL)

B2: STRATIGRAPHIC PICKS FOR SPECIFIC DRILL HOLES

APPENDIX B1

GUIDE TO DRILL HOLES ON FIGURE 1
(DRILL HOLE PENETRATIONS AT LANL)

GUIDE TO DRILL HOLES ON FIGURE 1 (DRILL HOLE PENETRATIONS AT LANL)			
NUMBER	**DRILL HOLE ID**	**DEPTH (ft)**	**GENERAL LOCATION**
1	10M-1	29	TA-49
2	10M-2	20	TA-49
3	1M-1	49	TA-49
4	1M-2	19	TA-49
5	1M-3	19	TA-49
6	1M-3A	49	TA-49
7	2M-1	49	TA-49
8	2M-2	10	TA-49
9	2M-3	19	TA-49
10	3M-1	50	TA-49
11	3M-2	19	TA-49
12	3M-3	20	TA-49
13	4M-1	49	TA-49
14	4M-2	20	TA-49
15	4M-3	19	TA-49
16	4M-4	19	TA-49
17	54-1001	318	TA-54
18	54-1002	310	TA-54
19	54-1003	299	TA-54
20	54-1004	340	TA-54
21	54-1005	291	TA-54
22	54-1006	323	TA-54
23	54-1007	150	TA-54
24	54-1008	150	TA-54
25	54-1009	150	TA-54
26	5M-1	39	TA-49
27	5M-2	19	TA-49

GUIDE TO DRILL HOLES ON FIGURE 1 (DRILL HOLE PENETRATIONS AT LANL)			
NUMBER	**DRILL HOLE ID**	**DEPTH (ft)**	**GENERAL LOCATION**
28	6M-1	19	TA-49
29	9M-1	19	TA-49
30	9M-2	19	TA-49
31	9M-3	19	TA-49
32	9M-4	19	TA-49
33	ALPHA	189	TA-49
34	APCO-1	20	Pueblo Canyon
35	B-1	5	TA-16
36	B-2	4	TA-16
37	B-3	14	TA-16
38	B-4	19	TA-16
39	B-5	12	TA-16
40	BETA	180	TA-49
41	C-1	18	near TA-50
42	C-2	18	near TA-50
43	C-3	18	near TA-50
44	CDBM-1	189	Cañada del Buey and Pajarito Canyon
45	CDBM-2	99	Cañada del Buey and Pajarito Canyon
46	CDBO-1	15	Cañada del Buey and Pajarito Canyon
47	CDBO-2	18	Cañada del Buey and Pajarito Canyon
48	CDBO-3	12	Cañada del Buey and Pajarito Canyon
49	CDBO-4	12	Cañada del Buey and Pajarito Canyon
50	CDBO-5	17.5	Cañada del Buey and Pajarito Canyon
51	CDBO-6	49	Cañada del Buey and Pajarito Canyon
52	CDBO-7	44	Cañada del Buey and Pajarito Canyon
53	CDBO-8	23	Cañada del Buey and Pajarito Canyon
54	CDBO-9	34	Cañada del Buey and Pajarito Canyon

GUIDE TO DRILL HOLES ON FIGURE 1 (DRILL HOLE PENETRATIONS AT LANL)			
NUMBER	**DRILL HOLE ID**	**DEPTH (ft)**	**GENERAL LOCATION**
55	CH-1	501	TA-49
56	CH-2	507	TA-49
57	CH-3	300	TA-49
58	CH-4	303	TA-49
59	DPS-1	NA	Los Alamos Canyon
60	DPS-1	50	TA-21
61	DPS-10	35	TA-21
62	DPS-11	50	TA-21
63	DPS-12	36	TA-21
64	DPS-13	35	TA-21
65	DPS-2	25	TA-21
66	DPS-2	NA	Los Alamos Canyon
67	DPS-3	NA	Los Alamos Canyon
68	DPS-3	50	TA-21
69	DPS-4	25	TA-21
70	DPS-4	NA	Los Alamos Canyon
71	DPS-5	50	TA-21
72	DPS-6	50	TA-21
73	DPS-7	25	TA-21
74	DPS-8	50	TA-21
75	DPS-9	25	TA-21
76	DT-10	1409	TA-49
77	DT-5	962	TA-49
78	DT-5A	1821	TA-49
79	DT-5P	692	TA-49
80	DT-9	1501	TA-49
81	E-1	86	near TA-50

GUIDE TO DRILL HOLES ON FIGURE 1 (DRILL HOLE PENETRATIONS AT LANL)			
NUMBER	**DRILL HOLE ID**	**DEPTH (ft)**	**GENERAL LOCATION**
82	FCO-1	29	Fence Canyon
83	FH-1	450	TA-57 (Fenton Hill)
84	FH-2	450	TA-57 (Fenton Hill)
85	FH-3	460	TA-57 (Fenton Hill)
86	G-1	2020	Guaje Well Field
87	G-1A	2071	Guaje Well Field
88	G-2	2006	Guaje Well Field
89	G-3	1996	Guaje Well Field
90	G-4	2002	Guaje Well Field
91	G-5	1993	Guaje Well Field
92	G-6	2005	Guaje Well Field
93	GAMMA	54	TA-49
94	GT-1	2575	Fenton Hill
95	GT-1	400	Guaje (lower Los Alamos Canyon)
96	GT-2	50	Guaje (lower Los Alamos Canyon)
97	GT-3	475	Guaje (lower Los Alamos Canyon)
98	GT-4	315	Guaje (lower Los Alamos Canyon)
99	GT-5	475	Guaje (lower Los Alamos Canyon)
100	H-1	652	Valle Toledo
101	H-10	589	Valle Grande
102	H-11	630	Valle Grande
103	H-13	800	Valle de los Posos
104	H-14	420	Divide
105	H-15	600	Valle Grande
106	H-16	1269	East Rim of Caldera
107	H-17	493	Valle de los Posos
108	H-19	2000	Pajarito Plateau

GUIDE TO DRILL HOLES ON FIGURE 1 (DRILL HOLE PENETRATIONS AT LANL)			
NUMBER	**DRILL HOLE ID**	**DEPTH (ft)**	**GENERAL LOCATION**
109	H-2	410	Valle Toledo
110	H-3	405	Valle Toledo
111	H-4	285	Valle Toledo
112	H-5	530	Valle Toledo
113	H-6	444	Valle Toledo
114	H-7	1185	Valle Grande
115	H-8	595	Valle Grande
116	H-9	595	Valle Grande
117	I	67	near TA-50
118	I	60	near TA-50
119	I	97	near Area 49
120	L-17	30	TA-16
121	L-18	30	TA-16
122	L-19	30	TA-16
123	L-20	30	TA-16
124	LA-1	1001	Los Alamos Well Field
125	LA-1B	2256	Los Alamos Well Field
126	LA-2	882	Los Alamos Well Field
127	LA-3	910	Los Alamos Well Field
128	LA-4	2019	Los Alamos Well Field
129	LA-5	2024	Los Alamos Well Field
130	LA-6	2030	Los Alamos Well Field
131	LADP-3	349	TA-21
132	LADP-4	800	TA-21
133	LAO-1	32	Los Alamos Canyon
134	LAO-1.2	38	Los Alamos Canyon
135	LAO-1.8	48	Los Alamos Canyon

GUIDE TO DRILL HOLES ON FIGURE 1 (DRILL HOLE PENETRATIONS AT LANL)			
NUMBER	**DRILL HOLE ID**	**DEPTH (ft)**	**GENERAL LOCATION**
136	LAO-2	32	Los Alamos Canyon
137	LAO-3	32	Los Alamos Canyon
138	LAO-3A	18	Los Alamos Canyon
139	LAO-4	31	Los Alamos Canyon
140	LAO-4.5	62	Los Alamos Canyon
141	LAO-4.5A	20	Los Alamos Canyon
142	LAO-4.5B	35	Los Alamos Canyon
143	LAO-4.5C	25	Los Alamos Canyon
144	LAO-5	27	Los Alamos Canyon
145	LAO-6	26	Los Alamos Canyon
146	LAO-6A	15	Los Alamos Canyon
147	LAO-C	14	Los Alamos Canyon
148	LAYNE WESTERN	157	Pajarito Plateau
149	LGC-85-09	120	TA-54
150	LGC-85-10	145	TA-54
151	LGM-85-06	60	TA-54
152	LGM-85-11	120	TA-54
153	LGP-85-07	60	TA-54
154	LLC-85-12	120	TA-54
155	LLC-85-13	120	TA-54
156	LLC-85-14	120	TA-54
157	LLC-85-15	120	TA-54
158	LLC-85-16	120	TA-54
159	LLC-85-17	150	TA-54
160	LLC-85-18	120	TA-54
161	LLC-86-19	201	TA-54
162	LLC-86-20	198	TA-54

GUIDE TO DRILL HOLES ON FIGURE 1 (DRILL HOLE PENETRATIONS AT LANL)			
NUMBER	**DRILL HOLE ID**	**DEPTH (ft)**	**GENERAL LOCATION**
163	LLC-86-21	198	TA-54
164	LLC-86-22	197	TA-54
165	LLC-86-23	199	TA-54
166	LLC-86-24	198	TA-54
167	LLC-86-25	198	TA-54
168	LLC-88-26	198	TA-54
169	LLC-88-27	263	TA-54
170	LLC-88-28	267	TA-54
171	LLC-88-29	298	TA-54
172	LLC-89-30	273	TA-54
173	LLC-89-31	291	TA-54
174	LLC-89-32	171	TA-54
175	LLC-89-33	293	TA-54
176	LLC-90-34	317	TA-54
177	LLC-90-35	351	TA-54
178	LLM-85-01	140	TA-54
179	LLM-85-02	145	TA-54
180	LLM-85-05	145	TA-54
181	LLP-85-03	120	TA-54
182	M-1	40	Bayo Canyon
183	M-2	20	Bayo Canyon
184	M-3	8	Bayo Canyon
185	MCC-8.2	184	Mortandad Canyon
186	MCM-12B	79	Mortandad Canyon
187	MCM-10	67	Mortandad Canyon
188	MCM-10-1	119	Mortandad Canyon
189	MCM-10-2	43	Mortandad Canyon

GUIDE TO DRILL HOLES ON FIGURE 1 (DRILL HOLE PENETRATIONS AT LANL)			
NUMBER	**DRILL HOLE ID**	**DEPTH (ft)**	**GENERAL LOCATION**
190	MCM-10-3A	33	Mortandad Canyon
191	MCM-10-3B	43	Mortandad Canyon
192	MCM-12A	98	Mortandad Canyon
193	MCM-1A	12	Mortandad Canyon
194	MCM-1B	11	Mortandad Canyon
195	MCM-2.2	90	Mortandad Canyon
196	MCM-2.8	60	Mortandad Canyon
197	MCM-2A	11	Mortandad Canyon
198	MCM-2B	1	Mortandad Canyon
199	MCM-3A	13	Mortandad Canyon
200	MCM-3B	10	Mortandad Canyon
201	MCM-4.5	48	Mortandad Canyon
202	MCM-4.8	33	Mortandad Canyon
203	MCM-4A	9	Mortandad Canyon
204	MCM-4B	24	Mortandad Canyon
205	MCM-5.1	112	Mortandad Canyon
206	MCM-5.9A	194	Mortandad Canyon
207	MCM-5A	25	Mortandad Canyon
208	MCM-5B	30	Mortandad Canyon
209	MCM-5C	37	Mortandad Canyon
210	MCM-6.5	95	Mortandad Canyon
211	MCM-6.5A	23	Mortandad Canyon
212	MCM-6A	18	Mortandad Canyon
213	MCM-6B	52	Mortandad Canyon
214	MCM-6C	57	Mortandad Canyon
215	MCM-6D	35	Mortandad Canyon
216	MCM-6E	21	Mortandad Canyon

GUIDE TO DRILL HOLES ON FIGURE 1 (DRILL HOLE PENETRATIONS AT LANL)			
NUMBER	**DRILL HOLE ID**	**DEPTH (ft)**	**GENERAL LOCATION**
217	MCM-7.5	94	Mortandad Canyon
218	MCM-8A	20	Mortandad Canyon
219	MCM-8B	30	Mortandad Canyon
220	MCM-8C	66	Mortandad Canyon
221	MCM-8D	86	Mortandad Canyon
222	MCM-8E	53	Mortandad Canyon
223	MCM-8F	23	Mortandad Canyon
224	MCO-1	8	Mortandad Canyon
225	MCO-11	23	Mortandad Canyon
226	MCO-12	64	Mortandad Canyon
227	MCO-12	112	Mortandad Canyon
228	MCO-13	112	Mortandad Canyon
229	MCO-2	10	Mortandad Canyon
230	MCO-3	18	Mortandad Canyon
231	MCO-4	24	Mortandad Canyon
232	MCO-4A	24	Mortandad Canyon
233	MCO-4B	34	Mortandad Canyon
234	MCO-5	47	Mortandad Canyon
235	MCO-6	82	Mortandad Canyon
236	MCO-6	82	Mortandad Canyon
237	MCO-6.5A	47	Mortandad Canyon
238	MCO-6.5B	42	Mortandad Canyon
239	MCO-6A	33	Mortandad Canyon
240	MCO-6B	48	Mortandad Canyon
241	MCO-7	77	Mortandad Canyon
242	MCO-7.5A	63	Mortandad Canyon
243	MCO-7.5B	63	Mortandad Canyon

GUIDE TO DRILL HOLES ON FIGURE 1 (DRILL HOLE PENETRATIONS AT LANL)			
NUMBER	**DRILL HOLE ID**	**DEPTH (ft)**	**GENERAL LOCATION**
244	MCO-7A	47	Mortandad Canyon
245	MCO-8	92	Mortandad Canyon
246	MCO-8.2	72	Mortandad Canyon
247	MCO-8A	52	Mortandad Canyon
248	MCO-9	57	Mortandad Canyon
249	MCO-9.5	57	Mortandad Canyon
250	MT-1	69	Mortandad Canyon
251	MT-2	64	Mortandad Canyon
252	MT-3	74	Mortandad Canyon
253	MT-4	74	Mortandad Canyon
254	N-1	97	near TA-50
255	N-1	94	near TA-50
256	N-2	112	near TA-50
257	NE-1	118	near TA-50
258	NE-1	97	near Area 49
259	NE-2	295	near Area 49
260	NW-1	97	near Area 49
261	O-1	2603	Otowi Well Field
262	O-4	2806	Otowi Well Field
263	P-0	135	TA-16
264	P-1	35	TA-16
265	P-10	150	TA-16
266	P-11	70	TA-16
267	P-12	200	TA-16
268	P-13	103	TA-16
269	P-14	85	TA-16
270	P-15	70	TA-16

GUIDE TO DRILL HOLES ON FIGURE 1 (DRILL HOLE PENETRATIONS AT LANL)			
NUMBER	**DRILL HOLE ID**	**DEPTH (ft)**	**GENERAL LOCATION**
271	P-16	105	TA-16
272	P-17	30	TA-16
273	P-18	30	TA-16
274	P-19	30	TA-16
275	P-2	10	TA-16
276	P-20	30	TA-16
277	P-3	9	TA-16
278	P-4	10	TA-16
279	P-5	35	TA-16
280	P-6	10	TA-16
281	P-7	35	TA-16
282	P-8	10	TA-16
283	P-9	35	TA-16
284	PC-1	2178	Fenton Hill
285	PC-1	3	Acid-Pueblo Canyon
286	PC-2	3	Acid-Pueblo Canyon
287	PC-2	1825	Fenton Hill
288	PCM-1	60	Cañada del Buey and Pajarito Canyon
289	PCM-2	120	Cañada del Buey and Pajarito Canyon
290	PCM-3	60	Cañada del Buey and Pajarito Canyon
291	PCM-4	60	Cañada del Buey and Pajarito Canyon
292	PCO-1	22	Cañada del Buey and Pajarito Canyon
293	PCO-2	22	Cañada del Buey and Pajarito Canyon
294	PCO-3	20	Cañada del Buey and Pajarito Canyon
295	PCTH-1	74	Potrillo Canyon
296	PM-1	2501	Pajarito Well Field
297	PM-2	2600	Pajarito Well Field

GUIDE TO DRILL HOLES ON FIGURE 1 (DRILL HOLE PENETRATIONS AT LANL)			
NUMBER	**DRILL HOLE ID**	**DEPTH (ft)**	**GENERAL LOCATION**
298	PM-3	2552	Pajarito Well Field
299	PM-4	2920	Pajarito Well Field
300	PM-5	3120	Pajarito Well Field
301	PO-1	16	Acid-Pueblo Canyon
302	PO-1A	36	Acid-Pueblo Canyon
303	PO-1B	18	Acid-Pueblo Canyon
304	PO-1C	22	Acid-Pueblo Canyon
305	PO-1D	23	Acid-Pueblo Canyon
306	PO-2	30	Acid-Pueblo Canyon
307	PO-2A	11	Acid-Pueblo Canyon
308	PO-2B	11	Acid-Pueblo Canyon
309	PO-3	27	Acid-Pueblo Canyon
310	PO-3A	33	Acid-Pueblo Canyon
311	PO-3B	73	Acid-Pueblo Canyon
312	PO-4	43	Acid-Pueblo Canyon
313	PO-4A	43	Acid-Pueblo Canyon
314	PO-4B	57	Acid-Pueblo Canyon
315	PO-5	22	Acid-Pueblo Canyon
316	PO-6	18	Acid-Pueblo Canyon
317	POTM-1	50	TA-36
318	POTM-2	56	TA-36
319	POTM-3	52	TA-36
320	POTO-4A	174	TA-36
321	POTO-4B	99	TA-36
322	POTO-4C	48	TA-36
323	POTO-5A	77.5	TA-36
324	POTO-5B	27	TA-36

GUIDE TO DRILL HOLES ON FIGURE 1 (DRILL HOLE PENETRATIONS AT LANL)			
NUMBER	**DRILL HOLE ID**	**DEPTH (ft)**	**GENERAL LOCATION**
325	RGT-1	53	Rio Grande
326	RGT-2	497	Rio Grande
327	RGT-3	495	Rio Grande
328	RGT-4	495	Rio Grande
329	S-1	295	near TA-50
330	S-1	90	near TA-50
331	S-2	56	near TA-50
332	S-3	43	near TA-50
333	SCO-1	79	Sandia Canyon
334	SCO-2	29	Sandia Canyon
335	SE-1	97	near TA-50
336	SE-1	97	near Area 49
337	SE-2	112	near TA-50
338	SE-3	295	near TA-50
339	SHB-1	700	TA-55
340	SHB-2	200	TA-3
341	SHB-3	860	TA-16
342	SHB-4	200	TA-18
343	SIGMA MESA	2292	Pajarito Plateau
344	SIMO	104	Mortandad Canyon
345	SIMO-1	163	Mortandad Canyon
346	SKI BASIN WELL	400	Pajarito Plateau
347	SW-1	97	near TA-50
348	TA-21	125	TA-21
349	TA-46	747	TA-21
350	TBM-1	139	TA-49
351	TBM-2	64	TA-49

GUIDE TO DRILL HOLES ON FIGURE 1 (DRILL HOLE PENETRATIONS AT LANL)			
NUMBER	**DRILL HOLE ID**	**DEPTH (ft)**	**GENERAL LOCATION**
352	TEST HOLE 1	23	Upper Guaje Canyon
353	TEST HOLE 1-53	49	TA-53
354	TEST HOLE 2	103	Upper Guaje Canyon
355	TEST HOLE 2-53	49	TA-53
356	TEST HOLE 3-53	49	TA-53
357	TEST HOLE 4-53	49	TA-53
358	TEST HOLE 5-53	100	TA-53
359	TEST HOLE 6-53	150	TA-53
360	TEST HOLE 7-53	NA	TA-53
361	TEST HOLE B-53	49	TA-53
362	TH-1	100	Valle Toledo
363	TH-1	123	TA-49
364	TH-1	89	Bayo Canyon
365	TH-2	25	Bayo Canyon
366	TH-2	100	Valle Toledo
367	TH-2	123	TA-49
368	TH-3	31	Valle Toledo
369	TH-3	123	TA-49
370	TH-3	70	Bayo Canyon
371	TH-4	79	Bayo Canyon
372	TH-4	123	TA-49
373	TH-5	361	Valle Toledo
374	TH-5	123	TA-49
375	TH-6	140	Valle Grande
376	TH-7	40	Valle Grande
377	TH-8	299	Valle Grande
378	TH-A	590	Fenton Hill

GUIDE TO DRILL HOLES ON FIGURE 1 (DRILL HOLE PENETRATIONS AT LANL)			
NUMBER	**DRILL HOLE ID**	**DEPTH (ft)**	**GENERAL LOCATION**
379	TH-B	650	Fenton Hill
380	TH-C	750	Fenton Hill
381	TH-D	500	Fenton Hill
382	TSCM-1	22	Mortandad Canyon
383	TSCO-1	37	Mortandad Canyon
384	TW-1	642	Pajarito Plateau
385	TW-1A	225	Pajarito Plateau
386	TW-2	834	Pajarito Plateau
387	TW-2A	133	Pajarito Plateau
388	TW-2B	223	Pajarito Plateau
389	TW-3	815	Pajarito Plateau
390	TW-4	1205	Pajarito Plateau
391	TW-8	1065	Pajarito Plateau
392	USGS TH	210	near TA-52
393	W-1	91	near TA-50
394	W-2	114	near TA-50
395	WCM-1	10	TA-49
396	WCM-2	10	TA-49
397	WCO-1	37	Water Canyon
398	WCO-2	38	Water Canyon
399	WCO-3	14	Water Canyon
400	42-1028	28	TA-42
401	42-1029	28.5	TA-42
402	42-1030	28	TA-42
403	42-1031	27	TA-42
404	48-2007	1	TA-48
405	48-2008	3	TA-48

GUIDE TO DRILL HOLES ON FIGURE 1 (DRILL HOLE PENETRATIONS AT LANL)			
NUMBER	**DRILL HOLE ID**	**DEPTH (ft)**	**GENERAL LOCATION**
406	48-2009	3	TA-48
407	48-2010	15	TA-48
408	48-2011	15	TA-48
409	48-2013	15	TA-48
410	48-2014	15	TA-48
411	48-2015	15	TA-48
412	48-2021	15	TA-48
413	48-2022	15	TA-48
414	48-2023	15	TA-48
415	48-2024	15	TA-48
416	48-2025	14	TA-48
417	48-2037	3	TA-48
418	48-2056	2	TA-48
419	48-2067	10	TA-48
420	48-2068	14	TA-48
421	48-2069	15	TA-48
422	35-2004	100	TA-35
423	35-2005	100	TA-35
424	35-2006	100	TA-35
425	35-2007	92	TA-35
426	35-2008	100	TA-35
427	35-2009	100	TA-35
428	35-2010	100	TA-35
429	35-2011	100	TA-35
430	35-2012	100	TA-35
431	35-2013	100	TA-35
432	35-2028	299	TA-35

GUIDE TO DRILL HOLES ON FIGURE 1 (DRILL HOLE PENETRATIONS AT LANL)			
NUMBER	**DRILL HOLE ID**	**DEPTH (ft)**	**GENERAL LOCATION**
433	LAOI(A)-1.1	323	TA-2
434	21-2523	320	TA-21
435	LAUZ-1	260	TA-21
436	LAUZ-2	15	TA-21
437	49-2-150-2	150	TA-49
438	49-2-700-1	700	TA-49
439	49-2-10-1	10	TA-49
440	49-2-10-2	10	TA-49
441	49-2-10-3	10	TA-49
442	49-2-10-4	10	TA-49
443	49-2-150-1	150	TA-49
444	AC-1	3	Acid-Pueblo Canyon
445	AC-2	3	Acid-Pueblo Canyon
446	AC-3	3	Acid-Pueblo Canyon
447	AC-4	3	Acid-Pueblo Canyon
448	AC-5	3	Acid-Pueblo Canyon
449	Acid Weir	3	Acid-Pueblo Canyon
450	CDB	NA	Cañada del Buey and Pajarito Canyon near TA-46
451	DPGS-1	NA	Los Alamos Canyon
452	Hamilton	3	Acid-Pueblo Canyon
453	LAGS-1	NA	Los Alamos Canyon
454	LAGS-2	NA	Los Alamos Canyon
455	LLN-85-04	120	Areas L and G (TA-54)
456	LLN-85-08	120	Areas L and G (TA-54)
457	MCGS-1	NA	Mortandad Canyon
458	MCGS-2	NA	Mortandad Canyon
459	MCO-4.9	42	Mortandad Canyon

GUIDE TO DRILL HOLES ON FIGURE 1 (DRILL HOLE PENETRATIONS AT LANL)			
NUMBER	**DRILL HOLE ID**	**DEPTH (ft)**	**GENERAL LOCATION**
460	MCS-3.9	NA	Mortandad Canyon
461	Otowi Seep	3	Acid-Pueblo Canyon
462	PC-10	3	Acid-Pueblo Canyon
463	PC-11	3	Acid-Pueblo Canyon
464	PC-3	3	Acid-Pueblo Canyon
465	PC-4	3	Acid-Pueblo Canyon
466	PC-5	3	Acid-Pueblo Canyon
467	PC-6	3	Acid-Pueblo Canyon
468	PC-6A	3	Acid-Pueblo Canyon
469	PC-7	3	Acid-Pueblo Canyon
470	PC-8	3	Acid-Pueblo Canyon
471	PC-9	3	Acid-Pueblo Canyon
472	PCS at SR-4	NA	Cañada del Buey and Pajarito Canyon
473	PCS near Sewage Lagoon	NA	Cañada del Buey and Pajarito Canyon
474	Pueblo 1	3	Acid-Pueblo Canyon
475	Pueblo 2	3	Acid-Pueblo Canyon
476	Pueblo 3	3	Acid-Pueblo Canyon
477	SCS-1	NA	Sandia Canyon
478	SCS-2	NA	Sandia Canyon
479	SCS-3	NA	Sandia Canyon
480	NORTH BOREHOLE	230	TA-33
481	MIDDLE BOREHOLE	315	TA-33
482	SOUTH BOREHOLE	246	TA-33
483	SM-1483	120	TA-3
484	SM-19	100	TA-60
485	SM-245	100	TA-3
486	SM-447	96	TA-3

GUIDE TO DRILL HOLES ON FIGURE 1 (DRILL HOLE PENETRATIONS AT LANL)			
NUMBER	**DRILL HOLE ID**	**DEPTH (ft)**	**GENERAL LOCATION**
487	T-5	263	Pajarito Plateau
488	T-6	300	Pajarito Plateau
489	T-7	55	Pajarito Plateau
490	Water Canyon near Beta Hole	NA	
491	H-12	634	Valle Grande
492	ASC-18	80	TA-39
493	ASC-19	79	TA-39
494	SC-5	40	TA-39
495	SC-6	40	TA-39
496	SC-7	40	TA-39
497	SC-8	37.5	TA-39
498	ASC-0	80	TA-39
499	ASC-1	80	TA-39
500	ASC-2	80	TA-39
501	ASC-3	80	TA-39
502	ASC-4	80	TA-39
503	ASC-11	80	TA-39
504	ASC-12	80	TA-39
505	ASC-13	80	TA-39
506	ASC-14	80	TA-39
507	ASC-15	80	TA-39
508	ASC-16	80	TA-39
509	ASC-17	80	TA-39
510	SC-9	15	TA-39
511	SC-10	15	TA-39
512	DMB-1	124	TA-39

GUIDE TO DRILL HOLES ON FIGURE 1 (DRILL HOLE PENETRATIONS AT LANL)			
NUMBER	**DRILL HOLE ID**	**DEPTH (ft)**	**GENERAL LOCATION**
513	DM-2	40	TA-39
514	DM-4	25	TA-39
515	UM-3	56.5	TA-39
516	DM-6	60	TA-39
517	54-1016	605	TA-54, Cañada del Buey
518	54-1015	530	TA-54, Cañada del Buey
519	DM-5	55	TA-39
520	bw1	1104	East of Rio Grande
521	bw2_old	12903	East of Rio Grande
522	bw3_new	1593	East of Rio Grande
523	1100_well	1036	Southeast of Rio Grande
524	xh_pt_143	300	TA-21
525	xh_pt_145	300	TA-21
526	xh_pt_146	300	TA-21
527	LAOR-1	NA	Los Alamos Canyon and TA-02
528	LAOR-2	NA	Los Alamos Canyon and TA-02
529	41-1045	27	TA-62
530	MDA-V	707	TA-21
531	TH-5	263	TA-36
532	TH-6	300	TA-36
533	xh_pt_149	200	TA-33
534	xh_pt_150	200	TA-33
535	xh_pt_151	200	TA-33
536	xh_pt_152	200	TA-33
537	xh_pt_153	200	TA-33
538	xh_pt_154	200	TA-33
539	xh_pt_155	200	TA-33

GUIDE TO DRILL HOLES ON FIGURE 1 (DRILL HOLE PENETRATIONS AT LANL)			
NUMBER	**DRILL HOLE ID**	**DEPTH (ft)**	**GENERAL LOCATION**
540	xh_pt_156	200	TA-33
541	cold hole	700	TA-49
542	TH-7	55	Ancho Canyon
543	MW(1-4)	26	TA-18
544	P-87-3	9	Cañon de Valle

APPENDIX B2

STRATIGRAPHIC PICKS FOR SPECIFIC DRILL HOLES*,**

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*A blank in any investigator's column indicates that the geologic interval described for a particular depth was not recognized by that individual.

Levels of confidence assigned to stratigraphic picks apply only to the geologic contacts.

**Data sources do not always distinguish between the Tsankawi Pumice Bed and the Cerro Toledo Interval. For the purposes of this report, the top of the Cerro Toledo Interval is considered to be the top of the Tsankawi Pumice Bed.

DRILL HOLE ID [APPENDIX B1 NUMBER]	STRATIGRAPHIC UNIT	DEPTH [ft]	THICKNESS [ft]	THIS REPORT'S ELEVATION	USGS (John 1966) ELEVATION	PURTYMUN ELEVATION	LEVEL OF CONFIDENCE
35-2028 [432]	ALLUVIUM	0-5	5				
	TSHIREGE MBR.	5-218	213				
	TSANKAWI PUMICE BED	218-220	2	6895			H
	CERRO TOLEDO INTERVAL	220-297	77	6883			H
	OTOWI FM.	297-299	2	6806			H
	SOURCE: David Broxton, Personal Communication (6/29/95); R. Kock, Personal Communication (7/95) LOCATION: Near Ten Site Canyon GL ELEVATION: 7103 ft. TD: 299 ft. (9804 ft. elevation) DATE DRILLED: 1994						
	NOTE:						
54-1001 [17]	TSHIREGE MBR.	0-264	264				
	TSANKAWI PUMICE BED	264-314	50	6518			H
	SOURCE: FIMAD LOCATION: Mesita del Buey GL ELEVATION: 6783 ft. TD: 318 ft. (6465 ft. elevation) DATE DRILLED: 1993						
	NOTE:						
54-1002 [18]	TSHIREGE MBR.	0-259	259				
	TSANKAWI PUMICE BED	259-288	29	6530			H
	SOURCE: FIMAD LOCATION: Mesita del Buey GL ELEVATION: 6789 TD: 310 ft. (6479 ft. elevation) DATE DRILLED: 1993						
	NOTE:						

DRILL HOLE ID (APPENDIX B1 NUMBER)	STRATIGRAPHIC UNIT	DEPTH [ft]	THICKNESS [ft]	THIS REPORT'S ELEVATION	USGS (John 1966) ELEVATION	PURTYMUN ELEVATION	LEVEL OF CONFIDENCE
54-1003 [19]	TSHIREGE MBR.	0-265	265				
	TSANKAWI PUMICE BED	265-297	32	6530			H
	SOURCE: FIMAD LOCATION: Mesita del Buey GL ELEVATION: 6795 ft. TD: 299 ft. (6496 ft. elevation) DATE DRILLED: 1993						
	~~NOTE:~~						
54-1004 [20]	TSHIREGE MBR.	0-256	256				
	TSANKAWI PUMICE BED	256-295	39	6532			M[1]
	OTOWI MBR.	295-340	45	6493			H
	SOURCE: FIMAD LOCATION: Mesita del Buey GL ELEVATION: 6788 ft. TD: 340 ft. (6448 ft. elevation) DATE DRILLED: 1993						
	NOTE:						
54-1005 [21]	TSHIREGE MBR.	0-246	246				
	TSANKAWI PUMICE BED	246-269	23	6534			H
	SOURCE: FIMAD LOCATION: Mesita del Buey GL ELEVATION: 6780 ft. TD: 291 ft. (6489 ft. elevation) DATE DRILLED: 1993						
	NOTE: Lithology from 269 to 291 (total depth) is not reported in FIMAD.						

DRILL HOLE ID [APPENDIX B1 NUMBER]	STRATIGRAPHIC UNIT	DEPTH [ft]	THICKNESS [ft]	THIS REPORT'S ELEVATION	USGS (John 1966) ELEVATION	PURTYMUN ELEVATION	LEVEL OF CONFIDENCE
54-1006 [22]	TSHIREGE MBR.	0-263	263				
	TSANKAWI PUMICE BED	263-320	57	6528			H
	SOURCE: FIMAD LOCATION: Mesita del Buey GL ELEVATION: 6791 ft. TD: 323 ft. (6468 ft. elevation) DATE DRILLED: 1993						
	NOTE:						
CDBM-1 [44]	ALLUVIUM	0-7	7				
	TSHIREGE MBR.	7-83	76				
	TSANKAWI PUMICE BED	83-94	11	6639		6639	M
	OTOWI MBR.	94-190	96	6628		6628	M'
	SOURCE: Purtymun (1995) LOCATION: Cañada del Buey LDS ELEVATION: 6722 ft. TD: 190 ft. (6532 ft. LDS elevation) DATE DRILLED: 1992 DEPTH TO WATER: dry						
	NOTE:						
CDBM-2 [45]	ALLUVIUM	0-14	14				
	TSHIREGE MBR.	14-51	37				
	TSANKAWI PUMICE BED	51-54	3	6582		6582	M
	OTOWI MBR.	54-100	46	6579		6579	M
	SOURCE: Purtymun (1995) LOCATION: Cañada del Buey GL ELEVATION: 6633 ft. TD: 100 ft. (6533 ft. LDS elevation) DATE DRILLED: 1992 DEPTH TO WATER: dry						
	NOTE:						

DRILL HOLE ID (APPENDIX B1 NUMBER)	STRATIGRAPHIC UNIT	DEPTH [ft]	THICKNESS [ft]	THIS REPORT'S ELEVATION	USGS (John 1966) ELEVATION	PURTYMUN ELEVATION	LEVEL OF CONFIDENCE
DT-5A [78]	TSHIREGE MBR.	0-641	641				
	OTOWI MBR.	641-839	198	6503	6503	6503	M[2]
	GUAJE PUMICE BED	839-930	91	6305	6305	6305	M
	PUYE FM.	930-1167	237	6214	6214	6214	M
	▾ TSCHICOMA FM.	1167-1293	126	5977	5977	5977	L
	PUYE FM.	1293-1431	138	5851	5851	5851	M
	TSCHICOMA FM.	1431-1457	26	5713	5713	5713	L
	PUYE FM.	1457-1475	18	5687	5687	5687	M
	TOTAVI FM./ TESUQUE FM.	1475-1821	346	5669	5669	5669	H
	TESUQUE FM.	1527-1821	294		5617		
	CHAQUEHUI FM.	1527-1821	294			5617	

SOURCE: Weir (1962)
LOCATION: Frijoles Mesa
GL ELEVATION: 7144 ft.
TD: 1821 ft. (5323 ft. elevation)
DATE DRILLED: 1959
DEPTH TO WATER: 1173 ft. (5971 ft. elevation)
WATER LEVEL: 1183 ft. (5961 ft. elevation) - 1993 LANL data

NOTE: It has been noted that discrepancies exist between apparent direction of dispersal plume and the observed thickness of the Guaje Pumice bed. Questions surrounding the occurrence of possible volcanic units of the Paliza Canyon lavas draw suspicion to the well log lithologic description and, therefore, of the top of the Puye Fm. Purtymun (1995) describes these intervals as basalts. It has been suggested that these intervals may represent volcanic units of the Paliza Canyon lavas (IWP, 1994).

DRILL HOLE ID [APPENDIX B1 NUMBER]	STRATIGRAPHIC UNIT	DEPTH [ft]	THICKNESS [ft]	THIS REPORT'S ELEVATION	USGS (John 1966) ELEVATION	PURTYMUN ELEVATION	LEVEL OF CONFIDENCE
DT-9 [80]	TSHIREGE MBR.	0-676	676		6937	6935	
	TSANKAWI PUMICE BED	609-618	9	6328			L
	CERRO TOLEDO INTERVAL	618-676	58	6319			L
	OTOWI MBR.	676-802	126	6261	6261	6259	M[1]
	GUAJE MBR.	802-850	48	6135	6135	6133	M
	PUYE FM.	850-924	74	6087	6087	6085	M
	▾ TSCHICOMA FM.	924-1162	238	6013	6013	6011	L
	PUYE FM.	1162-1319	157	5775	5775	5773	M
	TOTAVI FM.	1319-1357	182	5618	5618	5616	H
	SANTA FE GP. (undifferentiated)	1357-1501	144	5580			L
	CHAQUEHUI FM.	1357-1501	144			5578	
	TESUQUE FM.	1357-1501	144		5580		

SOURCE: Weir and Purtymun (1962)
LOCATION: Frijoles Mesa
GL ELEVATION: 6937 ft. (USGS), 6935 ft. (FIMAD and Purtymun)
TD: 1501 ft. (5436 elevation)
DATE DRILLED: 1960
DEPTH TO WATER: 1005 ft. (5932 ft. elevation)
WATER LEVEL: 1016 ft. (5921 ft. elevation) - 1993 LANL data

NOTE: It has been noted that discrepancies exist between apparent direction of dispersal plume and the observed thickness of the Guaje Pumice bed. Questions surrounding the occurrence of possible volcanic units of the Paliza Canyon lavas draw suspicion to the well log lithologic description and, therefore, of the top of the Puye Fm. Purtymun (1995) describes these intervals as basalts. It has been suggested that these intervals may represent volcanic units of the Paliza Canyon lavas (IWP, 1994).

DRILL HOLE ID (APPENDIX B1 NUMBER)	STRATIGRAPHIC UNIT	DEPTH [ft]	THICKNESS [ft]	THIS REPORT'S ELEVATION	USGS (John 1966) ELEVATION	PURTYMUN ELEVATION	LEVEL OF CONFIDENCE
DT-10 [76]	TSHIREGE MBR.	0-672	672				
	OTOWI MBR.	672-829	157	6348	6347	6348	M[2]
	GUAJE MBR.	829-864	35	6190	6190	6191	M
	PUYE FM.	864-972	108	6155	6155	6156	M
	TSCHICOMA FM.	972-1012	40	6047	6047	6048	L
	▾ BASALT	1012-1281	270	6007	6007		M
	PUYE FM.	1281-1356	75	5738	5738	5729	M
	TOTAVI FM.	1356-1402	46	5663	5663	5664	H
	TESUQUE FM.	1402-1409	7	5617	5617	5618	L

SOURCE: Weir and Purtymun (1962)
LOCATION: Frijoles Mesa
GL ELEVATION: 7019 ft.
TD: 1409 ft. (5610 ft. elevation)
DATE DRILLED: 1960
DEPTH TO WATER: 1085 ft. (5934 ft. elevation)
WATER LEVEL: 1096 ft. (5923 ft. elevation) - 1993 LANL data

NOTE: FIMAD refers to the Tschicoma and Tesuque Fms. as Basalt #2 and Chaquehui Fm., respectively. It has been noted that discrepancies exist between apparent direction of dispersal plume and the observed thickness of the Guaje Pumice bed. Questions surrounding the occurrence of possible volcanic units of the Paliza Canyon lavas draw suspicion to the well log lithologic description and, therefore, of the top of the Puye Fm. Purtymun (1995) describes these intervals as basalts. It has been suggested that these intervals may represent volcanic units of the Paliza Canyon lavas (IWP, 1994).

DRILL HOLE ID (APPENDIX B1 NUMBER)	STRATIGRAPHIC UNIT	DEPTH [ft]	THICKNESS [ft]	THIS REPORT'S ELEVATION	USGS (John 1966) ELEVATION	PURTYMUN ELEVATION	LEVEL OF CONFIDENCE
G-1 [86]	ALLUVIUM	0-12	12				
	PUYE FM.	12-24	12				
	TOTAVI FM.	24-75	51	5948		5816	H
	▾ SANTA FE GP. (undifferentiated)	75-2020	1945	5898	5898		M
	CHAQUEHUI FM.	75-680	605			5765	
	TESUQUE FM.	680-1540	860			5160	
	BASALT	1540-1850	310		4433	4300	
	TESUQUE FM.	1850-2020	170		4135	3990	

SOURCE: Griggs (1955)
LOCATION: Guaje Canyon (Guaje Well Field)
LSD ELEVATION: 5973 ft.
TD: 2020 ft. (3953 ft. LSD elevation)
DATE DRILLED: 1950
DEPTH TO WATER: 192 ft. (5781 ft. LSD elevation)
WATER LEVEL: 152 ft. (5821 ft. elevation) - 1993 LANL data

NOTE: FIMAD reported a ground level elevation of 5973 ft. which differs from the Purtymun elevation of 5840 ft. For the purposes of this report, an elevation consistent with the FIMAD data, and verified by a topographic map, was employed. The USGS notes the Tesuque Fm. specifically versus as part of the Santa Fe Grp.

DRILL HOLE ID [APPENDIX B1 NUMBER]	STRATIGRAPHIC UNIT	DEPTH [ft]	THICKNESS [ft]	THIS REPORT'S ELEVATION	USGS (John 1966) ELEVATION	PURTYMUN ELEVATION	LEVEL OF CONFIDENCE
G-1A [87]	ALLUVIUM	0-12					
	PUYE MBR.	12-59	47		6002	6002	
	TOTAVI FM.	59-122	63	5955	5955	5955	H
	▾SANTA FE GP. (undifferentiated)	122-2071	645	5154	5154		M
	CHAQUEHUI FM.	122-860	738			5822	
	TESUQUE FM.	860-1505	645			5154	
	BASALT	1505-1675	170			4509	
	TESUQUE FM.	1675-1755	80			4339	
	BASALT	1755-1790	35			4259	
	TESUQUE FM.	1790-2071	281			4224	

SOURCE: USGS (1960)
LOCATION: Guaje Canyon (Guaje Well Field)
LSD ELEVATION: 6014 ft.
TD: 2071 ft. (3943 ft. LSD elevation)
DATE DRILLED: 1954
DEPTH TO WATER: 250 ft. (5764 ft. LSD elevation)
WATER LEVEL: 315 ft. (5699 ft. elevation) - 1993 LANL data

NOTE: The USGS notes the Tesuque Fm. as part of the Santa Fe Grp.

DRILL HOLE ID [APPENDIX B1 NUMBER]	STRATIGRAPHIC UNIT	DEPTH [ft]	THICKNESS [ft]	THIS REPORT'S ELEVATION	USGS (John 1966) ELEVATION	PURTYMUN ELEVATION	LEVEL OF CONFIDENCE
G-2 [88]	ALLUVIUM	0-13	13				
	PUYE FM.	13-30	17		6043	6043	
	TOTAVI FM.	30-75	45	6026	6026	6026	H
	SANTA FE GP. (undifferentiated)	75-2006	1931	5981	5981		M
	CHAQUEHUI FM.	75-920	845			5981	
	TESUQUE FM.	920-2006	1086			5136	

SOURCE: Griggs (1955)
LOCATION: Guaje Canyon (Guaje Well Field)
LSD ELEVATION: 6056 ft.
TD: 2006 ft. (4050 ft. LSD elevation)
DATE DRILLED: 1951
DEPTH TO WATER: 259 ft. (5797 ft. LSD elevation)
WATER LEVEL: 359 ft. (5697 ft. elevation) - 1993 LANL data

NOTE: FIMAD includes three additional intervals of the Santa Fe Grp.: 5991-5981 ft.; 5931-5106; and 5106 to depth. The USGS notes the Tesuque Fm. as part of the Santa Fe Grp.

DRILL HOLE ID [APPENDIX B1 NUMBER]	STRATIGRAPHIC UNIT	DEPTH [ft]	THICKNESS [ft]	THIS REPORT'S ELEVATION	USGS (John 1966) ELEVATION	PURTYMUN ELEVATION	LEVEL OF CONFIDENCE
G-3 [89]	ALLUVIUM	0-17	17				
	PUYE FM.	17-58	41		6122	6122	
	TOTAVI FM.	58-110	52	6081	6081	6081	H
	▾ SANTA FE GP. (undifferentiated)	110-1997	1887	5971	5972		M
	CHAQUEHUI FM.	110-921	811			5971	
	BASALT	921-936	15		5218	5218	
	CHAQUEHUI FM.	936-1012	66			5203	
	BASALT	1012-1090	78		5127	5127	
	TESUQUE FM.	1090-1997	907			5049	

SOURCE: Griggs (1955)
LOCATION: Guaje Canyon (Guaje Well Field)
LSD ELEVATION: 6139 ft.
TD: 1997 ft. (4142 ft. LSD elevation)
DATE DRILLED: 1951
DEPTH TO WATER: 280 ft. (5859 ft. LSD elevation) - (1951)

NOTE: FIMAD includes an additional interval of the Santa Fe Grp. from 6004 to 5218 ft. otherwise it agrees with the Purtymun data. The USGS notes the Tesuque Fm. as part of the Santa Fe Grp.

DRILL HOLE ID [APPENDIX B1 NUMBER]	STRATIGRAPHIC UNIT	DEPTH [ft]	THICKNESS [ft]	THIS REPORT'S ELEVATION	USGS (John 1966) ELEVATION	PURTYMUN ELEVATION	LEVEL OF CONFIDENCE
G-4 [90]	ALLUVIUM	0-15	15				
	PUYE FM.	15-60	45		6214	6214	
	TOTAVI FM.	60-120	60	6169	6169	6169	H
	▾ SANTA FE GP. (undifferentiated)	120-2002	1882	6109			M
	CHAQUEHUI FM.	120-499	379			6109	
	BASALT	499-526	27		5730	5730	
	CHAQUEHUI FM.	526-855	329			5703	
	BASALT	855-925	70		5374	5374	
	CHAQUEHUI FM.	925-956	36			5304	
	BASALT	956-976	20		5273	5273	
	CHAQUEHUI FM.	976-1103	127			5253	
	BASALT	1103-1150	47		5126	5126	
	TESUQUE FM.	1150-2002	852			5079	

SOURCE: Griggs (1955)
LOCATION: Guaje Canyon (Guaje Well Field)
LSD ELEVATION: 6229 ft.
TD: 2002 ft. (4227 ft. LSD elevation)
DATE DRILLED: 1951
DEPTH TO WATER: 347 ft. (5882 ft. LSD elevation)
WATER LEVEL: 369 ft. (5860 ft. elevation) - 1993 LANL data

NOTE: FIMAD includes an interval of the Santa Fe Grp. from 5088 to 5079 ft. otherwise it agrees with Purtymun. The USGS notes the Tesuque Fm. as part of the Santa Fe Grp.

DRILL HOLE ID [APPENDIX B1 NUMBER]	STRATIGRAPHIC UNIT	DEPTH [ft]	THICKNESS [ft]	THIS REPORT'S ELEVATION	USGS (John 1966) ELEVATION	PURTYMUN ELEVATION	LEVEL OF CONFIDENCE
G-5 [91]	ALLUVIUM	0-8	8				
	PUYE FM.	8-127	119		6298	6298	
	▾ SANTA FE GP. (undifferentiated)	127-1997	1870	6179	6179		M
	CHAQUEHUI FM.	127-586	459			6179	
	BASALT	586-613	27		5720	5720	
	CHAQUEHUI FM.	613-906	293			5693	
	BASALT	906-1135	229		5400	5400	
	CHAQUEHUI FM.	1135-1211	76			5171	
	BASALT	1211-1330	119		5095	5095	
	TESUQUE FM.	1330-1997	667			4976	

SOURCE: Griggs (1955)
LOCATION: Guaje Canyon (Guaje Well Field)
LSD ELEVATION: 6306 ft.
TD: 1997 ft. (4309 ft. LSD elevation)
DATE DRILLED: 1951
DEPTH TO WATER: 411 ft. (5895 ft. LSD elevation) - Purtymun (1995)
WATER LEVEL: 463 ft. (5843 ft. elevation) - 1993 LANL data

NOTE: FIMAD elevations are 3 ft. greater than Purtymun's elevations. FIMAD also notes two additional basaltic and Santa Fe Grp. intervals from 5071-4991 ft. and also, a Santa Fe Grp. interval from 4922 ft. to total depth. The USGS notes the Tesuque Fm. as part of the Santa Fe Grp.

DRILL HOLE ID [APPENDIX B1 NUMBER]	STRATIGRAPHIC UNIT	DEPTH [ft]	THICKNESS [ft]	THIS REPORT'S ELEVATION	USGS (John 1966) ELEVATION	PURTYMUN ELEVATION	LEVEL OF CONFIDENCE
G-6 [92]	ALLUVIUM	0-40	40				
	PUYE FM.	40-130	110		6382	6382	
	TOTAVI FM.	130-200	70	6292	6292	6292	H
	▾SANTA FE GP. (undifferentiated)	200-2005	1795	6222	6222		M
	CHAQUEHUI FM.	200-1070	870			6222	
	BASALT	1070-1170	100		5352	5352	
	CHAQUEHUI FM.	1170-1180	10			5252	
	BASALT	1180-1220	40		5242	5242	
	CHAQUEHUI FM.	1220-1270	50			5202	
	BASALT	1270-1425	155		5152	5152	
	CHAQUEHUI FM.	1425-1445	20			4997	
	BASALT	1445-1470	25		4977	4977	
	TESUQUE FM.	1470-2005	535			4952	

SOURCE: Cooper (1965)
LOCATION: Guaje Canyon (Guaje Well Field)
LSD ELEVATION: 6422 ft.
TD: 2005 ft. (4417 ft. LSD elevation)
DATE DRILLED: 1964
DEPTH TO WATER: 585 ft. (5837 ft. LSD elevation)
WATER LEVEL: 562 ft. (5850 ft. elevation) - 1993 LANL data

NOTE: FIMAD refers to all of the basaltic units as Basalt Unit #1. The USGS notes the Tesuque Fm. as part of the Santa Fe Grp.

DRILL HOLE ID [APPENDIX B1 NUMBER]	STRATIGRAPHIC UNIT	DEPTH [ft]	THICKNESS [ft]	THIS REPORT'S ELEVATION	USGS (John 1966) ELEVATION	PURTYMUN ELEVATION	LEVEL OF CONFIDENCE
H-19 [108]	▾ ALLUVIUM	0-27	27				
	TSHIREGE MBR.	27-200	173		7151	7151	
	TSANKAWI PUMICE BED	124-130	6	7054			L
	CERRO TOLEDO INTERVAL	130-200	70	7048			L
	OTOWI MBR.	200-415	215	6978	6978	6978	M[1]
	▾ GUAJE MBR.	415-472	57	6763	6763	6763	H
	TSCHICOMA FM.	472-819	347	6706	6706	6706	H
	▾ PUYE FM.	819-1210	391	6359	6359	6359	H
	TSCHICOMA FM.	1210-1480	270	5968	5968	5968	H
	TOTAVI FM.	1480-1490	10	5698	5698	5698	H
	TSCHICOMA FM.	1490-2000	510	5688	5688	5688	H

SOURCE: Griggs (1955 and 1964)
LOCATION: Los Alamos Canyon
ELEVATION: 7178 ft.
TD: 2000 ft. (5178 ft. elevation)
DATE DRILLED: 1949
DEPTH TO WATER: 970 ft. (6208 ft. elevation) [Purtymun cites the same occurrence of water at 950 ft. (6228 ft. elevation)]; shallow perched at 14 ft. (7164 ft. elevation); and intermediate perched at 450 ft. (6728 ft. elevation)

NOTE:

DRILL HOLE ID (APPENDIX B1 NUMBER)	STRATIGRAPHIC UNIT	DEPTH [ft]	THICKNESS [ft]	THIS REPORT'S ELEVATION	USGS (John 1966) ELEVATION	PURTYMUN ELEVATION	LEVEL OF CONFIDENCE
LA-6 [130]	▾ ALLUVIUM	0-36	36				
	TESUQUE FM.	36-2030	1994		5734	5734	
	SOURCE: Purtymun (1995) LOCATION: Los Alamos Canyon (Los Alamos Well Field) LSD ELEVATION: 5770 ft. TD: 2030 ft. (3740 ft. LSD elevation) DATE DRILLED: 1948 DEPTH TO WATER: 2 ft. (5768 ft. LSD elevation)						
	NOTE: Both Purtymun and USGS refer to the Tesuque Fm. versus the Santa Fe Gp. (undifferentiated).						

DRILL HOLE ID (APPENDIX B1 NUMBER)	STRATIGRAPHIC UNIT	DEPTH [ft]	THICKNESS [ft]	THIS REPORT'S ELEVATION	USGS (John 1966) ELEVATION	PURTYMUN ELEVATION	LEVEL OF CONFIDENCE
LADP-3 [131]	▾ ALLUVIUM/ COLLUVIUM	0-65	65				
	OTOWI MBR.	65-308	243				
	▾ GUAJE PUMICE BED	308-328	20	6447			H
	▾ PUYE FM.	328-350	22	6427			H
	SOURCE: D. Broxton: preliminary results for bore holes LADP-3 and LADP-4 LOCATION: Los Alamos Canyon ELEVATION: 6755 ft. TD: 350 ft. (6406 ft. elevation) DATE DRILLED: 1993 DEPTH TO WATER: 325 ft. (6430 ft. elevation), and shallow perched at 25 ft. (6730 ft. elevation) WATER LEVEL: 321 ft. (6434 ft. elevation)						
	NOTE: FIMAD data notes the Otowi Member at 6682 ft., the Guaje Pumice Bed. at 6449 ft., and the Puye Fm. at 6429 ft.						
LADP-4 [132]	ALLUVIUM	0-8					
	TSHIREGE MBR.	8-250	242				
	TSANKAWI PUMICE BED	250-254	4	6801			H
	CERRO TOLEDO INTERVAL	254-293	39	6797			H
	OTOWI MBR.	293-545	252	6758			H
	GUAJE PUMICE BED	545-573	28	6506			H
	PUYE FM.	573-800	227	6478			H
	SOURCE: D. Broxton - preliminary results from bore holes LADP-3 and LADP-4 (Figure 6, page 7) LOCATION: DP Canyon LSD ELEVATION: 7051 ft. TD: 800 ft. (6251 ft. LSD elevation) DATE DRILLED: 1993						
	NOTE: FIMAD does not specify either the Alluvium or Tsankawi Pumice Bed.						

DRILL HOLE ID [APPENDIX B1 NUMBER]	STRATIGRAPHIC UNIT	DEPTH [ft]	THICKNESS [ft]	THIS REPORT'S ELEVATION	USGS (John 1966) ELEVATION	PURTYMUN ELEVATION	LEVEL OF CONFIDENCE
LAO-4.5 [140]	▾ ALLUVIUM	0-12					
	PUYE FM.	12-38	26			6440	
	BASALT	38-62	22	6414		6414	M
	SOURCE: Purtymun (1969 and 1995) LOCATION: Los Alamos Canyon LSD ELEVATION: 6452 ft. TD: 62 ft. (6390 ft. LSD elevation) DATE DRILLED: 1969 DEPTH TO WATER: 5 ft. (6447 ft. LSD elevation)						
	NOTE: FIMAD agrees with the Purtymun data.						
LAOI(A)-1.1 [433]	ALLUVIUM	0-16	16				
	OTOWI MBR.	16-294	278				
	▾ GUAJE PUMICE BED	294-316	22	6541			H
	PUYE FM.	316-323	7	6519			H
	SOURCE: FIMAD; Draft Borehole LAO1(A)-1.1 Drilling and Well Construction Detail (1994) LOCATION: Los Alamos Canyon ELEVATION: 6835 ft. TD: 323 ft. (6510 ft. elevation) DATE DRILLED: 1994 DEPTH TO WATER: 294 ft. (6541 ft. elevation)						
	NOTE: Water was also encountered at 316 ft. (6519 ft. elevation) in the Puye Fm.						

DRILL HOLE ID (APPENDIX B1 NUMBER)	STRATIGRAPHIC UNIT	DEPTH [ft]	THICKNESS [ft]	THIS REPORT'S ELEVATION	USGS (John 1966) ELEVATION	PURTYMUN ELEVATION	LEVEL OF CONFIDENCE
LAUZ-1 [435]	ALLUVIUM	0-7	7				
	TSHIREGE FM.	7-253	2465				
	TSANKAWI PUMICE BED	253-254	1	6907			H
	CERRO TOLEDO INTERVAL	254-260	6	6906			H
	SOURCE: FIMAD LOCATION: DP Canyon GL ELEVATION: 7160 ft. TD: 260 ft. (6900 ft. elevation) DATE DRILLED: 1994 DEPTH TO WATER: dry						
	NOTE:						
LLC-88-27 [169]	TSHIREGE MBR.	0-190	190				
	OTOWI MBR./ GUAJE MBR.	190-263	73	6595			L[2,3]
	SOURCE: FIMAD LOCATION: Mesita del Buey GL ELEVATION: 6785 ft. TD: 263 ft. (6761 ft. elevation) DATE DRILLED: 1988						
	NOTE: Recent drilling in this vicinity has indicated the presence of the Tsankawi Pumice Bed.						

DRILL HOLE ID [APPENDIX B1 NUMBER]	STRATIGRAPHIC UNIT	DEPTH [ft]	THICKNESS [ft]	THIS REPORT'S ELEVATION	USGS (John 1966) ELEVATION	PURTYMUN ELEVATION	LEVEL OF CONFIDENCE
LLC-88-28 [170]	TSHIREGE MBR.	0-198					
	OTOWI MBR./ GUAJE MBR.	198-263	68	6601			$L^{2,3}$
	BASALT	263-267	4	6533			H
	SOURCE: FIMAD LOCATION: Mesita del Buey GL ELEVATION: 6796 ft. TD: 267 ft. (6529 ft. elevation) DATE DRILLED: 1988						
	NOTE: Recent drilling in this vicinity has indicated the presence of the Tsankawi Pumice Bed.						
LLC-88-29 [171]	TSHIREGE MBR.	0-225					
	OTOWI MBR./ GUAJE PUMICE BED	225-298		6568			$L^{2,3}$
	SOURCE: FIMAD LOCATION: Mesita del Buey GL ELEVATION: 6793 ft. TD: 298 ft. (6498 ft. elevation) DATE DRILLED: 1988						
	NOTE: Recent drilling in this vicinity has indicated the presence of the Tsankawi Pumice Bed.						
LLC-89-30 [172]	TSHIREGE MBR.	0-205					
	OTOWI MBR./ GUAJE PUMICE BED	205-273	68	6577			$L^{2,3}$
	SOURCE: FIMAD LOCATION: Mesita del Buey GL ELEVATION: 6782 ft. TD: 273 ft. (6509 ft. elevation) DATE DRILLED: 1989						
	NOTE: Recent drilling in this vicinity has indicated the presence of the Tsankawi Pumice Bed.						

DRILL HOLE ID [APPENDIX B1 NUMBER]	STRATIGRAPHIC UNIT	DEPTH [ft]	THICKNESS [ft]	THIS REPORT'S ELEVATION	USGS (John 1966) ELEVATION	PURTYMUN ELEVATION	LEVEL OF CONFIDENCE
LLC-89-31 [173]	TSHIREGE MBR.	0-225	225				
	OTOWI MBR./ GUAJE PUMICE BED	225-291	66	6579			$L^{2,3}$
	SOURCE: FIMAD LOCATION: Mesita del Buey GL ELEVATION: 6804 ft. TD: 291 ft. (6513 ft. elevation) DATE DRILLED: 1989						
	NOTE: Recent drilling in this vicinity has indicated the presence of the Tsankawi Pumice Bed.						
LLC-89-32 [174]	TSHIREGE MBR.	0-150					
	OTOWI MBR./ GUAJE PUMICE BED	150-171	21	6520			$L^{2,3}$
	SOURCE: FIMAD LOCATION: Mesita del Buey GL ELEVATION: 6670 ft. TD: 171 ft. (6499 ft. elevation) DATE DRILLED: 1989 DEPTH TO WATER:						
	NOTE: Recent drilling in this vicinity has indicated the presence of the Tsankawi Pumice Bed.						
LLC-89-33 [175]	TSHIREGE MBR.	0-180					
	OTOWI MBR./ GUAJE PUMICE BED	180-293	113	6567			$L^{2,3}$
	SOURCE: FIMAD LOCATION: Mesita del Buey GL ELEVATION: 6747 ft. TD: 293 ft. (6454 ft. elevation) DATE DRILLED: 1989						
	NOTE: Recent drilling in this vicinity has indicated the presence of the Tsankawi Pumice Bed.						

DRILL HOLE ID [APPENDIX B1 NUMBER]	STRATIGRAPHIC UNIT	DEPTH [ft]	THICKNESS [ft]	THIS REPORT'S ELEVATION	USGS (John 1966) ELEVATION	PURTYMUN ELEVATION	LEVEL OF CONFIDENCE
LLC-90-34 [176]	TSHIREGE MBR.	0-195					
	OTOWI MBR./ GUAJE PUMICE BED	195-317	122	6605			$L^{2,3}$
	SOURCE: FIMAD LOCATION: Mesita del Buey GL ELEVATION: 6800 ft. TD: 317 ft. (6483 ft. elevation) DATE DRILLED: 1990						
	NOTE: Recent drilling in this vicinity has indicated the presence of the Tsankawi Pumice Bed.						
LLC-90-35 [177]	TSHIREGE MBR.	0-201					
	OTOWI MBR./ GUAJE PUMICE BED	201-351	150	6609			$L^{2,3}$
	SOURCE: FIMAD LOCATION: Mesita del Buey GL ELEVATION: 6810 ft. TD: 351 ft. (6459 ft. elevation) DATE DRILLED: 1990						
	NOTE: Recent drilling in this vicinity has indicated the presence of the Tsankawi Pumice Bed.						

DRILL HOLE ID [APPENDIX B1 NUMBER]	STRATIGRAPHIC UNIT	DEPTH [ft]	THICKNESS [ft]	THIS REPORT'S ELEVATION	USGS (John 1966) ELEVATION	PURTYMUN ELEVATION	LEVEL OF CONFIDENCE
MCC-8.2 [185]	▾ ALLUVIUM	0-76					
	TSHIREGE MBR.	76-84	8			6704	
	TSANKAWI PUMICE BED	84-104	20	6696		6696	H
	OTOWI MBR.	104-184	80	6676		6676	H
	SOURCE: Purtymun (1995), Stoker (1991) LOCATION: Mortandad Canyon LSD ELEVATION: 6780 ft. TD: 184 ft. (6596 ft. LSD elevation) DATE DRILLED: 1989 DEPTH TO WATER: 73 ft. (6707 ft. LSD elevation)						
	NOTE:						
MCM-5.1 [205]	▾ ALLUVIUM	0-31					
	TSHIREGE MBR.	31-93	62			6839	
	TSANKAWI PUMICE BED	93-112	19	6777		6777	H
	SOURCE: Stoker (1991) LOCATION: Mortandad Canyon ELEVATION (LSD): 6870 ft. TD: 111.5 ft. (6758.5 ft. elevation) DATE DRILLED: 1990 DEPTH TO WATER: alluvium (cased out of hole)						
	NOTE:						

DRILL HOLE ID (APPENDIX B1 NUMBER)	STRATIGRAPHIC UNIT	DEPTH [ft]	THICKNESS [ft]	THIS REPORT'S ELEVATION	USGS (John 1966) ELEVATION	PURTYMUN ELEVATION	LEVEL OF CONFIDENCE
MCM-5.9A [206]	▾ ALLUVIUM	0-38					
	TSHIREGE MBR.	38-98	50			6814	
	TSANKAWI PUMICE BED	98-118	20	6754		6754	H
	OTOWI MBR.	118-194	76	6734		6734	H
	SOURCE: Stoker (1991) LOCATION: Mortandad Canyon LSD ELEVATION: 6852 ft. TD: 194 ft. (6658 ft. LSD elevation) DATE DRILLED: 1990 DEPTH TO WATER: alluvium (cased out of hole)						
	NOTE:						
MDA-V [530]	TSHIREGE MBR.	0-298	298				
	TSANKAWI PUMICE BED	298-300	2	6862			H
	CERRO TOLEDO INTERVAL	300-332	32	6860			H
	OTOWI MBR.	332-685	353	6828			H
	GUAJE PUMICE BED	685-701	16	6475			H
	PUYE FM.	701-707	6	6459			H
	SOURCE: D. Broxton, personal communication (6/29/95) LOCATION: DP Canyon ELEVATION (LDS): 7160 ft. TD: 707 ft. (6453 ft. elevation) DATE DRILLED: 1994						
	NOTE:						

DRILL HOLE ID [APPENDIX B1 NUMBER]	STRATIGRAPHIC UNIT	DEPTH [ft]	THICKNESS [ft]	THIS REPORT'S ELEVATION	USGS (John 1966) ELEVATION	PURTYMUN ELEVATION	LEVEL OF CONFIDENCE
MW-1 [543]	ALLUVIUM	0-27	27				
	SOURCE: Los Alamos Technical Associates, Inc. (1991) LOCATION: Pajarito Canyon GL ELEVATION: 6760-6780 (taken from topographic map) TD: 27 ft. (6733-6753 ft. elevation) DATE DRILLED: 1990 DEPTH TO WATER: 14.5 ft. (6745.5-6765.5 ft. elevation) 11/90; and 7.3 ft. (6752.7-6772.7 ft. elevation)) 5/93						
	NOTE: Only generic lithologic logs for the MW-series wells are available in the source document.						
MW-2 [543]	ALLUVIUM	0-22	22				
	SOURCE: Los Alamos Technical Associates, Inc. (1991) LOCATION: Pajarito Canyon GL ELEVATION: 6760-6780 (taken from topographic map) TD: 22 ft. (6738-6758 ft. elevation) DATE DRILLED: 1990 DEPTH TO WATER: 16 ft. (6744-6764 ft. elevation) 11/90; and 8.3 ft. (6751.7-6771.7 ft. elevation) 5/93						
	NOTE: Only generic lithologic logs for the MW-series wells are available in the source document.						
MW-3 [543]	ALLUVIUM	0-21.5	21.5				
	SOURCE: Los Alamos Technical Associates, Inc. (1991) LOCATION: Pajarito Canyon GL ELEVATION: 6760-6780 (taken from topographic map) TD: 21.5 ft. (6738.5-6758.5 ft. elevation) DATE DRILLED: 1990 DEPTH TO WATER: 16 ft. (6744-6764 ft. elevation) 11/90; and 8.3 ft. (6751.7-6771.7 ft. elevation) 5/93						
	NOTE: Only generic lithologic logs for the MW-series wells are available in the source document.						

DRILL HOLE ID [APPENDIX B1 NUMBER]	STRATIGRAPHIC UNIT	DEPTH [ft]	THICKNESS [ft]	THIS REPORT'S ELEVATION	USGS (John 1966) ELEVATION	PURTYMUN ELEVATION	LEVEL OF CONFIDENCE
LA-1 [124]	ALLUVIUM	0-76	76				
	SANTA FE GP. (undifferentiated)	76-1001	925		5548	5548	
	SOURCE: Purtymun (1995) LOCATION: Los Alamos Canyon (Los Alamos Well Field) LSD ELEVATION: 5624 ft. TD: 1001 ft. (4623 ft. LSD elevation) DATE DRILLED: 1946 DEPTH TO WATER: (flowing)						
	NOTE: Both Purtymun and USGS refer to the Tesuque Fm. versus the Santa Fe Gp. (undifferentiated).						
LA-1B [125]	ALLUVIUM	0-78	78				
	TESUQUE FM.	78-2256	2178		5544	5544	
	SOURCE: Purtymun (1995) LOCATION: Los Alamos Canyon (Los Alamos Well Field) LSD ELEVATION: 5622 ft. TD: 2256 ft. (3366 ft. LSD elevation) DATE DRILLED: 1960 DEPTH TO WATER: (flowing)						
	NOTE: Both Purtymun and USGS refer to the Tesuque Fm. versus the Santa Fe Gp. (undifferentiated).						
LA-2 [126]	ALLUVIUM	0-60	60				
	TESUQUE FM.	60-882	822		5591	5591	
	SOURCE: Purtymun (1995) LOCATION: Los Alamos Canyon (Los Alamos Well Field) LSD ELEVATION: 5651 ft. TD: 882 ft. (4769 ft. LSD elevation) DATE DRILLED: 1946 DEPTH TO WATER: (flowing)						
	NOTE: Both Purtymun and USGS refer to the Tesuque Fm. versus the Santa Fe Gp. (undifferentiated).						

DRILL HOLE ID [APPENDIX B1 NUMBER]	STRATIGRAPHIC UNIT	DEPTH [ft]	THICKNESS [ft]	THIS REPORT'S ELEVATION	USGS (John 1966) ELEVATION	PURTYMUN ELEVATION	LEVEL OF CONFIDENCE
MW-4 [543]	ALLUVIUM	0-21	21				
	SOURCE: Los Alamos Technical Associates, Inc. (1991) LOCATION: Pajarito Canyon GL ELEVATION: 6760-6780 (taken from topographic map) TD: 21 ft. (6738-6758 ft. elevation) DATE DRILLED: 1990 DEPTH TO WATER: 15 ft. (6745-6765 ft. elevation) 11/90; and 8.5 ft. (6751.5-6771.5 ft. elevation) 5/93						
	NOTE: Only generic lithologic logs for the MW-series wells are available in the source document.						

DRILL HOLE ID (APPENDIX B1 NUMBER)	STRATIGRAPHIC UNIT	DEPTH [ft]	THICKNESS [ft]	THIS REPORT'S ELEVATION	USGS (John 1966) ELEVATION	PURTYMUN ELEVATION	LEVEL OF CONFIDENCE
	CHAQUEHUI FM.	1180-1506	326			5340	
	BASALT	1506-1510	4			5014	
	CHAQUEHUI FM.	1510-1546	36			5010	
	BASALT	1546-1548	2			4974	
	CHAQUEHUI FM.	1548-1798	250			4972	
	CHAMITA FM.	1798-1874	76			4722	
	TESUQUE FM.	1874-2501	627			4646	

SOURCE: Cooper (1965)
LOCATION: Sandia Canyon (Pajarito Well Field)
GL ELEVATION: 6520 ft.
TD: 2501 ft. (4019 ft. elevation)
DATE DRILLED: 1965
DEPTH TO WATER: 722 ft. (5798 ft. elevation) ; intermediate perched groundwater at 448 ft. (6072 ft. elevation)
WATER LEVEL: 756 ft. (5764 ft. elevation) - LANL 1993 data

NOTE: FIMAD does not specify the intervals of interbedded Chaquehui Fm. and basalts between 5725 and 4722 ft.

DRILL HOLE ID (APPENDIX B1 NUMBER)	STRATIGRAPHIC UNIT	DEPTH [ft]	THICKNESS [ft]	THIS REPORT'S ELEVATION	USGS (John 1966) ELEVATION	PURTYMUN ELEVATION	LEVEL OF CONFIDENCE
PM-2 [297]	ALLUVIUM	0-30	30				
	TSHIREGE MBR	30-100	100				
	▾ OTOWI MBR.	100-405	305	6615	6685	6685	L
	GUAJE PUMICE BED	405-432	27	6310	6310	6310	H
	BASALT	432-700	268	6283	6283	6283	H
	PUYE FM.	700-738	38	6015	6015	6015	H
	BASALT	738-770	32	5977		5981	M
	▾ PUYE FM.	770-1340	570	5945	5945	5945	M
	TOTAVI FM.	1340-1410	70	5375	5375	5375	M
	SANTA FE GP. (undifferentiated)	1410-2600	1190	5305			M
	CHAQUEHUI FM.	1410-1840	430			5305	
	BASALT	1840-1892	52			4875	
	CHAQUEHUI FM.	1892-2218	326			4823	
	BASALT	2218-2312	94			4497	
	CHAQUEHUI FM.	2312-2370	58			4403	

DRILL HOLE ID (APPENDIX B1 NUMBER)	STRATIGRAPHIC UNIT	DEPTH [ft]	THICKNESS [ft]	THIS REPORT'S ELEVATION	USGS (John 1966) ELEVATION	PURTYMUN ELEVATION	LEVEL OF CONFIDENCE
	CHAMITA FM.	2370-2470	100			4345	
	TESUQUE FM.	2470-2600	130			4245	

SOURCE: Cooper (1965)
LOCATION: Pajarito Canyon (Pajarito Well Field)
GL ELEVATION: 6715 ft.
TD: 2600 ft. (4115 ft. elevation)
DATE DRILLED: 1965
DEPTH TO WATER:823 ft. (5892 ft. elevation); intermediate perched groundwater at 335 ft. (6380 ft. elevation)
WATER LEVEL: 870 ft. (5845 ft. elevation) - LANL 1993 data

NOTE: Both the USGS and Purtymun do not recognize the presence of the Tshirege Member in the geologic log. As noted by Gardner (1993), a re-examination of the core log suggests that the Tshirege-Otowi contact may occur at 100 feet.

DRILL HOLE ID (APPENDIX B1 NUMBER)	STRATIGRAPHIC UNIT	DEPTH [ft]	THICKNESS [ft]	THIS REPORT'S ELEVATION	USGS (John 1966) ELEVATION	PURTYMUN ELEVATION	LEVEL OF CONFIDENCE
PM-3 [298]	ALLUVIUM	0-30	30				
	OTOWI MBR.	30-170	140			6610	
	GUAJE PUMICE BED	170-190	20	6470		6470	H
	PUYE FM.	190-215	25	6450		6450	H
	BASALT	215-540	325	6425		6425	H
	▾ PUYE FM.	540-745	205	6100		6100	H
	▾ TOTAVI FM.	745-805	60	5895		5895	H
	SANTA FE GP. (undifferentiated)	805-2552	1747	5835			M[4]
	CHAQUEHUI FM.	805-1105	300			5835	
	BASALT #1	1105-1315	210			5535	
	CHAQUEHUI FM.	1315-1495	180			5325	
	BASALT #1	1495-1540	45			5145	
	CHAQUEHUI FM.	1540-2060	520			5100	
	TESUQUE FM.	2060-2552	492			4580	

SOURCE: Record of water-supply well PM-3 (Purtymun, June 1967)
LOCATION: Sandia Canyon (Pajarito Well Field)
GL ELEVATION: 6640 ft.
TD: 2552 ft. (4088 ft. elevation)
DATE DRILLED: 1966
DEPTH TO WATER: 740 ft. (5900 ft. elevation)
WATER LEVEL: 771 ft. (5869 ft. elevation)

NOTE:

DRILL HOLE ID (APPENDIX B1 NUMBER)	STRATIGRAPHIC UNIT	DEPTH [ft]	THICKNESS [ft]	THIS REPORT'S ELEVATION	USGS (John 1966) ELEVATION	PURTYMUN ELEVATION	LEVEL OF CONFIDENCE
OTOWI-1 [261]	COLLUVIUM/ ALLUVIUM	0-50	50				
	PUYE FM.	50-80	30			6346	
	▾ BASALT	80-280	200	6316		6316	H
	PUYE FM.	280-440	170	6116		6116	H
	BASALT	440-470	30	5956		5956	H
	▾ PUYE FM.	470-690	220	5926		5926	H
	▾ TOTAVI FM.	690-750	60	5706		5706	H
	SANTA FE GP. (undifferentiated)	750-2609	1859	5646			M
	TESUQUE FM.	750-2219	1469			5646	
	BASALT	2219-2231	12			4177	
	TESUQUE FM.	2231-2609	378			4165	

SOURCE: Purtymun (1993 and 1995)
LOCATION: Pueblo Canyon (Otowi Well Field)
LSD ELEVATION: 6396 ft.
TD: 2609 ft. (3787 ft. LSD elevation)
DATE DRILLED: 1990
DEPTH TO WATER: 675 ft. (5721 ft. LSD elevation); perched intermediate at 183 ft. (6213 ft. elevation)
WATER LEVEL: 704 ft. (5692 ft. elevation) - Table 1, LANL 1993 data

NOTE: FIMAD data does not include an initial Puye Fm. interval (~6346 ft.). Shallow groundwater cased out of hole above 55 ft.

DRILL HOLE ID [APPENDIX B1 NUMBER]	STRATIGRAPHIC UNIT	DEPTH [ft]	THICKNESS [ft]	THIS REPORT'S ELEVATION	USGS (John 1966) ELEVATION	PURTYMUN ELEVATION	LEVEL OF CONFIDENCE
OTOWI-4 [262]	▾ ALLUVIUM	0-28	28				
	BANDELIER TUFF	28-183	155			6599	
	▾ PUYE FM.	183-290	107	6444		6444	H
	BASALT #2	290-413	123	6337		6337	H
	PUYE FM.	413-712	299	6214		6214	H
	▾ TOTAVI FM.	712-810	98	5915		5915	H
	SANTA FE GP. (undifferentiated)	810-2806	1996	5817			M
	CHAQUEHUI FM.	810-1154	344			5817	
	BASALT	1154-1347	193			5473	
	CHAQUEHUI FM.	1347-1421	74			5280	
	BASALT	1421-1465	44			5206	
	CHAQUEHUI FM.	1465-1852	387			5162	
	CHAMITA FM.	1852-1932	80			4287	
	TESUQUE FM.	1932-2806	874			4207	

SOURCE: Purtymun (1992 and 1995)
LOCATION: Los Alamos Canyon (Otowi Well Field)
ELEVATION: 6627 ft.
TD: 2806 ft. (3820 ft. elevation)
DATE DRILLED: 1990
DEPTH TO WATER: 780 ft. (5847 ft. elevation); intermediate perched at 253 ft. (6374 ft. elevation); shallow groundwater at 27-28 ft. (6599-6600 ft. elevation)
WATER LEVEL: 861 ft. (5766 ft. elevation)

NOTE: FIMAD and Purtymun note the "Bandelier Tuff" from 6599 to 6444 ft. FIMAD stratigraphic data varies from the Purtymun data at depths greater than 5162 ft. The Purtymun (1995) geologic log differs with the Purtymun (1992) geologic log.

DRILL HOLE ID (APPENDIX B1 NUMBER)	STRATIGRAPHIC UNIT	DEPTH [ft]	THICKNESS [ft]	THIS REPORT'S ELEVATION	USGS (John 1966) ELEVATION	PURTYMUN ELEVATION	LEVEL OF CONFIDENCE
P-87-3 [544]	COLLUVIUM/ ALLUVIUM	0-3	3				
	TSHIREGE MBR.	3-9	6				
	SOURCE: Brown (1987) LOCATION: Cañon de Valle GL ELEVATION: 7342 ft. TD: 9 ft. (7333 ft. elevation) DATE DRILLED: 1987 DEPTH TO WATER: visual water in borehole (1992 and 1993)						
	NOTE:						
PM-1 [296]	OTOWI MBR.	0-120	120		6520	6520	
	GUAJE PUMICE BED	120-159	39	6400	6400	6400	H
	EPICLASTIC ZONE	159-165	6	6361			L
	▾ BASALT	165-507	342	6355	6355	6355	H
	OLD ALLUVIUM	507-550	43		6013	6013	
	▾ PUYE FM.	507-775	268	6013			L
	TOTAVI FM.	775-795	20	5745	5745	5745	H
	SANTA FE GP. (undifferentiated)	795-2501	1706	5725	5725		M
	CHAQUEHUI FM.	795-836	1706			5725	
	BASALT	836-966	171			5684	
	CHAQUEHUI FM.	966-1054	88			5554	
	BASALT	1054-1094	40			5466	
	CHAQUEHUI FM.	1094-1166	72			5426	
	BASALT	1166-1180	14			5354	

DRILL HOLE ID [APPENDIX B1 NUMBER]	STRATIGRAPHIC UNIT	DEPTH [ft]	THICKNESS [ft]	THIS REPORT'S ELEVATION	USGS (John 1966) ELEVATION	PURTYMUN ELEVATION	LEVEL OF CONFIDENCE
LA-3 [127]	ALLUVIUM	0-51	51				
	TESUQUE FM.	51-910	859		5621	5621	
	SOURCE: Purtymun (1995) LOCATION: Los Alamos Canyon (Los Alamos Well Field) LSD ELEVATION: 5672 ft. TD: 910 ft. (4762 ft. LSD elevation) DATE DRILLED: 1947 DEPTH TO WATER: (flowing)						
	NOTE: Both Purtymun and USGS refer to the Tesuque Fm. versus the Santa Fe Gp. (undifferentiated).						
LA-4 [128]	ALLUVIUM	0-27	27				
	PUYE MBR.	27-113	86		5948	5948	
	TOTAVI FM.	113-163	50	5862	5862	5862	H
	▾ SANTA FE GP.	163-2019	1856	5812	5812	5812	M
	SOURCE: Purtymun (1995) LOCATION: Los Alamos Canyon (Los Alamos Well Field) LSD ELEVATION: 5975 ft. TD: 2019 ft. (3956 ft. LSD elevation) DATE DRILLED: 1948 DEPTH TO WATER: 189 ft. (5786 ft. LSD elevation) WATER LEVEL: 219 ft. (5756 ft. elevation)						
	NOTE: Both Purtymun and USGS refer to the Tesuque Fm. versus the Santa Fe Gp. (undifferentiated).						
LA-5 [129]	ALLUVIUM	0-42	42				
	▾ TESUQUE FM.	42-2024	1982		5798	5798	
	SOURCE: Purtymun (1995) LOCATION: Los Alamos Canyon (Los Alamos Well Field) LSD ELEVATION: 5840 ft. TD: 2024 ft. (3816 ft. LSD elevation) DATE DRILLED: 1948 DEPTH TO WATER: 71 ft. (5769 ft. LSD elevation)						
	NOTE: Both Purtymun and USGS refer to the Tesuque Fm. versus the Santa Fe Gp. (undifferentiated).						

DRILL HOLE ID [APPENDIX B1 NUMBER]	STRATIGRAPHIC UNIT	DEPTH [ft]	THICKNESS [ft]	THIS REPORT'S ELEVATION	USGS (John 1966) ELEVATION	PURTYMUN ELEVATION	LEVEL OF CONFIDENCE
PM-4 [299]	TSHIREGE MBR.	0-190					
	OTOWI MBR.	190-525	335	6731		6700	
	GUAJE PUMICE BED	525-600	75	6380		6380	H
	▾ BASALT #2	600-1090	490	6321		6320	H
	PUYE FM.	1090-1380	290	5831		5820	H
	TOTAVI FM.	1380-1420	40	5541		5540	H
	SANTA FE GP. (undifferentiated)	1420-2921	1501	5501		5500	H

SOURCE: Geologic log LANL ESH-18 files (Purtymun)
GL ELEVATION: 6920 ft.
LOCATION: Mesita del Buey (Pajarito Well Field)
TD: 2921 ft. (4000 ft. elevation)
DATE DRILLED: 1981
DEPTH TO WATER: 1060 ft. (5860 ft. elevation)
WATER LEVEL: 1084 ft. (5836 ft. elevation)

NOTE: FIMAD refers to the Santa Fe as the Chaquehui Fm. FIMAD also continues from 4970 to 4490 ft. with Chaquehui interbedded with Basalt #1. Purtymun (1995) agrees with FIMAD except with the elevation of the top of the Totavi Lentil. The Purtymun data agrees with the above elevation of 5540 ft. for the Totavi Interval.

DRILL HOLE ID (APPENDIX B1 NUMBER)	STRATIGRAPHIC UNIT	DEPTH [ft]	THICKNESS [ft]	THIS REPORT'S ELEVATION	USGS (John 1966) ELEVATION	PURTYMUN ELEVATION	LEVEL OF CONFIDENCE
PM-5 [300]	TSHIREGE MBR.	0-285	285				
	OTOWI MBR.	285-690	405	6810		6760	M[2]
	GUAJE PUMICE BED	690-740	50	6405		6385	M
	BASALT	740-1150	410	6355		6355	H
	▾ PUYE FM.	1150-1470	320	5945		5950	M
	TOTAVI FM.	1470-1550	80	5625		5625	H
	SANTA FE GP. (undifferentiated)	1550-2427	877	5545			M[4]
	CHAQUEHUI FM.	1550-2780				5545	
	CHAMITA FM.	2780-2860				4315	
	TESUQUE FM.	2860-3110				4235	

SOURCE: Gordon Herkenhoff & Associates (9/17/82).
LOCATION: Mesita del Buey (Pajarito Well Field)
GL ELEVATION: 7095 ft.
TD: 2427 ft. (4668 ft. elevation)
DATE DRILLED: 1982
DEPTH TO WATER: 1222 ft. (5873 ft. elevation)

NOTE:

DRILL HOLE ID (APPENDIX B1 NUMBER)	STRATIGRAPHIC UNIT	DEPTH [ft]	THICKNESS [ft]	THIS REPORT'S ELEVATION	USGS (John 1966) ELEVATION	PURTYMUN ELEVATION	LEVEL OF CONFIDENCE
POTO-4A [320]	ALLUVIUM	0-9					
	TSHIREGE MBR.	9-84	75			6611	
	TSANKAWI PUMICE BED/CERRO TOLEDO INTERVAL	84-104	20	6536		6536	H
	OTOWI MBR.	104-174	70	6516		6516	H
	SOURCE: Purtymun (1995) LOCATION: Potrillo Canyon ELEVATION (LDS): 6620 ft. TD: 174 ft. (6446 ft. LDS elevation) DATE DRILLED: 1991						
	NOTE: FIMAD agrees with Purtymun data.						
SHB-1 [339]	TSHIREGE MBR.	0-302	302				
	TSANKAWI PUMICE BED	302-306	4	7012			H
	CERRO TOLEDO INTERVAL	306-445	139	7008			H
	OTOWI MBR.	445-590	145	6869			H
	GUAJE PUMICE BED	590-631	41	6724			H
	PUYE FM.	631-644	13	6683			H
	BASALT	644-700	56	6670			H
	SOURCE: Gardner (1993); FIMAD LOCATION: Mesita del Buey ELEVATION (LDS): 7314 ft. TD: 700 ft. (6614 ft. elevation) DATE DRILLED: 1992						
	NOTE:						

DRILL HOLE ID (APPENDIX B1 NUMBER)	STRATIGRAPHIC UNIT	DEPTH [ft]	THICKNESS [ft]	THIS REPORT'S ELEVATION	USGS (John 1966) ELEVATION	PURTYMUN ELEVATION	LEVEL OF CONFIDENCE
SHB-3 [341]	TSHIREGE MBR.	0-320	335				
	TSANKAWI PUMICE BED	320-335	15	7287			H
	▾ CERRO TOLEDO INTERVAL	335-424	89	7272			H
	OTOWI MBR.	424-838	414	7183			H
	GUAJE PUMICE BED	838-839	1	6769			H
	PUYE FM.	839-860	21	6768			H
	SOURCE: Gardner (1993); FIMAD LOCATION: Water Canyon Mesa ELEVATION (LDS): 7607 ft. TD: 860 ft. (6747 ft. elevation) DATE DRILLED: 1992 DEPTH TO WATER: 346 ft. (6807 ft. elevation) - this elevation is suspect given that no water was cased out of hole.						
	NOTE: FIMAD agrees with data.						
SHB-4 [342]	TSHIREGE MBR.	0-117	117				
	TSANKAWI PUMICE BED	117-120	3	6584			H
	▾ OTOWI MBR.	120-200	>80	6581			H
	SOURCE: Gardner (1993); FIMAD LOCATION: Mesita del Buey GL ELEVATION: 6701 ft. TD: 200 ft. (6501 ft. elevation) DATE DRILLED: 1992 DEPTH TO WATER:						
	NOTE: Wet core was encountered from 125 to 145 ft.						

DRILL HOLE ID (APPENDIX B1 NUMBER)	STRATIGRAPHIC UNIT	DEPTH [ft]	THICKNESS [ft]	THIS REPORT'S ELEVATION	USGS (John 1966) ELEVATION	PURTYMUN ELEVATION	LEVEL OF CONFIDENCE
SIGMA MESA (E6H-LA-1) [343]	TSHIREGE MBR.	0-315	315				
	OTOWI MBR.	315-695	380	6900		6900	M
	GUAJE PUMICE BED	695-725	30	6520		6520	M
	PUYE FM.	725-910	185	6490		6490	M
	TSCHICOMA FM.	910-1050	140	6305		6305	M
	PUYE FM.	1050-1305	225	6165		6165	M
	▾ TOTAVI FM.	1305-1330	25	5910		5910	M
	SANTA FE GP. (undifferentiated)	1330-2292	962	5885			M
	CHAQUEHUI FM.	1330-1580	250			5885	
	BASALT	1580-1715	135			5635	
	CHAQUEHUI FM.	1715-1895	180			5500	
	BASALT	1895-2292	397			5320	

SOURCE: Purtymun (January 1995)
LOCATION: Pajarito Plateau
GL ELEVATION: 7215 ft.
TD: 2292 ft. (4923 ft. elevation)
DATE DRILLED: 1979
DEPTH TO WATER: 1330 ft. (5885 ft. elevation)

NOTE:

DRILLHOLE ID (APPENDIX B1 NUMBER)	STRATIGRAPHIC UNIT	DEPTH [ft]	THICKNESS [ft]	THIS REPORT'S ELEVATION	USGS (John 1966) ELEVATION	PURTYMUN ELEVATION	LEVEL OF CONFIDENCE
SIMO [344]	ALLUVIUM	0-11	11				
	TSHIREGE MBR.	11-47	36				
	TSANKAWI MBR.	47-64	17	6611	6611	6611	H
	OTOWI MBR.	64-104	40	6594	6594	6594	H
	SOURCE: Purtymun (1995), Stoker, et al. (1991) LOCATION: Mortandad Canyon ELEVATION (LSD): 6658 ft. TD: 104 ft. (6554 ft. elevation) DATE DRILLED: 1990 DEPTH TO WATER: dry						
	NOTE:						
SIMO-1 [345]	TSHIREGE MBR.	0-53	53				
	OTOWI MBR.	53-163	110	6597			M
	SOURCE: Purtymun (1995); FIMAD LOCATION: Mortandad Canyon GL ELEVATION: 6650 ft. TD: 163 ft. (6487 ft. elevation) DATE DRILLED: 1992 DEPTH TO WATER: dry						
	NOTE:						

DRILL HOLE ID (APPENDIX B1 NUMBER)	STRATIGRAPHIC UNIT	DEPTH [ft]	THICKNESS [ft]	THIS REPORT'S ELEVATION	USGS (John 1966) ELEVATION	PURTYMUN ELEVATION	LEVEL OF CONFIDENCE
SKI BASIN WELL [346]	TSHIREGE MBR.	0-35	35				M
	▾ TSCHICOMA FM.	35-400	365	9275			M
	SOURCE: FIMAD; Purtymun (1995) LOCATION: Pajarito Plateau GL ELEVATION: 9310 ft. TD: 400 ft. (8910 ft. elevation) DATE DRILLED: 1985 WATER LEVEL: 245 ft. (9065 ft. elevation) - Purtymun (1995)						
	NOTE: It is uncertain whether the water level recorded is the static water level after well completion or if this elevation was the first water encountered.						
TA-46 [349]	TSHIREGE MBR.	0-360	360				
	OTOWI MBR.	360-695	335	6745		6745	H
	GUAJE PUMICE BED	695-727	32	6410		6410	H
	PUYE FM.	727-747	20	6378		6378	H
	SOURCE: FIMAD; Purtymun (1995) LOCATION: Mesita del Buey GL ELEVATION: 7105 ft. TD: 747 ft. (6358 ft. elevation) DATE DRILLED: 1971 DEPTH TO WATER: dry						
	NOTE:						

DRILL HOLE ID (APPENDIX B1 NUMBER)	STRATIGRAPHIC UNIT	DEPTH [ft]	THICKNESS [ft]	THIS REPORT'S ELEVATION	USGS (John 1966) ELEVATION	PURTYMUN ELEVATION	LEVEL OF CONFIDENCE
TA-49 Cold Hole [541]	TSHIREGE MBR.	0-557	557				
	TSANKAWI PUMICE BED	557-561	4	6573			H
	CERRO TOLEDO INTERVAL	561-596	35	6569			H
	OTOWI MBR.	596-700	104	6534			H
	SOURCE: David Broxton, Personal Communication (6/29/95); site visit during drilling LOCATION: Frijoles Mesa ELEVATION (LDS): 7130 ft. TD: 700 ft. (6430 ft. elevation) DATE DRILLED: 1994						
	NOTE:						
TEST HOLE 7-53 [360]	ALLUVIUM	0-1					
	TSHIREGE MBR.	1-23	22				
	TSANKAWI PUMICE BED	23-42	19	6677			M
	OTOWI MBR.	42-79	37	6658			M
	SOURCE: FIMAD; LANL RCRA Part B Permit Application (1992) LOCATION: Mesita de los Alamos GL ELEVATION: 6701 ft. TD: 79 ft. (6622 ft. elevation) DATE DRILLED: unknown						
	NOTE:						

DRILL HOLE ID (APPENDIX B1 NUMBER)	STRATIGRAPHIC UNIT	DEPTH [ft]	THICKNESS [ft]	THIS REPORT'S ELEVATION	USGS (John 1966) ELEVATION	PURTYMUN ELEVATION	LEVEL OF CONFIDENCE
TH-1 [364]	ALLUVIUM	0-8					
	BANDELIER TUFF	8-85	77				
	PUYE FM.	85-89	4	6575			L
	SOURCE: FIMAD LOCATION: Bayo Canyon GL ELEVATION: 6660 ft. TD: 89 ft. (6571 ft. elevation) DATE DRILLED: 1961						
	NOTE:						
TH-3 [370]	ALLUVIUM	0-7	7				
	BANDELIER TUFF	7-65	58	6603			
	PUYE FM.	65-70	5	6545			L
	SOURCE: FIMAD LOCATION: Bayo Canyon GL ELEVATION: 6610 ft. TD: 70 ft. (6540 ft. elevation) DATE DRILLED: 1961						
	NOTE:						

DRILL HOLE ID (APPENDIX B1 NUMBER)	STRATIGRAPHIC UNIT	DEPTH [ft]	THICKNESS [ft]	THIS REPORT'S ELEVATION	USGS (John 1966) ELEVATION	PURTYMUN ELEVATION	LEVEL OF CONFIDENCE
TH-4 [371]	ALLUVIUM	0-8	8				
	TSHIREGE MBR.	8-77	69	6662			
	PUYE FM.	77-79	2	6593			L
	SOURCE: FIMAD LOCATION: Bayo Canyon GL ELEVATION: 6670 ft. TD: 79 ft. (6591 ft. elevation) DATE DRILLED: 1961						
	NOTE:						
TH-5 [531]	ALLUVIUM	0-23	23				
	TSHIREGE MBR.	23-50	27		6569	6569	
	TSANKAWI PUMICE BED/CERRO TOLEDO INTERVAL	50-120	70	6542			L
	OTOWI MBR.	120-160	40	6472	6552	6552	L
	GUAJE PUMICE BED	160-171	11	6432	6432	6432	H
	BASALT	171-263	92	6421	6421	6421	H
	SOURCE: Black & Veatch (1950) LOCATION: Pajarito Canyon ELEVATION (LDS): 6592 ft. TD: 263 ft. (6329 ft. elevation) DATE DRILLED: 1950 DEPTH TO WATER: dry						
	NOTE: The original geologist's logs do not provide sufficient data to determine the Tshirege-Otowi contact. Angular fragments of the Tschicoma volcanic rocks are noted in logs from 50 to 120 feet. Purtymun report cites Griggs (1955) and agrees with USGS data.						

DRILL HOLE ID (APPENDIX B1 NUMBER)	STRATIGRAPHIC UNIT	DEPTH [ft]	THICKNESS [ft]	THIS REPORT'S ELEVATION	USGS (John 1966) ELEVATION	PURTYMUN ELEVATION	LEVEL OF CONFIDENCE
TH-6 [532]	▾ ALLUVIUM	0-25					
	TSHIREGE MBR.	25-85	60		6680	6617	
	OTOWI MBR.	85-275	190	6613	6620	6557	L
	GUAJE PUMICE BED	275-300	25	6423	6440	6377	L
	PUYE FM.				6420	6357	L
	SOURCE: Black & Veatch (1950) LOCATION: Pajarito Canyon ELEVATION (LDS): 6698 ft. (original log) TD: 300 ft. (6398 ft. elevation) DATE DRILLED: 1950 DEPTH TO WATER: 15 ft. (6683 ft. elevation); shallow perched groundwater from 15 to 25 ft.						
	NOTE: The original geologist's logs do not provided sufficient data to determine the Tshirege-Otowi contact as well as, the Guaje-pre-Bandelier Tuff contact. Purtymun (1995) agrees with the USGS picks, but differs in GL elevation (6642 ft. Purtymun and 6705 ft. USGS). Purtymun report cites Griggs (1955) and agrees with USGS data.						
TH-7 [542]	ALLUVIUM	0-10	10				
	OTOWI MBR.	10-45	35		6214	6214	
	BASALT #2	45-55	10	6179	6179	6179	H
	SOURCE: Black & Veatch (1950), Griggs (1955) LOCATION: Ancho Canyon ELEVATION (LDS): 6224 ft. TD: 55 ft. (6169 ft. elevation) DATE DRILLED: 1950 DEPTH TO WATER: dry						
	NOTE: The original geologist's logs do not mention the Guaje Pumice Bed. Purtymun report cites Griggs (1955) and agrees with USGS data. FIMAD does not have an entry for TH-7 at an elevation of 6224 ft.						

DRILL LE ID (APPENDIX B1 NUMBER)	STRATIGRAPHIC UNIT	DEPTH [ft]	THICKNESS [ft]	THIS REPORT'S ELEVATION	USGS (John 1966) ELEVATION	PURTYMUN ELEVATION	LEVEL OF CONFIDENCE
TW-1 (TH1-C) [384]	ALLUVIUM	0-50	50				
	BASALT	50-173	123		6321	6319	
	PUYE FM.	173-176	3	6198	6206	6204	H
	BASALT	176-255	79	6193	6195	6193	H
	PUYE FM.	255-410	155	6116	6116	6114	H
	BASALT	410-510	100	5961	5961	5959	H
	▾ PUYE FM.	510-605	95	5861	5861	5859	H
	▾ TOTAVI FM.	605-642	37	5766	5764	5766	H

SOURCE: Geologist's log, Griggs (1955 and 1964)
LOCATION: Pueblo Canyon
ELEVATION: 6371 ft. (original geologist's log and Griggs)
TD: 642 ft. (6729 ft. elevation)
DATE DRILLED: 1950
DEPTH TO WATER: 623 ft. (5748 ft. elevation)
WATER LEVEL: 585 ft. (5786 ft. elevation) - Griggs (1950); 549 ft. (5822 ft. elevation) - LANL (1993)

NOTE:

DRILL[illegible]LE ID [APPENDIX B1 NUMBER]	STRATIGRAPHIC UNIT	DEPTH [ft]	THICKNESS [ft]	THIS REPORT'S ELEVATION	USGS (John 1966) ELEVATION	PURTYMUN ELEVATION	LEVEL OF CONFIDENCE
TW-1A [385]	PUYE FM.	0-50	50				
	BASALT	50-165	115		6320	6319	
	PUYE FM.	165-176	11	6205	6205	6204	H
	▾ BASALT	176-225	49	6194	6194	6193	H
	SOURCE: Griggs (1955 and 1964) LOCATION: Pueblo Canyon GL ELEVATION: 6370 ft. TD: 225 ft. (6145 ft. elevation) DATE DRILLED: 1950 DEPTH TO WATER: 211 ft. (6159 ft. elevation) WATER LEVEL: 184 ft. (6168 ft. elevation) - 1950						
	NOTE:						
TW-2 [386]	ALLUVIUM	0-11	11				
	OTOWI MBR.	11-35	24		6635	6638	
	GUAJE PUMICE BED	35-63	28	6611	6615	6618	H
	PUYE FM.	63-700	637	6583	6583	6586	H
	▾ TOTAVI FM.	700-834	134	5946	5946	5949	H
	SOURCE: Griggs 1955 and 1964 LOCATION: Pueblo Canyon ELEVATION: 6646 ft. (USGS and original geologist's log), 6648 ft. (Purtymun) TD: 834 ft. (5812 ft. elevation) DATE DRILLED: 1949 DEPTH TO WATER: 765 ft. (5881 ft. elevation) WATER LEVEL: 759 ft. (5887 ft. elevation) - 1949; 791 ft. (5855 ft. elevation) - LANL (1993)						
	NOTE: Purtymun's elevation (6648 ft.) is thought to be the total elevation of the ground surface and the height of the concrete around the hole and not the true elevation. Intermediate perched groundwater was encountered at 112 to 115 ft.						

DRILL[illegible]LE ID (APPENDIX B1 NUMBER)	STRATIGRAPHIC UNIT	DEPTH [ft]	THICKNESS [ft]	THIS REPORT'S ELEVATION	USGS (John 1966) ELEVATION	PURTYMUN ELEVATION	LEVEL OF CONFIDENCE
TW-2A [387]	ALLUVIUM	0-11	11				
	OTOWI MBR.	11-31	20		6635	6635	
	GUAJE PUMICE BED	31-63	32	6615	6615	6615	H
	▾ PUYE FM.	63-133	70	6583	6583	6583	H
	SOURCE: Griggs (1955 and 1964) LOCATION: Pueblo Canyon GL ELEVATION: 6646 ft. TD: 133 ft. (6513 ft. elevation) DATE DRILLED: 1950 DEPTH TO WATER: 112 ft. (6534 ft. elevation) WATER LEVEL: 121 ft. (6525 ft. elevation) - LANL (1993); 93 ft. (6553 ft. elevation) - 1950						
	NOTE: FIMAD uses GL elevation of 6650 ft.; thus, FIMAD's picks vary accordingly.						
TW-3 [389]	ALLUVIUM	0-37	37				
	OTOWI MBR.	37-175	138				
	GUAJE PUMICE BED	175-285			6485	6455	L[3]
	PUYE FM.	285-266	91	6450	6450	6420	M
	BASALT	266-388	122	6359	6359	6329	M
	PUYE FM.	388-620	232	6237	6287	6257	
	▾ TOTAVI FM.	620-815	195	6005	5872	5842	
	SOURCE: Griggs (1955 and 1964) LOCATION: Los Alamos Canyon ELEVATION: 6625 ft. (original log and USGS); 6595 (Purtymun) TD: 815 ft. (5810 ft. elevation) DATE DRILLED: 1949 DEPTH TO WATER: 790 ft. (5835 ft. elevation) WATER LEVEL: 743 ft. (5882 ft. elevation) - 1949; 806 ft. (5819 ft. elevation) - LANL (1993)						
	NOTE:						

DRILL HOLE ID [APPENDIX B1 NUMBER]	STRATIGRAPHIC UNIT	DEPTH [ft]	THICKNESS [ft]	THIS REPORT'S ELEVATION	USGS (John 1966) ELEVATION	PURTYMUN ELEVATION	LEVEL OF CONFIDENCE
TW-4 [390]	TSHIREGE MBR.	0-258	258				
	TSANKAWI PUMICE BED	258-330	72	6985			L[1]
	CERRO TOLEDO INTERVAL	330-340	10	6913			L[1]
	OTOWI MBR.	340-368	28	6903	6963	6965	M[1]
	GUAJE PUMICE BED	368-395	27	6875	6875	6877	H
	▾ TSCHICOMA FM.	395-1184	789	6850			L
	▾ PUYE FM.	1184-1195	11	6059	6848	6850	L
	TSCHICOMA FM.	1195-1205	10	6048	6608	6610	L

SOURCE: Griggs (1955 and 1964)
LOCATION: Acid Mesa
ELEVATION: 7243 ft. (original log and USGS), 7245 ft. (Purtymun)
TD: 1205 ft. (6038 ft. elevation)
DATE DRILLED: 1950
DEPTH TO WATER: 1184 ft. (6059 ft. elevation); 1166 ft. (6077 ft. elevation) - USGS
WATER LEVEL: 1171 ft. (6074 elevation) - LANL (1993)

NOTE: FIMAD agrees with Purtymun data except for elevation.

DRILL HOLE ID [APPENDIX B1 NUMBER]	STRATIGRAPHIC UNIT	DEPTH [ft]	THICKNESS [ft]	THIS REPORT'S ELEVATION	USGS (John 1966) ELEVATION	PURTYMUN ELEVATION	LEVEL OF CONFIDENCE
TW-8 [391]	ALLUVIUM	0-45	45				
	TSHIREGE MBR.	45-110	65		6827	6838	
	TSANKAWI PUMICE BED	110-145	35	6762			M
	OTOWI MBR.	145-445	300	6727	6727	6818	M[1]
	GUAJE PUMICE BED	445-490	45	6427	6427	6433	M
	PUYE FM.	490-575	85	6382	6382	6388	M
	BASALT	575-725	150	6297	6307	6298	M
	▾ PUYE FM.	725-1065	340	6147	6147	6153	M

SOURCE: Baltz, et al. (1963)
LOCATION: Mortandad Canyon
GL ELEVATION: 6872 ft. (Baltz, et al.), 6878 ft. (Purtymun)
TD: 1065 ft. (5807 ft. elevation)
DATE DRILLED: 1960
DEPTH TO WATER: 985 ft. (5887 ft. elevation)
WATER LEVEL: 963 ft. (5909 ft. elevation); 987 ft. (5885 ft. elevation) - LANL (1993)

NOTE:

1. Well log lithologic descriptions are too vague to distinguish between the Tsankawi Pumice Bed and the Cerro Toledo Interval with the top of the Otowi Member.

2. The absence of mention of the Tsankawi Pumice Bed and the Cerro Toledo Interval in the log draws question to the Tshirege/Otowi Members' contact.

3. The Guaje Pumice Bed is noted as being undifferentiated from the Otowi Member.

4. For the purposes of this report, the Santa Fe Group is undifferntiated between the Chamita Formation and the Tesuque Formation.

APPENDIX C

MATERIAL DISPOSAL AREA TABLES

MDA-A (SWMU 21-014)	POTENTIAL FOR RELEASE TO GROUNDWATER: Moderate to High
LOCATION:	On mesa between DP (to north) and Los Alamos Canyon (to south); MDA-T and MDA-V to west and east, respectively
DESCRIPTION:	1.25 ac.; 5 pits, 2 underground storage tanks, and 100 drums
DISTANCE TO SURFACE WATER:	~250 feet
DISTANCE TO GROUND WATER:	~250 feet
FRACTURE DENSITY:	High
RELEASE INFORMATION:	RFI Workplan documents a release LANL ER Ranking High (50) SWMU Report documents that a release may have occurred (leaking drums)
PARAMETERS/CONSTITUENTS OF CONCERN:	Pu, Po, Am, radioactive iodine, and solvents
MOBILITY OF CONSTITUENTS:	High probability of mobilization and transport of COCs into nearest drainage
INTEGRITY OF MDA:	Unit is assumed to be unlined
PERIOD OF OPERATION:	1944 to 1947 and 1969 to 1978

MDA-B (SWMU 21-015)	POTENTIAL FOR RELEASE TO GROUNDWATER: Moderate to High
LOCATION:	Near TA-21; on mesa top south of DP Road
DESCRIPTION:	6 ac.; inactive landfill which may consist of several pits or one large pit
DISTANCE TO SURFACE WATER:	400+ feet
DISTANCE TO GROUND WATER:	300+ feet
FRACTURE DENSITY:	Fractures present, but density not quantified
RELEASE INFORMATION:	RFI Workplan radionuclide release from unknown source has affected surface and subsurface soils LANL ER Ranking High (56) SWMU Report no release documented to date
PARAMETERS/CONSTITUENTS OF CONCERN:	Pu, Po, R, Am, Cm, Ac, fission products from Trinity Test, organics, perchlorates, ethers, and solvents
MOBILITY OF CONSTITUENTS:	High probability for mobilization and transport of COCs into nearest drainage
INTEGRITY OF MDA:	Unit is unlined; MDA may consist of several pits or one large pit covered and expanded as necessary
PERIOD OF OPERATION:	1945 to 1948

MDA-C (SWMU 50-009)	POTENTIAL FOR RELEASE TO GROUNDWATER: Moderate to High
LOCATION:	On mesa top; Pajarito Canyon to the south; head of Ten Site Canyon to the northeast; bounded by Pajarito Road to the south
DESCRIPTION:	11.8 ac.: consists of 7 pits, 107 shafts, and one unnumbered shaft for a single ^{90}Sr disposal; 118,000 cubic yards of TRU waste
DISTANCE TO SURFACE WATER:	~150 feet (drainage is to the northeast into Ten Site Canyon)
DISTANCE TO GROUND WATER:	≥300 feet
FRACTURE DENSITY:	High
RELEASE INFORMATION:	RFI Workplan documents a release in the vapor phase LANL ER Ranking High (60) SWMU Report documents radioactivity above background
PARAMETERS/CONSTITUENTS OF CONCERN:	TCE, B, H_2SO_4, Hg, Cn, Cu, Co, ^{227}Ac, ^{226}Ra, ^{3}H, ^{241}Am, U, graphite, Pu, Pb, waste oil, acids (unspecified), Be, and Ag
MOBILITY OF CONSTITUENTS:	High probability for mobilization and transport of COCs into nearest drainage
INTEGRITY OF MDA:	Parts of unit are lined with concrete, however, most is unlined
PERIOD OF OPERATION:	1948 to 1974

MDA-D (SWMU 33-003[a,b])	POTENTIAL FOR RELEASE TO GROUNDWATER: Low to Moderate
LOCATION:	East end of mesa named "TA-33 East Site"; mesa formed by Ancho and White Rock Canyons
DESCRIPTION:	2 chambers used for ^{210}Po-bearing experiments
DISTANCE TO SURFACE WATER:	1,000 feet
DISTANCE TO GROUND WATER:	≥300 feet
FRACTURE DENSITY:	Inferred faulting occurs in the area (Dransfield and Gardner, 1985)
RELEASE INFORMATION:	RFI Workplan documents elevated Ba (51 to 125 ppm) and Pb (1.9 to 3.3 ppm); proposed for NFA LANL ER Ranking Low (17) SWMU Report indicates no known releases have occurred
PARAMETERS/CONSTITUENTS OF CONCERN:	Be, Ba, Pb, ^{210}Po and HE
MOBILITY OF CONSTITUENTS:	Very low probability for mobilization and transport of COCs into nearest drainage
INTEGRITY OF MDA:	Unit is unlined
PERIOD OF OPERATION:	1948 to 1952

MDA-E (SWMU 33-001[a-e])	POTENTIAL FOR RELEASE TO GROUNDWATER: Moderate
LOCATION:	On the mesa top bounded by Chaquehui Canyon and one of its tributaries; lies ~50 feet from cliff face
DESCRIPTION:	1 underground chamber and 6 pits
DISTANCE TO SURFACE WATER:	0.5 to 1 mile
DISTANCE TO GROUND WATER:	≥300 feet
FRACTURE DENSITY:	Inferred faulting occurs in the area (Dransfield and Gardner, 1985)
RELEASE INFORMATION:	LANL ER Ranking Moderate (22) SWMU Report documents Po and U in 1952 and 1954 soil samples; unknown if release occurred
PARAMETERS/CONSTITUENTS OF CONCERN:	Ni, Cd, Pb, W, ^{210}Po, ^{3}H, ^{137}Cs, Be, and U
MOBILITY OF CONSTITUENTS:	Low probability for mobilization and transport of COCs into nearest drainage
INTEGRITY OF MDA:	Pits are unlined and were compacted
PERIOD OF OPERATION:	1949 to 1963

MDA-F (SWMU 6-007[a])	POTENTIAL FOR RELEASE TO GROUNDWATER: Low to Moderate
LOCATION:	North of Two Mile Mesa Road in TA-6; Tributaries A and B, which drain MDA-F, are to the northeast and east, respectively; Pajarito Canyon is to the south
DESCRIPTION:	Pits and shafts which have not been accurately located
DISTANCE TO SURFACE WATER:	~0.5 mile east
DISTANCE TO GROUND WATER:	>300 feet
FRACTURE DENSITY:	Unknown
RELEASE INFORMATION:	LANL ER Ranking Moderate (40) SWMU Report indicates no known release; however, a sample from the perimeter of one of the pits recorded a reading of >300 pCi/kg
PARAMETERS/CONSTITUENTS OF CONCERN:	Gross gamma, HE, VOCs, SVOCs, U, ^{90}Sr, ^{137}Cs, and metals
MOBILITY OF CONSTITUENTS:	Low probability for mobilization and transport of COCs into nearest drainage
INTEGRITY OF MDA:	Unit is assumed to be unlined
PERIOD OF OPERATION:	1950 to 1952

MDA-G (SWMU 54-017 through 54-020)	**POTENTIAL FOR RELEASE TO GROUNDWATER: Moderate to High**
LOCATION:	On Mesita del Buey approximately 2 miles southeast of the intersection of Pajarito Road and Rex Drive
DESCRIPTION:	181 shafts (lined and unlined), and 30 pits or trenches used for the storage and disposal of radioactive waste (specific number of shafts and pits uncertain)
DISTANCE TO SURFACE WATER:	>0.25 mile
DISTANCE TO GROUND WATER:	>300 feet
FRACTURE DENSITY:	Presence of fault between MDA-I and MDAs H and J is suspected; down-to-the-north offsets observed at Pit 22 (Dransfield and Gardner, 1985)
RELEASE INFORMATION:	RFI Workplan documents releases to the surrounding Tuff; significant levels of ^{3}H first detected in 1970; TCA, PCE, TCE, chloroform, toluene, and freon-11 found in vapor phase (1985); ^{238}Pu and ^{239}Pu surface contamination found near disposal pits and shafts LANL ER Ranking High (60) SWMU Report provides the same information as the RFI Workplan, as well as, citing elevated levels of $^{238/239}Pu$ in stream sediments and air
PARAMETERS/CONSTITUENTS OF CONCERN:	^{3}H, ^{7}Be, ^{14}C, ^{22}Na, ^{32}P, ^{35}S, ^{36}Cl, ^{46}Sc, ^{48}V, ^{51}Cr, ^{54}Mn, ^{55}Fe, ^{59}Fe, ^{56}Co, ^{58}Co, ^{60}Co, ^{63}Ni, ^{65}Zn, ^{75}Se, ^{82}Br, ^{85}K, ^{82}Sr, ^{89}Sr, ^{90}Sr, ^{88}Y, ^{95}Zr, ^{94}Nb, ^{99}Tc, ^{99m}Tc, ^{103}Ru, ^{106}Ru, ^{110}Ag, ^{109}Cd, ^{125}I, ^{131}I, ^{134}Cs, ^{137}Cs, ^{139}Ba, ^{140}Ba, ^{152}Eu, ^{182}Ta, ^{144}Ce, ^{147}Pm, ^{192}Ir, ^{203}Hg, ^{210}Po, ^{226}Ra, ^{228}Ra, ^{227}Ac, ^{228}Th, ^{229}Th, ^{230}Th, ^{232}Th, ^{231}Pa, ^{232}U, ^{233}U, ^{235}U, ^{238}U, ^{237}Np, ^{238}Pu, ^{239}Pu, ^{240}Pu, ^{241}Pu, ^{242}Pu, ^{241}Am, ^{243}Am, ^{244}Cm, ^{249}Cf, ^{252}Cf PCBs, Be, asbestos, metals (unspecified),Pb, and VOCs
MOBILITY OF CONSTITUENTS:	High probability for mobilization and transport of COCs into nearest drainage
INTEGRITY OF MDA:	Some shafts are lined with a metal casing
PERIOD OF OPERATION:	Disposal began in 1959; storage continues to present

MDA-H (SWMU 54-004)	POTENTIAL FOR RELEASE TO GROUNDWATER: Moderate to High
LOCATION:	Immediately inside the western boundary of TA-54 on the south side of Mesita del Buey Road, across from MDA-J; 300 feet or more from the rim of the canyon
DESCRIPTION:	0.3 ac.: 9 vertical shafts along a line 15 feet from the TA's southern fence line
DISTANCE TO SURFACE WATER:	≥1 mile
DISTANCE TO GROUND WATER:	>300 feet
FRACTURE DENSITY:	Presence of fault between MDA-L and MDAs H and J is suspected (Dransfield and Gardner, 1985)
RELEASE INFORMATION:	RFI Workplan documents a release of ^{3}H (2.0×10^{9} Pci/L) in the moisture of Shaft 8 LANL ER Ranking High (54) SWMU Report documents a release of trace amounts of ^{3}H to the subsurface near the shafts
PARAMETERS/CONSTITUENTS OF CONCERN:	W, W-carbide, phenolin, Cu, solid radioactive waste, graphite, lithium fluoride, PBX, Be, Ti, Li, ^{3}H, Mg, lithium hydride, Pu, Pb, lithium boride, motor oil, and HE
MOBILITY OF CONSTITUENTS:	High probability for mobilization and transport of COCs into nearest drainage
INTEGRITY OF MDA:	Unit is unlined
PERIOD OF OPERATION:	Disposal began in 1959; storage continues to present

MDA-J (SWMU 54-005)	POTENTIAL FOR RELEASE TO GROUNDWATER: Low to Moderate
LOCATION:	On Mesita del Buey, less than 100 feet from edge of Canada del Buey; north of Mesita del Buey Road; north of Pajarito Canyon
DESCRIPTION:	2.65 ac.: 4 pits and 2 shafts containing primarily scrap metal, construction debris, discarded furniture, classified materials, and empty containers; 96% by weight non-hazardous wastes
DISTANCE TO SURFACE WATER:	≥1 mile
DISTANCE TO GROUND WATER:	>300 feet
FRACTURE DENSITY:	Presence of a fault between MDA-I and MDAs H and J suspected (Dransfield and Gardner, 1985)
RELEASE INFORMATION:	RFI Workplan recommends a limited sampling program LANL ER Ranking Low to Moderate (24) SWMU Report indicates it is unknown if releases occurred
PARAMETERS/CONSTITUENTS OF CONCERN:	Ba, inorganics, organics
MOBILITY OF CONSTITUENTS:	Low probability for mobilization and transport of COCs into nearest drainage
INTEGRITY OF MDA:	Unit is unlined
PERIOD OF OPERATION:	1961 to 1987

MDA-K (SWMU 33-002[a through e])	POTENTIAL FOR RELEASE TO GROUNDWATER: Moderate to High
LOCATION:	East of TA-33-86; equidistant from Ancho and Chaquehui Canyons (~2,000 feet)
DESCRIPTION:	~1 ac.: a septic system, 2 unlined sumps, and a roof drain discharging to an outfall east of the building
DISTANCE TO SURFACE WATER:	>0.5 mile
DISTANCE TO GROUND WATER:	>300 feet
FRACTURE DENSITY:	Inferred northeast striking fault slightly west of the radiotelescope antenna at TA-33; inferred northwest striking fault in Frijoles Canyon south of OU 1122 (Dransfield and Gardner, 1985)
RELEASE INFORMATION:	RFI Workplan indicates the presence of ^{3}H possibly from airborne emissions and not septic system; NPDES outfall on site LANL ER Ranking High (51) SWMU Report states that the septic system releases to a leach field; in 1961, two releases of Pu were noted
PARAMETERS/CONSTITUENTS OF CONCERN:	^{3}H, Pu, U, ethanol, methanol, TCE, benzene, acetone, Be, Hg, propanol, ^{235}U, and ^{238}U
MOBILITY OF CONSTITUENTS:	High probability for mobilization and transport of COCs into nearest drainage
INTEGRITY OF MDA:	Sumps are unlined; heavily vegetated
PERIOD OF OPERATION:	Septic system (1954-present), sumps inactive in 1959, roof drain still active

MDA-L (SWMUs 54-001[a through e], 54-002, 54-015[g], 54-008, 54-012[b], 54-009, 54-014[a], and 54-015[l])	POTENTIAL FOR RELEASE TO GROUNDWATER: Moderate to High
LOCATION:	On top of Mesita del Buey south of MDA-J along Mesita del Buey Road; Pajarito Canyon and Canada del Buey to the south and north, respectively; 100 feet or less from the rim of Canada del Buey
DESCRIPTION:	2.58 ac.: 1 pit, 3 surface impoundments, and 10 storage units; historically used as disposal for hazardous chemicals; currently used to store and treat RCRA-permitted waste under interim status
DISTANCE TO SURFACE WATER:	>0.25 mile
DISTANCE TO GROUND WATER:	>300 feet
FRACTURE DENSITY:	Presence of fault between MDA-L and MDAs H and J is suspected (Dransfield and Gardner, 1985)
RELEASE INFORMATION:	RFI Workplan documents a VOC plume in the subsurface (1987); LANL ER Ranking High (65); SWMU Report plume is in the process of characterization
PARAMETERS/CONSTITUENTS OF CONCERN:	TCA, TCE, PCE, chloroform, toluene, freon, and organics
MOBILITY OF CONSTITUENTS:	High probability for mobilization and transport of COCs into nearest drainage
INTEGRITY OF MDA:	Unit is unlined
PERIOD OF OPERATION:	? to 1985

MDA-M (PRS 9-013)	POTENTIAL FOR RELEASE TO GROUNDWATER: Moderate to High
LOCATION:	On mesa top between Pajarito Canyon and Starmer Gulch
DESCRIPTION:	~3 ac.: solid waste disposal area
DISTANCE TO SURFACE WATER:	~200 feet
DISTANCE TO GROUND WATER:	~30 feet
FRACTURE DENSITY:	High degree of horizontal and vertical fracturing
RELEASE INFORMATION:	RFI Workplan documents release of radionuclides to soil LANL ER Ranking High (56) SWMU Report documents no releases thus far
PARAMETERS/CONSTITUENTS OF CONCERN:	^{3}H, U, asbestos, SVOCs, VOCs, organochlorine, pesticides, PCBs, metals, TXT, RDX, HMX, PETN, Tetryl, other explosives, gross alpha, gross beta, and gross gamma
MOBILITY OF CONSTITUENTS:	High probability for mobilization and transport of COCs into nearest drainage
INTEGRITY OF MDA:	Unit is assumed to be unlined
PERIOD OF OPERATION:	? to 1965

MDA-N (SWMU 15-007[a])	POTENTIAL FOR RELEASE TO GROUNDWATER: Low to Moderate
LOCATION:	On mesa top with Three-Mile Canyon and Cañon del Valle to the north and southwest, respectively
DESCRIPTION:	0.10 ac.: trench
DISTANCE TO SURFACE WATER:	1,100 feet
DISTANCE TO GROUND WATER:	>300 feet
FRACTURE DENSITY:	Moderate to high
RELEASE INFORMATION:	No information available to document a release LANL ER Ranking Moderate (28) SWMU Report indicates no known releases
PARAMETERS/CONSTITUENTS OF CONCERN:	U, Th, Ag, Be, Pb, Hg, VOCs, and SVOCs
MOBILITY OF CONSTITUENTS:	Moderate probability for mobilization and transport of COCs into nearest drainage
INTEGRITY OF MDA:	Vegetated; unit assumed to be unlined
PERIOD OF OPERATION:	? to 1965

MDA-P (SWMU 16-018)	POTENTIAL FOR RELEASE TO GROUNDWATER: Moderate to High
LOCATION:	Near the south rim of Cañon del Valle; located north of the burning grounds operation; extends down the slope of the Cañon del Valle and forms a shelf over the original slope
DESCRIPTION:	~2 ac.:inactive industrial landfill containing waste from the synthesis, processing, and testing of HE; and an impact area ~ 170 feet by 400 feet
DISTANCE TO SURFACE WATER:	0 feet (MDA located in canyon bottom)
DISTANCE TO GROUND WATER:	<10 feet
FRACTURE DENSITY:	Moderate
RELEASE INFORMATION:	LANL ER Ranking High (53) SWMU Report documents a release: vertical migration of Ba and nitrates at concentrations of 37.8 ppm and 3.4 ppm, respectively, at a depth of ~6 feet
PARAMETERS/CONSTITUENTS OF CONCERN:	construction debris, Ba-contaminated sand, Pb-azide, Tl-azide, HE, nitrate, barium, lead, and possibly organics
MOBILITY OF CONSTITUENTS:	High probability for mobilization and transport of COCs into nearest drainage
INTEGRITY OF MDA:	Units are assumed to be unlined
PERIOD OF OPERATION:	1940s to 1985

MDA-Q (PRS 8-006[a,b])	POTENTIAL FOR RELEASE TO GROUNDWATER: Moderate
LOCATION:	On mesa bounded by Pajarito Canyon and Canon de Valle to the north and south, respectively; a level area at TA-8 on the west side of Anchor Ranch Road
DESCRIPTION:	>30 square feet: burial ground for naval guns at TA-8 gun-firing site
DISTANCE TO SURFACE WATER:	> ¼ mile
DISTANCE TO GROUND WATER:	30 to 100 feet
FRACTURE DENSITY:	Moderate
RELEASE INFORMATION:	No releases have been documented to date LANL ER Ranking Low (0)
PARAMETERS/CONSTITUENTS OF CONCERN:	Cu, Pb, Be, gross alpha, gross beta, U, and HE
MOBILITY OF CONSTITUENTS:	Low probability for mobilization and transport of COCs into nearest drainage
INTEGRITY OF MDA:	Unit is unlined
PERIOD OF OPERATION:	1946 (only)

MDA-R (SWMU 16-019)	POTENTIAL FOR RELEASE TO GROUNDWATER: Moderate to High
LOCATION:	On top of mesa; intersects Cañon del Valle drainage; on level terrain sloping moderately to the north; drops off 80 feet into Cañon de Valle
DESCRIPTION:	2.27 ac.; 3 pits and 1 waste disposal area used for the detonation and disposal of explosive wastes
DISTANCE TO SURFACE WATER:	~50 feet (Cañon de Valle is principal drainage for MDA-P and MDA-R)
DISTANCE TO GROUND WATER:	<100 feet
FRACTURE DENSITY:	Moderate
RELEASE INFORMATION:	RFI Workplan documents a release LANL ER Ranking Moderate(36) SWMU Report does not document a release
PARAMETERS/CONSTITUENTS OF CONCERN:	undetonated HE, HE detonation products, HE burn products, U, metals, and asbestos
MOBILITY OF CONSTITUENTS:	High probability for mobilization and transport of COCs into nearest drainage
INTEGRITY OF MDA:	Unit is assumed to be unlined
PERIOD OF OPERATION:	? to 1951

MDA-S (SWMU 11-009)	POTENTIAL FOR RELEASE TO GROUNDWATER: Low to Moderate
LOCATION:	North of Water Canyon and south of Canon de Valle
DESCRIPTION:	100 square feet; maximum depth of 2 feet; used for the study of soil and weather on the decomposition of explosives buried within tubes
DISTANCE TO SURFACE WATER:	>1,000 feet
DISTANCE TO GROUND WATER:	>300 feet
FRACTURE DENSITY:	unknown
RELEASE INFORMATION:	LANL ER Ranking SWMU Report documents no known releases
PARAMETERS/CONSTITUENTS OF CONCERN:	80 grams of HE (decomposition products may be present)
MOBILITY OF CONSTITUENTS:	High probability for mobilization and transport of COCs into nearest drainage
INTEGRITY OF MDA:	Tubing has fine, stainless steel mesh screen at bottom; sample containers are buried with tops flush with ground surface
PERIOD OF OPERATION:	1965 to present

MDA-T (SWMU 21-016)	POTENTIAL FOR RELEASE TO GROUNDWATER: Moderate to High
LOCATION:	On mesa top at DP West approximately 200 feet west of MDA-A
DESCRIPTION:	2 ac.; 4 adsorption beds, 4 sumps, 1 pit, and 62 shafts
DISTANCE TO SURFACE WATER:	<300 feet horizontal distance from ephemeral stream in DP Canyon and 300 to 500 feet from Los Alamos Canyon
DISTANCE TO GROUND WATER:	~250 feet
FRACTURE DENSITY:	Moderate
RELEASE INFORMATION:	RFI Workplan documents a release to surface and subsurface (Pu and Am at depths of 28 meters in Tuff) LANL ER Ranking High (57) SWMU Report documents a release
PARAMETERS/CONSTITUENTS OF CONCERN:	Pu, Am, and TRU wastes, fluorine, ammonium citrate, nitrogen and chlorine compounds, Pb, Hg, Cd, and others
MOBILITY OF CONSTITUENTS:	High probability for mobilization and transport of COCs into nearest drainage
INTEGRITY OF MDA:	MDA may consist of several pits or one large pit covered and expanded as necessary. Pits and adsorption beds are unlined; sumps are lined with concrete
PERIOD OF OPERATION:	1945 to 1952 and 1968 to 1983

MDA-U (SWMU 21-017)	POTENTIAL FOR RELEASE TO GROUNDWATER: Moderate to High
LOCATION:	On mesa top near DP East (close to cliff edge) 400 feet east of MDA-K
DESCRIPTION:	0.25 ac.; 2 adsorption beds used for disposal of contaminated liquid wastes
DISTANCE TO SURFACE WATER:	~200 feet from DP Canyon stream; >500 feet from Los Alamos Canyon
DISTANCE TO GROUND WATER:	~250 feet
FRACTURE DENSITY:	Moderate
RELEASE INFORMATION:	RFI Workplan documents a release LANL ER Ranking High (50) SWMU Report documents storm water outfalls discharge into canyon; surface overflow may have occurred
PARAMETERS/CONSTITUENTS OF CONCERN:	Ac, U, ^{3}H, possibly organics, Be, and PCBs
MOBILITY OF CONSTITUENTS:	High probability for mobilization and transport of COCs into nearest drainage
INTEGRITY OF MDA:	Unit assumed to be unlined
PERIOD OF OPERATION:	1948 to 1968

MDA-V (SWMU 21-018)	POTENTIAL FOR RELEASE TO GROUNDWATER: Moderate to High
LOCATION:	On top of DP Mesa immediately east of MDA-B
DESCRIPTION:	0.88 ac.; 3 adsorption beds for liquid waste
DISTANCE TO SURFACE WATER:	~500 feet from Los Alamos Canyon; <500 feet from DP Canyon
DISTANCE TO GROUND WATER:	~400 feet
FRACTURE DENSITY:	High
RELEASE INFORMATION:	RFI Workplan documents a release LANL ER Ranking High (42) SWMU Report documents that pits discharged onto soil, and into canyons and subsurface (17.7 meters)
PARAMETERS/CONSTITUENTS OF CONCERN:	^{89}Sr, ^{90}Sr, ^{140}Ba, ^{140}La, ^{239}Pu, ^{240}Pu, ^{3}H, U, and possibly solvents
MOBILITY OF CONSTITUENTS:	Moderate to high probability for mobilization and transport of COCs
INTEGRITY OF MDA:	Unit assumed to be unlined
PERIOD OF OPERATION:	1945 to 1961

MDA-Y (SWMU 39-001[b] - Pit 1)	POTENTIAL FOR RELEASE TO GROUNDWATER: Moderate to High
LOCATION:	On the bottom of the north fork of Ancho Canyon; east of Ancho Road, northeast of Building TA-39-56
DESCRIPTION:	2,960 square feet: 1 pit containing debris from firing site experiments, empty chemical containers, and office waste
DISTANCE TO SURFACE WATER:	<100 feet from ephemeral stream in Ancho Canyon
DISTANCE TO GROUND WATER:	>300 feet (potential for shallower ground water exists)
FRACTURE DENSITY:	unknown
RELEASE INFORMATION:	RFI Workplan borehole data suggests contamination may have spread laterally toward the stream channel LANL ER Ranking High (65) SWMU Report documents metals, ^{235}U, total U, and ^{40}K in soil samples from 4th trench
PARAMETERS/CONSTITUENTS OF CONCERN:	Ag, Ba, Be, Cd, Cr_6, Cu, Fe, He, Hg, Pb, Pu, Tl, Zn, ^{235}U, total U, ^{40}K, ^{232}Th, solvents, and PCBs
MOBILITY OF CONSTITUENTS:	High probability for mobilization and transport of COCs into nearest drainage
INTEGRITY OF MDA:	Unit is unlined
PERIOD OF OPERATION:	1973 to ?

MDA-Z (SWMU 15-007[b])	POTENTIAL FOR RELEASE TO GROUNDWATER: Moderate to High
LOCATION:	On mesa top between Cañon del Valle and Portrillo Canyon
DESCRIPTION:	20,000 square feet: inactive disposal area for construction debris from tests at PHERMX and other miscellaneous debris
DISTANCE TO SURFACE WATER:	≥500 feet (Cañon del Valle)
DISTANCE TO GROUND WATER:	>300 feet
FRACTURE DENSITY:	Fault planes may be present beneath TA-15 (Dransfield and Gardner, 1985)
RELEASE INFORMATION:	LANL ER Ranking High (40) SWMU Report documents ^{26}Al, $^{235/236}$U, ^{56}Co, ^{230}Th, ^{137}Cs, metals, and VOCs were detected, but no known release occurred
PARAMETERS/CONSTITUENTS OF CONCERN:	U, Be, Pb, Hg, HE, and VOCs
MOBILITY OF CONSTITUENTS:	High probability for mobilization and transport of COCs into nearest drainage
INTEGRITY OF MDA:	Debris is uncovered and exposed to the weather; unit is assumed to be unlined
PERIOD OF OPERATION:	1965 to 1981

MDA-AA (PRS 36-001)	POTENTIAL FOR RELEASE TO GROUNDWATER: Moderate
LOCATION:	On leveled area south of the lower Slobbovia firing site at the bottom of Portrillo Canyon
DESCRIPTION:	2 to 4 trenches with the following dimensions: 30 x 200 x 10 feet
DISTANCE TO SURFACE WATER:	Streamflow within Portrillo Canyon is ephemeral
DISTANCE TO GROUND WATER:	<30 feet (suspected)
FRACTURE DENSITY:	Unknown
RELEASE INFORMATION:	RFI Workplan documents one measurement of Cd above background and depleted U present in low concentrations LANL ER Ranking High (43) SWMU Report indicates no known releases other than combustion products
PARAMETERS/CONSTITUENTS OF CONCERN:	Ba, Cr, Cd, Cu, Pb, U, and Zn
MOBILITY OF CONSTITUENTS:	High probability for mobilization and transport of COCs into nearest drainage
INTEGRITY OF MDA:	Leaching of constituents from unlined trenches may have occurred
PERIOD OF OPERATION:	? to 1989

MDA-AB (SWMU 49-001[a-g])	POTENTIAL FOR RELEASE TO GROUNDWATER: Moderate to High
LOCATION:	TA-49 occupies Frijoles Mesa at LANL's southern boundary; bounded by Water and Ancho Canyons to the north and south, respectively
DESCRIPTION:	1986 report states MDA-AB contains 80% (by radioactive content) of LANL's inventory of TRU waste. Approximately 45 shafts, ranging in depth from 31 to 108 feet, used for hydronuclear and other related experiments.
DISTANCE TO SURFACE WATER:	≥1 mile
DISTANCE TO GROUND WATER:	≥300 feet
FRACTURE DENSITY:	Guaje fault is projected to be beneath TA-49 (Dransfield and Gardner, 1985)
RELEASE INFORMATION:	RFI Workplan documents soil contamination in Areas 1, 2, 2A, 2B, 3, and 4; and documents a release to the surface at Area 2 LANL ER Ranking Moderately high at Area 2(39) and moderate at all other Areas SWMU Report documents contaminate migration in the drainage northeast of Areas 11 and 2 trending toward Water Canyon
PARAMETERS/CONSTITUENTS OF CONCERN:	Pu, U, Pb, and Be
MOBILITY OF CONSTITUENTS:	Low probability for mobilization and transport of COCs into nearest drainage except for Area 2 (high)
INTEGRITY OF MDA:	Holes backfilled with sand and capped with concrete
PERIOD OF OPERATION:	? to 1989

APPENDIX D

D1: STANDARDS OR ACTION LEVELS USED FOR DETERMINING A RELEASE TO GROUND WATER

D2: RELEASES TO GROUND WATER TABLES

APPENDIX D1

STANDARDS OR ACTION LEVELS USED FOR DETERMINING A RELEASE TO GROUND WATER

In order to detect if a ground water sampling point was affected by a release from LANL, a chemical standard or action level, herafter referred to as "triggers," for ground water had to be exceeded. Depending on the type of constituent being considered, a trigger was chosen from one of the four following possible references:

1. EPA promulgated or proposed Maximum Contaminant Level (MCL)
2. New Mexico Water Quality Control Commission ground water standard.
3. DOE's Derived Concentration Guide for Public Dose
4. Table J-1 Screening Action Levels (SALs) of LANL's 1993 Installation Work Plan

In general, the lowest possible trigger was used for this report. In a few cases, such as 2,4-DNT and 2,6-DNT, NMED relied upon Screening Action Levels (SALs) developed by LANL because neither EPA nor NM WQCC had an appropriate standard.

For radiological constituents, NMED relied almost entirely on DOE's Derived Concentration Guide for Public Dose or LANL's SALs for choosing an appropriate trigger. In all cases, the lowest possible activity level was chosen. Only four radiological parameters had a MCL developed by EPA: tritium, ^{90}Sr, gross alpha, and gross beta.

Therefore, the following table presents the reader with four possible triggers for each listed chemical. The triggers used for this report are denoted by bold-faced type.

CONSTITUENT	EPA PROMULGATED OR PROPOSED MCL (ppm)	NEW MEXICO GROUND WATER STANDARD (ppm)	DOE'S DERIVED CONCENTRATION GUIDE FOR PUBLIC DOSE (pCi/L)	TABLE J-1 LANL SCREENING ACTION LEVEL OF LANL'S IWP, NOVEMBER 1993 (ppm)
aluminum (Al)	0.05-0.2 (a)[1]	**5.0 (I)**[2]	NA[3]	NA
antimony (Sb)	**0.006**	NA	NA	0.006
arsenic (As)	**0.05**	0.1	NA	0.05
barium (Ba)	2.0	**1.0**	NA	2.0
beryllium (Be)	**0.004**	NA	NA	0.004
benzo[a]anthracene	**0.0001 (p)**[4]	NA	NA	0.0001
benzo[a]pyrene	**0.0002**	0.0007	NA	0.0002
benzo[b]fluoranthene	**0.0002 (p)**	NA	NA	0.0002
benzo[k]fluoranthene	**0.0002 (p)**	tox[5]	NA	0.0002
boron (B)	0.06 (HA)[6]	**0.75 (I)**	NA	NA
chrysene	**0.0002 (p)**	NA	NA	0.0002
cadmium (Cd)	**0.005**	0.01	NA	0.005
chloride (Cl)	250 (a)	**250 (a)**	NA	NA
chromium (Cr)	0.1	**0.05**	NA	0.1
cobalt (Co)	NA	**0.05 (I)**	NA	NA
copper (Cu)	**1.3 (al)**[7]	NA	NA	1.3
cyanide	**0.2**	0.2	NA	0.2
1,2-dibromo-3-chloropropane	**0.0002**	NA	NA	NA
1,2-dibromoethane	**0.00005**	0.0001	NA	NA
2,4-dinitrotoluene	NA	tox	NA	**0.00005**
2,6-dinitrotoluene	NA	NA	NA	**0.00005**
fluoride (F)	**1.4***[1]	1.6	NA	NA

[1]"a" means aesthetic standard

[2]"I" means standard for irrigation

[3]"NA" means not available or not applicable

[4]"p" means EPA proposed standard

[5]"tox" means a numerical standard has not been established, but the contaminant is listed in a narrative standard of "toxic pollutant"(Section 1-101 of the New Mexico Water Quality Control Commission regulations).

[6]"HA" means health advisory level developed by EPA

[7]"al" means action level developed by EPA that, if exceeded, requires water treatment

NOTE: Standards indicated in **bold** are those used to determine a release to ground water. Non-"bolded" standards are provided for the reader's information.

CONSTITUENT	EPA PROMULGATED OR PROPOSED MCL (ppm)	NEW MEXICO GROUND WATER STANDARD (ppm)	DOE'S DERIVED CONCENTRATION GUIDE FOR PUBLIC DOSE (pCi/L)	TABLE J-1 LANL SCREENING ACTION LEVEL OF LANL'S IWP, NOVEMBER 1993 (ppm)
hexachlorobenzene	**0.001**	tox	NA	0.0001
1,2,3-c, d - indeno pyrene	**0.0004 (p)**	NA	NA	0.0004
iron (Fe)	0.3 (a)	**1.0 (a)**	NA	NA
lead (Pb)	**0.015 (al)**	0.05	NA	0.05
manganese (Mn)	0.05 (a)	**0.2 (a)**	NA	0.18
mercury (Hg)	**0.002**	0.002	NA	0.002
nickel (Ni)	**0.1**	0.2 (l)	NA	0.1
nitrate-N	**10**	10	NA	10
nitrite-N	**1**	NA	NA	1
pentachlorophenol	**0.001 (p)**	tox	NA	0.001
selenium (Se)	**0.01***	0.05	NA	0.05
silver (Ag)	**0.05**	0.05	NA	0.17
sodium (Na)	**20 (HA)**	NA	NA	NA
strontium (Sr)	**17 (HA)**	NA	NA	21
sulfate (SO_4)	250 (a) / 400 (p)	**600 (a)**	NA	NA
thallium (Tl)	**0.002**	NA	NA	0.002
1,1,1-trichloroethane	0.2	**0.06**	NA	0.2
total dissolved solids	500 (a)	**1,000 (a)**	NA	NA
vanadium (V)	**0.02 (HA)**	NA	NA	0.24
vinyl chloride	0.002	**0.001**	NA	0.002
zinc (Zn)	5.0 (a)	**10 (a)**	NA	10
gross alpha	**15.0 pCi/L**	NA	NA	NA
gross beta	**50 pCi/L****	NA	NA	NA
uranium (U)	**0.02 (p)**	5.0	3×10^{-2} mg/L	NA
^{234}U	NA	NA	20	**19 pCi/L**
^{235}U	NA	NA	24	**21 pCi/L**

*Appendix III, 40 CFR Part 265

**Pre-1995 EPA promulgated standard in pCi/L (used to compare older data); current EPA standard is 4 mrem/yr

NOTE: Standards indicated in **bold are those used to determine a release to ground water. Non-"bolded" standards are provided for the reader's information.**

CONSTITUENT	EPA PROMULGATED OR PROPOSED MCL (ppm)	NEW MEXICO GROUND WATER STANDARD (ppm)	DOE'S DERIVED CONCENTRATION GUIDE FOR PUBLIC DOSE (pCi/L)	TABLE J-1 LANL SCREENING ACTION LEVEL OF LANL'S IWP, NOVEMBER 1993 (ppm)
^{238}U	NA	NA	24	**6.7 pCi/L**
^{238}Pu	NA	NA	**1.6**	15 pCi/L
^{239}Pu	NA	NA	**1.2**	15 pCi/L
^{240}Pu	NA	NA	**1.2**	NA
^{241}Am	NA	NA	**1.2**	15 pCi/L
^{137}Cs	NA	NA	120	**110 pCi/L**
^{90}Sr	**8 pCi/L*****	NA	40	8 pCi/L
^{3}H (tritium)	**20,000 pCi/L*****	NA	8×10^4	2×10^4 pCi/L

***EPA-calculated values from the beta particle and photon radioactivity standard. See USEPA Region 6 Water Supply Branch *Current and Proposed National Primary and Secondary Drinking Water Regulations and Health Advisories for Other Contaminants* (7/29/94)

NOTE: Standards indicated in **bold** are those used to determine a release to ground water. Non-"bolded" standards are provided for the reader's information.

APPENDIX D2

RELEASE TO GROUND WATER TABLES

Appendix D2 contains preliminary tables which summarize radioactive and hazardous constituents found at levels of concern in ground water in the Los Alamos area. Data were collected from annual LANL environmental surveillance reports, RCRA Facility Investigations, DOE Oversight Bureau reports, and various other scientific reports published by LANL. The following tables were compiled to provide a plateau-wide summary of where hazardous constituents have been detected at concentrations above accepted standards or action levels in ground water. A map (Figure 18 and Plate 17) indicating where releases to ground water are known or suspected was also compiled from this data.

The standard for each element or compound shown in these tables is chosen from one of the following four sources: EPA Maximum Contaminant Level (**MCL**), New Mexico Water Quality Control Commission (**NM WQCC**) Ground Water Standard, DOE's Derived Concentration Guide for Public Dose, and Screening Action Levels (**SALs**) published in LANL's IWP.

For all elements and compounds other than total uranium, radioactive constituents, and organic compounds, the tables only show those concentrations which exceed the EPA MCL, the NM WQCC standard, or in some cases, the LANL SAL. All concentrations of total uranium greater than two standard deviations above the detection limit are reported, as well as, all concentrations of radioactive components and organic compounds. These concentrations, although below standards, are reported because of their traceability to anthropogenic sources. A blank in the table indicates that the constituent was either not detected at levels of concern or that it was not analyzed for.

Areas of potential ground water concern, in combination with other site specific information (such as source locations, modes of ground water occurrence, geology, etc.) substantiate recommendations for future investigations.

Known and Suspected Release Justification Criteria

Except for tritium, ^{90}Sr, gross beta, and gross alpha, which have established MCLs, a known release of a **radiological parameter** must be evinced by a concentration which exceeds either DOE's Derived Concentration Guide for Public Dose or the SAL. A concentration of **^{90}Sr, gross beta, or gross alpha** which exceeds the EPA MCL was considered evidence of a known release.

Concentrations of **tritium** in a ground water sample must exceed the EPA MCL of 20,000 pCi/L for it to be considered a result of a LANL release. However, LANL has recently

published a report (Blake et al., 1995) which states: "Waters containing ≥300 T.U. ^3H [984 pCi/L] and collected after about 1990 can not be modeled for age, and their ^3H can only come from nearby laboratory sources" [pp. 33; May, 1995]. Thusly, this report incorporates LANL's own criteria for a release of tritium to ground water: a known release is considered when a ground water sample collected after 1990 contains concentrations of tritium greater than or equal to 984 pCi/L.

A known release of hazardous **inorganic** constituents is considered when inorganic concentrations are one order of magnitude above EPA MCLs or the NM WQCC standards. Since inadequate background data for LANL is available, a release of inorganic constituents is *suspected* when concentrations are less than or equal to one order of magnitude above the appropriate standard.

A known release of an **organic** hazardous constituent is considered when concentrations exceed the EPA MCL, NM WQCC standard, or the LANL SAL (whichever is applicable). Since inadequate background data for LANL is available, a release is *suspected* when organic concentrations are below MCLs or NM WQCC standards, but above the detection limit.

Ground water is suspected of LANL influence when **water quality parameter** (such as TDS, nitrates, Mn, F, Fe, Cl, Na, and Al) concentrations exceed MCLs or the NM WQCC standards.

LAO-1							
Reference	**Gross Beta (pCi/L)**	**^{3}H (pCi/L)**	**^{90}Sr (pCi/L)**	**^{238}Pu (pCi/L)**	**^{239}Pu (pCi/L)**	**F (ppm)**	**Fe (ppm)**
Longmire 1995			**11.8**				
NMED 1993	**64**	8,600					
LANL May 1993		**31,000**					
LANL July 1994		9,300	**11.8**				
LANL August 1993		6,200	**14**				
LANL March 1992		**35,000**					***1.8***
LANL 1988		19,000				**1.8**	
LANL (FUSRAP)							
1975	**56**	7,000					
1974	**147**	**27,000**					
1973	**140**	**36,000**			0.06		
1972	**127**	19,600		0.17	0.18		
1971	**94**	**20,750**		0.05	0.27		
1970	**76**			0.05	0.05		
1969		**22,000**			0.06		
1968		**30,000**			0.08		
1967		**41,000**					
EPA Promulgated or Proposed Standard	**50**	**20,000**	**8**	NA	NA	**1.4**	0.3
NM WQCC Standard	NA	NA	NA	NA	NA	1.6	**1.0**
DOE Standard	NA	80,000	40	**1.6**	**1.2**	NA	NA
LANL SAL	NA	20,000	8	15	15	NA	NA

LAO-2										
Reference		Gross Beta (pCi/L)	^{3}H (pCi/L)	^{90}Sr (pCi/L)	^{238}Pu (pCi/L)	^{239}Pu (pCi/L)	NO_3-N (ppm)	F (ppm)	Fe (ppm)	TDS (ppm)
Longmire 1995				**23**						
LANL May 1993			**29,000**							
LANL July 1994			1,200	**23.2**						
LANL August 1993			3,100	**42**						
LANL March 1992			1,300			0.077			***2.6***	556
LANL 1989			2,900							
LANL June 1989			500							
LANL 1988			1,300							
LANL 1988			7,200					1.1		
LANL April 1986			3,100					***5.5***		
LANL April 1984			19,000				***89***	***1.6***		468
LANL April 1983			**36,000**							
LANL (FUSRAP)	1975	**157**				0.05				
	1974	**247**				0.1				
	1973	**294**				0.11				
	1972	**188**			0.09	0.19				
	1971	**101**			0.15	0.33				
	1970	**80**				0.14				
	1969	**77**			0.1	0.6				
	1968	**59**				0.06				
	1967	**91**								
EPA Promulgated or Proposed Standard		**50**	**20,000**	**8**	NA	NA	**10**	**1.4**	0.3	500
NM WQCC Standard		NA	NA	NA	NA	NA	10	1.6	**1.0**	**1,000**
DOE Standard		NA	80,000	40	**1.6**	**1.2**	NA	NA	NA	NA
LANL SAL		NA	20,000	8	15	15	10	NA	NA	NA

LAO-3											
Reference		Gross Beta (pCi/L)	^{3}H (pCi/L)	^{90}Sr (pCi/L)	^{238}Pu (pCi/L)	^{239}Pu (pCi/L)	^{241}Am (pCi/L)	NO_3-N (ppm)	F (ppm)	Fe (ppm)	TDS (ppm)
Longmire 1995				**50**							
NMED 1993B											
LANL May 1993			1,700								
LANL July 1994		**86**	1,000	**49.9**			0.067				74
LANL August 1993			2,400	**55**							268
LANL March 1992			100			0.046				***2.3***	542
LANL 1989			2,100								
LANL June 1989			900						***1.8***		
LANL 1988			1,500						1.1		
LANL April 1986			**26,000**						3		417
LANL April 1984			**26,000**					***89***	***1.6***		499
LANL (FUSRAP)	1975	**81**	11,000								
	1974	**75**	11,000		0.35	0.08					
	1973		**35,000**		0.06	0.05					
	1972	**92**	**187,000**		0.1	0.15					
	1971	**95**	**38,000**		0.07	0.08					
	1970	**56**	**73,000**			0.08					
	1969		**350,000**			0.06					
	1968	**61**	**126,000**		0.07	0.08					
	1967		**214,000**			0.05					
EPA Promulgated or Proposed Standard		**50**	**20,000**	**8**	NA	NA	NA	**10**	**1.4**	0.3	500
NM WQCC Standard		NA	NA	NA	NA	NA	NA	10	1.6	**1.0**	**1,000**
DOE Standard		NA	80,000	40	**1.6**	**1.2**	**1.2**	NA	NA	NA	NA
LANL SAL		NA	20,000	8	15	15	15	10	NA	NA	NA

LAO-4							
Reference	**^{3}H (pCi/L)**	**^{238}Pu (pCi/L)**	**^{239}Pu (pCi/L)**	**^{137}Cs (pCi/L)**	**F (ppm)**	**Fe (ppm)**	**TDS (ppm)**
LANL August 1993	2,300		0.23				
LANL March 1992	1,000		0.393			*2*	882
LANL 1988					*2*		
LANL (FUSRAP)							
1970	**66,000**						
1969	**55,500**						
1968	**61,000**	0.05	0.05	**250**			
1967	**222,000**		0.06				
EPA Promulgated or Proposed Standard	**20,000**	NA	NA	NA	**1.4**	0.3	500
NM WQCC Standard	NA	NA	NA	NA	1.6	**1.0**	**1,000**
DOE Standard	80,000	**1.6**	**1.2**	120	NA	NA	NA
LANL SAL	20,000	15	15	**110**	NA	NA	NA

LAO-4.5							
Reference	**Gross Beta (pCi/L)**	**^{3}H (pCi/L)**	**^{238}Pu (pCi/L)**	**^{239}Pu (pCi/L)**	**F (ppm)**	**Fe (ppm)**	**TDS (ppm)**
LANL August 1993		2,300		0.23			
LANL March 1992		1,000		0.393		*2*	882
LANL 1988					*2*		
LANL (FUSRAP)							
1975		18,000		0.06			
1974	**107**	**8,000**					
1973		**22,000**					
1972		**28,000**	0.09	0.06			
1971		**24,000**	0.07	0.08			
1970		**78,000**	0.06	0.07			
1969		**43,000**					
EPA Promulgated or Proposed Standard	**50**	**20,000**	NA	NA	**1.4**	0.3	500
NM WQCC Standard	NA	NA	NA	NA	1.6	**1.0**	**1,000**
DOE Standard	NA	80,000	**1.6**	**1.2**	NA	NA	NA
LANL SAL	NA	20,000	15	15	NA	NA	NA

LAO-C									
Reference	**^{3}H (pCi/L)**	**^{90}Sr (pCi/L)**	**^{238}Pu (pCi/L)**	**^{239}Pu (pCi/L)**	**V (ppm)**	**Pb (ppm)**	**Mn (ppm)**	**Fe (ppm)**	**TDS (ppm)**
Longmire 1995		2							
LANL March 1992	200				***0.0309***	***0.0237***	***2.47***	***30***	610
LANL April 1984	3,700								
LANL April 1983	3,200								
LANL (FUSRAP)			0.06	0.07					
EPA Promulgated or Proposed Standard	**20,000**	**8**	NA	NA	**0.02**	**0.015**	0.05	0.3	500
NM WQCC Standard	NA	NA	NA	NA	NA	0.05	**0.2**	**1.0**	**1,000**
DOE Standard	80,000	40	**1.6**	**1.2**	NA	NA	NA	NA	NA
LANL SAL	20,000	8	15	15	0.24	0.05	0.18	NA	NA

LAOR-1								
Reference	**Gross Alpha (pCi/L)**	**Gross Beta (pCi/L)**	**^{3}H (pCi/L)**	**Cr (ppm)**	**Pb (ppm)**	**Al (ppm)**	**Fe (ppm)**	**Mn (ppm)**
NMED (DOE OB) 1993	**93[1]**	**276[2]**	9,177	***0.08***	***0.09***	***70***	***55***	***3.73***
NMED (DOE OB) 1993	**166[3]**	**250[4]**						
EPA Promulgated or Proposed Standard	**15**	**50**	**20,000**	0.1	**0.015**	0.05-0.2	0.3	0.05
NM WQCC Standard	NA	NA	NA	**0.05**	0.05	**5.0**	**1.0**	**0.2**
DOE Standard	NA	NA	80,000	NA	NA	NA	NA	NA
LANL SAL	NA	NA	20,000	0.1	0.05	NA	NA	0.18

1. Measured with ^{241}Am reference
2. Measured with ^{137}Cs reference
3. Measured with natural U reference
4. Measured with ^{90}Sr reference

LA-SERIES WELLS			
Well	**Reference**	**V (ppm)**	**As (ppm)**
LA-1B	LANL March 1992	***0.043***	
LA-2	LANL March 1992	***0.024***	
LA-6	LANL March 1992		**0.155**
EPA Promulgated or Proposed Standard		**0.02**	**0.05**
NM WQCC Standard		NA	0.1
DOE Standard		NA	NA
LANL SAL		0.24	0.05

MCO-3												
Reference	**Gross Alpha (pCi/L)**	**Gross Beta (pCi/L)**	**^{3}H (pCi/L)**	**^{90}Sr (pCi/L)**	**^{238}Pu (pCi/L)**	**^{239}Pu (pCi/L)**	**^{241}Am (pCi/L)**	**Se (ppm)**	**NO_3-N (ppm)**	**Cl (ppm)**	**F (ppm)**	**TDS (ppm)**
LANL July 1994		**300**	**54,500**	**18.5**	0.195	0.294	**1.62**		***22.7***			
LANL August 1993								0.05				
LANL March 1992			**22,000**		0.705	**1.84**			***12.7***			
LANL 1989									***111***	***294***	***6.4***	***1,700***
LANL 1988									***56***		***7.7***	
LANL April 1986									***15***		***3.2***	
LANL April 1984									***130***		***3.1***	
Purtymun 1983												
1978	**21**	**304**	**95,000**		**5.4**	0.59						
1977	**25**	**490**	**316,000**	**36**	**6.5**	0.59						
1976	**76**	**320**	**211,000**	**62**	**5.8**	0.57	**7.4**					
1975		**460**	**195,000**		**5.4**	0.45	0.36					
1974		**210**	**76,000**		**6.1**	0.41						
1973	**29**	**343**	**99,000**		**7.9**	0.46						
1972		**612**	**47,000**		**3.9**	0.35	0.5					
1971	**21**	**1,470**	**40,000**		**3.1**	0.44						
1970		**505**	**688,000**		1	0.47						
1969		**93**	**36,000**		0.27	0.35						
1968		**166**	**27,000**		0.27	0.22						
1967		**116**	**56,000**			0.14						
EPA Promulgated or Proposed Standard	**15**	**50**	**20,000**	**8**	NA	NA	NA	**0.01**	**10**	250	**1.4**	500
NM WQCC Standard	NA	NA	NA	NA	NA	NA	NA	0.05	10	**250**	1.6	**1,000**
DOE Standard	NA	NA	80,000	40	**1.6**	**1.2**	**1.2**	NA	NA	NA	NA	NA
LANL SAL	NA	NA	20,000	8	15	15	15	0.05	10	NA	NA	NA

MCO-4

Reference	Gross Alpha (pCi/L)	Gross Beta (pCi/L)	^{3}H (pCi/L)	^{90}Sr (pCi/L)	^{238}Pu (pCi/L)	^{239}Pu (pCi/L)	^{241}Am (pCi/L)	^{137}Cs (pCi/L)	Cr (ppm)	V (ppm)	Se (ppm)	NO_3-N (ppm)	F (ppm)	Fe (ppm)	TDS (ppm)
LANL July 1994	18	260	103,700	132.4	1.42	4.56	21.7					*58.3*			
LANL August 1993											0.09	*34.7*			500
LANL March 1992			100,000		0.701	2.65			0.051	0.215		*63.1*	*1.7*		910
LANL 1989												*107*	*1.7*		*1,060*
LANL 1988												*44*	*3.9*		601
LANL April 1986												*56*	*4.7*		642
Penrose 1990															
1983						13,500	8,500					*360*	*6.2*	*2.7*	
1982						7	8,500								
Purtymun 1983															
1978	90	304	303,000	80	19	3.8		75							
1977	46	90	371,000		5.4	0.96		30							
1976	17	320	200,000	84	4.9	0.72	1.3	23							
1975		460	49,000		4.1	0.7	0.84	70							
1974		210	44,000		4.5	0.84									
1973		343	65,000		2.5	0.38	0.24	50							
1972		612	64,000		0.93	0.16	0.1								
1971		1,470	49,000		0.23	0.07									
1970		505	592,000		0.11	0.08									
1969		93	25,000		0.14	0.12									
1968		166	38,000		0.13	0.43									
1967		116	128,000			0.06									
EPA Promulgated or Proposed Standard	15	50	20,000	8	NA	NA	NA	NA	0.1	0.02	0.01	10	1.4	0.3	500
NM WQCC Standard	NA	NA	NA	NA	NA	NA	NA	NA	0.05	NA	0.05	10	1.6	1.0	1,000
DOE Standard	NA	NA	80,000	40	1.6	1.2	1.2	120	NA	NA	NA	NA	NA	NA	NA
LANL SAL	NA	NA	20,000	8	15	15	15	110	NA	0.24	0.05	10	NA	NA	NA

MCO-5											
Reference	**Gross Beta (pCi/L)**	**^{3}H (pCi/L)**	**^{90}Sr (pCi/L)**	**^{238}Pu (pCi/L)**	**^{239}Pu (pCi/L)**	**^{241}Am (pCi/L)**	**Se (ppm)**	**NO_3-N (ppm)**	**F (ppm)**	**Fe (ppm)**	**Al (ppm)**
LANL July 1994	**110**	**85,800**	**35.2**	0.133	0.219	0.559		***21.9***			
LANL August 1993							**0.08**	***35.8***			
LANL March 1992		**190,000**		0.159	0.446			***86.2***	***1.9***	***1.3***	
LANL 1989								***106***	***1.6***		
LANL 1988								***118***	***3***		
LANL April 1986								***61***			
Penrose 1990											
1983					**3,400**	**2,700**		***430***	***5.5***	***3.8***	***7***
1982					**539**	**13,000**					
Purtymun 1983											
1978	**66**	**540,000**	2.6	0.78	0.19						
1977		**510,000**		1.2	0.09		**15**				
1976		**1,030,000**	2.5	0.55	0.09		**87**				
1975		**44,000**		1.3	0.21	0.34	**9**				
1974	**51**	**42,000**		**2.2**	0.28		**70**				
1973	**50**	**51,000**		**2.3**	0.17	0.62	**30**				
1972	**112**	**78,000**		0.13	0.08	0.19					
1971	**186**	**64,000**		0.09							
1970		**695,000**		0.05							
1969		**34,000**		0.05	0.08						
1968		**88,000**		0.1	0.63						
1967		**119,000**									
EPA Promulgated or Proposed Standard	**50**	**20,000**	**8**	NA	NA	NA	**0.01**	**10**	**1.4**	0.3	0.05-0.2
NM WQCC Standard	NA	NA	NA	NA	NA	NA	0.05	10	1.6	**1.0**	**5.0**
DOE Standard	NA	80,000	40	**1.6**	**1.2**	**1.2**	NA	NA	NA	NA	NA
LANL SAL	NA	20,000	**8**	15	15	15	0.05	10	NA	NA	NA

MCO-6														
Reference	**Gross Alpha (pCi/L)**	**Gross Beta (pCi/L)**	**^{3}H (pCi/L)**	**^{90}Sr (pCi/L)**	**^{238}Pu (pCi/L)**	**^{239}Pu (pCi/L)**	**^{241}Am (pCi/L)**	**^{137}Cs (pCi/L)**	**Pb (ppm)**	**Se (ppm)**	**NO_3-N (ppm)**	**F (ppm)**	**Fe (ppm)**	**TDS (ppm)**
NMED 1993											***33***			
LANL July 1994		**76**	111.2	**17.4**			0.134				***19.3***			
LANL August 1993										***0.07***	***28.5***			584
LANL March 1992			**180,000**		0.093	0.234			***0.016***		***76.2***	***1.9***	***2***	
LANL 1989											***81***	***1.9***		782
LANL 1988											***75***	***3.3***		751
LANL April 1986											***54***			618
Penrose 1990														
1983						**340**	**2,700**				***400***	***4.2***	***2***	899
1982						**68**	**13,000**							

MCO-6														
Reference	Gross Alpha (pCi/L)	Gross Beta (pCi/L)	^{3}H (pCi/L)	^{90}Sr (pCi/L)	^{238}Pu (pCi/L)	^{239}Pu (pCi/L)	^{241}Am (pCi/L)	^{137}Cs (pCi/L)	Pb (ppm)	Se (ppm)	NO_3-N (ppm)	F (ppm)	Fe (ppm)	TDS (ppm)
Purtymun 1993														
1978	**18**	**59**	**305,000**	2.8	**2.2**	0.28		21						
1977	**30**	**54**	**515,000**		0.28	0.04		43						
1976	**20**		**1,760,000**		0.34	0.04	0.1							
1975			**24,000**		0.55	0.06	0.47							
1974		77	**42,000**		0.99	0.13		20						
1973			**48,000**		0.8	0.3	0.4	10						
1972		**132**	**60,000**		0.08	0.05	0.22							
1971		**168**	**51,000**											
1970			**755,000**											
1969			**34,000**											
1968			**89,000**		0.07									
1967			**94,000**											
EPA Promulgated or Proposed Standard	**15**	**50**	**20,000**	**8**	NA	NA	NA	NA	**0.015**	**0.01**	**10**	**1.4**	0.3	500
NM WQCC Standard	NA	NA	NA	NA	NA	NA	NA	NA	0.05	0.05	10	1.6	**1.0**	**1,000**
DOE Standard	NA	NA	80,000	40	**1.6**	**1.2**	**1.2**	120	NA	NA	NA	NA	NA	NA
LANL SAL	NA	NA	20,000	8	15	15	15	**110**	0.05	0.05	10	NA	NA	NA

MCO-6B				
Reference	**Ba (ppm)**	**Be (ppm)**	**Pb (ppm)**	**Tl (ppm)**
LANL March 1992[1]		*0.004*	*0.07*	
LANL March 1992[2]	*1.67*	*0.0083*	**0.163**	**2.1**
EPA Promulgated or Proposed Standard	2.0	**0.004**	**0.015**	**0.002**
NM WQCC Standard	**1.0**	NA	0.05	NA
DOE Standard	NA	NA	NA	NA
LANL SAL	2.0	0.004	0.05	0.002

1. Measured by IT Corporation (1990)
2. Measured by LANL Environmental and Health Chemistry Group, ESE-9

Reference	Gross Beta (pCi/L)	^{3}H (pCi/L)	^{90}Sr (pCi/L)	^{238}Pu (pCi/L)	^{239}Pu (pCi/L)	^{241}Am (pCi/L)	^{137}Cs (pCi/L)	V (ppm)	Se (ppm)	NO_3-N (ppm)	F (ppm)	Fe (ppm)	Al (ppm)	Mn (ppm)	TDS (ppm)
NMED 1993										*63.4*					
LANL July 1994		**62,700**				0.183				*16.1*					
LANL August 1993									*0.07*	*26*					
LANL March 1992		18,000			0.042			*0.022*			*1.9*	*3.9*	*7.4*	*0.214*	
LANL 1989										*82*					762
LANL June 1989										*111*	*2.8*				
LANL 1988										*62*	*3.3*				775
LANL April 1986										*110*					*1,040*
LANL April 1984										*300*					688
Purtymun 1993															
1978		**105,000**	0.2	0.06	0.02		15								
1977		**240,000**		0.12	0.04		**120**								
1976		**266,000**	5.1	0.41	0.03	0.04	12								
1975		**26,000**		0.59	0.07	1.1									
1974		**38,000**		0.74	0.09		20								
1973		**53,000**		0.13		0.8	80								
1972	**73**	**69,000**		0.09	0.06	0.08									
1971	**105**	**84,000**		0.08											
1970		**460,000**													
1969		**43,000**			0.05										
1968		**132,000**			0.1										
1967		**204,000**			0.05										
EPA Promulgated or Proposed Standard	**50**	**20,000**	**8**	NA	NA	NA	NA	**0.02**	**0.01**	**10**	**1.4**	0.3	0.05-0.2	0.05	500
NM WQCC Standard	NA	NA	NA	NA	NA	NA	NA	NA	0.05	10	1.6	**1.0**	**5.0**	**0.2**	**1,000**
DOE Standard	NA	80,000	40	**1.6**	**1.2**	**1.2**	120	NA	NA	NA	NA	NA	NA	NA	NA
LANL SAL	NA	20,000	**8**	15	15	15	**110**	NA	0.05	10	NA	NA	NA	0.18	NA

MC 5													
Reference	Gross Alpha (pCi/L)	Gross Beta (pCi/L)	^{3}H (pCi/L)	^{90}Sr (pCi/L)	^{238}Pu (pCi/L)	^{239}Pu (pCi/L)	^{241}Am (pCi/L)	^{137}Cs (pCi/L)	Se (pCi/L)	NO_3-N (ppm)	F (ppm)	Fe (ppm)	TDS (ppm)
LANL July 1994			62,300							*27.6*			
LANL August 1993							0.26		0.08	*27*			
LANL March 1992			110,000							*77*		*3.3*	792
LANL 1989										*82*	*1.6*		770
LANL June 1989										*109*	*2.8*		
LANL 1988										*62*	*3.2*		777
LANL April 1986										*111*			*1,049*
Penrose 1990													
1983						17	5,400			*450*			
1982						43	17,000						
Purtymun 1993													
1978	22		180,000	1.6	0.29	0.06		15					
1977	42	64	950,000		0.3	0.01		93					
1976	46		205,000		0.23	0.05	0.08	3					
1975			33,000		1	0.12	0.9						
1974			36,000		0.21	0.1		90					
1973			61,000		0.1	0.05	0.44	50					
1972		70	49,000		0.08	0.11	1.1						
1971		68	122,000		0.12								
1970			326,000		0.32	0.37							
1969			59,000		0.07	0.15							
1968			171,000		0.1	0.32							
1967			389,000			0.06							
EPA Promulgated or Proposed Standard	15	50	20,000	8	NA	NA	NA	NA	0.01	10	1.4	0.3	500
NM WQCC Standard	NA	NA	NA	NA	NA	NA	NA	NA	0.05	10	1.6	1.0	1,000
DOE Standard	NA	NA	80,000	40	1.6	1.2	1.2	120	NA	NA	NA	NA	NA
LANL SAL	NA	NA	20,000	8	15	15	15	110	0.05	10	NA	NA	NA

MCO-7A		
Reference	**Be (ppm)**	**Pb (ppm)**
LANL March 1992[1]		*0.05*
LANL March 1992[2]	*0.0047*	*0.094*
EPA Promulgated or Proposed Standard	**0.004**	**0.015**
NM WQCC Standard	NA	0.05
DOE Standard	NA	NA
LANL SAL	0.004	0.05

1. Measured by IT Corporation (1990)
2. Measured by LANL Environmental and Health Chemistry Group, ESE-9

MCO-8					
Reference	**^{3}H (pCi/L)**	**^{238}Pu (pCi/L)**	**^{239}Pu (pCi/L)**	**^{241}Am (pCi/L)**	**^{137}Cs (pCi/L)**
Purtymun 1993					
1977	**630,000**	0.28	0.01		**130**
1976	**25,000**	0.15	0.04		**8**
1975	**41,000**	0.51	0.1	0.24	
1973	**84,000**	0.93		0.66	50
1972	**130,000**	0.1	0.52	0.31	
1970	**97,000**				
1969	**141,000**				
1968	**342,000**		0.08		
1967	**942,000**				
EPA Promulgated or Proposed Standard	**20,000**	NA	NA	NA	NA
NM WQCC Standard	NA	NA	NA	NA	NA
DOE Standard	80,000	**1.6**	**1.2**	**1.2**	120
LANL SAL	20,000	**15**	15	15	**110**

SPRINGS															
Spring	**Reference**	**Gross Beta (pCi/L)**	**^{3}H (pCi/L)**	**^{241}Am (pCi/L)**	**Cd (ppm)**	**V (ppm)**	**TCE (ppm)**	**PCE (ppm)**	**Pb (ppm)**	**Se (ppm)**	**Tl (ppm)**	**U (ppm)**	**Al (ppm)**	**Fe (ppm)**	**NO_3-N (ppm)**
Ancho Spring	NMED 1994B			0.045											
	LANL June 1989					*0.022*									
Basalt Spring	Longmire 1995		162												
	NMED 1995														*13.2*
	Fact 1994		160												
	Fact 1994		121												
Burning Ground Spring	NMED 1995B						*0.0026*	*0.0028*							
DP Spring	NMED 1993B	**234**[1]	1,023												
	Blake '95														
	1992		1,120												
	1991		1,855												
	1990		2,770												
Homestead Spring	NMED 1995												*6.7*		
Indian Spring	LANL July 1994										*0.0037*				
	LANL August 1993								**0.199**	*0.07*		**0.0202**			
	LANL March 1992											0.0188			
La Mesita Spring	NMED 1995				*0.007*										
	NMED 1993													*1.4*	
	LANL April 1984														*10*
EPA Promulgated or Proposed Standard		**50**	**20,000**	NA	**0.005**	**0.02**	**0.005**	**0.005**	**0.015**	**0.01**	**0.002**	**0.02**	0.05-0.2	0.3	**10**
NM WQCC Standard		NA	NA	NA	0.01	NA	0.1	0.02	0.05	0.05	NA	5.0	**5**	**1.0**	10
DOE Standard		NA	80,000	**1.2**	NA	NA	NA	NA	NA	NA	NA	0.03	NA	NA	NA
LANL SAL		NA	20,000	15	0.005	0.24	0.005	0.005	0.05	0.05	0.002	NA	NA	NA	10

1. Measured with a ^{137}Cs reference.

SPRINGS												
Spring	**Reference**	**^{3}H (pCi/L)**	**^{239}Pu (pCi/L)**	**TCE (ppm)**	**PCE (ppm)**	**Hg (ppm)**	**2,2-DNT (ppm)**	**Pb (ppm)**	**Al (ppm)**	**F (ppm)**	**Mn (ppm)**	**NO_3-N (ppm)**
Perkin's Spring	NMED 1995B											***29***
Sacred Spring	LANL July 1994		0.021									
Sandia Spring	NMED 1995										***0.24***	
	LANL March 1992							***0.0195***				
	LANL June 1989										***0.82***	
	LANL 1988					***0.002***						
Starmer's Spring	NMED 1995B								***6.3***			
	EC 1995						**0.00152**					
SWSC Line Spring	NMED 1995B			***0.0022***	***0.0023***							
Water Canyon Gallery Spring	Longmire 1995	41.5										
	LANL August 1993	1,000										
	LANL 1989							***0.015***	***8***	***2.9***		
EPA Promulgated or Proposed Standard		**20,000**	NA	**0.005**	**0.005**	**0.002**	NA	**0.015**	0.05-0.2	**1.4**	0.05	**10**
NM WQCC Standard		NA	NA	0.1	0.02	0.002	TOX	0.05	**5**	1.6	**0.2**	10
DOE Standard		80,000	**1.2**	NA	NA	NA	NA	NA	NA	NA	NA	NA
LANL SAL		20,000	15	0.005	0.005	0.002	**0.00005**	0.05	NA	NA	0.18	10

PCO-SERIES WELLS												
Well	**Reference**	**Gross Alpha[1] (pCi/L)**	**Gross Beta[2] (pCi/L)**	**Cr (ppm)**	**Pb (ppm)**	**Co (ppm)**	**Ba (ppm)**	**NO_3-N (ppm)**	**Mn (ppm)**	**Al (ppm)**	**Fe (ppm)**	**TDS (ppm)**
PCO-1	NMED 1993							***594***	***0.57***	***6.4***	***5.2***	
	LANL July 1994								***0.257***			
	LANL March 1992											612
	LANL June 1989								***10.1***		***32***	
PCO-2	NMED 1993			**0.38**	***0.035***			***462***	***1.06***	***38***	***39***	
	LANL March 1992											600
	LANL June 1989								***9.7***		***21***	
PCO-3	NMED 1993	**113**	**92**	**0.34**	**0.107**	***0.05***	***2.3***		***9.76***	***110***	***84***	***1,431***
	LANL August 1993											622
	LANL June 1989								***8.8***		***13***	
EPA Promulgated or Proposed Standard		**15**	**50**	0.1	**0.015**	NA	2.0	**10**	0.05	0.05-0.2	0.3	500
NM WQCC Standard		NA	NA	**0.05**	0.05	**0.05**	**1.0**	10	**0.2**	**5.0**	**1.0**	**1,000**
DOE Standard		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
LANL SAL		NA	NA	0.1	0.05	NA	10	10	0.18	NA	NA	NA

1. Measured with a natural U reference.
2. Measured with a ^{137}Cs reference

PM-SERIES WELLS			
Well	**Reference**	**Year**	**^3H (pCi/L)**
PM-1	Longmire 1994		1.65
	Fact 1994	1992	2.2
		1991	1.6
PM-2	Longmire 1994		1.57
	Fact 1994	1993	1.57
		1992	0.13
		1992	0.48
PM-3	Longmire 1994		0.45
			0.032
			0.032
			0.74
			0.42
	Fact 1994	1993	21.3
		1993	0.19
		1992	1.2
PM-5	Longmire 1994		0.29
	Fact 1994	1992	1.2
		1991	0.288
EPA Promulgated or Proposed Standard			**20,000**
NM WQCC Standard			NA
DOE Standard			80,000
LANL SAL			20,000

TW-SERIES WELLS														
Well	Reference	H^3 (pCi/L)	^{239}Pu (pCi/L)	Cd (ppm)	Pb (ppm)	U (ppm)	V (ppm)	Se (ppm)	Sb (ppm)	Zn (ppm)	NO_3-N (ppm)	Fe (ppm)	Mn (ppm)	TDS (ppm)
TW-1	**Hargis 1993**													
	1993				**1.04 (f)[1]**				**0.0164**					
	Longmire 1995	366												
	Fact 1994	362												
	NMED 1993					***0.03***	**0.26**	**0.24**						
	Fact 1994	349												
	LANL July 1994								***0.008***					
	Hargis 1993				***0.022***									
	LANL April 1984										***25***			
TW-1A	Longmire 1995	148												
	Fact 1994													
	5/19/93	147												
	10/8/92	132												
	LANL March 1992													548
	LANL June 1989				***0.098***					***12.8***		***5.4***		
	LANL April 1986										***12***			
	LANL April 1984										***52***			
TW-2	Hargis 1993				***0.03***									
	LANL July 1994											***2.58***		
	LANL August 1993				***0.053***									

TW-SERIES WELLS														
Well	**Reference**	**H^3 (pCi/L)**	**^{239}Pu (pCi/L)**	**Cd (ppm)**	**Pb (ppm)**	**U (ppm)**	**V (ppm)**	**Se (ppm)**	**Sb (ppm)**	**Zn (ppm)**	**NO_3-N (ppm)**	**Fe (ppm)**	**Mn (ppm)**	**TDS (ppm)**
TW-2A	Longmire 1995	2,265												
	Fact 1994													
	1993	2,237												
	1992	2,234												
	LANL July 1994	2,900	**1.28**											
	LANL March 1992			***0.0087***	***0.065***							***26***	***0.228***	
	LANL June 1989				***0.109***									
TW-3	NMED 1993						***0.07***					***1.94***	***5.2***	
	NMED 5/93											***2.4***		
TW-4	Hargis 1993				***0.0596***								***0.23***	
TW-8	Hargis 1993													
	1991				**0.36**									
	1988				***0.06***									
EPA Promulgated or Proposed Standard		**20,000**	NA	**0.005**	**0.015**	**0.02**	**0.02**	**0.01**	**0.006**	5.0	**10**	0.3	0.05	500
NM WQCC Standard		NA	NA	0.01	0.05	5.0	NA	0.05	NA	**10**	10	**1.0**	**0.2**	**1,000**
DOE Standard		80,000	**1.2**	NA	NA	0.03	NA	NA	NA	NA	NA	NA	NA	NA
LANL SAL		20,000	15	0.005	0.05	NA	0.24	0.05	0.006	10	10	NA	0.18	NA

1. Sample was filtered (f).

APCO-1							
Reference	**^{239}Pu (pCi/L)**	**^{241}Am (pCi/L)**	**Cr (ppm)**	**Pb (ppm)**	**Be (ppm)**	**Mn (ppm)**	**Al (ppm)**
LANL July 1994	0.119	0.064	***0.06***		***0.008***	***2.6***	***7.02***
LANL March 1992				***0.08***	***0.004***		
EPA Promulgated or Proposed Standard	NA	NA	0.1	**0.015**	**0.004**	0.05	0.05-0.2
NM WQCC Standard	NA	NA	**0.05**	0.05	NA	**0.2**	**5**
DOE Standard	**1.2**	**1.2**	NA	NA	NA	NA	NA
LANL SAL	15	15	0.1	0.05	0.004	0.18	NA

CDBO-SERIES WELLS								
Well	**Reference**	**Pb (ppm)**	**As (ppm)**	**Ba (ppm)**	**Be (ppm)**	**Fe (ppm)**	**Al (ppm)**	**Mn (ppm)**
CDBO-6	NMED 1994A	***0.016***				***2***		
	LANL July 1994		***0.0722***				***11.4***	
CDBO-7	NMED 1994A	***0.026***		***1.4***	***0.006***	***3.7***	***9.3***	***0.47***
EPA Promulgated or Proposed Standard		**0.015**	0.1	2.0	**0.004**	0.3	0.05-0.2	0.05
NM WQCC Standard		0.05	**0.05**	**1.0**	NA	**1.0**	**5**	**0.2**
DOE Standard		NA	NA	NA	NA	NA	NA	NA
LANL SAL		0.05	0.1	2.0	0.004	NA	NA	0.18

DT-SERIES WELLS										
Well	**Reference**	**H^3 (pCi/L)**	**^{90}Sr (pCi/L)**	**^{241}Am (pCi/L)**	**^{238}Pu (pCi/L)**	**^{239}Pu (pCi/L)**	**As (ppm)**	**Pb (ppm)**	**Sb (ppm)**	**Fe (ppm)**
DT-5A	NMED 1994C			0.144				**0.29**		
	NMED 5/93							**4.6**	**0.22**	
	Hargis 1993									
	9/2/93							**2.7**		
								0.14 (f)[1]		
	8/9/93							**0.41**		
								0.8-0.1 (f)		
	1993					0.23	0.00457	**9**	**0.28**	
	LANL July 1994							**0.209 (f)**		
	LANL August 1993		3					***0.033***		
	LANL June 1989							***0.048***		
DT-9	NMED 1994C			0.117	0.000135					***5.6***
	NMED 1993B							***0.02***		***1.77***
	Hargis 1993							***0.053***		***4.7***
	LANL July 1994							***0.055***		***12***
	Hargis 1993									
	1991							***0.026***		
	LANL June 1989							***0.017***		

DT-SERIES WELLS										
Well	**Reference**	**H^3 (pCi/L)**	**^{90}Sr (pCi/L)**	**^{241}Am (pCi/L)**	**^{238}Pu (pCi/L)**	**^{239}Pu (pCi/L)**	**As (ppm)**	**Pb (ppm)**	**Sb (ppm)**	**Fe (ppm)**
DT-10	NMED 1993							***0.04***		
	Hargis 1993							***0.075***		
	LANL July 1994							***0.05***		
	LANL August 1993							***0.28***		
	LANL June 1989							***0.039***		
EPA Promulgated or Proposed Standard		**20,000**	**8**	NA	NA	NA	**0.05**	**0.015**	**0.006**	0.3
NM WQCC Standard		NA	NA	NA	NA	NA	0.1	0.05	NA	**1.0**
DOE Standard		80,000	40	**1.2**	**1.6**	**1.2**	NA	NA	NA	NA
LANL SAL		20,000	8	15	15	15	0.05	0.05	0.006	NA

1. Sample was filtered (f).

G-SERIES WELLS				
Well	**Reference**	**^{239}Pu (pCi/L)**	**Pb (ppm)**	**V (ppm)**
G-1	LANL July 1994			***0.04***
	Hargis 1993			
	1991		***0.049***	
G-1A	LANL July 1994			***0.05***
	LANL March 1992			***0.04***
G-2	Hargis 1993		***0.039***	
	LANL July 1994			***0.09***
	LANL March 1992			***0.079***
G-3	LANL April 1986		***0.02***	
G-4	LANL August 1993	0.669		
G-5	LANL August 1993		***0.095***	
	Hargis 1993			
	1991		***0.095***	
EPA Promulgated or Proposed Standard		NA	**0.015**	**0.02**
NM WQCC Standard		NA	0.05	NA
DOE Standard		**1.2**	NA	NA
LANL SAL		15	0.05	0.24

LADP-3				
Reference	**^3H (pCi/L)**	**Mn (ppm)**	**Na (ppm)**	**TDS (ppm)**
Broxton 1994				
1993[1]	6,000	***0.44***	***33.8***	229.3
1993[2]	5,500			
EPA Promulgated or Proposed Standard	**20,000**	0.05	**20**	500
NM WQCC Standard	NA	**0.2**	NA	**1,000**
DOE Standard	80,000	NA	NA	NA
LANL SAL	20,000	0.18	NA	NA

1. Analyzed at the University of Florida
2. Analyzed at LANL

SPRINGS AND SEEPS															
Spring/ Seep	Reference	Gross Alpha (pCi/L)	H^3 (pCi/L)	^{241}Am (pCi/L)	^{238}Pu (pCi/L)	^{239}Pu (pCi/L)	TCA (ppm)	V (ppm)	Pb (ppm)	As (ppm)	Hg (ppm)	U (ppm)	Cd (ppm)	Fe (ppm)	Mn (ppm)
Twomile Canyon Tributary Seep	SWMU 3-010a (1994)		413				0.0079								
			458				0.013								
							0.012								
Spring 1	NMED 1995 (3/30/95)													*2.4*	
	LANL March 1992							*0.024*	*0.018*					*2.6*	
	LANL June 1989							*0.024*							
	LANL 1988													*2.9*	
Spring 2	LANL July 1994							*0.04*						*2.1*	
	LANL March 1992							*0.038*							
	LANL June 1989							**0.15**		*0.06*					*0.95*
	LANL 1988													*1.57*	
Spring 3	NMED 1994B			0.059											
	NMED 1993		1,873												
	LANL March 1992								*0.016*						
	LANL June 1989							*0.034*							
Spring 3A	NMED 1994B			0.045											
	LANL March 1992								*0.015*						
	LANL June 1989							*0.06*							

SPRINGS AND SEEPS															
Spring/ Seep	**Reference**	**Gross Alpha (pCi/L)**	**H^3 (pCi/L)**	**^{241}Am (pCi/L)**	**^{238}Pu (pCi/L)**	**^{239}Pu (pCi/L)**	**TCA (ppm)**	**V (ppm)**	**Pb (ppm)**	**As (ppm)**	**Hg (ppm)**	**U (ppm)**	**Cd (ppm)**	**Fe (ppm)**	**Mn (ppm)**
Spring 3AA	LANL March 1992								0.0162					*1.7*	
	LANL June 1989							*0.05*						*1.2*	*0.26*
	LANL 1988													*1.71*	
Spring 3B	NMED 1994B	**17.61**				0.023						*0.0205*			
	LANL July 1994	**16**													
	LANL August 1993	**18**													
	LANL March 1992				0.069			*0.069*	*0.029*						
	LANL June 1989							*0.074*							
Spring 4	LANL June 1989							*0.06*						*2.3*	
Spring 4A	LANL August 1993												**0.0138**		
	LANL March 1992								*0.0209*						
	LANL June 1989							*0.02*							
Spring 5	NMED 1994B			0.05											
	LANL June 1989							*0.04*							
Spring 5A	LANL March 1992													*1.5*	
Spring 5AA	LANL June 1989														*0.53*
	LANL 1988													*1.99*	
Spring 5B	LANL July 1994		1,100												
	LANL June 1989							*0.02*							

SPRINGS AND SEEPS															
Spring/ Seep	**Reference**	**Gross Alpha (pCi/L)**	**H^3 (pCi/L)**	**^{241}Am (pCi/L)**	**^{238}Pu (pCi/L)**	**^{239}Pu (pCi/L)**	**TCA (ppm)**	**V (ppm)**	**Pb (ppm)**	**As (ppm)**	**Hg (ppm)**	**U (ppm)**	**Cd (ppm)**	**Fe (ppm)**	**Mn (ppm)**
Spring 7	LANL March 1992								***0.017***						
	LANL June 1989							***0.05***							
Spring 8	LANL March 1992								***0.022***						
Spring 9	LANL 1988										***0.002***				
Spring 9A	LANL March 1992								***0.023***						
EPA Promulgated or Proposed Standard		**15**	**20,000**	NA	NA	NA	0.2	**0.02**	**0.015**	**0.05**	**0.002**	**0.02**	**0.005**	0.3	0.03
NM WQCC Standard		NA	NA	NA	NA	NA	**0.06**	NA	0.05	0.1	0.002	5.0	0.01	**1.0**	**0.2**
DOE Standard		NA	80,000	**1.2**	**1.6**	**1.2**	NA	NA	NA	NA	NA	0.03	NA	NA	NA
LANL SAL		NA	20,000	15	15	15	0.2	0.24	0..05	0.05	0.002	NA	0.005	NA	0.18

LAUZ-1					
FIMAD 1995		EPA Promulgated or Proposed Standard	NM WQCC Standard	DOE Standard	LANL SAL
Gross Beta (pCi/L)	**1,080**	**50**	NA	NA	NA
^{90}Sr (pCi/L)	**526**	**8**	NA	40	8
Benzo[a]anthracene (ppm)	**0.01**	**0.0001**	NA	NA	0.0001
Benzo[a]pyrene (ppm)	**0.01**	**0.0002**	NA	NA	0.0002
Benzo[b]fluoranthene (ppm)	**0.01**	**0.0002**	NA	NA	0.0002
Benzo[k]fluoranthene (ppm)	**0.01**	**0.0002**	TOX	NA	0.0002
Chrysene (ppm)	**0.01**	**0.0002**	NA	NA	0.0002
Dibromo-3-chloropropane [1,2-] (ppm)	**0.01**	**0.0002**	NA	NA	NA
Dibromoethane[1,2-] (ppm)	**0.005**	**0.0005**	0.0001	NA	NA
2,4-DNT (ppm)	**0.01**	NA	TOX	NA	**0.00005**
2,6-DNT (ppm)	**0.01**	NA	NA	NA	**0.00005**
Hexachlorobenzene (ppm)	**0.01**	**0.001**	TOX	NA	0.0001
Indeno[1,2,3-c, d] pyrene (ppm)	**0.01**	**0.0004**	NA	NA	0.0004
Pentachlorophenol (ppm)	**0.052**	**0.001**	TOX	NA	0.001
Vinyl Chloride (ppm)	**0.01**	0.002	**0.001**	NA	0.002
Mn (ppm)	***0.398***	0.05	**0.2**	NA	0.18
Na (ppm)	***79.1***	**20**	NA	NA	NA

Drill Hole Penetrations at LANL

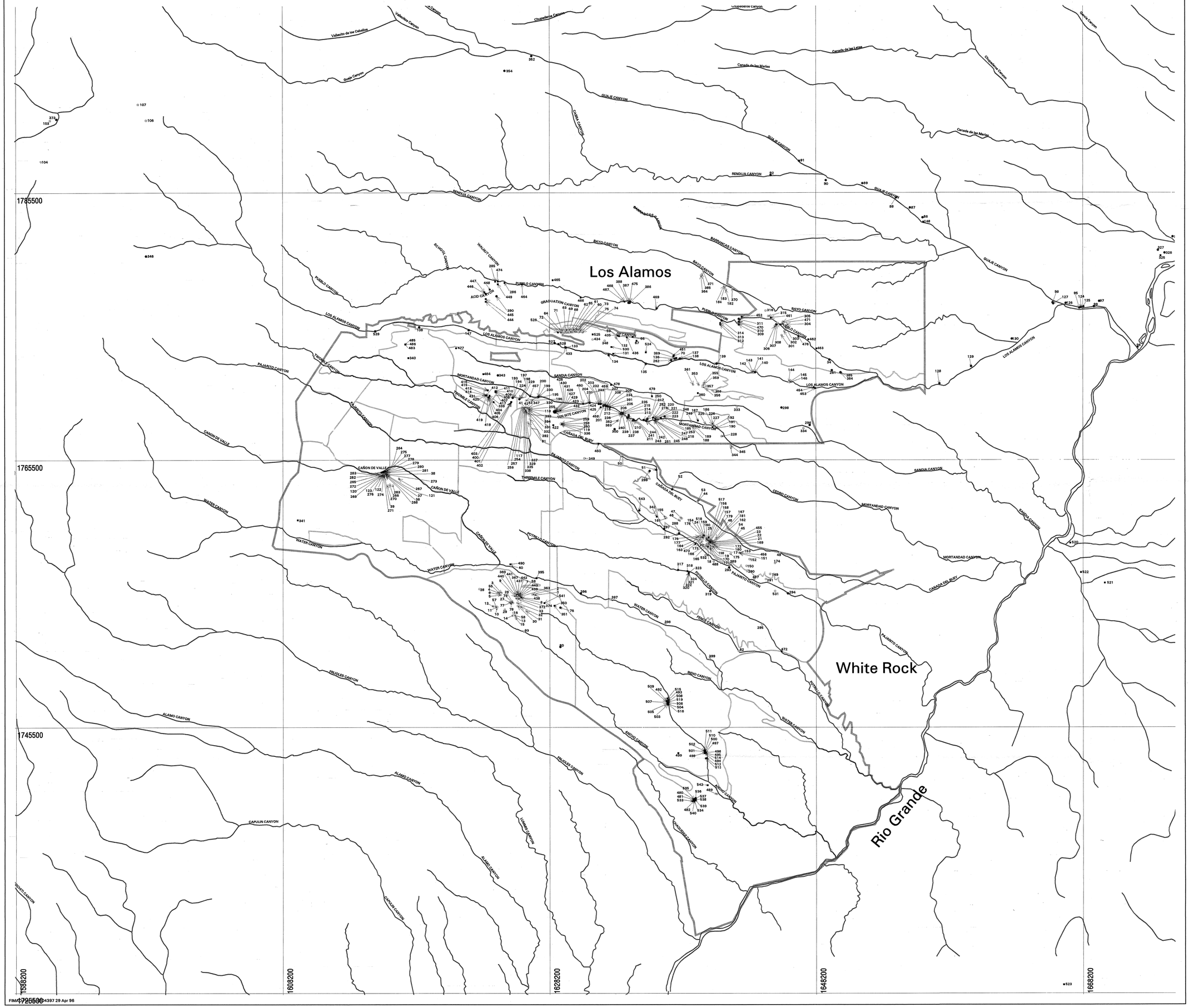
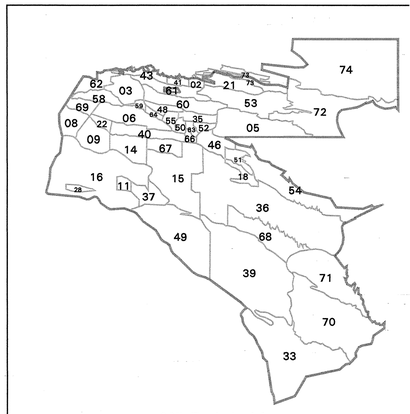


PLATE 1

EXPLANATION

- Boundary, LANL
- Boundary, TA
- Drainage
- Dry Penetration (see note)
- Saturated Penetration (see note)
- Penetration, Unknown if Dry or Saturated

NOTE: Not all penetrations may be represented and some duplicates exist. The existence of saturation was estimated from available information and should not be considered definitive.



LANL Technical Areas

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: 20000
Feet per inch on map = 3000

SCALE 1:36000

0 914 1828 2742 3656

METERS

0 3000 6000 9000 12000

FEET

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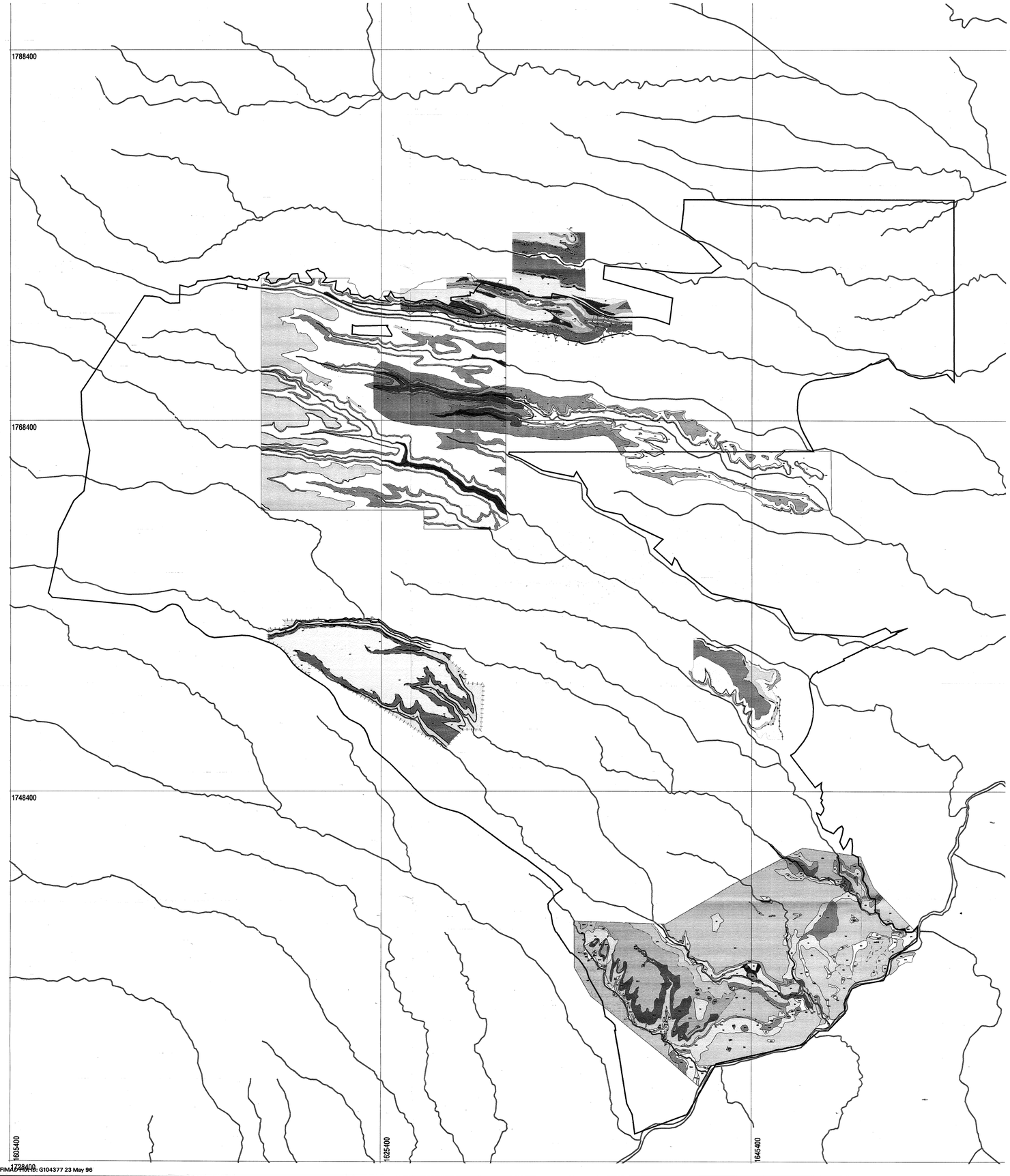

FIMAD Plot ID: G104377 23 May 96

LANL Surfical Geology

EXPLANATION

MORTANDAD CANYON GEOLOGY

- Qal
- Qbo
- Qbt1a
- Qbt1b
- Qbt2
- Qbt2a
- Qbt2b
- Qbt3

NORTH-CENTRAL GEOLOGY

- Unit 4 Sandy tuff with small pumice fragments
- Nonwelded slope-forming interval
- Unit 3 Poorly-welded cliff-forming tuff of Pajarito Mesa surface
- Nonwelded slope-forming interval
- Unit 2 Moderately- to densely-welded cliff-forming unit of Twomile Canyon.
- Unit 1v Poorly-welded, vapor-phase altered. Unit 1g Nonwelded glassy tuff.
- Undifferentiated reworked tuffs, Cerro Toledo airfall, and Otowi Member in Los Alamos Canyon
- Zones of intense fracturing Source: Vaniman, D. and Wohletz, K. Los Alamos National Laboratory Memorandum EES-1-SH90-17.

TA-49 GEOLOGY

- Qal Alluvium; mapped only in Water Canyon
- Qbt6 Unit 6; light-pinkish-gray to brownish- pink, moderately welded, rhyolite tuff; cliff-forming unit. Locally includes 2-6 feet of water-laid pumice at top. Covered by thin clayey soil on flat upland areas
- Qbt4 Unit 4; gray, friable to moderately welded, pumiceous, rhyolite tuff; cliff- forming unit
- Qbt3 Unit 3; light-gray, friable, pumiceous, rhyolite tuff; slope-forming unit
- Qbt2 Unit 2; light-purplish-gray, welded, rhyolite tuff; cliff-forming unit
- Qbt1B Unit 1B; light-gray to light-pink, pumiceous, rhyolite tuff containing numerous rock fragments; slope-forming unit

TA-21 GEOLOGY

- Qf Artificial fill and disturbed soils on mesa tops.
- Qmt Mesa top soils; soils developed in weathered Bandelier Tuff, loess, and alluvium on mesa tops; includes small bedrock outcrops.
- Qtc Talus and Colluvium; slope wash and rock fall from local sources; includes small landslides, small alluvial fans, and small patches of alluvium on canyon sides.
- Qal Alluvium; stream deposits of gravel, sand, silt, and clay in valley bottoms.
- Qoal Terrace Gravel; older alluvium that lies along margin of DP Canyon.

------ Tshirege Member, Bandelier Tuff ------

- Qbt-3 Unit 3; cliff-forming, nonwelded to partially welded ignimbrite; combined with nonwelded Unit in east side of map area.
- Qbt-nw Slope-forming, nonwelded unit; jagged contact lines show approximate eastern limit of unit, combined with Unit 3 in east side of map area.
- Qbt-2 Unit 2; cliff-forming, partially to moderately welded ignimbrite.
- Qbt-1 Unit 1; nonwelded to partially welded ignimbrite; vapor-phase notch occurs in this unit and vapor-phase alteration is widespread above this feature; Tsankawi pumice fall at base of Unit 1.
- Qct Cerro Toledo interval; equivalent in time to Cerro Toledo Rhyolite; pumice fall deposits interbedded with Puye-like fluvial gravel, cobble, and boulder deposits.
- Qbo Otowi Member, Bandelier Tuff; slope-forming nonwelded ignimbrite; undivided.

TA-33 GEOLOGY

- artifical fill
- Qa3 Alluvial deposits (Holocene and Pleistocene)
- Qa2 Alluvial and lacustrine deposits (late Pleistocene)
- Qf3 Alluvial fan deposit (Holocene and late Pleistocene)
- Qf2 Alluvial fan deposit (late Pleistocene)
- Qf1 Alluvial fan deposit (middle Pleistocene)
- Qt Talus deposit (Holocene and late Pleistocene)
- Qc Colluvial deposits (middle Pleistocene to Holocene)
- Qls Landslide deposit (Pleistocene)
- Qlsa Alluvial and Colluvial deposits on landslides (Pleistocene)
- Tpf Puye Formation, fanglomerate facies (Pliocene)
- Tpt Puye Formation, ancestral Rio Grande facies (Pliocene)
- Tsfu Santa Fe Group, undivided (middle Miocene to early(?) Pliocene)
- Qec El Cajete pumice (late Pleistocene)
- Qbt-1 Bandelier Tuff, Tshirege member, Unit 1 (early Pleistocene)
- Qbt-2 Bandelier Tuff, Tshirege member, Unit 2 (early Pleistocene)
- Qbt-3 Bandelier Tuff, Tshirege member, Unit 3 (early Pleistocene)
- Qbt Bandelier Tuff, Tshirege member, undivided (early Pleistocene)
- Qbo Bandelier Tuff, Otowi member (early Pleistocene)
- Tcc Cinder cone deposit (Pliocene)
- Tcm Phreatomagmatic deposit (Pliocene)
- Tcb3 Basalt flows (late Pliocene)
- Tcba Basaltic andesite and related flows (Pliocene)
- Tcbm Basalt flows and interlayered Phreatomagmatic deposits (Pliocene)
- Tcb2 Basalt flows (Pliocene)
- Tcb1 Basaltic flows (Pliocene)
- Tcbu Basalt flows, undivided (Pliocene)

TA-36 GEOLOGY

- Unit 2u (undifferentiated)
- Unit 2w
- Unit 1u (Upper)
- Unit 1u (Lower)
- Unit 1w
- Alluvium

- Boundary, LANL
- Drainages
- Fault, locations are estimated assembled from multiple sources

PLATE 2

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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: 20000
Feet per inch on map = 3000

SCALE 1:36000

0 914 1828 2742 3656

METERS

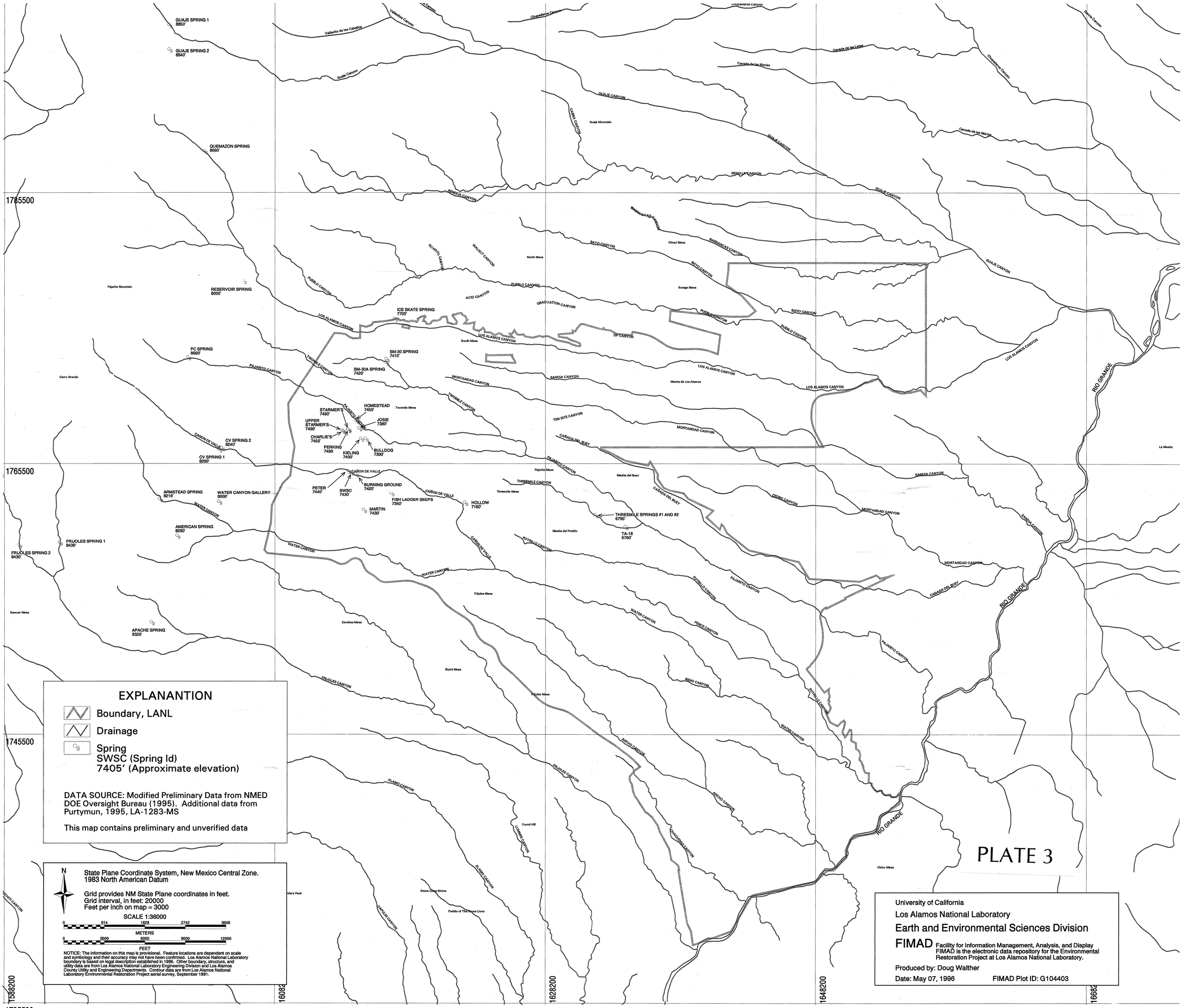
0 3000 6000 9000 12000

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. Other boundary, structure, and utility data are from Los Alamos National Laboratory Engineering Division and Los Alamos County Utility and Engineering Departments. Contour data are from Los Alamos National Laboratory Environmental Restoration Project aerial survey, September 1991.

12819

Perched Ground Water - Tschicoma Formation and Tshirege Member



EXPLANANTION

Boundary, LANL

Drainage

Spring
SWSC (Spring Id)
7405' (Approximate elevation)

DATA SOURCE: Modified Preliminary Data from NMED DOE Oversight Bureau (1995). Additional data from Purtymun, 1995, LA-1283-MS

This map contains preliminary and unverified data

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: 20000
Feet per inch on map = 3000

SCALE 1:36000

0 914 1828 2742 3656

METERS

0 3000 6000 9000 12000

FEET

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PLATE 3

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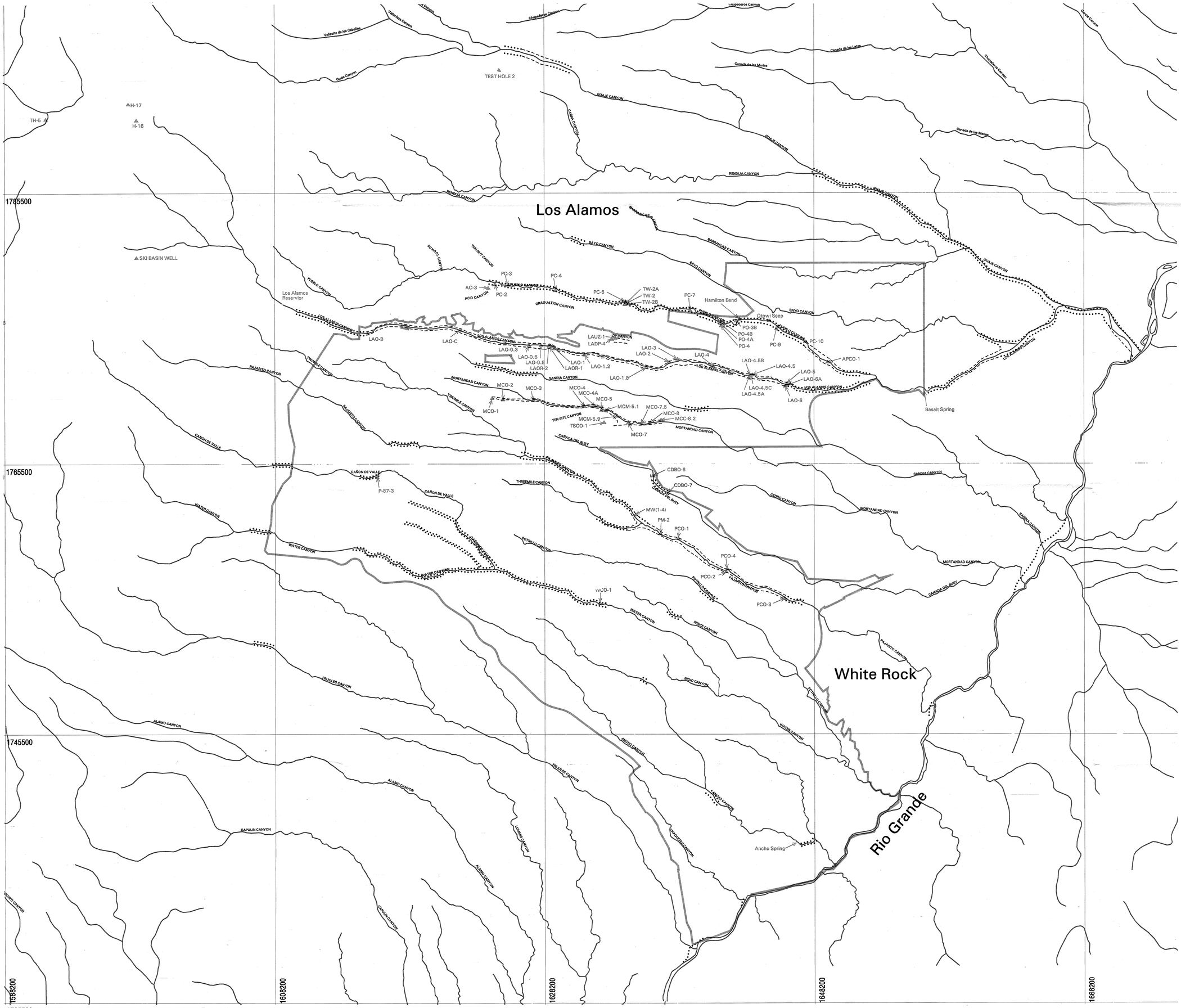
12819 -C

Shallow-Perched "Alluvial" Ground Water

PLATE 4



EXPLANATION

- Boundary, LANL
- Drainage
- Shallow-Perched "Alluvial" Ground Water, Known Extent
- Shallow-Perched "Alluvial" Ground Water, Suspect Extent
- Wells and Holes
- Spring

This map contains preliminary and unverified data.

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: 20000
Feet per inch on map = 3000

SCALE 1:36000

0 914 1828 2742 3656

METERS

0 3000 6000 9000 12000

FEET

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Date: April 29, 1996 FIMAD Plot ID: G104387

FIMAD Plot ID: G104387 29 Apr 96

12819

Known Intercepts of Intermediate Perched Ground Water

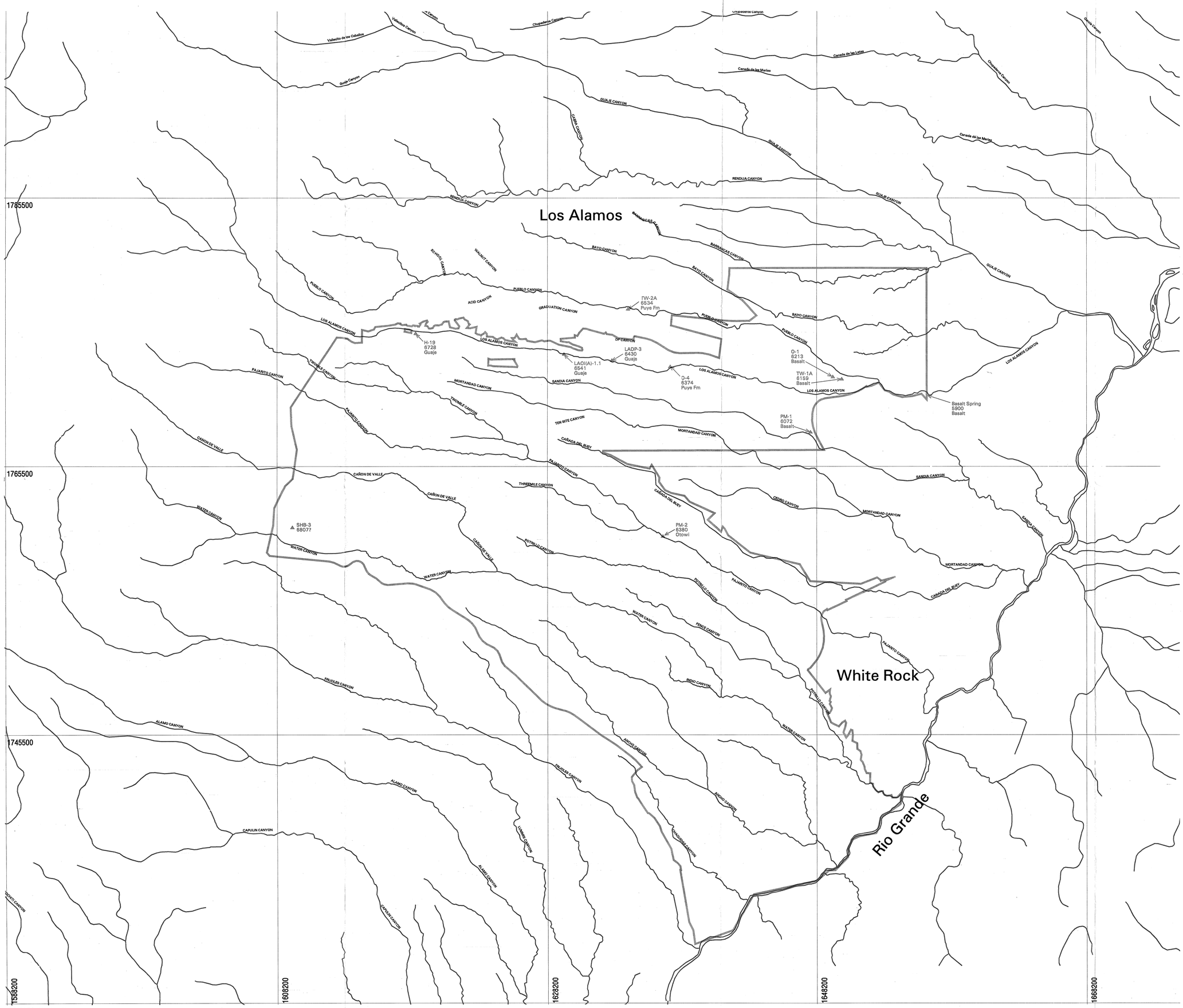

PLATE 5

EXPLANATION

- Boundary, LANL
- Drainage
- Well
  PM-2: Well id
  6380: Elevation of water bearing zone encountered while drilling or spring elevation. (ft)
  Otowi: Geologic strata associated with top of water-bearing zone
- Spring

This map contains preliminary and unverified data.

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: 20000
Feet per inch on map = 3000

SCALE 1:36000

0 914 1828 2742 3656

METERS

0 3000 6000 9000 12000

FEET

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12819

Top of Saturated Zone - Regional ("Main") Aquifer

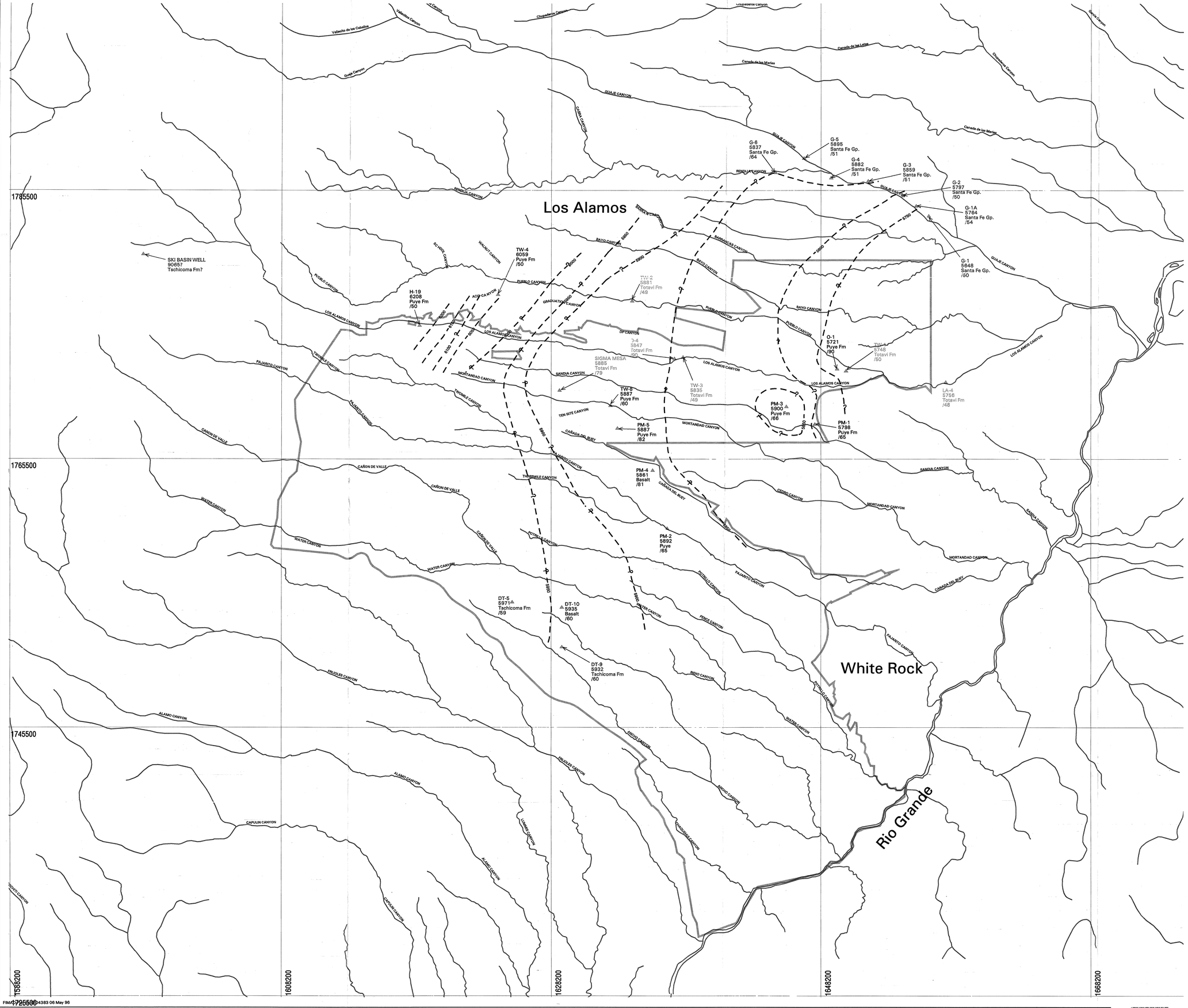

PLATE 6

EXPLANATION

- Boundary, LANL
- Drainage
- Top of Main Aquifer Contour
  C.I. = 50 Feet
- Geology Characterization Well
  PM-2: Well id
  5892: Elevation of water bearing zone encountered (top of main aquifer) (ft)
  Puye Fm: Geologic stratum at top of the saturated zone
  /65: Year well was drilled

Color of text indicates different lithologies
Green = Basalt
Blue = Puye Formation
Purple = Santa Fe Group
Orange = Totavi Formation
Brown = Tschicoma Formation

This map contains preliminary and unverified data.

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: 20000
Feet per inch on map = 3000

SCALE 1:36000

0 914 1828 2742 3656
METERS
0 3000 6000 9000 12000
FEET

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FIMAD G104383 06 May 96

Regional "Main" Aquifer Water-Levels (1993)

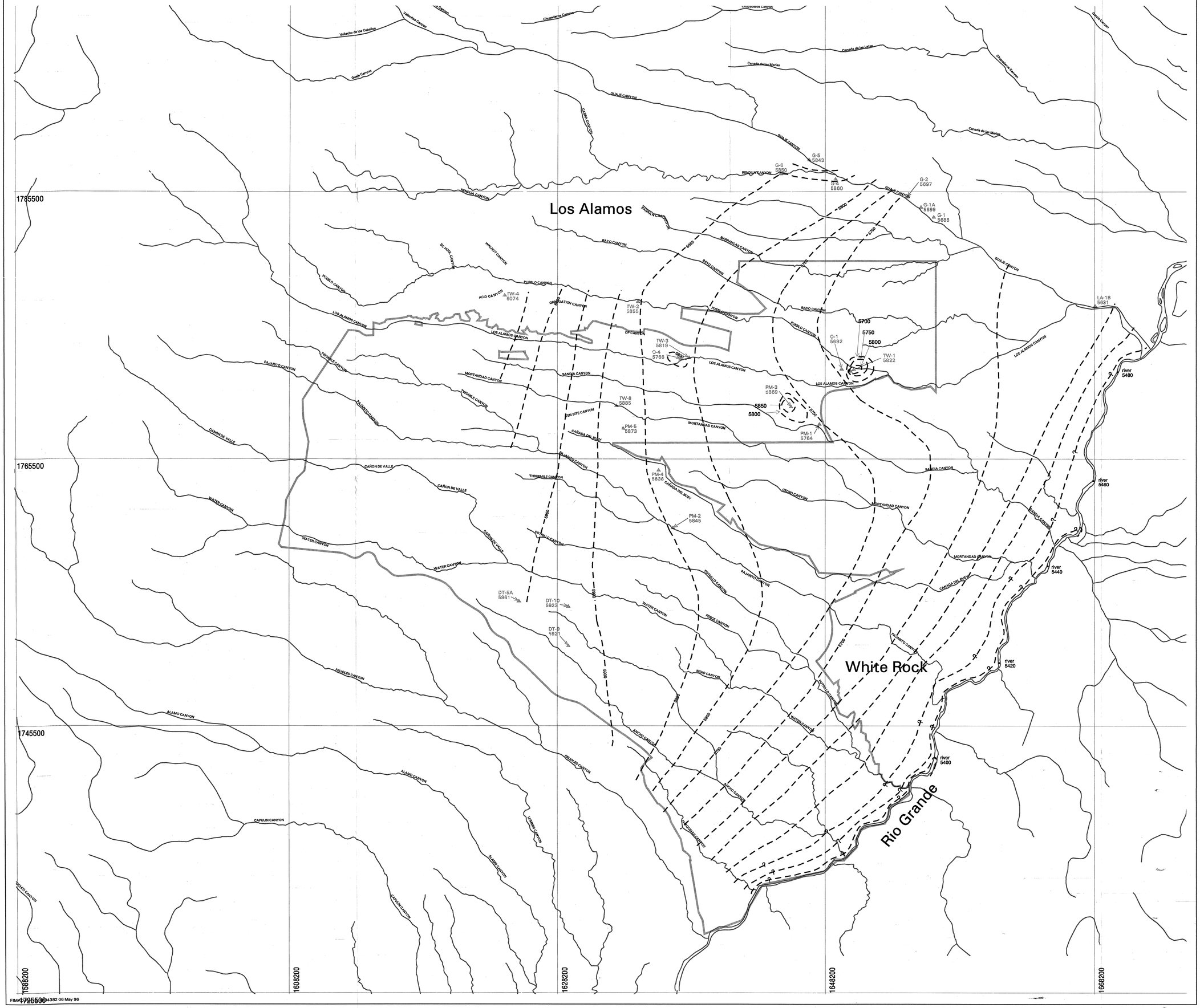

PLATE 7

EXPLANATION

- Boundary, LANL
- Drainage
- Main Aquifer Water Level C.I. = 50 feet
- Well
  PM-2: Well id
  5845: Non-pumping water-level elevation (1993)

This map contains preliminary and unverified data.

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: 20000
Feet per inch on map = 3000

SCALE 1:36000

0 914 1828 2742 3655

METERS

0 3000 6000 9000 12000

FEET

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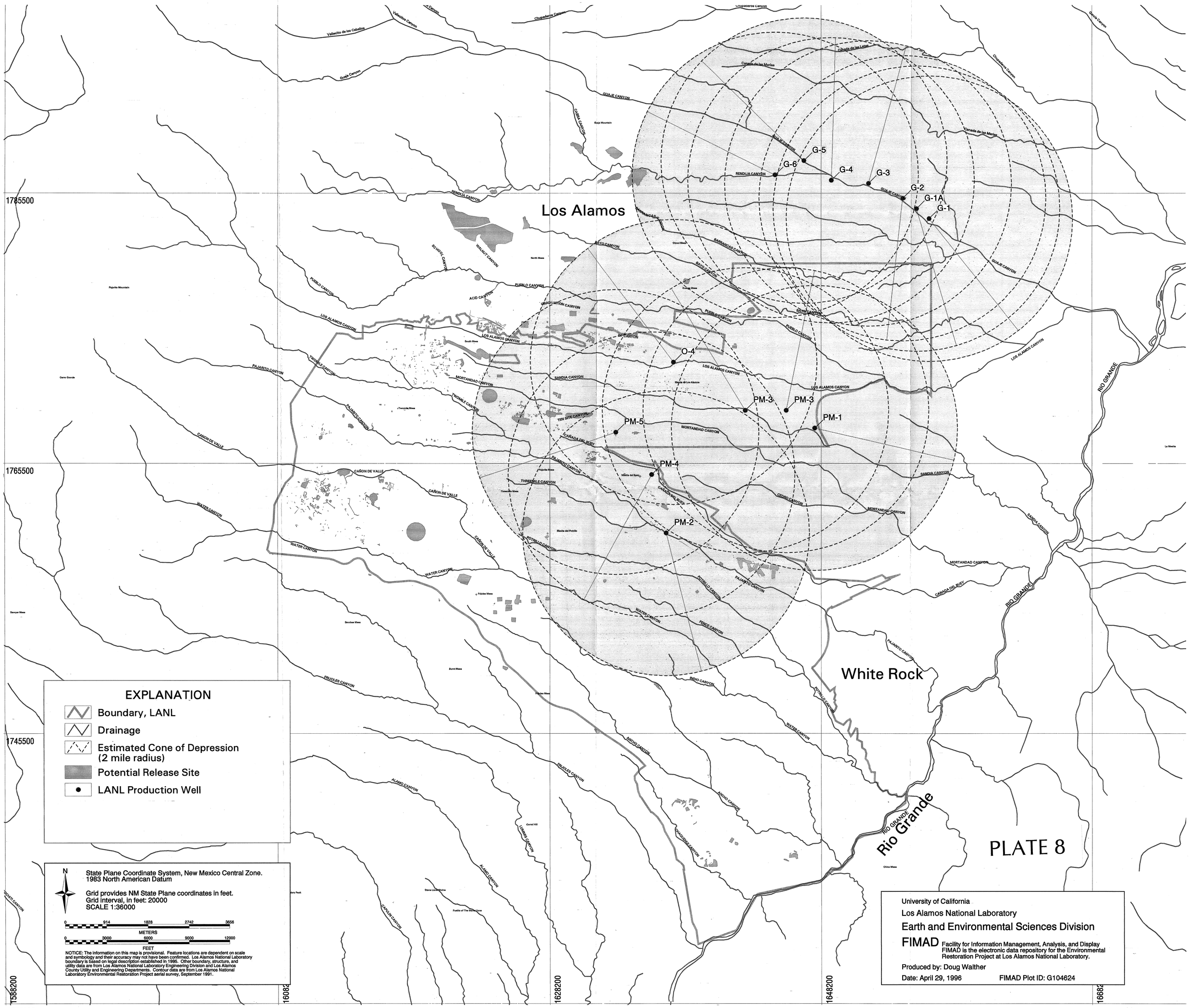
FIMAD Plot ID: G104382 06 May 96

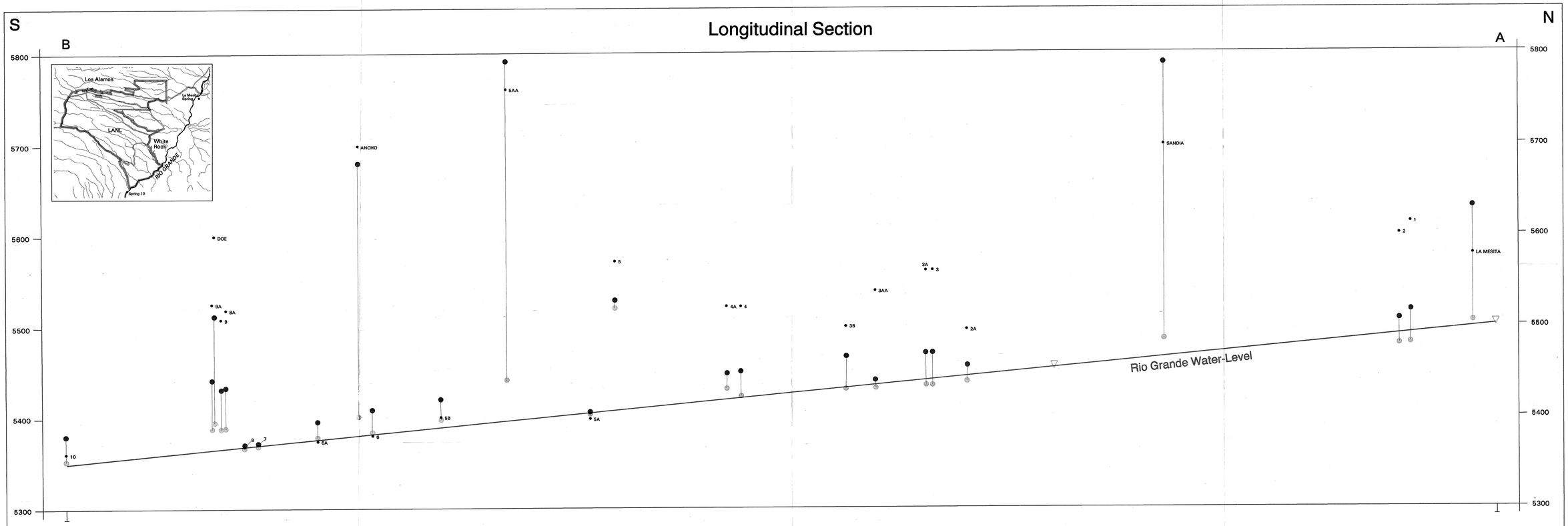
Estimated Radius of Effect for LANL Production Wells



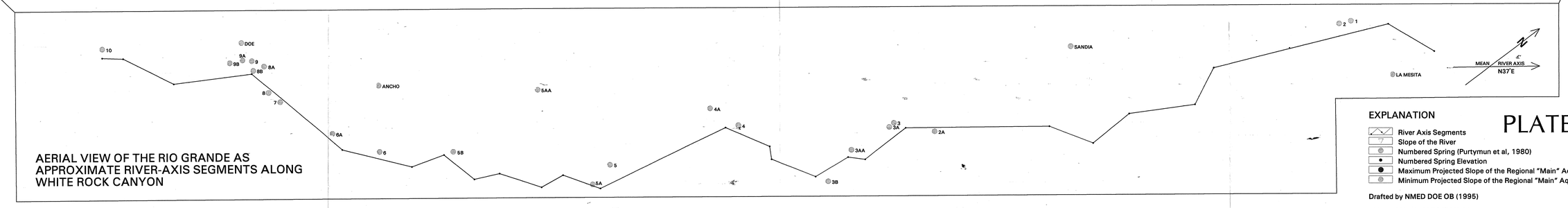
12819_H

White Rock Canyon Springs in Relation to the Rio Grande

Longitudinal Section



Plan View



AERIAL VIEW OF THE RIO GRANDE AS APPROXIMATE RIVER-AXIS SEGMENTS ALONG WHITE ROCK CANYON

EXPLANATION

- River Axis Segments
- Slope of the River
- Numbered Spring (Purtymun et al, 1980)
- Numbered Spring Elevation
- Maximum Projected Slope of the Regional "Main" Aquifer
- Minimum Projected Slope of the Regional "Main" Aquifer

PLATE 9

Drafted by NMED DOE OB (1995)

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Earth and Environmental Sciences Division
Facility for Information Management, Analysis, and Display (FIMAD)

G104441 29 Apr 96

12819

Paleotopography - Totavi Formation

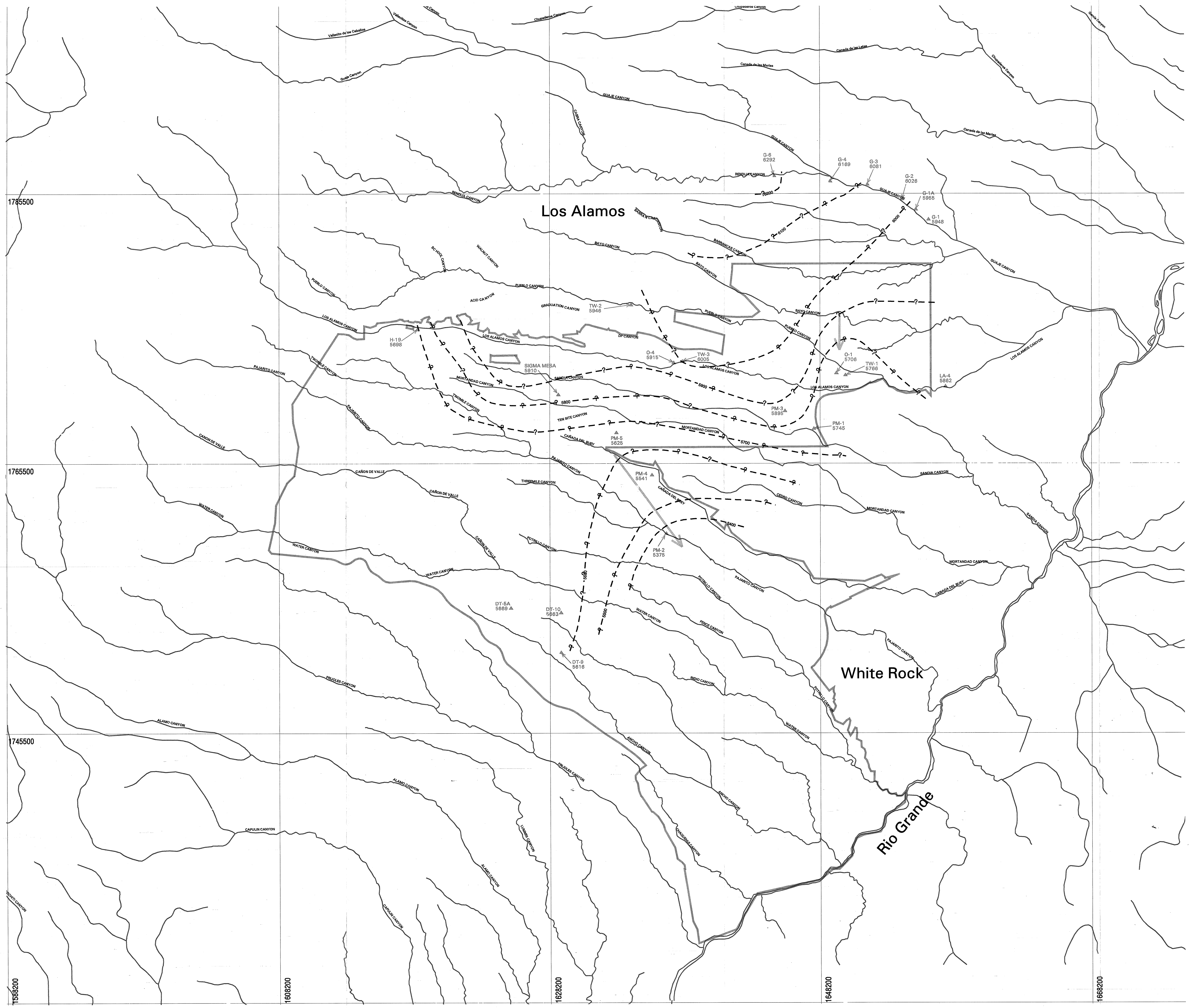

PLATE 10

EXPLANATION

- Boundary, LANL
- Drainage
- Paleodrainage
- Top of the Totavi Formation
  C.I. = 100 feet
- Well
  PM-2: Well id
  5375: Elevation of the top of the Totavi Formation

This map contains preliminary and unverified data.
Outcrop data are not included in this map

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: 20000
Feet per inch on map = 3000

SCALE 1:36000

0 914 1828 2742 3656
METERS

0 3000 6000 9000 12000
FEET

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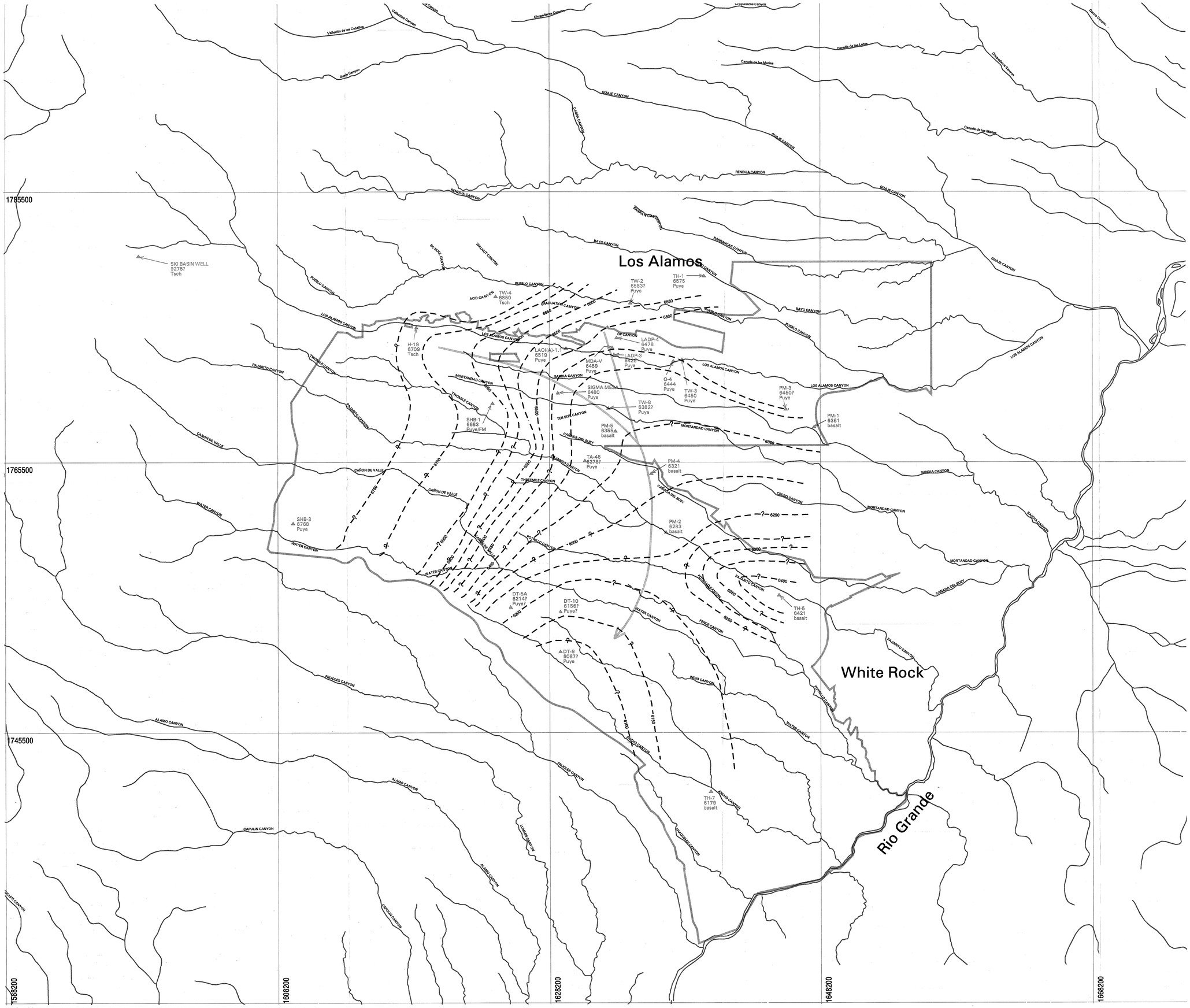
Date: May 06, 1996 FIMAD Plot ID: G104381

12819

Paleotopography - Pre-Bandelier Tuff

PLATE 11



EXPLANATION

- Boundary, LANL
- Drainage
- Paleodrainage
- Pre-Bandelier Paleotopography Contour, C.I. = 50 Feet
- Geology Characterization Well
  LADP-4: Well Id
  6459: Elevation of Pre-Bandelier Paleotopography
  Puye: Pre-Bandelier Paleogeology

This map contains preliminary and unverified data.
Outcrop data are not included in this map

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: 20000
Feet per inch on map = 3000

SCALE 1:36000

0 914 1828 2742 3656

METERS

0 3000 6000 9000 12000

FEET

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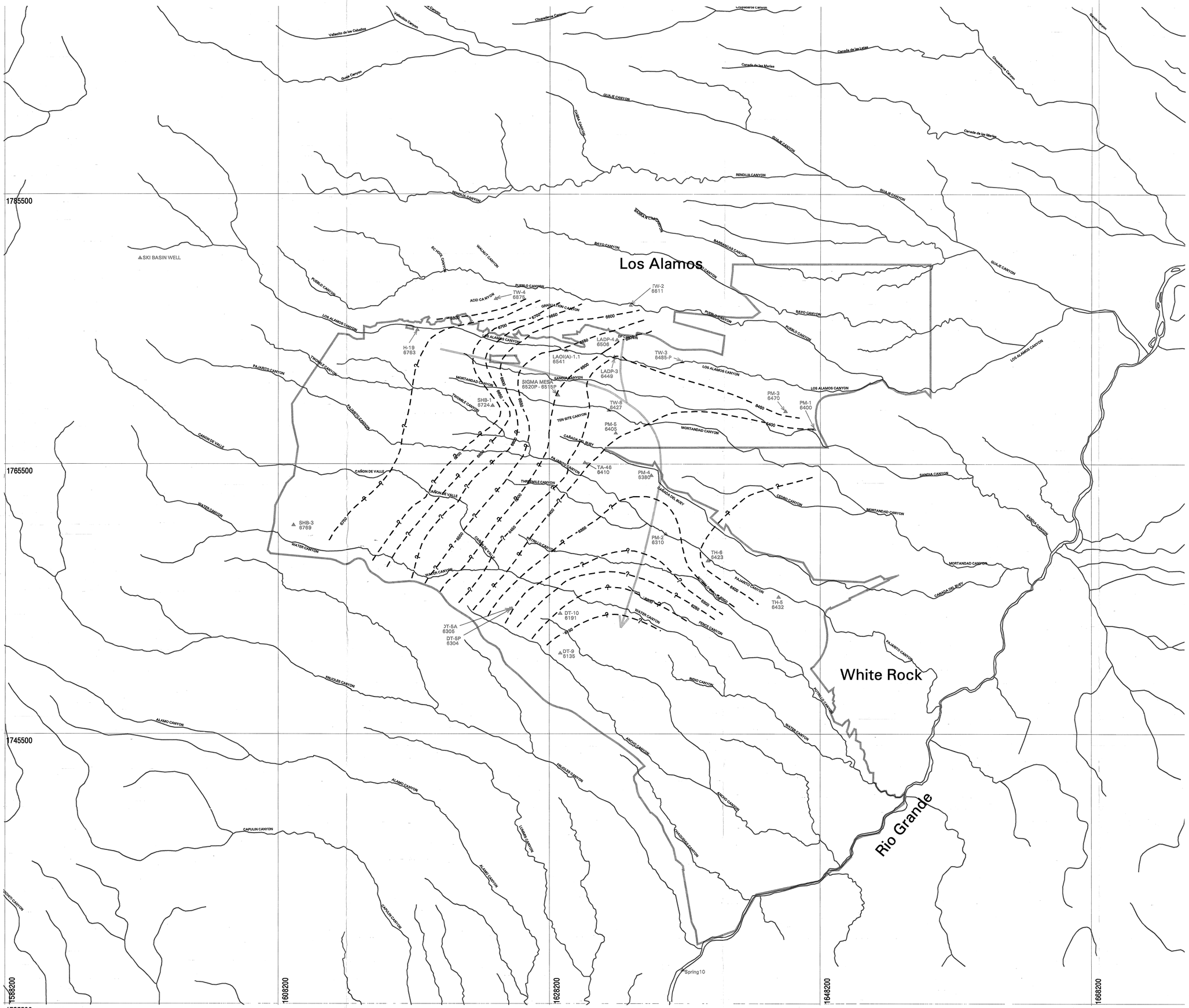
Produced by: Doug Walther

Date: April 29, 1996 FIMAD Plot ID: G104388

FIMAD G104388 29 Apr 96

Paleotopography - Guaje Pumice Bed

PLATE 12



EXPLANATION

- Boundary, LANL
- Drainage
- Paleodrainage
- Top of Guaje Pumice Bed (geologic unit of the Bandelier Tuff) C.I. = 50 feet
- Geology Characterization Well
  PM-2: Well Id
  6310: Elevation of Top of Guaje Pumice Bed, (ft)

This map contains preliminary and unverified data.
Outcrop data are not included in this map

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: 20000
Feet per inch on map = 3000

SCALE 1:36000

0 914 1828 2742 3656 METERS

0 3000 6000 9000 12000 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. Other boundary, structure, and utility data are from Los Alamos National Laboratory Engineering Division and Los Alamos County Utility and Engineering Departments. Contour data are from Los Alamos National Laboratory Environmental Restoration Project aerial survey, September 1991.

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FIMAD Facility for Information Management, Analysis, and Display
FIMAD is the electronic data repository for the Environmental Restoration Project at Los Alamos National Laboratory.

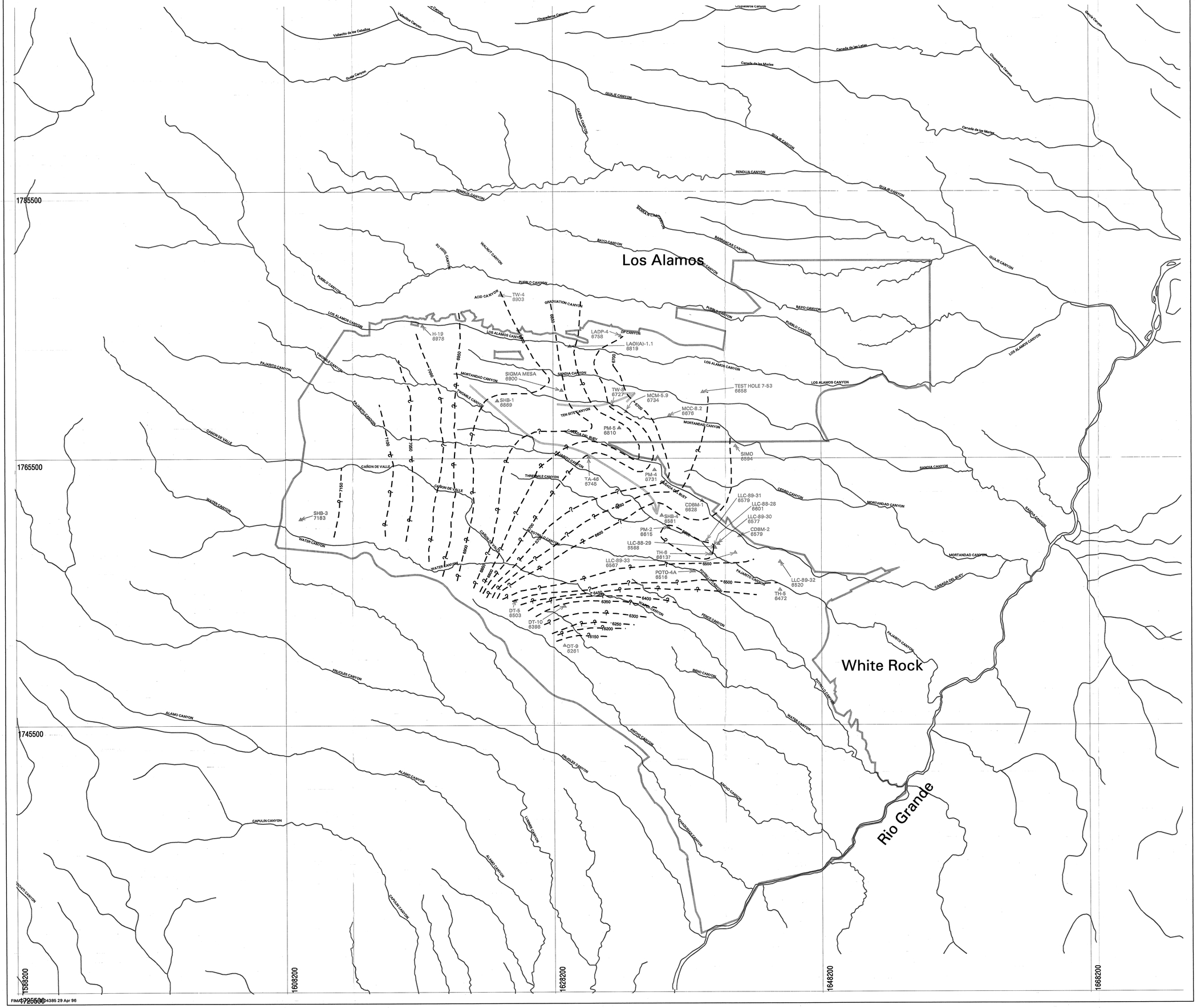
Produced by: Doug Walther

Date: April 29, 1996 FIMAD Plot ID: G104390

FIMAD G104390 29 Apr 96

Paleotopography - Otowi Member

PLATE 13



EXPLANATION

- Boundary, LANL
- Drainage
- Paleodrainage
- Top of Otowi Member (geologic member of the Bandelier Tuff) C.I. = 50 feet
- Geology Characterization Well PM-2: Well Id 6610: Elevation of Top of Otowi Member, (ft)

This map contains preliminary and unverified data. Outcrop data are not included in this map

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: 20000 Feet per inch on map = 3000

SCALE 1:36000

0 914 1828 2742 3656

METERS

0 3000 6000 9000 12000

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. Other boundary, structure, and utility data are from Los Alamos National Laboratory Engineering Division and Los Alamos County Utility and Engineering Departments. Contour data are from Los Alamos National Laboratory Environmental Restoration Project aerial survey, September 1991.

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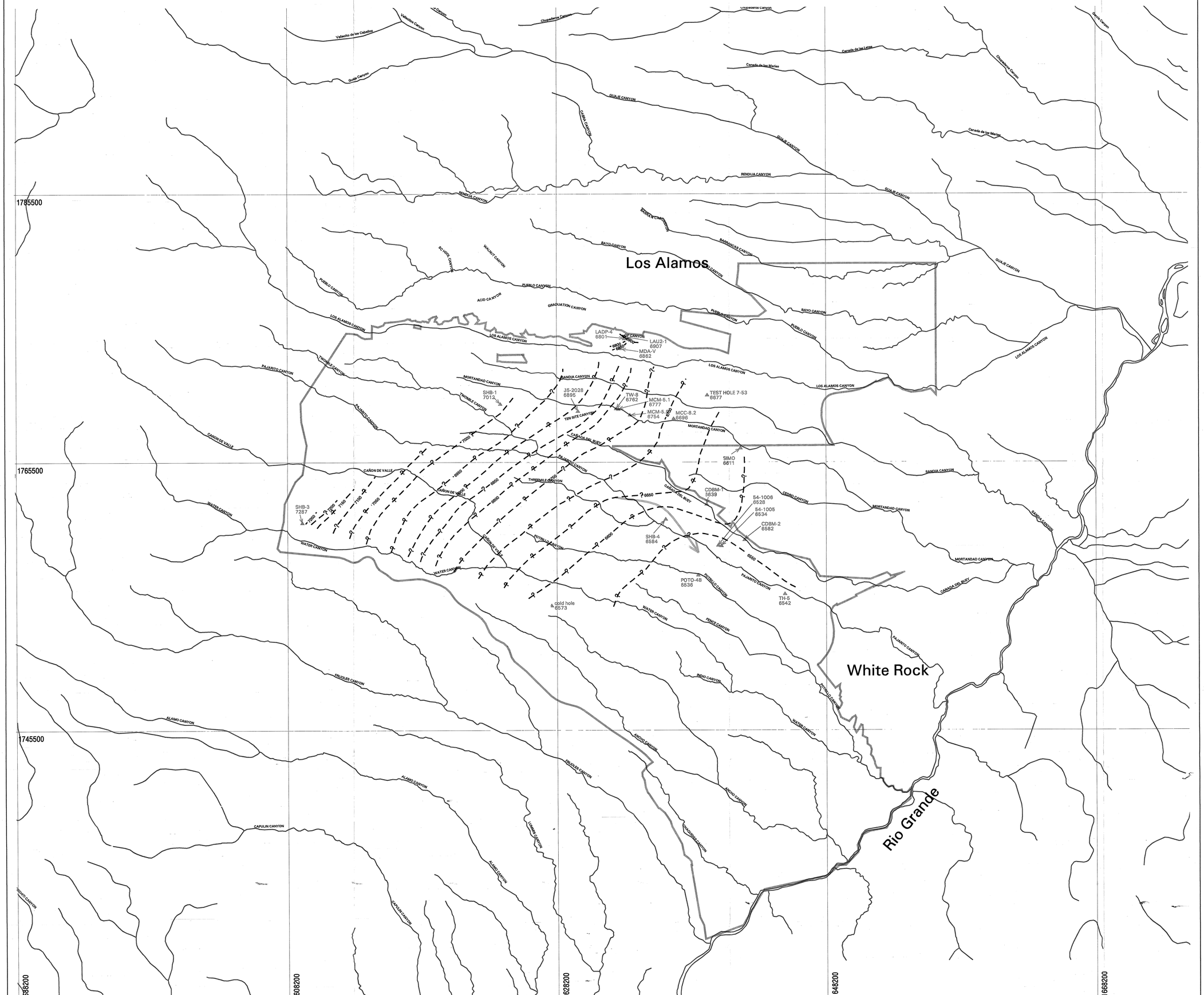
Produced by: Doug Walther

Date: April 29, 1996 FIMAD Plot ID: G104385

FIMAD G104385 29 Apr 96

Paleotopography - Tsankawi Pumice Bed

PLATE 14



EXPLANATION

- Boundary, LANL
- Drainage
- Paleodrainage
- Top of Tsankawi Pumice Bed (geologic unit of the Bandelier Tuff) C.I. = 50 feet
- Geology Characterization Well
  TH-5: Well Id
  6542: Elevation of Top of Tsankawi Pumice Bed, (ft)

This map contains preliminary and unverified data.
Outcrop data are not included in this map

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: 20000
Feet per inch on map = 3000

SCALE 1:36000

0 914 1828 2742 3656

METERS

0 3000 6000 9000 12000

FEET

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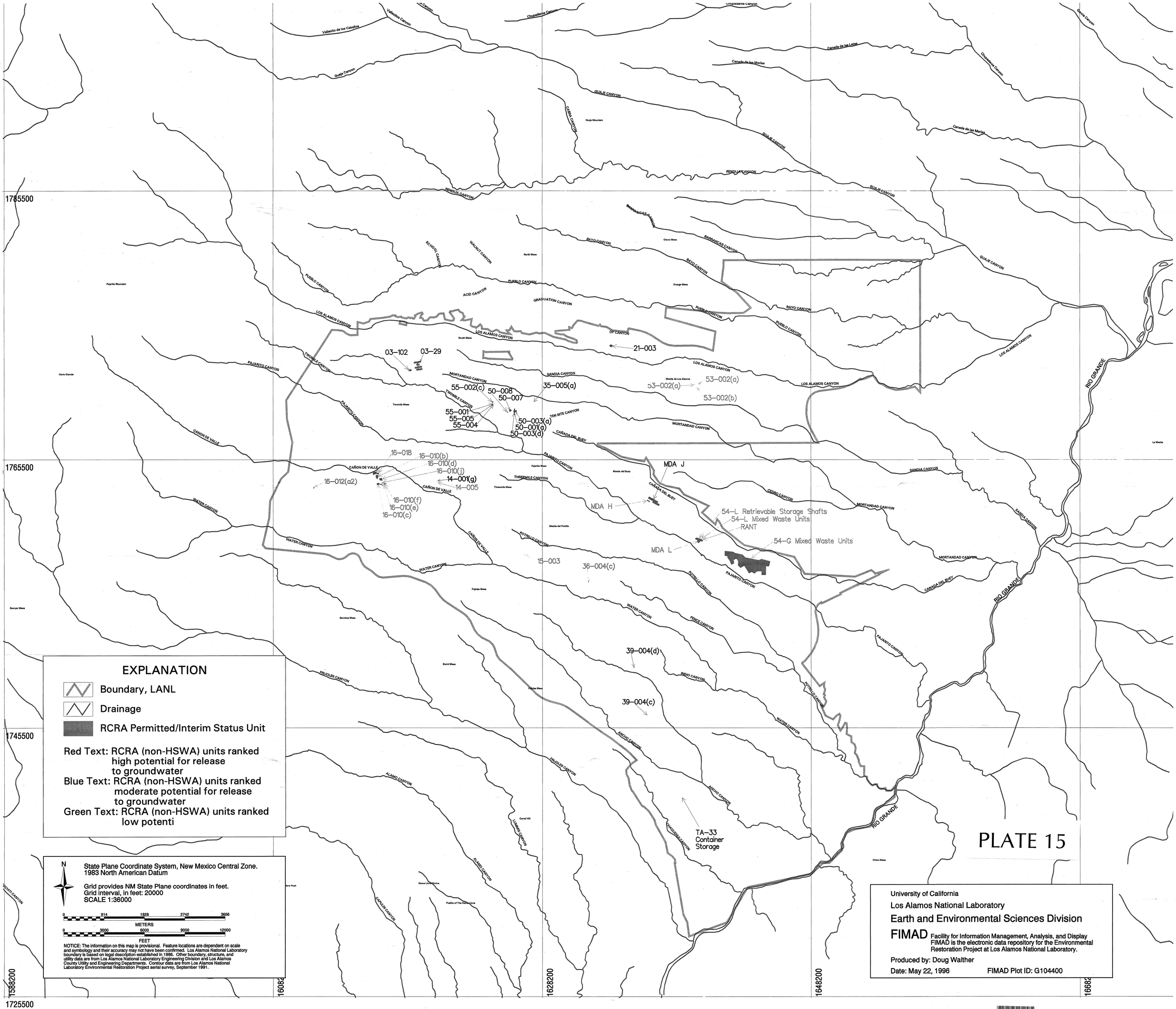
Produced by: Doug Walther

Date: April 29, 1996 FIMAD Plot ID: G104379

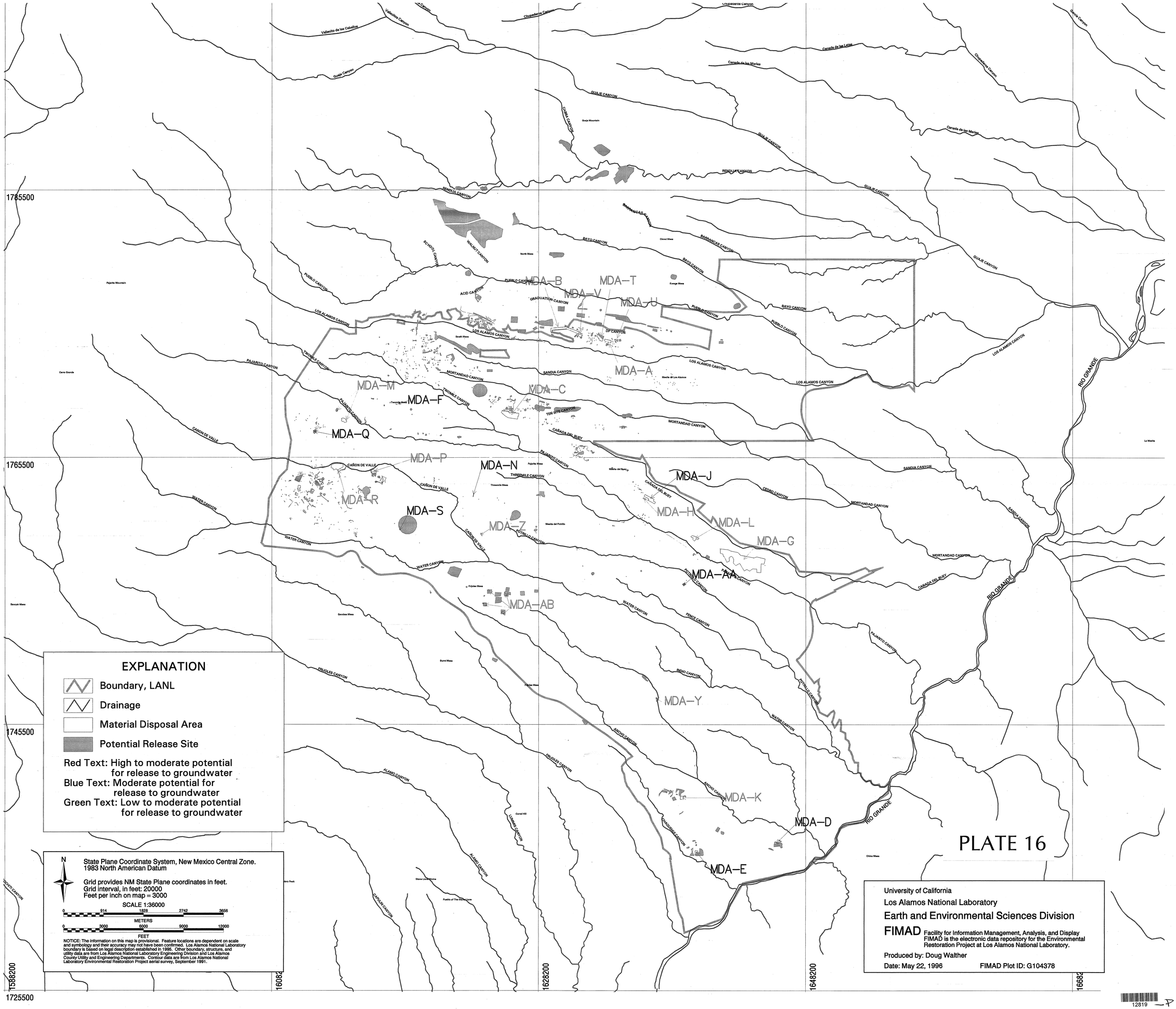
FIMAD G104379 29 Apr 96

RCRA Permitted/Interim Status Units - LANL



12819

Potential Release Sites



EXPLANATION

- Boundary, LANL
- Drainage
- Material Disposal Area
- Potential Release Site

Red Text: High to moderate potential for release to groundwater
Blue Text: Moderate potential for release to groundwater
Green Text: Low to moderate potential for release to groundwater

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: 20000
Feet per inch on map = 3000

SCALE 1:36000

0 914 1828 2742 3656

METERS

0 3000 6000 9000 12000

FEET

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PLATE 16

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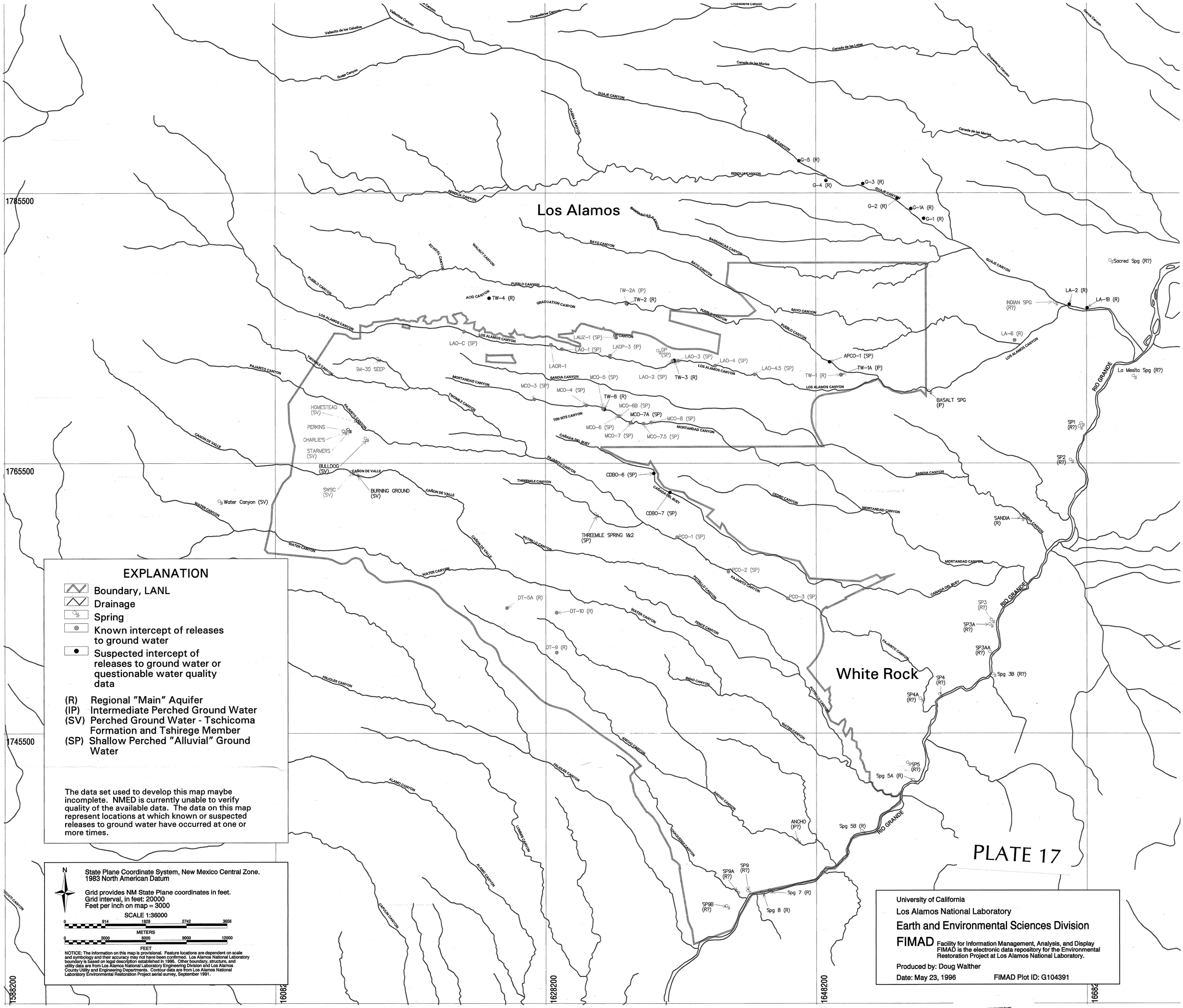
Produced by: Doug Walther
Date: May 22, 1996 FIMAD Plot ID: G104378

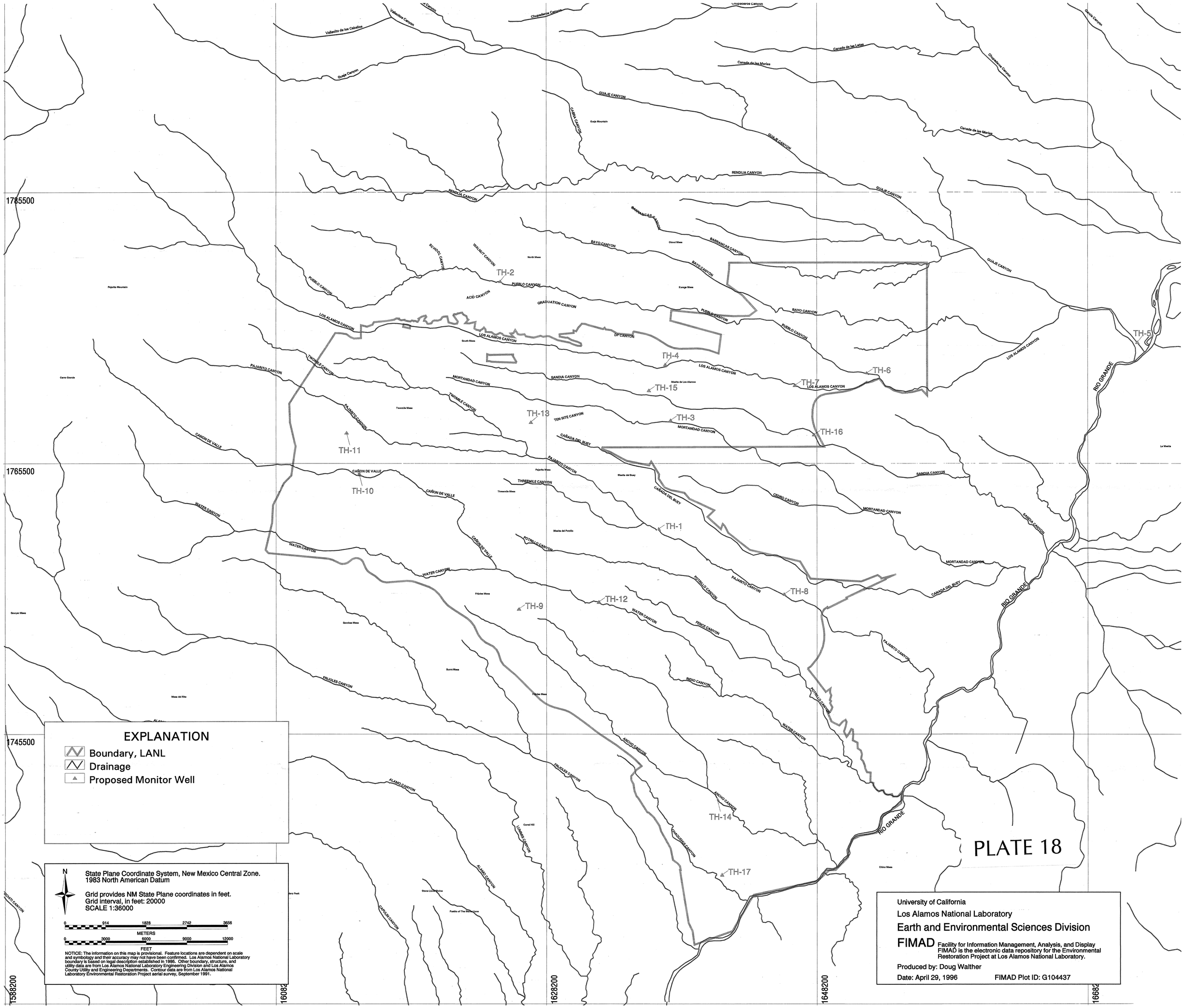
12819 —P

Known and Suspected Releases to Ground Water



12819 - Q

Proposed Monitor Well Locations



12819