GROUNDWATER ANNUAL STATUS SUMMARY REPORT FY97

Los Alamos National Laboratory
March 25, 1998

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1.0 INTRODUCTION

This Annual Report provides the Department of Energy (DOE), the New Mexico Environment Department (NMED), and other interested stakeholders with a status of the groundwater protection and management activities performed during fiscal year 1997; a summary of the changes made to the Laboratory's conceptual model of the hydrogeologic setting, as a result of integrating the new data; and a projection of the planned activities for the upcoming year. This document is specifically written as a summary-level report, and is not intended to convey all the technical data and reports that support its contents.

The need to prepare this Annual Report comes from commitments made in the Groundwater Protection Management Program Plan and the Hydrogeologic Workplan. The following information is provided to familiarize the reader with these and other documents germane to the protection and management of groundwater at Los Alamos National Laboratory (Laboratory).

1.1 Groundwater Protection Management Program Plan

As a Department of Energy (DOE) facility, Los Alamos National Laboratory (Laboratory) is required to conduct its operations in an environmentally safe manner. DOE Order 5400.1: "General Environmental Protection Program" establishes environmental protection requirements, authorities, and responsibilities for all DOE facilities (DOE 1990). The goal of this order is to ensure that operations at DOE facilities comply with all applicable environmental laws and regulations, executive orders, and departmental policies.

In accordance with the requirements of Chapter III, Section 4a, of DOE Order 5400.1, the Laboratory has prepared a Groundwater Protection Management Program Plan (GWPMPP). The Order requires establishment of a groundwater protection management program that will provide:

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), Resource Conservation and Recovery Act (RCRA) and Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) actions;

4. A summary and identification of areas that may be contaminated with hazardous substances;

5. Strategies for controlling sources of these contaminants;

6. A remedial action program that is part of the site CERCLA program required by DOE 5400.4: "Comprehensive Environmental Response, Compensation, and Liability Act Requirements";

7. Decontamination and decommissioning and other remedial programs contained in DOE directives.

The GWPMPP was also prepared to fulfill the requirements of Chapter IV, Section 9 of DOE Order 5400.1. This section requires development of a Groundwater Monitoring Plan as a specific element of the

GWPMPP. The Groundwater Monitoring Plan must identify all DOE requirements and regulations applicable to groundwater protection and include monitoring strategies for sampling, analysis, and data management. The general requirements outlined in Section 9b include:

1. Determination of baseline groundwater quality and quantity conditions;

2. Demonstration of compliance with, and implementation of, all applicable regulations and DOE Orders;

3. Providing data that will allow early detection of groundwater pollution or contamination;

4. Providing a reporting mechanism for early detection of groundwater pollution or contamination;

5. Identifying existing and potential groundwater contamination sources and to maintain surveillance of these sources;

6. Providing data upon which decisions can be made concerning land disposal practices and the management and protection of groundwater resources.

Section 9c of Chapter IV requires that groundwater monitoring needs be determined by site-specific characteristics, and where appropriate, groundwater monitoring programs be designed and implemented in accordance with 40 CFR Part 264, Subpart F, or 40 CFR Part 265, Subpart F. This Section also requires that monitoring for radionuclides be in accordance with DOE Orders in the 5400 series dealing with radiation protection of the public and environment.

The mission of the GWPMPP is to provide enhanced groundwater monitoring and program documentation in order to ensure long-term protection of the local and regional groundwater resource.

The specific Program objectives are:

- Consolidate the activities of different Laboratory environmental projects and programs to ensure a unified approach to groundwater protection and prevent duplication of effort;

- Establish an information system in which all groundwater-related data will be stored and which will be accessible to the Laboratory, stakeholders, and the public;

- Address the requirements of the RCRA/HSWA Permit, particularly Module 8, Task III;

- Provide enhanced groundwater documentation to support a Laboratory-wide Environmental Impact Statement, as requested by the DOE under the National Environmental Policy Act (NEPA);

- Maintain ongoing groundwater protection activities and address new issues as they occur.

1.2 Hydrogeologic Workplan

In order to meet regulatory requirements, and meet the mission and objectives of the Groundwater Protection Management Program Plan, the Laboratory prepared a Hydrogeologic Workplan, which was issued to the New Mexico Environment Department (NMED) in draft on December 6, 1996. The

Hydrogeologic Workplan describes activities proposed to be performed by the Laboratory to characterize the hydrogeologic setting beneath the Laboratory, and to enhance the Laboratory's groundwater monitoring program. The need for characterization of the hydrogeologic setting beyond that already established by studies conducted by the Laboratory over the past 50 years, and the possible need for an enhanced groundwater monitoring program at the Laboratory, are driven by requirements, with which the DOE and the Laboratory are committed to comply, and the Laboratory's own commitment to groundwater protection.

The Workplan was specifically prepared as a result of a written request from NMED dated August 17, 1995 which stated that the Laboratory should prepare a Hydrogeologic Workplan that addressed the requirements of the Resource Conservation and Recovery Act (RCRA) and the Hazardous and Solid Waste Amendments of 1984 (HSWA) as detailed in regulations and the Laboratory's RCRA/HSWA permit.

The NMED issued a request for Supplemental Information regarding the draft Workplan on November 17, 1997, to which the Laboratory, through the Department of Energy's (DOE) Los Alamos Area Office (LAAO), responded on February 5, 1998. Incorporation of the Laboratory responses to the NMED comments, and finalization of the draft Workplan will occur following receipt of NMED approval in the near future. In the meantime, tasks and activities delineated in the Workplan are being implemented.

Section 7.2 of the GWPMPP provides for the submittal of an annual groundwater status report to DOE summarizing the status of the groundwater protection activities in the GWPMPP. Since the Hydrogeologic Workplan has become the implementation plan for the GWPMPP, this Annual Report serves as the annual status report for both documents. The Annual Report will proceed the annual meeting held in March each year between the Laboratory, DOE, and NMED to discuss the Annual Report and negotiate any proposed changes to the Hydrogeologic Workplan scheduled activities for the year. In future years, the Annual Report will be prepared by the Laboratory during the last quarter of the calendar year, and delivered to NMED in December, allowing ample review time prior to the March annual meeting. However, time constraints for this first Annual Report necessitated its delivery to NMED within days of the annual meeting scheduled March 30, 1998.

1.3 Conceptual Design Report

The Conceptual Design Report (CDR) for the Monitoring Well Installation Project (MWIP) is a secondary document that compliments the Hydrogeologic Workplan's implementation. It describes the justification and design concept for installing sixteen (16) regional aquifer wells, including all borehole sampling and testing. The 100% draft of the CDR was completed in May, 1997 as part of the funding request requirements to obtain funding from DOE Defense Programs (DP). In addition to the 16 regional aquifer wells funded by DP, the CDR includes reference to the installation of 51 alluvial, 1 intermediate perched zone, and 16 regional aquifer wells by the Environmental Management's Environmental Restoration (ER) Project. The combination of both the DP funded wells and the ER funded wells make up the Laboratory's MWIP.

1.4 Organization of the Annual Report

Both the GWPMPP and the Hydrogeologic Workplan describe data collection and analysis activities. These activities consist of both non-field and field activities. Non-field activities include tasks such as historical data compilation, data management, and computer modeling. The status of non-field activities is described in Section 2 of this report. Field activities include some that are regional in scale (e.g.

sample all springs) and some that are specific to particular geographic areas, referred to as Aggregates in the Hydrogeologic Workplan. The results of aggregate-specific field investigations and regional scale field investigations are described in Section 3. Section 4 contains proposed work for FY98 and proposed changes from the program as described in the GWPMPP and the Hydrogeologic Workplan.

2.0 STATUS OF NON-FIELD ACTIVITIES

2.1 Data Management

During 1997, a team consisting of personnel from ESH groups responsible for environmental surveillance worked with ER personnel assigned to the Facility for Information Management and Display (FIMAD) to determine the scope and cost of loading environmental surveillance data into the FIMAD system. The objective was to centralize analytical data collected by different groups so that it is readily available to all users. FIMAD personnel are continuing to work with the ESH groups to format environmental surveillance data and modify the FIMAD system to facilitate data access by all users.

The Groundwater Integrating Team (GIT) has contracted with Harding Lawson Associates (HLA) to perform a user needs assessment in 1998. Based on the assessment, HLA will recommend an implementation plan for creating a central data repository. The repository will be designed to combine the environmental data collected by current projects and programs (i.e., environmental surveillance, groundwater protection, watershed management, and the environmental restoration data currently in the FIMAD database).

Data and data analysis tools will be designed to support the implementation of the Data Quality Objectives (DQOs) and the Data Quality Assessment (DQA) processes required by the GWPMPP. Data generated from previously drilled wells will be used to refine future drilling requirements and data collection activities. These tools will be designed to meet the needs of these users and will include three dimensional data modeling and data visualization capabilities.

2.2 Modeling

Table 2-1 includes a description of modeling tasks, subtasks, a short synopsis of 1997 status, and future activities. The tasks in Table 2-1 are not directly correlative to those listed in the Hydrogeologic Workplan, sections 1 and 3. The tasks from the Hydrogeologic Workplan have been recombined in Table 2-1 into three major tasks: Develop Geologic Model, Develop Hydrologic Model, and Develop Geochemical Model. Subtasks within the three major tasks are the same as those listed in the Hydrogeologic Workplan. Tasks that were completed prior to 1997 are not included in this update.

Groundwater flow and transport modeling has been proposed in the Hydrogeologic Work Plan (1996) as a significant component of Laboratory efforts to better understand the hydrogeology and geochemistry of the regional aquifer. Long term goals of both flow and transport modeling include:

1. Support for the deep well drilling program including well siting.

2. Integration of stratigraphic, hydrologic, and geochemical data available for the Pajarito Plateau,

3. Testing of hypotheses concerning predominant flow directions, recharge zones, and potential contaminant migration in the regional aquifer.

The first step in achieving these goals is to develop a flow model for the regional aquifer that represents our current knowledge of subsurface stratigraphy and hydrogeology. A reasonable basin-scale model is critical to the success of site-scale model, as regional flow directions undoubtedly influence local flow. We propose to generate a flow model at the scale of the Española Basin, with coarse resolution off the Pajarito Plateau and fine resolution on the plateau. Existing basin-scale models (Frenzel, 1995; McAda and Wasiolek, 1988) are of limited value for accurate site-scale predictions because they poorly reproduce observed vertical gradients, their grid resolution is coarse and does not represent known geologic structures, and boundaries were arbitrarily placed near Los Alamos in order to minimize influence on predictions in the Santa Fe area (Mc Ada, 1998, pers. comm). We propose to improve on these models by making several key changes:

1. Move northern and western boundaries away from the plateau to minimize their impact on local flow predictions and to reflect physical meaningful boundaries,

2. Increase grid resolution so as to represent geologic controls on flow and to better predict vertical head gradients, and

3. Increase the number of head observations to be used during model calibration.

The FEHM (Finite Element Heat and Mass Transfer) Code is currently being used for groundwater flow and transport modeling in support of the Groundwater Protection Plan and ER activities. FEHM is ideally suited for the complex geologic and geochemical conditions associated with these studies. It is capable of modeling saturated and unsaturated flow and transport processes in fractured and porous media. The transport module is completely coupled with the flow module and is capable of both particle track simulations and fully reactive transport and speciation of multiple interacting solutes and colloids. FEHM links directly with the GEOMESH automatic grid generation software, making it one of the few if not only groundwater modeling software packages capable of directly incorporating exactly three dimensional geologic models from such software packages as StrataModel and EarthVision. FEHM has full QA, Verification, and Validation documents (see references). This software has been specifically designed and is currently being used for saturated and unsaturated zone flow and radionuclide transport calculations for DOE studies at Yucca Mountain, the Nevada Test Site Underground Test Area, and Los Alamos National Laboratory. The capabilities of FEHM include:

- Fully Three-Dimensional
- Heterogeneous/Anisotropy Capability
- Transient and Steady State
- Flux and Pressure Boundary Conditions (includes recharge)
- Point and Distributed Sources
- Saturated/Unsaturated Flow
- Nonisothermal/Isothermal
- Multiphase
- Dual Permeability, Dual Porosity
- Fault Zones
- Fully Coupled Transport
- Reactive Transport (Decay, Sorption, Complexation, Precipitation,
- Dispersion, Diffusion, ...)
- Particle Tracking (Decay, Sorption, Diffusion, Dispersion)
- Highly Efficient and Accurate Solver Technology
- Verification and Validation (V&V) Documented
- GEOMESH interface for complex representation of stratigraphic and
- mineralogic models.

The Laboratory expects the flow model to be a useful tool for environmental restoration planning and for addressing regulatory issues related to groundwater protection. As new data becomes available from the deep well drilling program, it will be incorporated into the flow model. The model will be a particularly important tool for siting future monitoring and characterization wells.

Much of the foundation for regional-scale flow modeling has been laid by activities during FY97. Basin-scale and site-scale hydrologic and geochemical data were gathered and analyzed. In addition, at the Española Basin workshop in January, scientists from around the state gathered to develop consensus on basin geology and hydrostratigraphy. These activities, along with decades of site-related work by Laboratory scientists, will provide the framework for this modeling effort.

Specific activities in FY98 will include:

1. Development of a framework model, integrating the existing site-scale stratigraphic model with a basin-scale hydostratigraphic model. Initial stages of basin-scale hydrostratigraphic model development were completed in FY97 as described above.

2. Translation of the hydrostratigraphic model into a finite-volume grid for FEHM.

3. Assignment of hydrologic properties to each hydrostratigraphic unit, using a combination of published values from pumping tests, existing flow models, and stochastic methods (if appropriate).

4. Building of FEHM flow model, boundary specification, etc.

5. Calibration to observed head data.

6. Sensitivity analyses and testing of hypotheses concerning flow directions and locations of recharge.

Table 2-1. STATUS OF NON-FIELD ACTIVITIES

TASK	SUBTASKS	1997 STATUS	FUTURE ACTIVITIES
Develop Geologic Model	Compile and publish drilling and completion data from all significant boreholes.	Prepared individual reports for alluvial and intermediate wells installed in Aggregate 1.	Develop completion reports for alluvial, perched intermediate, and regional aquifer wells as they are installed.
	Perform comprehensive review of 3-dimensional stratigraphy including analytical chemistry and mineralogy necessary to make stratigraphic correlations between boreholes; integrate newly-collected geologic data into structure-contour maps, isopach maps and cross-section.	Activities in FY97 were directed at supporting the site-wide 3-D Geologic Model.	Data from R-9 and other boreholes are being incorporated into cross-sections and structure contour maps. Correlations of basalt and tephras are being made through geochemical and geochronology studies.
	Develop 3-dimensional geological database to include surface geology, structural geology, and borehole stratigraphy.	QA performance on initial model as contact surfaces and isopachs evaluated to provide an internally consistent model of the 3-D stratigraphy.	A. QA of integrated model. B. Incorporation of basaltic unit into model. C. Incorporation of new drill hole and surface data into model. D. Development of integrated data management and analysis plan.
	Salvage of data from stratigraphic and geochemical analysis of available canyon bottom core samples.	No activities in 1997.	ER Project's Canyons Focus Area will hire a GRA in FY 98 to begin logging these sediments.
Develop Hydrologic Model	Compile and publish hydraulic characteristic data: 1) Bandelier Tuff – Assemble hydrologic laboratory test results of Bandelier Tuff core from across the Plateau. Evaluate test results for validity. Calculate unsaturated hydraulic properties from moisture retention characteristics. Summarize data by stratigraphic unit	1) Bandelier Tuff test results complete from tests conducted through 1994 (Rogers and Gallaher, 1995). Newer data from TA-21 and TA-49 are being incorporated into ER Project RFI reports for those sites.	1) ER Project RFI hydrologic reports for TA-21 and TA-49 will be published in FY98.

TASK	SUBTASKS	1997 STATUS	FUTURE ACTIVITIES
	and locations.		
	2) Determination of vadose zone fluxes in Los Alamos mesas using chloride and stable isotope profiles. Analyze soil moisture for chloride mass and isotope ratios. Calculate fluxes from tracer profiles.	2) Completed profile work and flux calculations for Mesita del Buey, DP Mesa, and Frijoles Mesa (TA-49). Nine boreholes were examined for chloride and three boreholes were examined for stable isotopes.	2) A report will be written comparing the chloride profile results from DP mesa and TA-16.
	3) Hydrologic parameter estimation for the Pajarito Plateau, including in-situ hydraulic testing of wells. Load available hydrologic measurements in 3-dimensional database. Statistically describe zones and regions.	3) Basin-scale and site-scale hydrologic data was gathered and analyzed; slug tests were conducted in DP Canyon alluvium and in saturated zones encountered in R-9.	3) Hydraulic properties for regional aquifer to be incorporated into saturated zone model to be developed starting in FY98. Pump test new water supply wells GR-1, GR-2, GR-3, and GR-4 in Guaje Canyon during 1998 before these wells enter routine service. Run spinner logs in new supply wells GR-1, GR-2, GR-3, and GR-4 in Guaje Canyon during 1998 in conjunction with aquifer pump tests.
	Water Quality Data: 1) Consolidate historical water quality data in database and perform trend analysis.	1) All of the historic environmental surveillance data for ground water, surface water, and sediments have been loaded into a Microsoft Access database. These data cover the period from the early 1950s to the present and include 173,000 records. All sample values and units have been corrected to a set of standard units to facilitate data analysis. We chose data collected on or near the San Idelfonso Pueblo as the first data for trend analysis. We have completed trend analysis for these data set and are writing up the	1)The historic data has not been adequately verified and QA-checked. We will continue to confirm that these data matches the published record. We will complete the write-up of the trend analysis on the San Idelfonso data and publish this report. We will continue trend analysis on the historic data and expect to focus on evaluating trends by drainage basins.

TASK	SUBTASKS	1997 STATUS	FUTURE ACTIVITIES
		results.	
	2) Evaluate water quality variations and vertical stratification within the regional aquifer using water samples from supply wells. Pull permanent pump and isolate discrete sample zones (46-ft lengths) in each well using hydraulic packers. Sample with temporary pump.	2) In December 1996 O-1 was zonally sampled prior to its scheduled entry into routine service as a municipal water supply well.	2) Zonally sample new supply wells GR-1, GR-2, GR-3, and GR-4 in Guaje Canyon during 1998 before these wells enter routine service.
	Inventory springs on-site and near Lab boundaries by reviewing existing Laboratory and USGS reports for initial inventory. Perform additional field reconnaissance. Supplement with aerial photography where possible. Select springs with discrete discharge points. Install flow and monitoring probes.	Flow measurement equipment has been installed at 4 key TA-16 and TA-18 locations to determine nature of apparent spring discharges. The NMED DOE OB continued to make spot measurements of flow at selected discharge points. Flow and chemistry sampling equipment was installed at three springs. Quarterly sampling was conducted for major anions and cations, and contaminants. Daily sampling was conducted for bromide.	Continue to obtain field observations from Laboratory and NMED personnel. Continue ER Project investigations at critical discharge points (particularly TA-16 and TA-18) where there is uncertainty if flow is natural spring-fed or perennial. Continue monitoring of flow and for bromide tracer and other chemical constituents. Analyses of the flow and chemistry time series will be conducted.
	Long-term water balance estimates for the Pajarito Plateau. Install stream gages at upstream and downstream boundaries of the Laboratory. Continuously measure ET, Precipitation, and groundwater levels.	Data collected in most regional aquifer test wells, and some intermediate and shallow alluvial wells. Stream flow measurements collected from 19 stations. Precipitation data collected from 7 stations and ET data collected from 2 stations.	Water level, stream flow, precipitation and ET data will be collected on a continuing basis.
	Groundwater flow modeling using the FEHM code.	Organized stratigraphic information relating to Pajarito Plateau and surrounding Española Basin.	Establish geologic framework model for Pajarito Plateau and surrounding Española Basin. Create model grid for FEHM code. Assign hydrologic properties and boundary conditions. Sensitivity analyses and testing of hypotheses concerning flow directions

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

3.0 STATUS OF FIELD ACTIVITIES

3.1 Regional Field Activities (Aggregate 9)

3.1.1 Aggregate 9 FY97 Investigations

During 1997, data were collected and new instrumentation was deployed to help estimate the overall water balance for the Laboratory site. The following bullets summarize investigations and Table 3-1 gives measurements, locations, and modes.

Surface hydrology work included stream flow measurements at 19 gaging stations.
Spring discharge measurement equipment was installed at three springs at TA-16 near the western Laboratory boundary.
Groundwater levels were continuously recorded at 33 locations using pressure transducers installed in shallow, intermediate, and deep wells.
Other wells in normally dry canyon bottoms were checked for water.
Precipitation was measured at seven stations.
Evapotranspiration was measured at two stations, one near the western boundary at TA-6 (measured since 1993) and one near the eastern boundary at TA-54 (new in 1996).

Table 3-1. Water Budget Hydrologic Data Collected at LANL in 1997

Measurement	Location	Mode
Stream flow (19 stations)	Ancho Canyon	1 gage: Ancho @ SR-4
	Water Canyon	2 gages: Water @ SR-502, Water @ SR-4
	Cañon de Valle	1 gage: Cañon de Valle @ SR-502
	Potrillo Canyon	1 gage: Potrillo @ SR-4
	Pajarito Canyon	3 gages: Pajarito @ SR-502, Pajarito near TA-18, Pajarito @ SR-4
	Cañada del Buey	2 gages: CDB north of TA-54, CDB @ SR-4
	Mortandad Canyon	4 gages: Mortandad @ GS-1, Mortandad above sediment traps, Mortandad below sediment traps, Mortandad @ Laboratory eastern boundary
	Sandia Canyon	1 gage: Sandia @ SR-4
	Los Alamos Canyon	3 gages: LA @ Skating Rink, LA above DP Canyon, LA @ SR-4
	Pueblo Canyon	1 gage: Pueblo @ SR-4
Spring flow (3 stations)	TA-16	3 springs: SWSC line, Burning Ground, Martin

Table 3-1. Water Budget Hydrologic Data Collected at LANL in 1997 (cont)		
Measurement	**Location**	**Mode**
Groundwater levels (33 stations)	Mortandad Canyon Alluvium	12 wells: MCWB-5, MCWB-5.5A, MCWB-5.5B, MCWB-6.2A, MCWB-6.5C, MCWB-6.5E, MCWB-7A, MCWB-7B, MCWB-7.2, MCWB-7.4A, MCWB-7.4B, MCWB-7.7B
	Los Alamos Canyon Alluvium	8 wells: LAO-C, LAO-0.7, LAO-1, LAO-2, LAO-3, LAO-4, LAO-4.5C, LAO-6A
	Intermediate Depth Groundwater and Regional Aquifer	13 wells:LAOI-1.1, LADP-3, LA-1B, TW-1A, TW-2A, TW-1, TW-2, TW-3, TW-4, TW-8, DT-5A, DT-9, DT-10
Precipitation (7 stations)		7 stations: North Community, TA-16, TA-6, TA-49, TA-53, TA-54, TA-74, Pajarito Mountain
Evapotranspiration (2 stations)		2 stations: TA-6, TA-54

3.1.2 Conceptual Model Refinement

3.1.2.1 Surface Water Balance

A water balance study for the Laboratory cannot yet be completed as many of the components necessary for determining outflow remain unmeasured. The following information is compiled to estimate the relative magnitude of some near-surface components of the water balance within the Laboratory boundary. The discussion targets evapotranspiration, precipitation, stream flow, and effluent discharges.

The long-term (1961-1990) average annual precipitation for the Laboratory is 18.73 inches. This is equivalent to approximately 43,000 ac-ft per year.

Evapotranspiration measurements show that the major water loss from the Laboratory is through ET, which annually has varied between 79% and 100% of total precipitation. As a first-order estimate, approximately 37,000 ac-ft of water evaporates or is transpired to the atmosphere from Laboratory lands each year. This estimate assumes an average ET of 87%, based on measurements at the mesa sites. ET rates for canyons, often with more vegetation than the mesas, are not yet available.

The remaining approximately 6,000 ac-ft of precipitation is assumed to infiltrate or contribute to stream flow. Note that additional evapotranspiration may occur in the canyon bottoms. Based on limited stream gaging discussed below, there is relatively little off-site stream flow.

Total volumes of Laboratory effluents discharged per year during the mid-1990s are approximately double that of the stream flow onto the Laboratory, according to estimates made for this report by the Water Quality and Hydrology Group (ESH-18). When flows from the Los Alamos County Bayo Sewage Treatment Plant are added in, total effluent releases in the near-vicinity of the Laboratory are estimated to be approximately 1100 ac-ft per year, 3 times greater than the incoming stream flow. Sewage effluent discharges comprise nearly 65 percent of the effluent flow. Table 3-2 summarizes estimates of the major NPDES effluent discharges operating during the mid-1990s.

Table 3-2. Surface Water Discharges in 1997.			
Type of Discharge	**Discharge Name**	**Receiving Drainage**	**Vol. (ac-ft/yr)**
Cooling Tower	TA-21 Steam Plant	DP/Los Alamos Canyon	4
LANL Sewage	SWSC Plant	Sandia Canyon	313
Radioactive Wastewater	TA-50	Mortandad Canyon	6
Cooling Towers	TA-53 Cooling Towers	Los Alamos Canyon	364
High Explosive Wastewater	HEWTF	Water Canyon/Cañon de Valle	2
Los Alamos County Sewage	Bayo Plant	Pueblo Canyon	436
Total			1126

Stream flow at the Laboratory upstream and downstream boundaries is measured by stream gages (Shaull et al. 1996a, 1996b, 1998). The largest mean flows are in Pueblo, Los Alamos, and Sandia Canyons. Most of the flow in Pueblo Canyon is derived from effluent releases from the County Bayo Sewage Treatment Plant. Stream flow onto the Laboratory varies significantly by drainage (Shaull et al. 1996a, 1996b, 1998). Three-fourths of the stream flow entering the Laboratory is in Los Alamos Canyon. Approximately 350 ac-ft of stream flow crossed the upstream boundary of the Laboratory, averaged over 3 years of measurement. An average of approximately 950 ac-ft crossed the downstream boundary. The increase in downstream flow is principally due to the addition of effluent discharges. Table 3-3 details the stream flow and effluent discharges for each drainage.

Table 3-3. Average Stream Flow and Effluent Discharges by Canyon (ac-ft/yr).			
Canyon	**Inflow to LANL**	**Effluent Discharge**	**Outflow from LANL**
Pueblo	0	436	757
Los Alamos	261	368	172
Sandia	0	313	2
Cañada del Buey	0	0	6
Mortandad	0	6	0
Pajarito	74	0	12
Potrillo	0	0	1
Water	10	2	1
Ancho	0	0	4
Total	345	1125	955

3.1.2.2 Canyon Systems

Infiltration will likely be enhanced beneath the canyon floors that have either a relative abundance of natural stream flow, or have a long history of effluent releases. The review of the stream flow and effluent discharges shown above supports the Laboratory's strategy to focus initial characterization activities on the Los Alamos/Pueblo drainage system (Aggregate 1), as infiltration is most likely in those canyons.

Characterization of Aggregate 1 indicates that percolation of water below the canyon floor alluvium is locally variable and dependent on the permeability of the underlying earth materials, as well as topography and underlying geology. Thus, recharge beneath the wetter canyon floors may occur at several locations at variable distances from the original contaminant source location. This is consistent with the current conceptual model.

Investigations confirm that the Puye Formation and the basalts provide potential horizons for perching groundwater. Beneath the wetter canyon systems, this leads to the possibility of multiple perched systems developing, with recharge to each one possibly coming from different areas.

3.1.2.3 Mesa Top Systems

Investigations at both TA-54 and TA-49 indicate that the portion of the mesa at an elevation above the neighboring canyon bottom is subjected to higher rates of pore water evaporation than the part of the mesa lying below the canyon bottom. This enhanced evaporation apparently occurs by air movement along fractures or lithologic features such as surge beds. The consistency in results at the two sites, one on the eastern edge of the Laboratory and the other on the south central edge of the Laboratory, indicates that this phenomenon may occur at most mesa settings. This drying process results in very low infiltration rates within the mesa.

Drilling at the western boundary of the Laboratory (TA-16) indicates that a laterally extensive perched groundwater zone within the Bandelier Tuff is not present. Spring discharge may be occurring as a result of highly channelized flow along discrete fractures rather than as discharge from a large storage volume.

3.1.3 Aggregate 9 FY98 Planned Activities

FY98 planned activities include collection of stream flow, spring flow, groundwater level, precipitation, and evapotranspiration data of the same type and quantity as that collected during 1997.

3.2 Aggregate-Specific Field Activities

The FY97 investigations that occurred within Aggregates 1-8 are described in the following sections. Based on the data collected in the investigations, refinements to the conceptual models are presented. A brief description of proposed FY98 activities is also included.

3.2.1 Aggregate 1

Aggregate 1 is bounded on the north by Pueblo Canyon, on the south by Sandia Canyon, on the east by State Route 4, and to the west by the Jemez Mountains (Figure 3-1). Aggregate 1 includes the Los Alamos townsite, and currently active Technical Areas (TA) TA-21 which is on DP Mesa, TA-43 the site of the Los Alamos Medical Center, TA-53 which is the site of the Los Alamos Neutron Science Center (LANSCE), and TA-73 which is the Los Alamos Airport. This aggregate also includes two inactive TAs (TA-0 and TA-45) where early Laboratory operations took place.

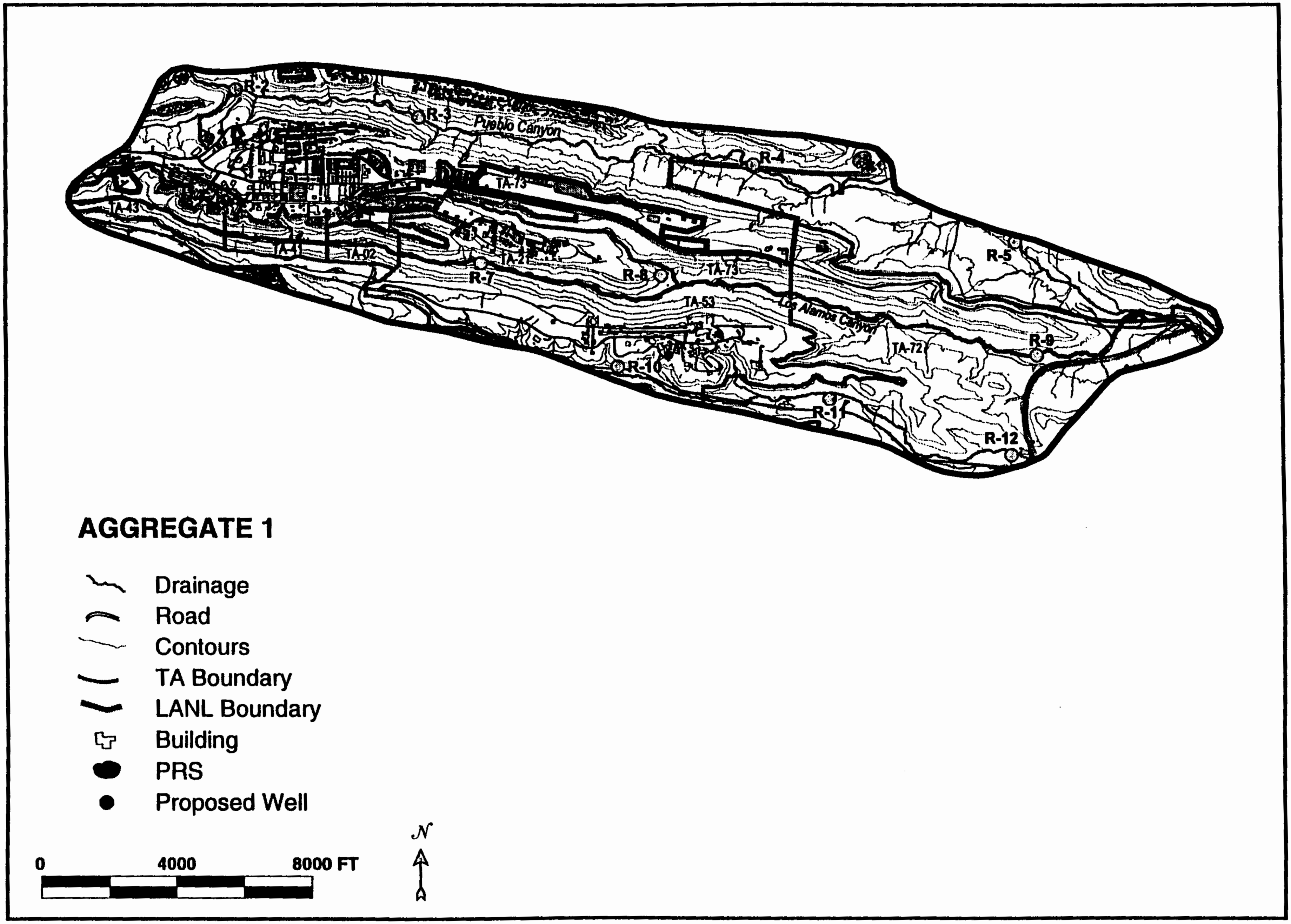


Figure 3-1. PRSs and proposed wells in Aggregate 1.

3.2.1.1 Aggregate 1 FY97 Investigations

DP Canyon

- A Sampling and Analysis Plan based on a Canyons approach was prepared.

- Geomorphic mapping was initiated on the canyon floor, and a first round of sediment samples was collected for full-suite analysis.

- Consistently elevated concentrations of 137-Cs were found in the post-1942 sediments in the canyon. Isotopic Pu, Am, and Sr are also elevated in the canyon sediments. Cs and Sr contamination are collocated.

- Alluvial wells LAUZ-1 and LAUZ-2 were redeveloped to optimize well performance and slug tests were performed in both wells, providing data for a proposed tracer test scheduled for later this year to test the hypothesis of alluvial water from these wells discharging at DP Spring.

- Two quarters of water quality samples were collected from LAUZ-1 and LAUZ-2. One water quality sample was collected from DP Spring. Filtered water samples from LAUZ-1 and -2 contained 100 to 108 pCi/L 90-Sr. The sample from DP Spring contained 39 pCi/L 90-Sr.

Airport Landfill (TA-53)

8 characterization boreholes 20 ft to 80 ft deep were drilled into the landfill. The boreholes penetrated landfill material and botttomed 5 ft to 10 ft into the underlying tuff. One to two samples were collected for contaminant characterization from the tuff in each borehole. Metals in the tuff samples were below UTLs, and SVOCs, pesticides, and PCBs were below detection limits. VOCs were detected in three samples at scattered locations. Saturated conditions were not found in any of the boreholes, although some moist areas were found in landfill materials and at the landfill/tuff interface.

Hillside 138 (Former TA-1)

A BMP was implemented to stabilize the hill slope and prevent the transport of Pu and Hg into Los Alamos Canyon.

Hillside 140 (Former TA-1)

A BMP was implemented to stabilize the hill slope and prevent the transport of U into Los Alamos Canyon.

MDA T (TA-21)

19 characterization boreholes 7 ft to 200 ft deep were drilled through or next to absorption beds or angled beneath waste disposal shafts. No zones of saturation were encountered. Tritium concentrations decreased with depth, but concentrations above background were found at the bottoms of some of the deepest boreholes. Contaminants found in the characterization boreholes were primarily Pu, Am, 137-Cs, 90-Sr; slightly elevated concentrations of Pb, Cr, and Be were found in various boreholes at various depths.

Los Alamos and Pueblo Canyons

- Three shallow alluvial characterization wells (PAO-4, LLAO-1B, and LLAO-3) were installed by the ER Project in FY97 in Pueblo and lower Los Alamos Canyons (Figures 3-2, 3-3, and 3-4). Alluvial characterization well PAO-4 replaces PO-4 and LLAO-1B replaces LLAO-1A because of improper well completion. Both abandoned alluvial wells were plugged with bentonite grout following NMED guidelines. The 3 new alluvial wells supplement 17 previously sampled shallow wells within Los Alamos and Pueblo Canyons.

- Shallow alluvial well LAO-3.5 was described in the Los Alamos and Pueblo Canyons workplan to identify a shallow mixing zone, possibly within the Guaje Pumice Bed, occurring between LAO-3 and LAO-4. Concentrations of TDS and activities of ^{90}Sr decrease in the alluvium between these two wells. The mixing zone is within the alluvium and/or the weathered Otowi Member of the Bandelier Tuff and not within the Guaje Pumice Bed as originally projected in the workplan. The depth to the Guaje Pumice Bed at the proposed location of LAO-3.5 is over 100 ft below ground surface (bgs). Consequently, LAO-3.5 will not be drilled because of these reasons.

- A borehole (R-9) was drilled using stratex-holte techniques to the regional aquifer (Puye Formation) in upper Los Alamos Canyon at State Road 4 (Figure 3-3). Borehole R-9 was drilled to characterize intermediate-depth perched groundwater(s) and the upper 100 ft of the region aquifer. A temporary 4-in diameter observation well was constructed to a total depth of approximately 706.75 ft bgs. The screened interval was set from 683.8 to 703.9 ft bgs.

- The characterization wells were installed to measure water levels, conduct slug tests, collect groundwater samples, evaluate groundwater geochemistry, and evaluate local flow conditions within the alluvium, perched intermediate zones, and the regional aquifer. The alluvial wells were drilled using hollow-stem auger methods (Table 3-4). The screen lengths in the alluvial characterization wells are variable and the top of the screens were generally set at the water table, although the saturated thickness of the alluvium fluctuates seasonally. These alluvial characterization wells constructed of PVC were installed by Laboratory contractors (ERM/Golder) as part of both of the Los Alamos and Pueblo Canyons work plan and the LANL-wide Hydrogeologic work plan.

- At the R-9 borehole site, two perched zones were encountered in the basalt at depths of 180 ft and 275 ft, respectively. The upper perched zone in the basalt showed significant piezometric head (approximately 43 psi). The bases of the upper and lower perching units occur at depths of 225-236 and 282 ft bgs, respectively. Four saturated zones were encountered at depths of 579 ft, 615(?) ft, 624 ft, and 688 ft bgs within the Puye Formation or the regional aquifer. The upper five saturated zones (180 ft, 274 ft, 579 ft, 615(?) ft, and 624 ft bgs) are confined whereas the lower-most saturated zone (688 ft) is unconfined. All saturated zones were sealed with a bentonite grout during drilling to prevent mixing of groundwaters. The temporary characterization well (R-9) will be replaced with a permanent well completion after the drilling borehole R-12 in Sandia Canyon and evaluating local hydrologic and geochemical conditions within the regional aquifer and perched groundwater zones for the two canyons.

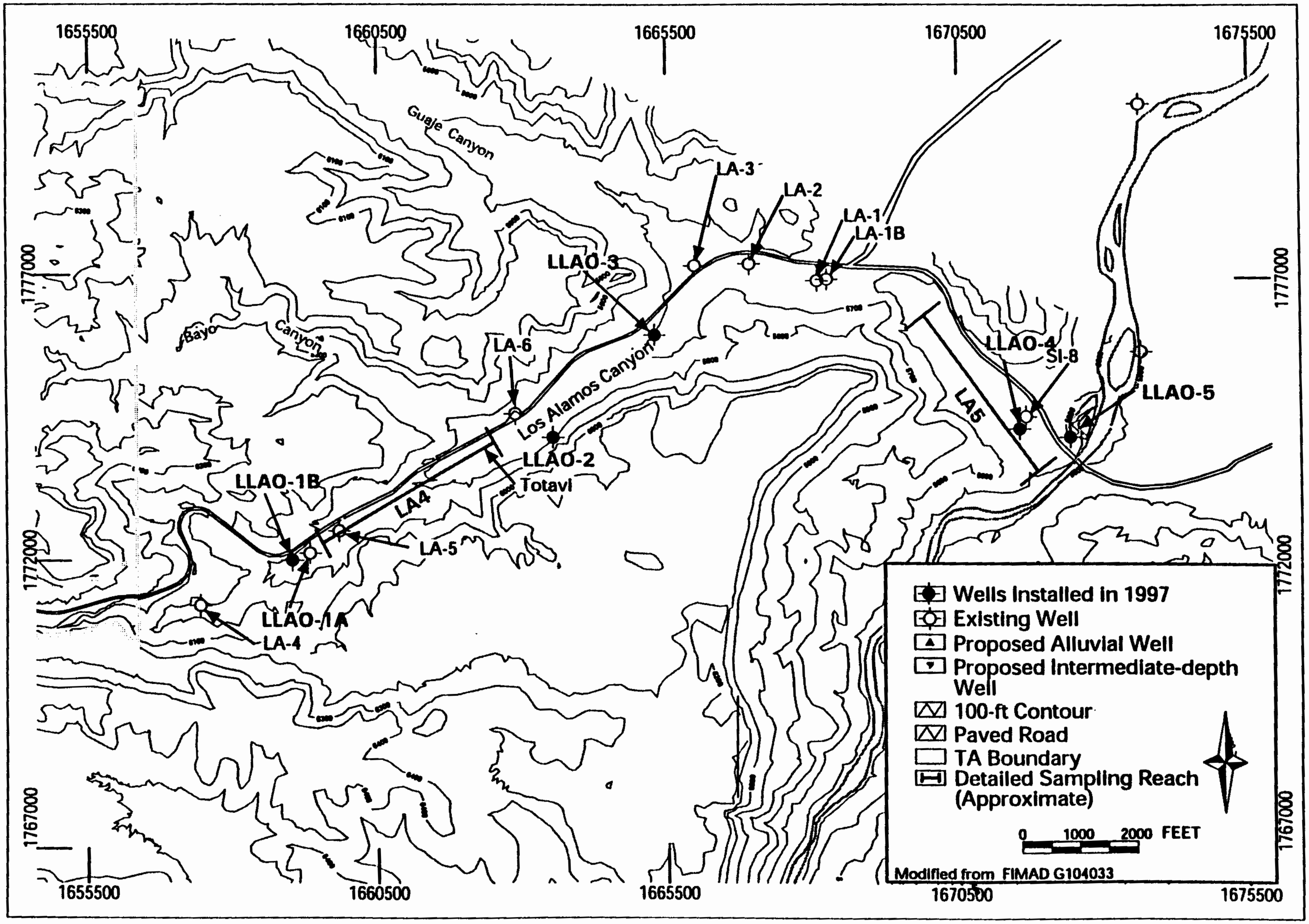


Figure 3-2. Wells installed in 1997 and other p roposed well locations: eastern Los Alamos and Pueblo Canyons

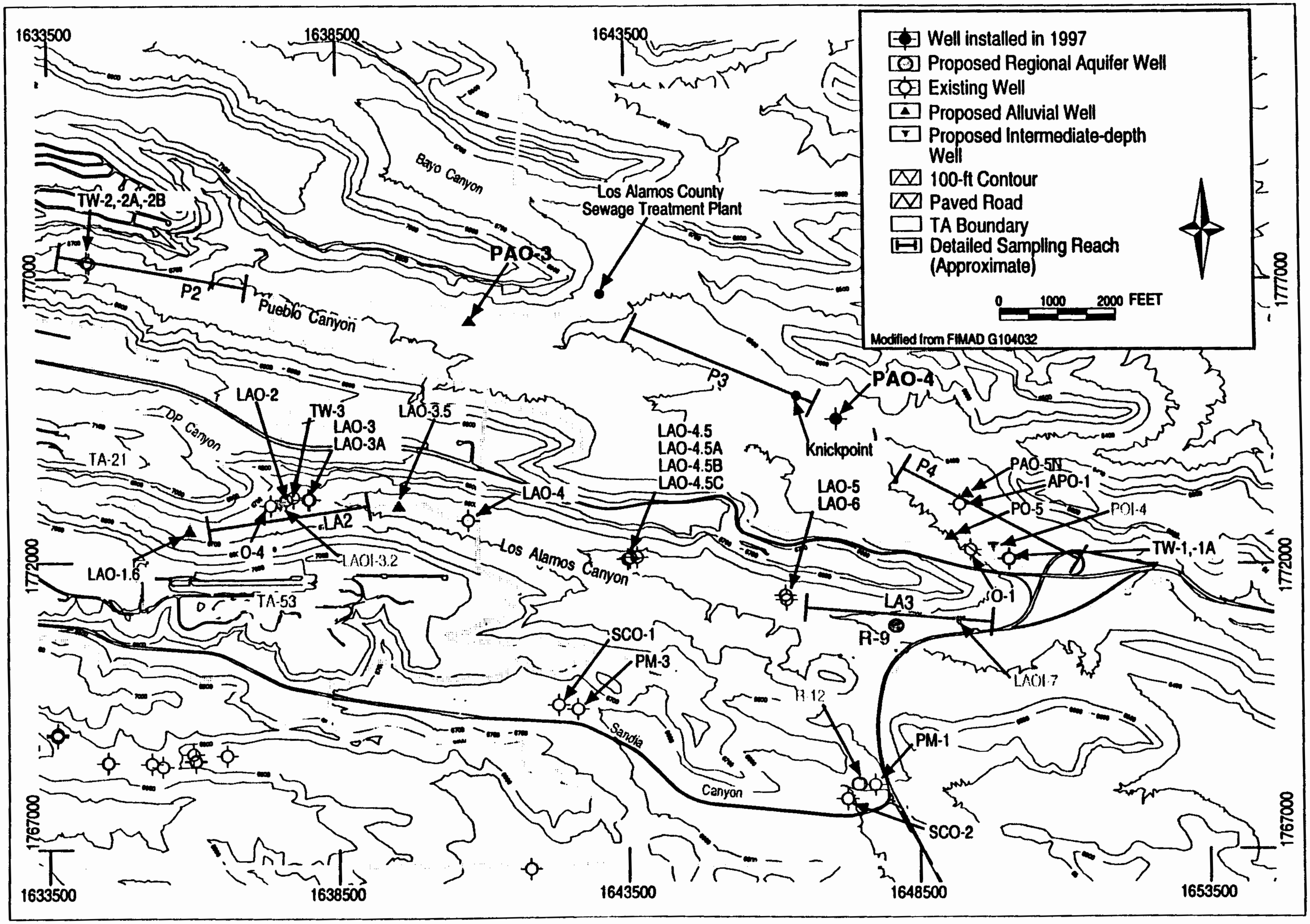


Figure 3-3. Wells installed in 1997 and other proposed well locations: central Los Alamos and Pueblo Canyons

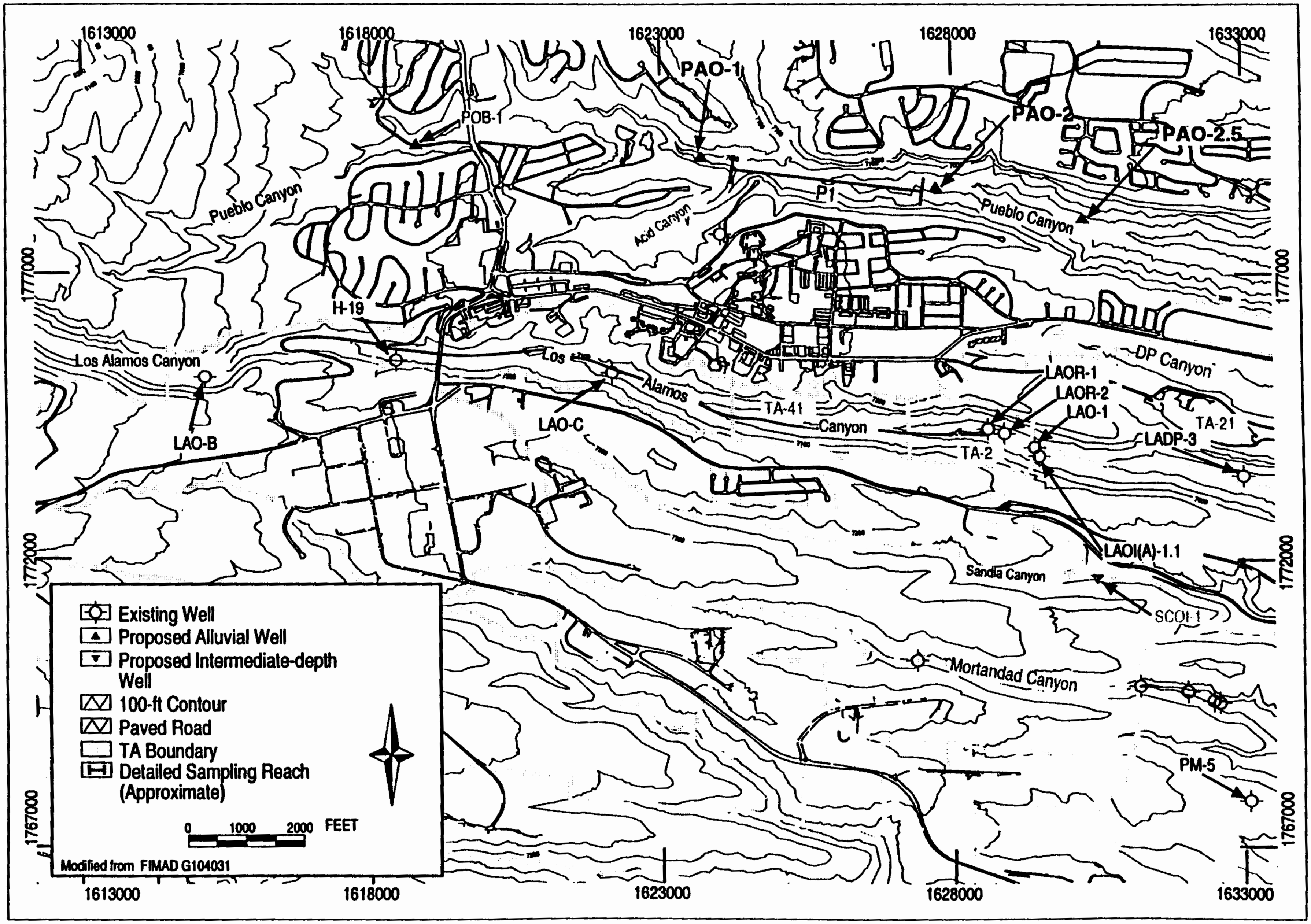


Figure 3-4. Proposed well locations: western Los Alamos and Pueblo Canyons

Table3-4. Summary Of Characterization Wells In Los Alamos And Pueblo Canyons Drilled In 1997				
Char. Well	**PAO-1**	**LLAO-1A**	**LLAO-3**	**R-9**
Drilling Method	Hollow Stem Auger	Hollow Stem Auger	Hollow Stem Auger	Air Rotory Odex
Drilling Date	23-24 July 97	14-16 July 97	17-22 July 97	15 Sept 97-1 Feb 98
Location	Pueblo Canyon west of PO-4	Lower LA Canyon at LA-5	Lower LA Canyon west of Guaje Canyon	Upper LA Canyon at State Road 4
Screen Int. (ft)	2.1-6.9	12-22	8.9-18.7	not determined
Well Complet. (ft)	9.8	24.5	21.6	not determined
Total Depth (ft)	15.5	25	22	688
Depth to Ground-water (BGS) (ft)	3	14	14	137, 274, 579, 615, 624, 688
Sat. Thick. (ft)	6	8	>10	variable
Aquifer Material	Alluvium	Alluvium	Alluvium	basalt, Puye Formation
Remarks	PAO-1 replaces PO-4	LLAO-1B replaces LLAO-1A		

- Groundwater samples were collected from alluvial characterization wells in April and May 1997 including PO-4 (plugged), LAO-1.6G, LLAO-2, LLAO-4, LLAO-5 and intermediate characterization well POI-4 (Figures 3-3 and 3-4). Borehole R-9 was sampled from September through December 1997 and supply well Otowi-1 was sampled in December 1996 and January 1997. The characterization wells were purged by pumping a minimum of three well volumes before sampling.

3.2.1.2 Conceptual Model Refinement

The following bulleted items represent specific refinements to the hydrogeologic model resulting from extensive data collection in Aggregate 1 during FY97 (Figures 3-5 and 3-6). Detailed backup information for these refinements has been provided in section 3.2.1.3. Specific refinements are as follows:

- Two intermediate perched zones in Los Alamos Canyon were encountered in basalt at well R-9. The chemistries of these zones are similar to the chemistry of alluvial groundwater in Los Alamos Canyon. Recharge to these two perched zones probably occurs from different reaches within upper Los Alamos Canyon.

- Perched groundwater was encountered in basalt at well POI-4 in lower Pueblo Canyon. The chemistry of the water is similar to the basalt perched zone in TW-1A suggesting the possibility of continuous saturation in the basalt between the two wells. Both wells contain elevated concentrations (compared to background) of chloride, nitrate, boron, and phosphate which is believed to be derived from the Los Alamos County sewage treatment plant effluent.

- Perched groundwater encountered in POI-4 is chemically different from the perched zones encountered in R-9 suggesting different sources and no hydraulic connectivity between Pueblo and Los Alamos canyons.

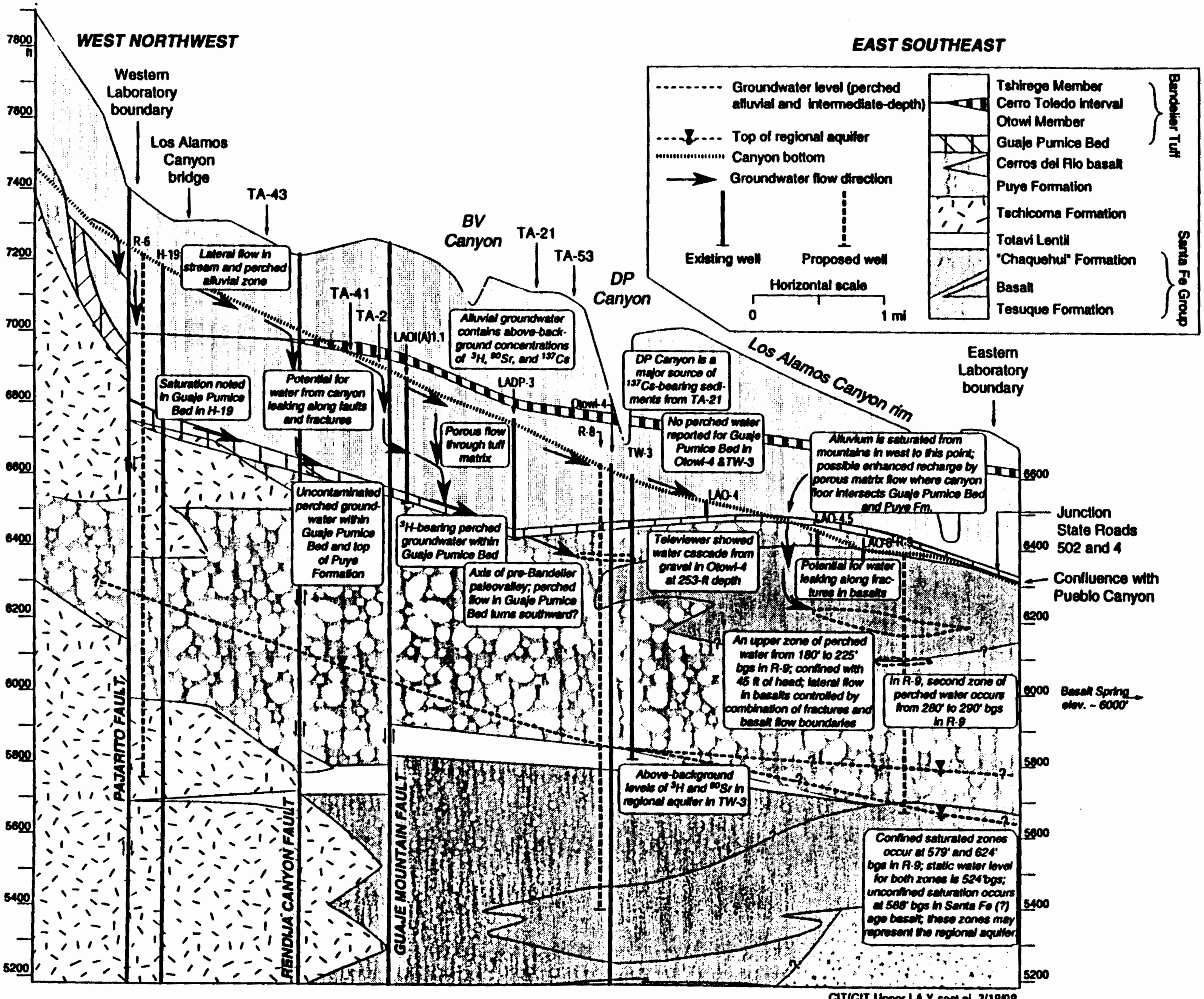


Figure 3-5. Schematic cross section showing conceptual model, R-9 results, and proposed regional aquifer wells for upper Los Alamos Canyon.

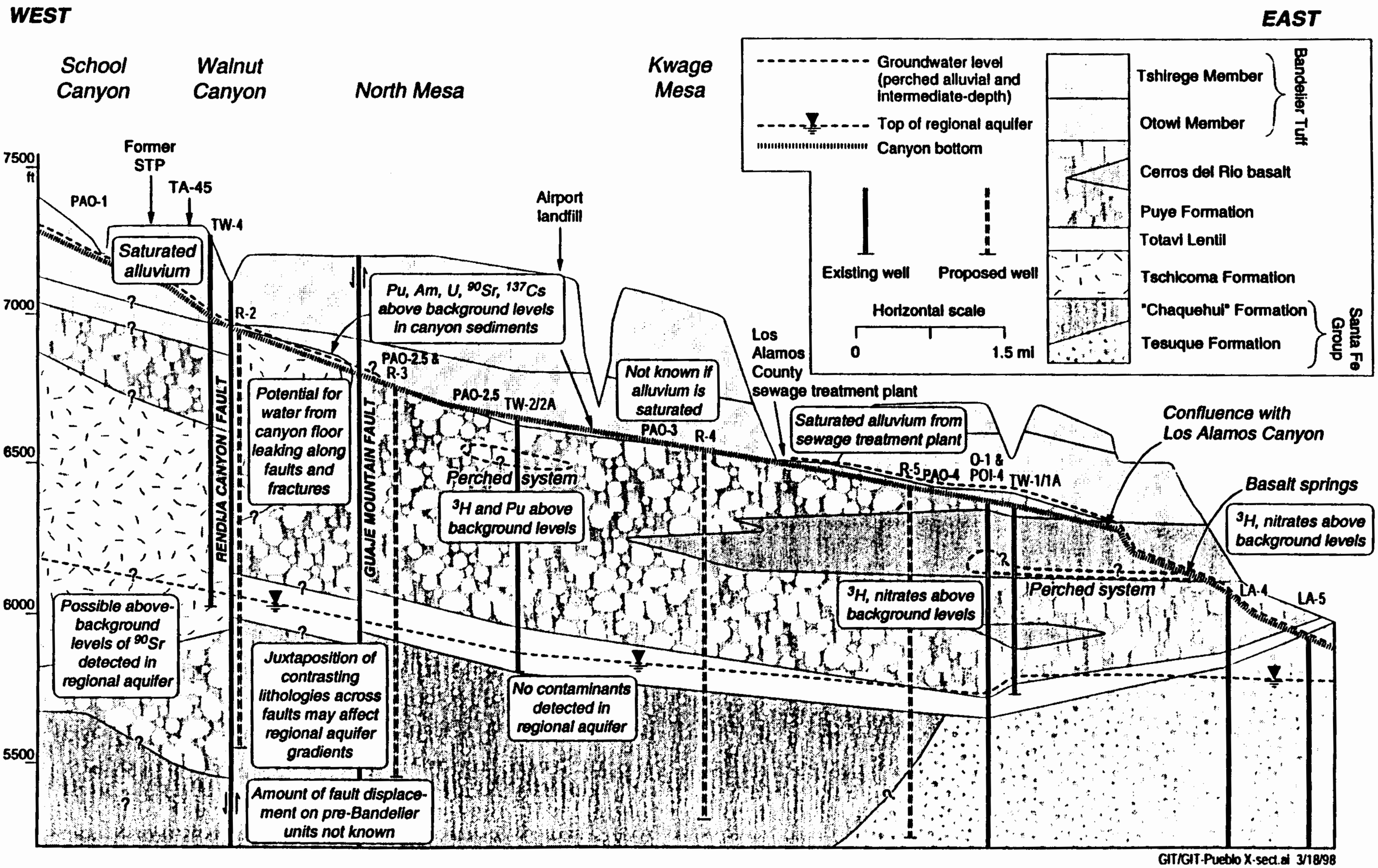


Figure 3-6. Schematic cross section showing conceptual model and proposed regional aquifer wells for Pueblo Canyon.

- The regional aquifer in R-9 is represented by groundwater at a depth of 688 feet bgs. Drilling R-9 has revealed that the regional aquifer is made up of a series of separate water-bearing zones with differing piezometric heads and chemistries.

3.2.1.3 Basis For Aggregate 1 Conceptual Model Refinements

Alluvial Groundwater in Upper Los Alamos and DP Canyons

- Filtered and nonfiltered groundwater samples were analyzed for different chemicals, including major cations and anions, trace elements, trace metals, stable isotopes, radionuclides, and organic compounds. Field-measured parameters recorded at the time of sample collection include pH, temperature, specific conductance, and turbidity. All groundwater samples collected in the field were stored at 4^{o}C until analyzed.Groundwater samples were analyzed using a variety of laboratory techniques specified in EPA-SW 846 (EPA, 1986) including ion chromatography (IC), graphite furnace atomic absorption (GFAA), cold vapor atomic absorption (CVAA), and inductively-coupled plasma emission spectroscopy (ICPES) (Table 3-5). Radionuclide activity in groundwater was determined by liquid scintillation counting (LSC) (tritium), electrolytic enrichment (low-level tritium), laser-induced kinetic phosphorimetry (LIKP) (uranium), thermal ionization mass spectrometry (TIMS) (uranium isotopes), alpha spectrometry (americium, plutonium, and uranium isotopes), gamma spectrometry (^{137}Cs and other isotopes) and gas proportional counting (^{90}Sr). This work was performed at LANL contract laboratories (Paragon Analytics, Inc., Teledyne, Weston, University of Miami), and at LANL laboratories (EES-1 and CST-7). Sample duplicates, laboratory blanks, and field blanks were collected and analyzed according to EPA and LANL procedures. The precision limits for major ions and trace elements were generally $\pm$ 10%. Groundwater samples were analyzed for volatile and semivolatile organic compounds using gas chromatography and gas chromatography-mass spectrometry.
- Alluvial groundwater in upper Los Alamos Canyon varies from a native Ca^{2+}-Na^{+}-HCO_3^- ionic composition to a Na^{+}-Ca^{2+}-Cl^--HCO_3^- ionic composition, with increasing chloride and sodium concentrations occurring downgradient of facility discharges to the east (Figure 3-7). Native groundwater in the alluvium (LAO-B) has a Na^{+}-Ca^{2+}-HCO_3^- ionic composition with an average TDS concentration less than 120 mg/L (Longmire et al., 1996). The TDS content of alluvial groundwater also increases along the flow path (to the east) in Los Alamos Canyon. Characterization well LAO-B serves as a background well for upper Los Alamos Canyon and is located near the western boundary of the Laboratory. Activities of tritium measured at LAO-B are less than 65 pCi/L (Longmire et al., 1996), which is within the range of rainfall and snowmelt (Adams et al., 1995) and background springs discharging from the Bandelier Tuff (Blake et al., 1995).
- Dissolved organic carbon (DOC) occurs in the 1 to 5 mgC/L range in upper Los Alamos Canyon, in the form of low-molecular weight organic acids produced by the decomposition of forest litter (Longmire, unpublished data). These naturally-occurring hydrophilic and hydrophobic organic acids may contribute to the localized reducing conditions in the alluvium. The anions of organic acids are known to be complexing agents capable of binding with dissolved metals including uranium and plutonium and other cations (Stevenson, 1994).

- Identifiable anthropogenic organic compounds, including volatile and semivolatile compounds, have not been detected in alluvial and perched groundwater in upper Los Alamos Canyon. Unknown organic compound, however, are present in the treated County Bayo plant sewage effluent.

Table 3-5
Analytical Suite For Alluvial Groundwater Samples[a]

Field-Measured Parameters		
Alkalinity	PH	Temperature
Dissolved oxygen	Specific conductance	Turbidity
Major and Minor Ions		
Aluminum	Fluoride	Nitrite
Bromide	Iron	Phosphate
Calcium	Magnesium	Potassium
Chlorate	Manganese	Sodium
Chloride	Nitrate	Sulfate
Trace Elements		
Aluminum	Chromium	Silver
Antimony	Cobalt	Thallium
Arsenic	Copper	Titanium
Barium	Lead	Uranium
Beryllium	Mercury	Vanadium
Boron	Nickel	Zinc
Cadmium	Selenium	
Organic Compounds		
VOCs		
SVOCs		
Dissolved Organic Carbon (fractionation analysis)		
Total Suspended Solids		
Total Dissolved Solids		
Neutral Species (SiO_2)		
Hardness		
Cyanide		
Radionuclides		
^{241}Am	^{90}Sr	^{238}U
^{137}Cs	^{234}U	Gamma spectroscopy
^{238}Pu	^{235}U	Gross-alpha, -beta, and –gamma
$^{239,240}Pu$	^{236}U	Tritium[b]

a. Filtered (<0.45 μm) and unfiltered water samples will be collected.
b. Low-detection-limit at MCO-0.6, TSCO-6, MCO-13A, and MCO-13B only; high-detection-limit for other alluvial and Cerro Toledo interval groundwater samples

Table 3-5 (cont) Analytical Suite For Intermediate Perched Zone And Regional Aquifer Groundwater Samples*			
Field-Measured Parameters			
Alkalinity	PH		Temperature
Dissolved oxygen	Specific conductance		Turbidity
Major and Minor Ions			
Aluminum	Fluoride		Nitrite
Bromide	Iron		Phosphate
Calcium	Magnesium		Potassium
Chlorate	Manganese		Sodium
Chloride	Nitrate		Sulfate
Trace Elements			
Aluminum	Chromium		Silver
Antimony	Cobalt		Thallium
Arsenic	Copper		Titanium
Barium	Lead		Uranium
Beryllium	Mercury		Vanadium
Boron	Nickel		Zinc
Cadmium	Selenium		
Organic Compounds			
VOCs			
SVOCs			
Dissolved Organic Carbon (fractionation analysis)			
Total Suspended Solids			
Total Dissolved Solids			
Neutral Species (SiO_2)			
Hardness			
Cyanide			
Stable and Radiogenic Isotopes			
^{14}C, ^{13}C			
^{36}Cl			
Deuterium/hydrogen			
$^{18}O/^{16}O$			
Radionuclides			
^{241}Am	$^{239,240}Pu$	^{235}U	Gamma spectroscopy
^{137}Cs	^{90}Sr	^{236}U	Gross-alpha, -beta, and -gamma
^{238}Pu	^{234}U	^{238}U	Tritium (low-detection-limit)
*Filtered (<0.45 µm) and unfiltered water samples will be collected.			

Table 3-5 (cont) Estimated Detection Limits And Analytical Methods For Inorganic Chemicals In Groundwater Samples[a]			
Analyte	**EDL (µg/L)**	**Analytical Method**	**Analytical Protocol[b]**
Metals (total and dissolved)			
Aluminum	10	ICPES	SW-6010B
Antimony	0.1	ICPMS	SW-6020
Arsenic	1	ETVAA	SW-7060A
Barium	2	ICPES	SW-6010B
Beryllium	5	ICPES	SW-6010B
Boron	10	ICPES	SW-6010B
Cadmium	1	ICPMS	SW-6020
Calcium	10	ICPES	SW-6010B
Chromium	2	ICPES	SW-6010B
Cobalt	2	ICPES	SW-6010B
Copper	2	ICPES	SW-6010B
Iron	10	ICPES	SW-6010B
Lead	3	ETVAA or ICPMS	SW-7421 or SW-6020
Magnesium	10	ICPES	SW-6010B
Manganese	2	ICPES	SW-6010B
Mercury	0.2	CVAA	SW-7470A
Nickel	2	ICPES	SW-6010B
Potassium	10	ICPES	SW-6010B
Selenium	0.2	ETVAA	SW-7740
Silver	0.2	ICPES	SW-6010B
Sodium	50	ICPES	SW-6010B
Thallium	2	ICPMS	SW-6020
Titanium	2	ICPES	SW-6010B
Uranium	1	ICPMS	SW-6020
Vanadium	2	ICPES	SW-6010B
Zinc	10	ICPES	SW-6010B
Anions (dissolved)			
Bromide	20	IC	SW-9056
Chlorate	20	IC	SW-9056
Chloride	20	IC	SW-9056
Fluoride	20	IC	SW-9056
Nitrate	40	IC	SW-9056
Nitrite	40	IC	SW-9056
Orthophosphate	20	IC	SW-9056
Sulfate	100	IC	SW-9056
Other Inorganic Chemicals (dissolved)			
Silica	200	Colorimetry	EPA Method 370.1
Total cyanide	50	Colorimetry	SW-9012A

a. Both unfiltered (total) and filtered (dissolved) water samples will be collected. Water samples will be filtered at the time of collection to remove particles larger than 0.45 µm.
b. EPA SW-846 Method (EPA 1986, 31732) or equivalent

Table 3-5 (cont) Minimum Detectable Activity And Analytical Methods For Radionuclides In Groundwater Samples[a]				
Analyte	**Half-Life (yr)**	**Detected Emission**	**MDA (pCi/L)**	**Analytical Method**
^{241}Am	432.2	α	0.05	α-Spectrometry
^{238}Pu	87.7	α	0.05	α-Spectrometry
$^{239,240}Pu$[b]	2.411×10^4	α	0.05	α-Spectrometry
^{90}Sr	28.7	β	1.0	GPC
Tritium	12.3	β	250	LSC
Tritium (low level)	12.3	β	1	Electrolytic enrichment/GPC
^{234}U	2.46×10^5	α	0.1	α-Spectrometry[c]
^{235}U	7.04×10^8	α	0.1	α-Spectrometry[c]
^{236}U[d]	2.342×10^7	α	0.1	TIMS
^{238}U	4.47×10^9	α	0.1	α-Spectrometry[c]
Gamma spectroscopy[e]	N/A[f]	γ	10[g]	γ-Spectroscopy
Gross-alpha	N/A	α	1.0	GPC or LSC
Gross-beta	N/A	β	1.0	GPC or LSC
Gross-gamma	N/A	γ	20	NaI(Tl) or HPGe detection

a. All water samples will be filtered at the time of collection to remove particles larger than 0.45 μm.
b. The ^{239}Pu and ^{240}Pu isotopes cannot be distinguished by alpha spectrometry. The half-life of ^{239}Pu is given.
c. Radionuclide may also be analyzed by ICPMS.
d. Water sampling for ^{236}U analysis should use clean protocols including EPA 1669 or United States Geological Survey 94-539
e. The gamma spectroscopy analyte list is given in Table 7.2.6-5.
f. N/A = not applicable
g. The MDA for ^{137}Cs is 15 pCi/L; the MDAs for other analytes will vary.

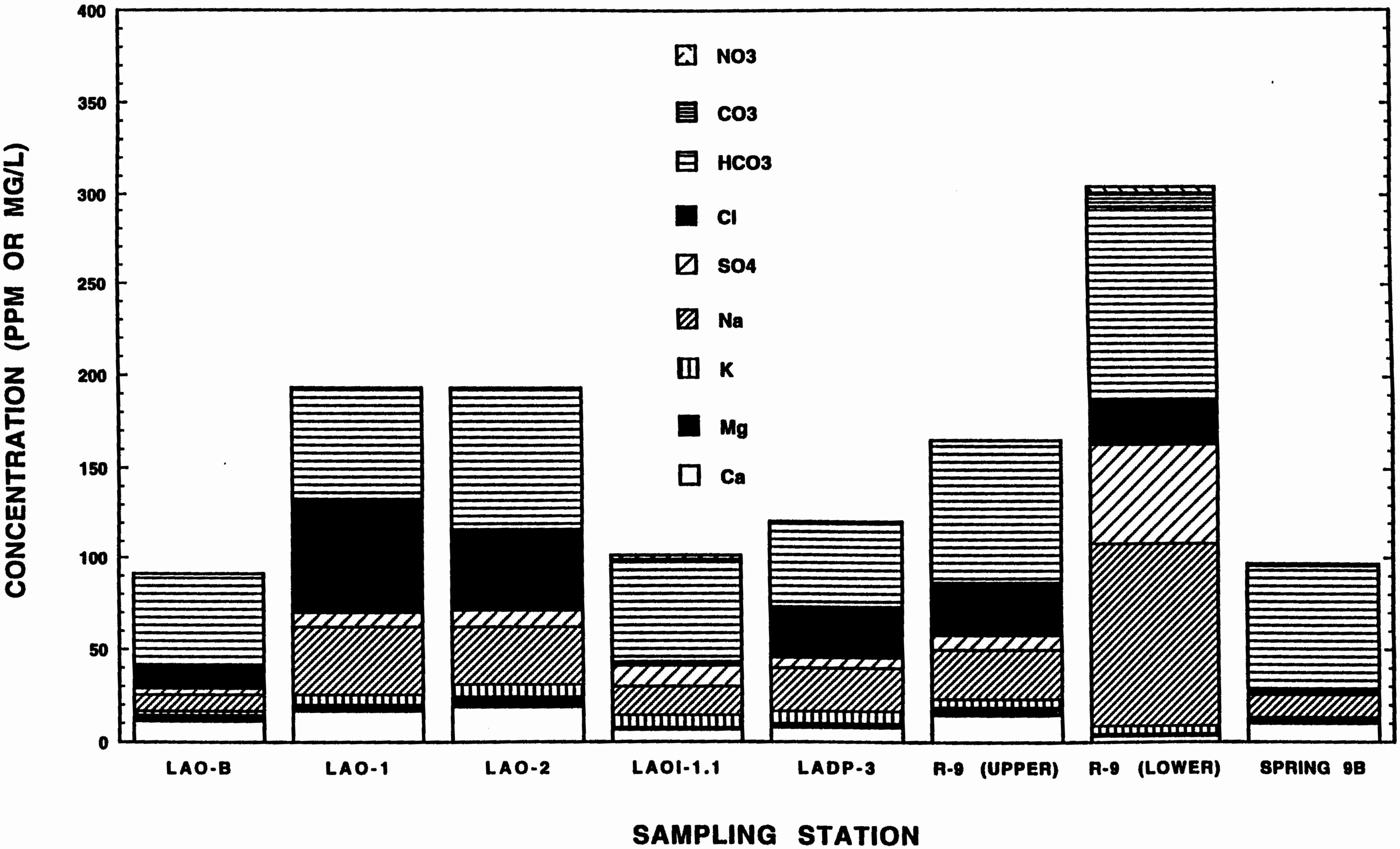
Table 3-5 (cont) Analytical Methods For Additional Parameters In Groundwater Samples[a]	
Analyte	**Analytical Method**
Stable and Radiogenic Isotopes[b]	
Carbon-14, Carbon-13	Accelerator MS
Deuterium/hydrogen	Accelerator MS
Oxygen-18/oxygen-16	MS
Chlorine-36	MS
Organic Compounds	
VOCs	SW-8260[c]
SVOCs	SW-8270
Other Analytes	
Total organic carbon	SW-415.1[d]
Dissolved organic carbon (humic substances)	USGS/WRI 79-4
Hardness (as $CaCO_3$)	EPA Method 130

a. All water samples will be filtered at the time of collection to remove particles larger than 0.45 µm.
b. Stable isotopes will be measured in intermediate-depth and regional aquifer groundwater samples.
c. EPA SW-846 Methods (EPA 1986, 31733)
d. EPA 1983, 56406

Table 3-5 (cont) Field Measurements For Groundwater Samples		
Measurement	**Precision[a]**	**Method**
Alkalinity	±1 mg/L $CaCO_3$	EPA Method 310.1
Dissolved oxygen	±0.1 mg/L	LANL-ER-SOP-06.02[b]
PH	±0.02	LANL-ER-SOP-06.02
Specific conductance	±1 mmho/cm (µS/cm)	LANL-ER-SOP-06.02
Temperature	±1 °C	LANL-ER-SOP-06.02
Turbidity (nephelometric)	±1 NTU	EPA Method 180.1

a. Precision with which measurement will be recorded
b. LANL 1991, 21556

FIGURE 3-7. MAJOR ION AND NUTRIENT CHEMISTRIES OF GROUNDWATERS IN ALLUVIUM, GUAJE PUMICE BED, AND BASALT ON THE PAJARITO PLATEAU.



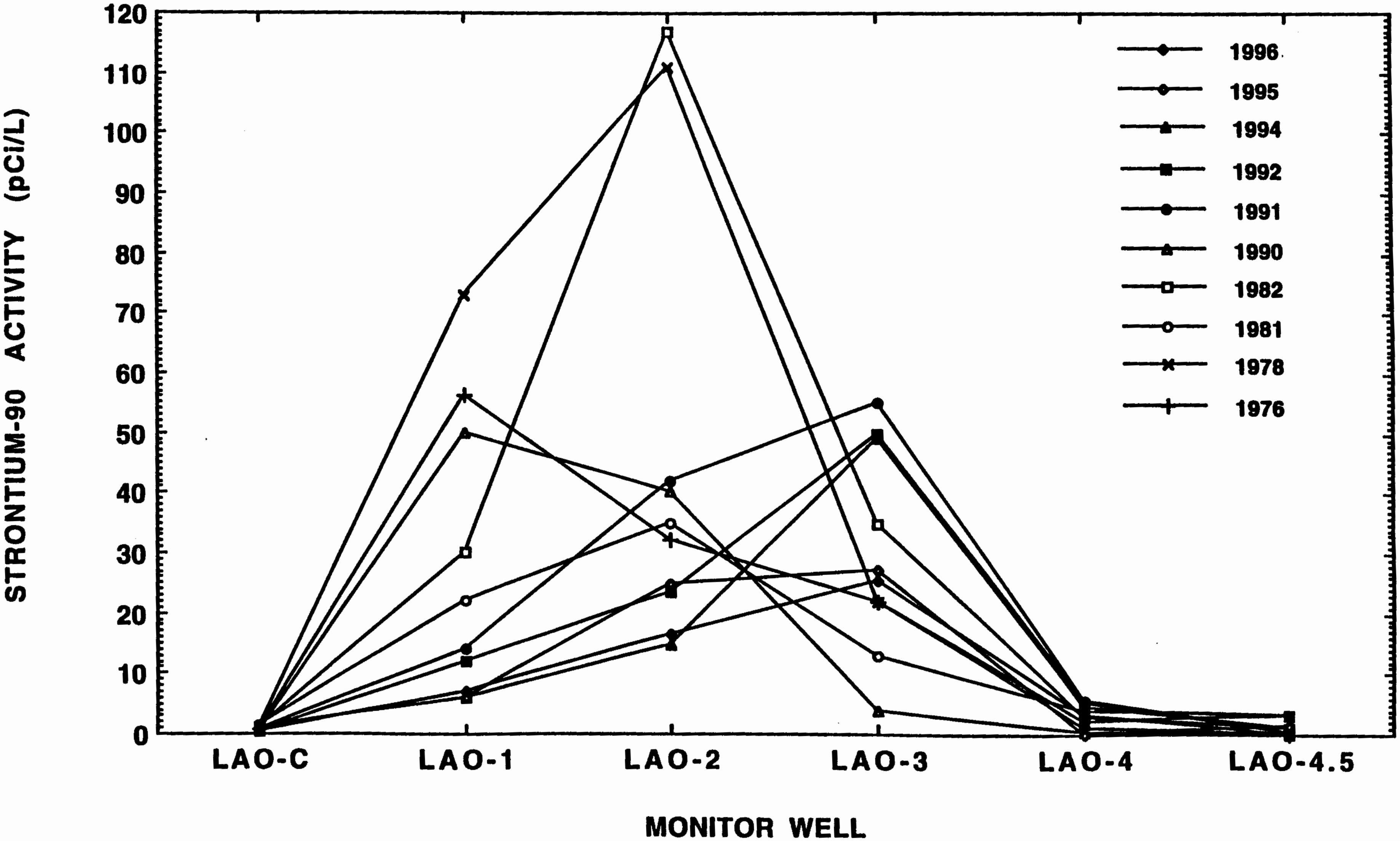
Distributions of ^{90}Sr and Tritium Within Upper Los Alamos Canyon

- The two major sources of ^{90}Sr and tritium in and adjacent to upper Los Alamos Canyon include TA-2 (SWMU no. 2-009) and TA-21 discharges via DP Canyon. Downgradient or east of TA-2 and within DP Canyon, activities of ^{90}Sr and tritium have been elevated above background in alluvial groundwater for the past several decades (Figure 3-8) (ESH, variable years between 1976-1997). Analyses of most recent samples collected by ESH-18 (1997) show that measurable activities of ^{90}Sr in alluvial groundwater range from 3.1 to 25.4 pCi/L and are generally decreasing with time. Maximum activities of this radionuclide shift downgradient to the east over time, illustrating migration of this contaminant plume. Activities of tritium in alluvial groundwater in 1996 are typically less than 400 pCi/L (ESH, 1997). Activities of ^{90}Sr are less than 3 pCi/L within Pueblo Canyon and lower Los Alamos Canyon.
- Batch sorption experiments for strontium were conducted on 20 soil samples and 16 channel sediment samples collected in TA-2, TA-21, and TA-41, upper Los Alamos Canyon (Kung, 1995; Longmire et al., 1996). Sorption coefficients (Kd) for strontium, measured on Los Alamos Canyon soils and channel sediments, range from 15.8 to 67.7 ml/g, with a mean value of 35.7 ml/g, for the soils and from 8.8 to 41.3 ml/g, with a mean value of 21.4 ml/g, for the channel sediments (Longmire et al., 1996). Strontium exchange was found to be strongly dependent on solid organic matter and less dependent on clay-sized material for all soil and channel sediment samples. The Kd values for strontium, measured on a poorly-developed soil and channel sediments exposed near state road 4 containing small amounts of solid organic matter (< 1 weight percent), range from zero to 10 ml/g.

Chromium Distributions in Soil and Alluvial Groundwater at TA-2

- Potassium dichromate ($K_2Cr_2O_7$) was used prior the mid 1970s as an anti-corrosive agent for the cooling water at TA-2 (Longmire et al., 1996, 1997). Concentrations of chromium in soil adjacent to the cooling tower are as high as 700 ppm based on analytical results obtained from phase 1 investigations conducted at TA-2. Background chromium concentrations in LANL canyon sediments are 10.5 ppm (Ryti et al., 1998). Concentrations of chromium at monitor well LAO-1 at the eastern boundary of TA-2 increase by a factor of 11 (0.011 mg/L) above background samples (0.001 mg/L) collected from other characterization wells west of TA-2 (Longmire et al., 1996, 1997). The MCL for dissolved chromium (Cr(III) and Cr(VI)) is 0.1 mg/L, and no analytical results of groundwater samples collected in upper Los Alamos Canyon exceed this standard.
- Longmire et al. (1997) presented experimental data from selective extractions using both EPA extraction procedures and SW 846 analytical methods, which suggest that Cr(III) is the stable oxidation state of chromium in the organic-rich sediment adjacent to the cooling tower at TA-2. Potassium dichromate is reduced to form Cr(III) aqueous species over time. Cationic Cr(III) species strongly adsorbed onto mineral surfaces, accounting for the elevated above background concentrations of chromium in soil. Chromium may eventually precipitate from solution as $Cr(OH)_3$ and $Cr_{1-x}Fe_x(OH)_3$ phases within the alluvium in the presence of chemical reductants including solid organic matter. The alluvium contains organic matter, the principal reductant, which is derived from decaying plants.

FIGURE 3-8. DISTRIBUTION OF STRONTIUM-90 IN SHALLOW GROUNDWATER (ALLUVIAM, BANDELIER TUFF, AND PUYE FORMATION) WITHIN UPPER LOS ALAMOS CANYON (ESH-18).



- Results of the initial experiments suggest that chromium-contaminated soil at TA-2 may not have to be removed from the site because chromium (as Cr(III)) does not pose an unacceptable risk to receptors potentially ingesting the soil (as based on current Laboratory soil SALs). Erosion control measures, however, are recommended to eliminate movement of the chromium-contaminated soil into the water course.

- *Distributions of Uranium in Alluvial Groundwater*

- Background concentrations of dissolved uranium in alluvial groundwater and surface water at the Los Alamos Reservoir in upper Los Alamos Canyon are less than 1 microgram per liter (µg/L) (Longmire et al., 1996; ESH, 1997). Concentrations of total (unfiltered) uranium as high as 15 µg/L, however, are observed at LAO-0.7 east of TA-41 (ESH, 1996). This elevated uranium may have originated from former TA-1 on the north side of upper Los Alamos Canyon west of TA-41 and TA-2 (TA-1 workplan, phase 1 analytical data). Concentrations of total uranium in alluvial groundwater are below the proposed EPA MCL of 20 µg/L of dissolved uranium and the New Mexico Water Quality Control Commission (NMWQCC) standard of 5 mg/L of dissolved uranium. Elevated above background concentrations of uranium are observed in groundwater samples collected from observation wells LAO-1, LAO-2, LAO-3, LAO-3, LAO-4, and LAO-4.5 (Longmire et al., 1996; ESH-18, 1991-1997). Former TA-1 and TA-21 are possible sources of natural uranium discharged or released into upper Los Alamos Canyon prior to the 1950s.
- In addition, elevated above background concentrations of uranium have been documented in surface water samples collected in DP Canyon (LANL, 1981). This may account for the elevated uranium concentrations observed in alluvial groundwater east of the DP Canyon and Los Alamos Canyon confluence.

Perched (Basalt) Groundwater in Upper Los Alamos Canyon (R-9)

- The upper perched zone in the middle of the Cerros del Rio Basalt beneath upper Los Alamos Canyon is one of the thickest intermediate-depth groundwater bodies found beneath the Laboratory thus far. In Borehole R-9 (Figure 3-9) water was first encountered at 180 ft depth, and the water-bearing zone is ~45 ft thick. Water quickly rose to 43 ft above the depth that water was first encountered, indicating permeable, highly pressurized (~40 psi) conditions. The top of the perched zone is confined by a clay-rich rubble zone that separates two basalt flows. The perching layer at the base of the zone appears to be massive unfractured basalt. Rare fractures present in the massive basalt are notably clay poor compared to clay-rich fractures in the basalt rubble zone. A network of intercommunicating open fractures probably provides the primary groundwater pathways in this upper perched zone.
- In Borehole R-9 in upper Los Alamos Canyon water in the lower perched zone at the base of the Cerros del Rio Basalt was first encountered at a depth of 275 ft. The water-bearing zone is ~7 ft thick. After penetrating the top of this zone, water slowly rose 10 ft above the upper confining layer. Slow recovery after bailing water samples and results from an open hole slug test suggest that the hydraulic conductivity of this lower zone is significantly lower than in the upper perched zone. The top of the lower perched zone is confined by a clay-rich rubble zone at the base of a thick basalt flow unit. The perching layer at the base of the lower groundwater zone consists of stratified fine-grained basaltic tephra that marks the transition into sedimentary rocks of the underlying Puye Formation. Flow within the basalt rubble zone appears to provide the primary groundwater pathway in this lower perched zone.

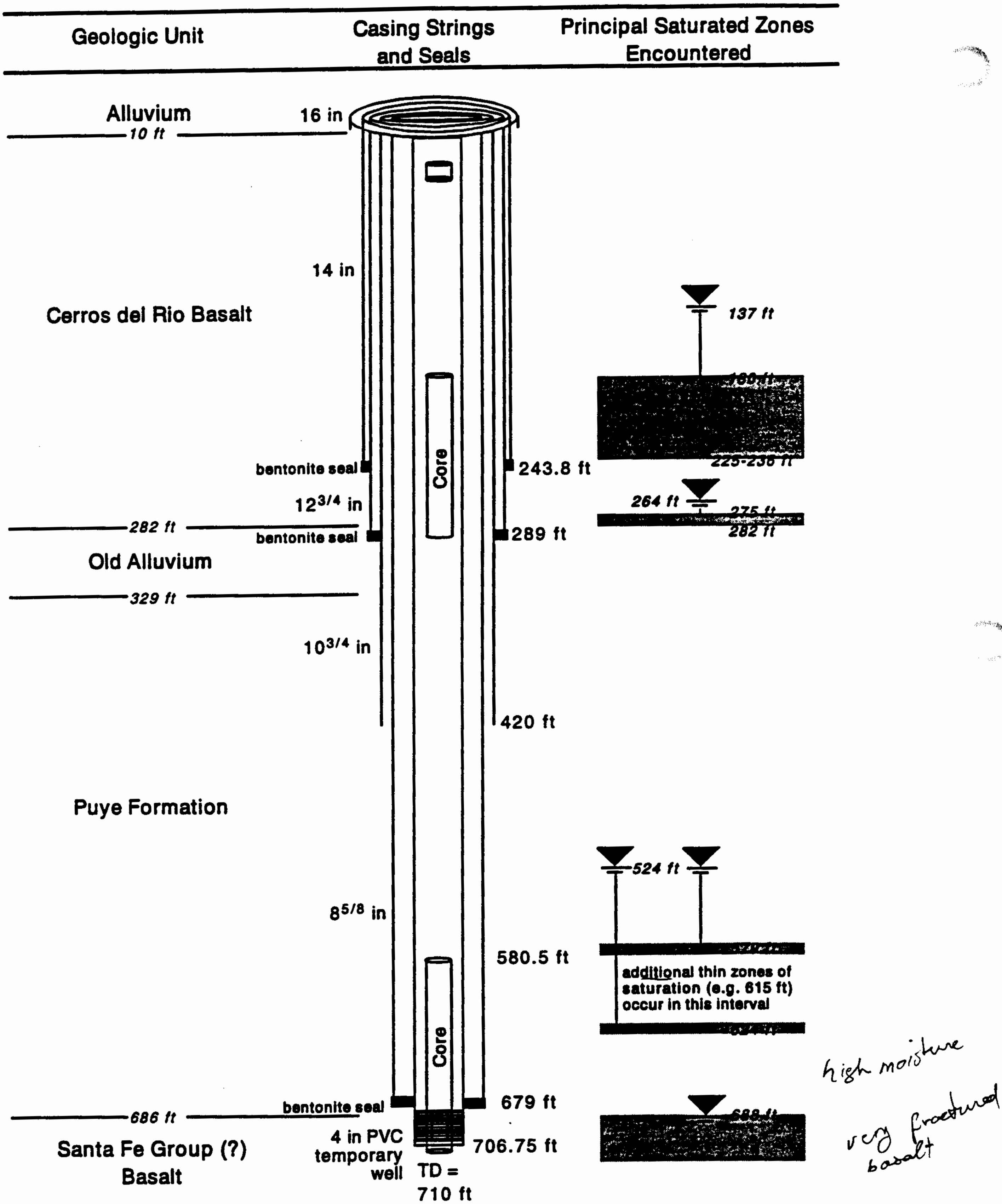


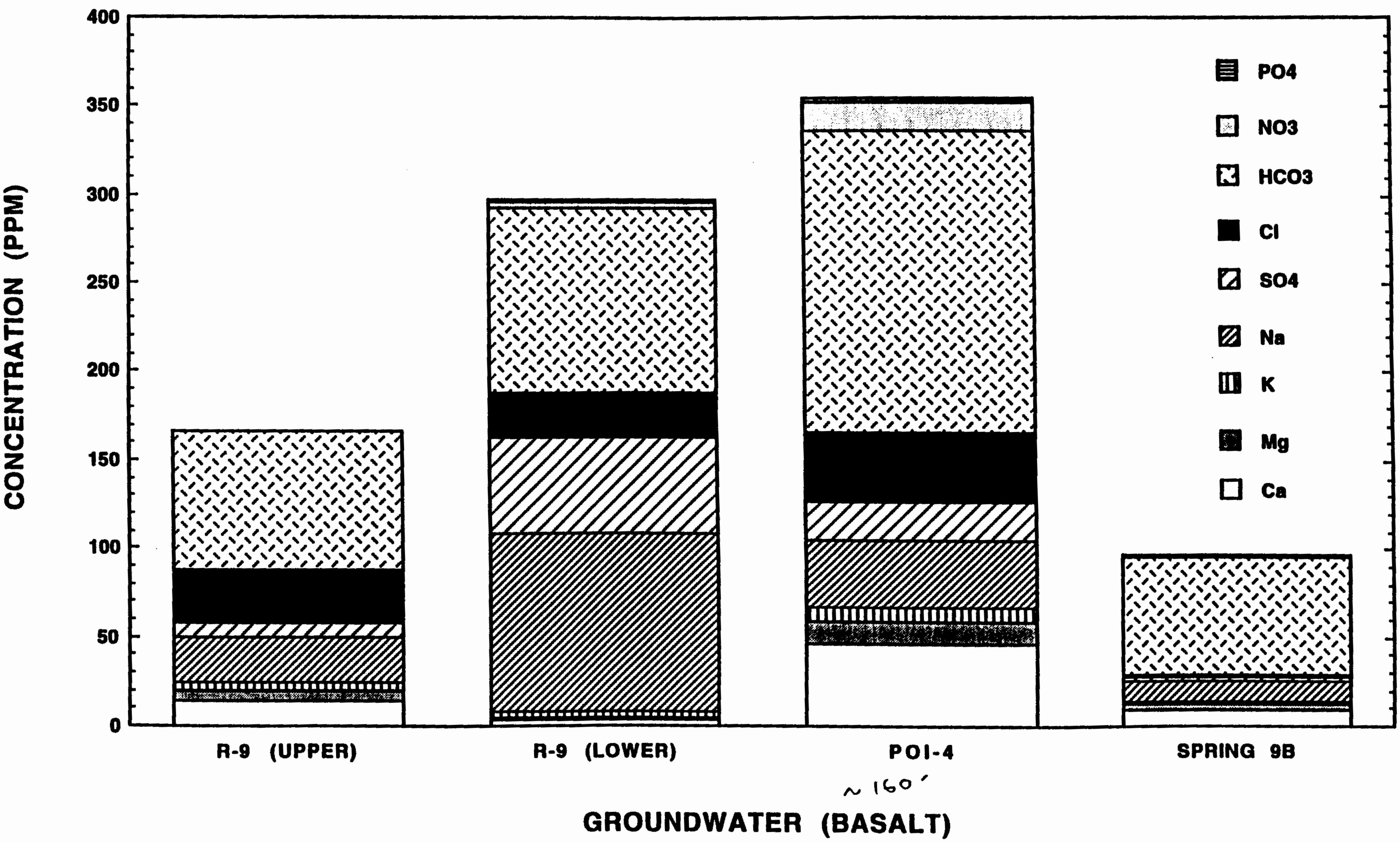
Figure 3-9. Configuration of Borehole R-9 as of 1/30/98 showing geologic units and groundwater zones encountered, casing strings and temporary 4" PVC well, and cored intervals.

- Two perched groundwater zones were encountered at depths of 180 and 274 ft bgs within several basalt flows at borehole R-9. The upper saturated zone is characterized by a Na^{+}-Ca^{2+}-Cl^{-}-HCO_3^{-} ionic composition (Figure 3-10). The lower saturated zone is characterized by a Na^{+}-SO_4^{2-}-HCO_3^{-} ionic composition. The lower zone has a higher TDS content (341 ppm) than the upper zone (255 ppm) possibly reflecting a longer residence time of groundwater within the deeper zone. The major ion chemistry of the upper zone is chemically similar to alluvial well LAO-2 (see Figure 3-7). The two perched groundwater zones contain a component of alluvial groundwater (LAO-2) based on the presence of elevated above background concentrations of chloride (29 ppm) and tritium (347 pCi/L in upper zone and 106 pCi/L in lower zone). Concentrations of chloride are 45.4 mg/L in LAO-2 (ESH, 1997).
- Spring 9B in White Rock Canyon serves as a background spring for basalt, which has a Ca^{2+}-Na^{+}-HCO_3^{-} ionic composition. Spring 9B does not contain measurable tritium (< 1pCi/L). Spring 9B is the only known uncontaminated spring discharging from basalt on the Pajarito Plateau. Based on mixing calculations using chloride as a tracer, the upper and lower perched zones contain 63 and 54 volume percent alluvial groundwater, respectively. This suggests that alluvial groundwater recharges the perched zones within the basalt flows. Background concentrations of chloride are 1.93 ppm in Spring 9B discharging from basalt in White Rock Canyon (Figure 3-10).
- Results of analytical data collected from the two perched zones at borehole R-9 show that these groundwaters are not chemically similar to POI-4 in lower Pueblo Canyon (Figure 3-10). This suggests that there is not a hydraulic connection within the basalts between Pueblo and Los Alamos Canyons at this location. Perched-intermediate groundwater beneath Pueblo Canyon probably flows to the east-southeast and partially discharges at Basalt Spring. POI-4 contains higher concentrations of phosphate (2.49 ppm), nitrate (16.4 ppm), boron (0.17 ppm), and chloride (38.5 ppm) than do the upper and lower perched zones in R-9 (phosphate: upper zone, 0.14 ppm; lower zone, 0.61 ppm) (nitrate: upper zone, <0.02 ppm; lower zone, 3.61 ppm) (boron: upper zone, 0.023 ppm; lower zone, <0.01 ppm) (chloride: upper zone, 29.2 ppm; lower zone, 25.5 ppm)
- Activities of tritium measured in the upper and lower perched zones are 347 and 106 pCi/L, respectively. Activities of radionuclides (^{137}Cs, ^{90}Sr, ^{238}Pu, $^{239,240}Pu$, ^{241}Am) in groundwater samples collected at collected from the perched zones are near analytical detection limits or minimum detectable activity for alpha and gamma spectrometry and gas proportional counting.
- Perched groundwaters within both the fractured basalt (upper zone) and tephra deposits (lower zone) possibly are reducing with respect to oxalate, uranium, iron, and manganese. Reducing conditions enhance the precipitation of $USiO_4$, UO_2, and amorphous UO_2, which decreases the mobility of uranium.

Guaje Pumice Bed Groundwater

- Native groundwater in the Gauje Pumice Bed also has a Na^{+}-Ca^{2+}-HCO_3^{-} ionic composition with an average TDS concentration (not including SiO_2) less than 150 mg/L (see Figure 3-7) (Longmire et al., 1996). Concentrations of sodium and bicarbonate are higher in the Guaje Pumice Bed relative to LAO-B, which is a result of longer groundwater residence times occurring beneath the highly permeable alluvium.

FIGURE 3-10. MAJOR ION AND NUTRIENT CHEMISTRIES OF SEVERAL GROUNDWATERS WITHIN BASALT FLOWS IN LOS ALAMOS, PUEBLO, AND WHITE ROCK CANYONS.



- Observation well LAO-I(A)-1.1 serves as a provisional background well for the Guaje Pumice Bed and is located at the eastern end of TA-2. Concentrations of chloride measured at LAO-I(A)-1.1 are less than 2 mg/L, which is much lower than chloride concentrations measured in background alluvial groundwater (LAO-B) (see Figure 3-7). Activities of tritium measured at LAO-I(A)-1.1 are less than 3 pCi/L which suggests that the Guaje Pumice Bed is recharged by meteoric water west of TA-2 possibly within the Pajarito fault system (Longmire et al., 1996). Activities of tritium in the overlying alluvial groundwater at LAO-I(A) in upper Los Alamos Canyon have been as high as 35,000 pCi/L in the early 1990s.
- Groundwater samples collected from LADP-3 east of TA-2, which is also completed in the Guaje Pumice Bed, are characterized by mixed-ion composition where Na^+, HCO_3^-, and Cl^- are the dominant species (see Figure 3-7). The similarity in proportions of major ion concentrations between alluvial groundwater (LAO-1) and LADP-3 suggests that alluvial groundwater is recharging the Guaje Pumice Bed in this reach of upper Los Alamos Canyon (see Figure 3-7).
- In addition, tritium was detected in groundwater samples collected from LADP-3 at activities of approximately 6,000 pCi/L in 1993 (Broxton et al., 1995b), confirming an alluvial groundwater component within the saturated Guaje Pumice Bed. Activities of tritium have decreased in samples collected from LADP-3 since 1993 to 887 pCi/L in December 1996. This suggests that the groundwater travel time through the Otowi Member of the Bandelier Tuff may range from 3 to 12 years depending on the degree of saturation and volumetric flux within the Otowi Member (Broxton et al., 1995b).

Puye Formation and Santa Fe Group (?) Groundwater in Upper Los Alamos Canyon (Borehole R-9)

- In Borehole R-9 within Los Alamos Canyon the saturated zones within Puye Formation (579 ft, 615 ft, and 624 ft) occur within thin transmissive sand and gravel beds intercalated within a thick sequence of relatively impermeable clay-rich tuffaceous sedimentary deposits. These impermeable clay-rich tuffaceous sedimentary deposits act as aquitards. When the top of the saturated zone at 579 ft depth was penetrated, water levels rose 55 ft in the borehole to a depth of 524 ft indicating confining conditions. Saturation at 615 ft depth appeared while the borehole rested over a weekend. The saturation in this zone appears to be related to relatively tight clay-rich tuffaceous sedimentary deposits and is not a highly transmissive zone. The saturated zone at 624 ft depth is associated with transmissive sand and gravels. When the top of this zone was penetrated, water levels rose 100 ft in the borehole to a depth of 524 ft indicating confining conditions and probable hydrologic connection with the saturated zone at 579 ft depth.
- The saturated zone within the Santa Fe Group (?) basalt near the bottom of R-9 in Los Alamos Canyon was first penetrated at a depth of 688 ft, 2 ft below the upper contact of the basalt. The water in this zone is unconfined. The assignment of this basalt to the Santa Fe Group is provisional until an age date can be obtained, but it appears to correlate with thick Santa Fe Group basalts identified near the top of the Santa Fe Group in PM-1, 1 km to the south.
- At present, we believe the regional aquifer in R-9 is represented by groundwater at 688 ft depth. The origin and nature of the saturated zones at 579 ft and 624 ft is less certain. The static water level for the saturated zones at 579 ft and 624 ft depths is 524 ft, and these zones must be hydraulically connected. Overall, the zones at 579 and 624 ft depth have similar major cation and anion compositions supporting the interpretation that these zones are interconnected somewhere upgradient of this site. The difference in pressure heads between 579/624 ft and 688 ft may reflect release of pressure in the 688 ft zone from pumping of nearby water-supply wells. For example, PM-1 is 1 km south of R-9, and it has been producing 30,000,000 to 100,000,000 gals

of water a year for the county and Laboratory since 1965. Overall, water levels in this part of the Laboratory have declined 80 ft since the Laboratory's wells were first installed (Rogers et al, 1996). The pumping may have more strongly affected the 688 ft which may be more strongly interconnected with the producing zones than the saturation zones at 579 and 624 ft depth which are somewhat decoupled from the deeper system because of the tuffacaceous aquitards (Figures 3-11 and 3-12).

- Four groundwater zones were encountered at depths of 579, 615(?), 624, and 688 ft bgs within the Puye Formation (regional aquifer) at borehole R-9. These four groundwater zones are characterized by different major ion chemistries. The upper three zones may represent dewatering of the regional aquifer because the drawdown is estimated to be approximately 75 feet since pumping of nearby supply wells PM-1, PM-3, and O-4 began in the mid 1960s and in 1990. The upper saturated zone is characterized by a Ca^{2+}-Na^{+}-HCO_3^- ionic composition with a TDS content of 313 ppm, including dissolved silica (Figure 3-13). The second saturated zone is characterized by an overall Na^{+}-Cl^- ionic composition with a TDS content of 677 ppm, including dissolved silica (Figure 3-13). This second saturated zone has unique chemistry as evidenced by elevated sodium (167 ppm) and chloride (177 ppm) concentrations. Calcium and HCO_3^- are present in lower concentrations in the second saturated zone. The third saturated zone is characterized by a Na^{+}-Ca^{2+}-HCO_3^- ionic composition with a TDS content of 258 ppm, including dissolved silica (Figure 3-13). Sulfate and Cl^- are also present in this groundwater. The lower-most saturated zone is characterized by a Ca^{2+}-Na^{+}-HCO_3^- ionic composition with a TDS content of 353 ppm, including dissolved silica. The Puye Formation groundwaters (579, 624, and 688 ft bgs) have TDS contents less than the lower perched zone in the basalt and slightly higher than that of the upper perched zone (compare Figures 3-10 and 3-13). The ionic compositions of the Puye Formation groundwaters are dissimilar to the two perched zones within the overlying basalt flows.
- Two of the four groundwater zones in the Puye Formation, at 579 and 688 ft bgs, in borehole R-9 have major ion chemistries similar to those of supply wells PM-1 and PM-3 (Figure 3-13). Groundwater chemistries in the Puye Formation (R-9), however, are different from those characteristic of TW-1, TW-3, and O-1.
- Concentrations of dissolved nitrate (as NO_3) in the uppermost saturated zone are 10.6 ppm, which is elevated to other wells completed in the Puye Formation (excluding TW-1) and the Santa Fe Group sediments (Figure 3-13). Concentrations of this solute decrease with depth ranging from 3.41 to 8.66 ppm.

Alluvial-Puye Formation Groundwater in Pueblo Canyon

- Alluvial-Puye Formation groundwater in lower Pueblo Canyon at PO-4 (plugged) is characterized by a Na^{+}-Ca^{2+}-Cl^--HCO_3^- ionic composition (Figure 3-14), with increasing concentrations of nitrate and phosphate occurring downstream and downgradient of the Bayo sewage treatment plant discharge.
- Native groundwater in the alluvium probably occurs in the upper reaches of Pueblo Canyon, however, its chemical composition is not known. Characterization well LAO-B serves as a surrogate background well for Pueblo Canyon. Characterization well PO-4 contains elevated concentrations of chloride, sodium, nitrate, phosphate, and sulfate relative to LAO-B (Figure 3-14); however, all solutes are below their respective MCLs.

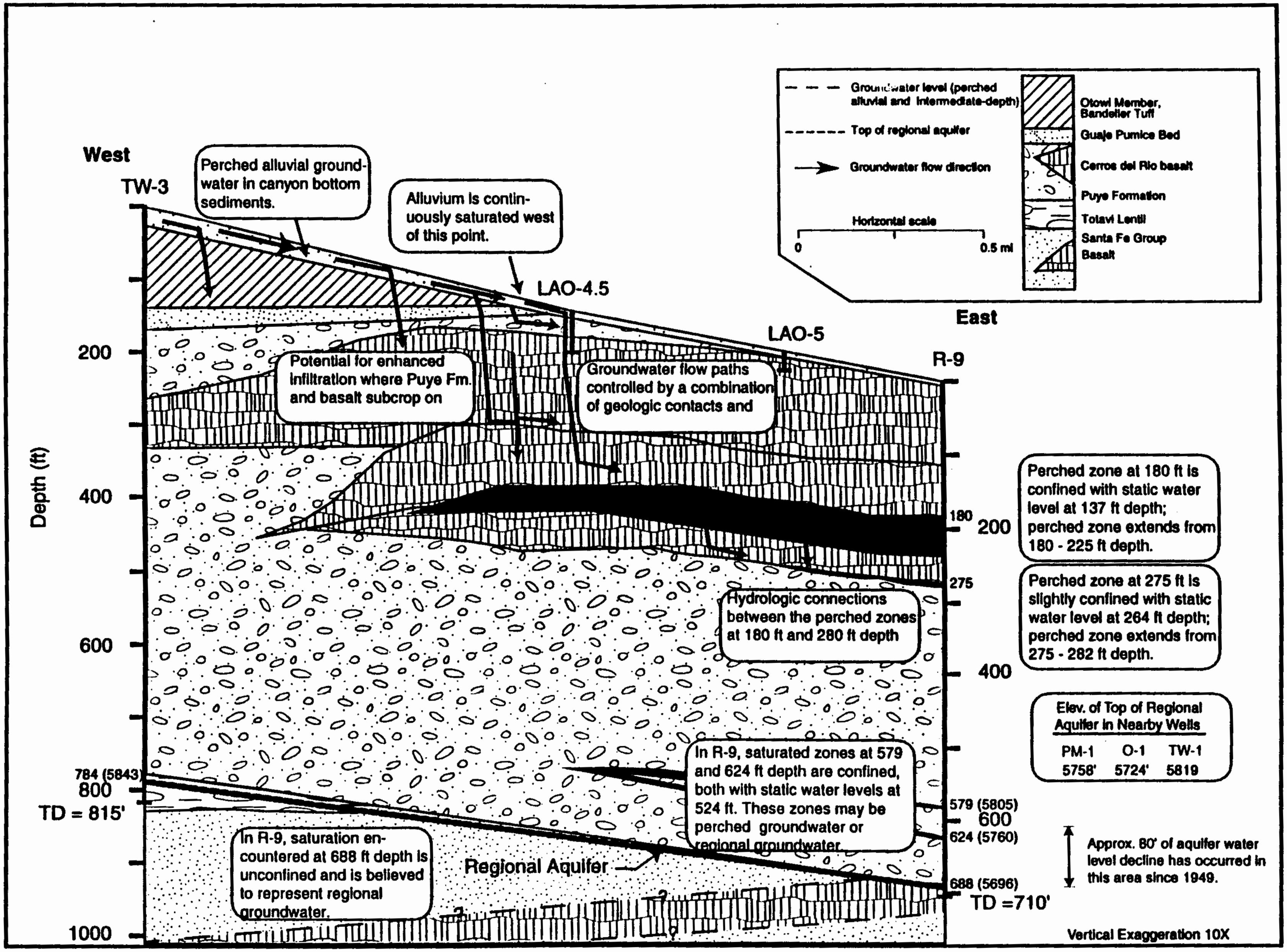


Figure 3-11. East-West Cross Section in Upper Los Alamos Canyon

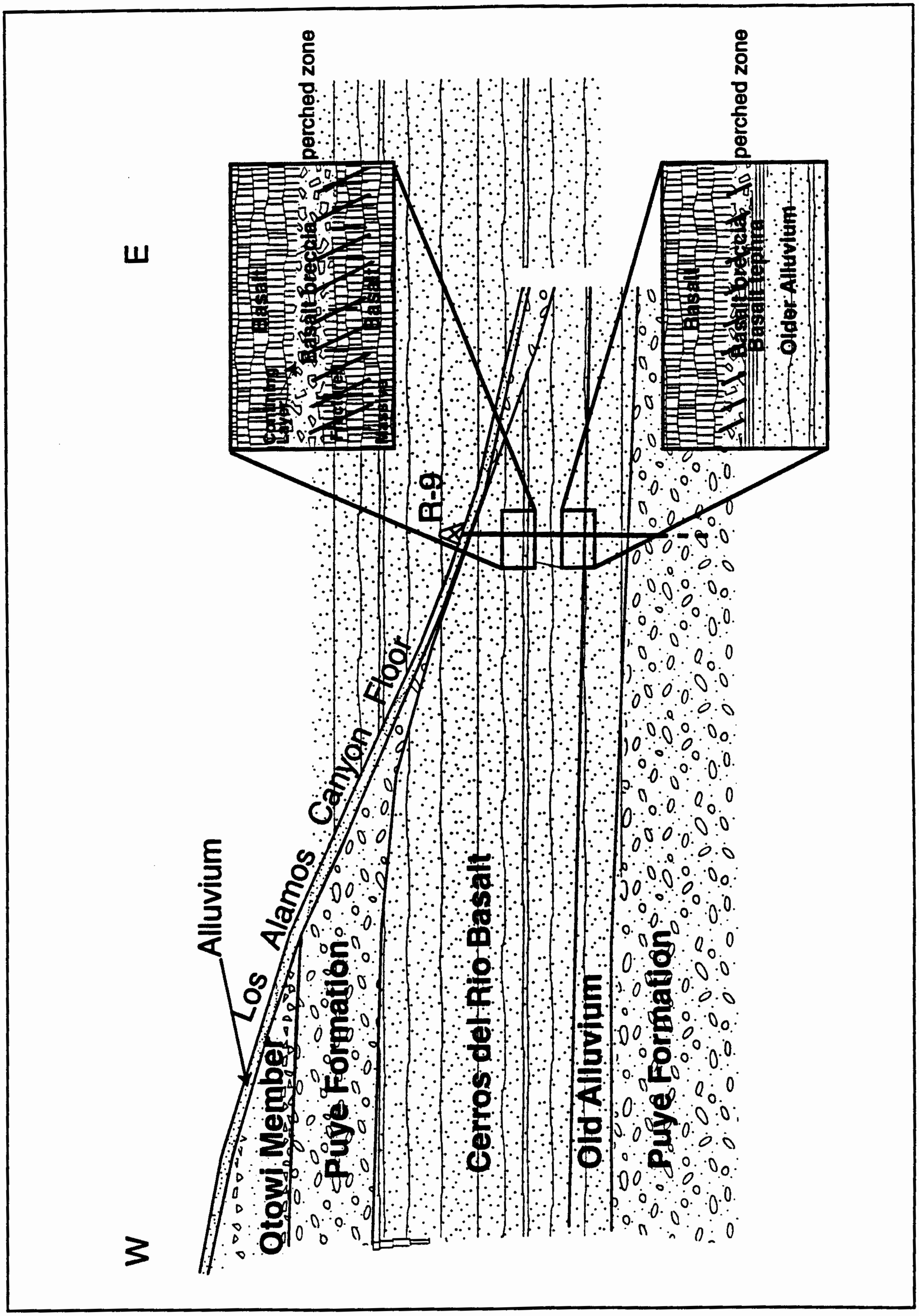
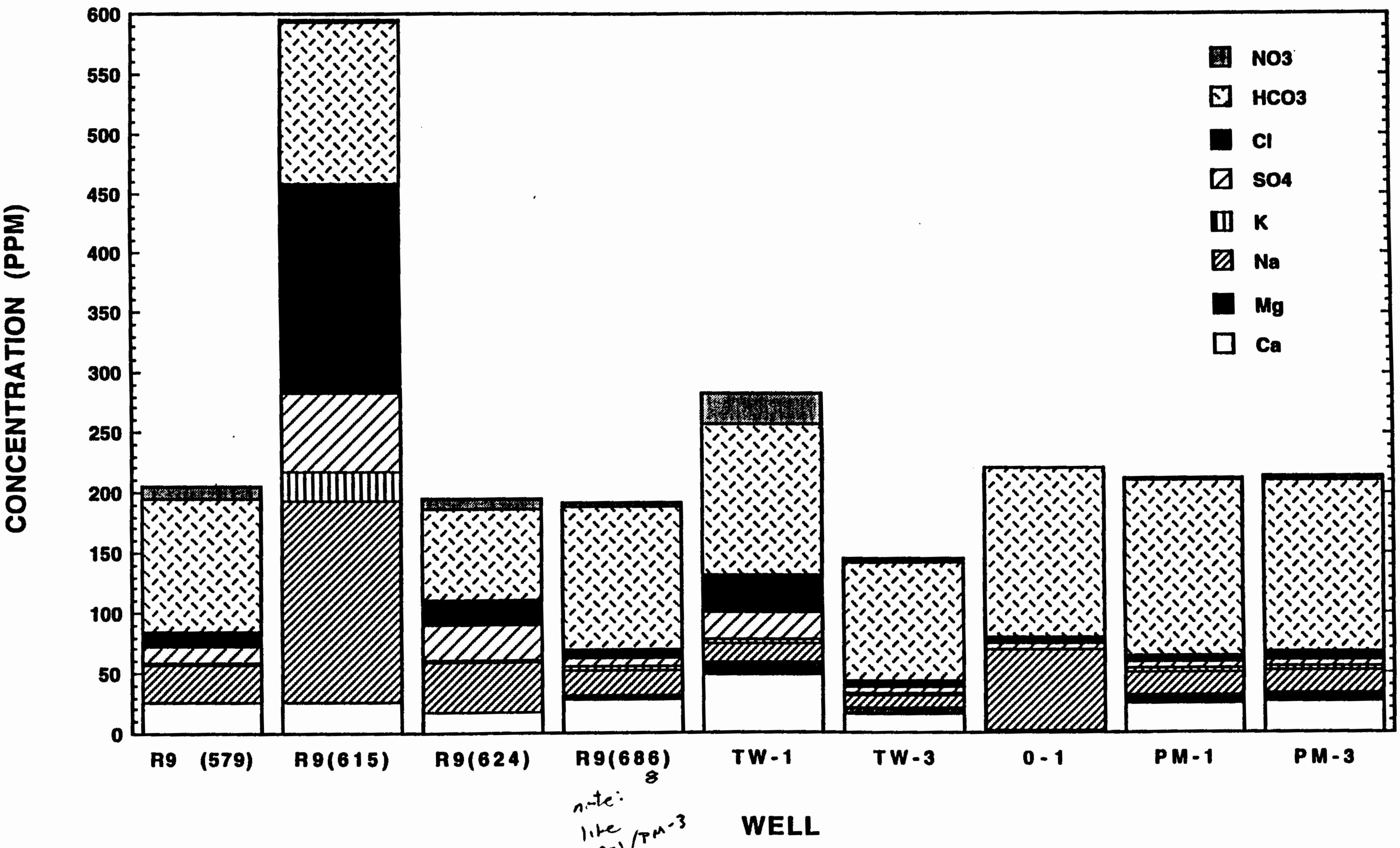


Figure 3-12. Perched Zones in the Cerros del Rio Basalt.

FIGURE 3-11. MAJOR ION AND NUTRIENT CHEMISTRIES OF THE PUYE FORMATION (R9, TW-1, TW-3) AND SANTA FE GROUP SEDIMENTS (PM-1, PM-3, O-1) GROUNDWATERS.



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- Activities of tritium measured at PO-4 are approximately 26 pCi/L, which are within the range of rainfall and snowmelt (Adams et al., 1995) and background springs (Blake et al., 1995). Activities of radionuclides (^{90}Sr, ^{238}Pu, $^{239, 240}Pu$) in PO-4 are less than 1 pCi/L and are below DOE derived concentration guidelines (DCGs) for drinking water systems.
- East of the Bayo sewage treatment plan, alluvial groundwater recharges the Puye Formation and underlying the basalt flows, which discharges at Basalt Spring in lower Los Alamos Canyon. This spring is characterized by elevated concentrations of chloride, nitrate, phosphate, boron, and other major cations and anions and its chemistry is similar to that of the Bayo sewage treatment plant. Concentrations of these species discharging at Basalt Spring, however, are below NMWQCC and EPA drinking water standards.

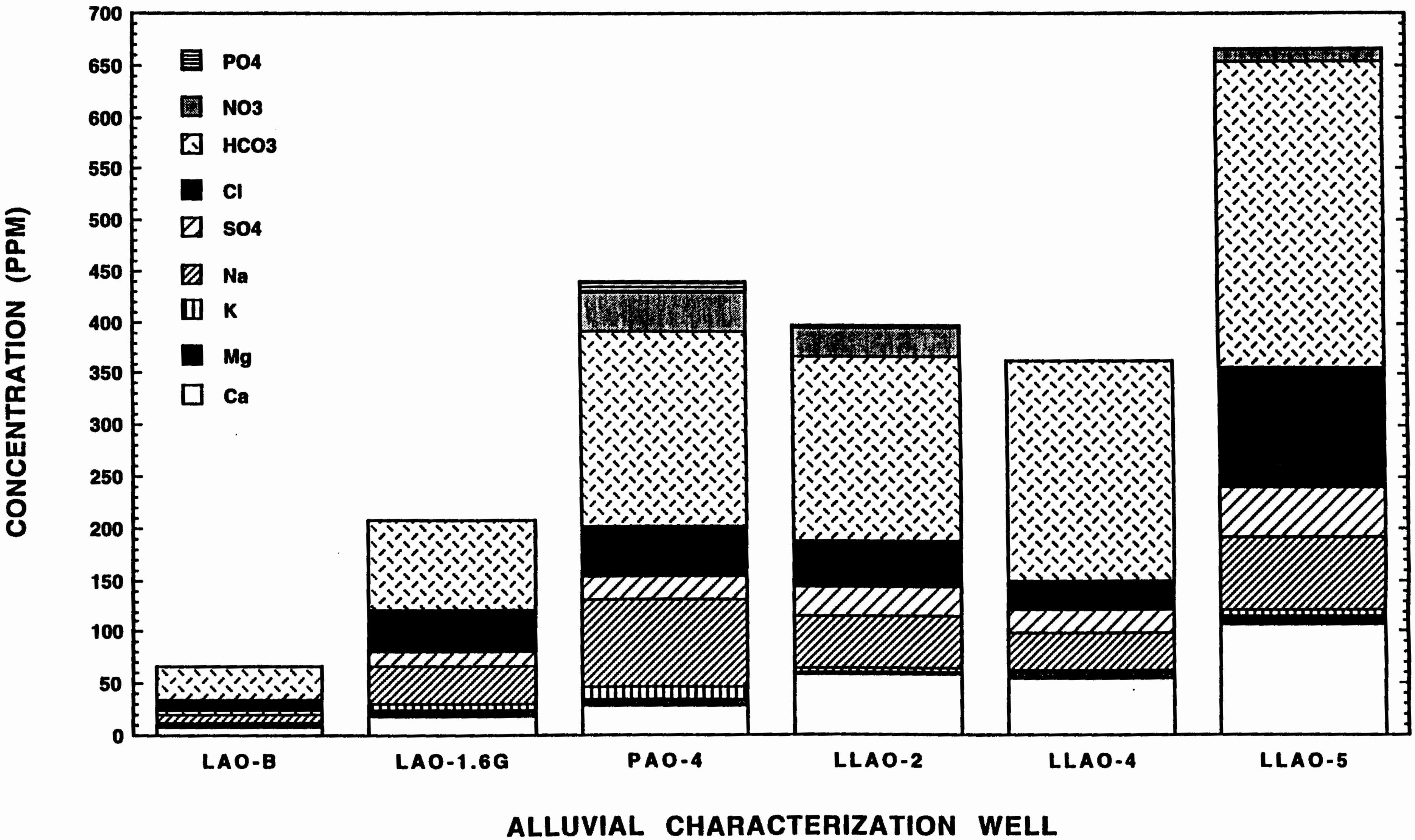
Perched (Basalt) Groundwater in Pueblo Canyon

- Perched groundwater was encountered at a depth of 159 ft bgs within the basalt at characterization well POI-4 in lower Pueblo Canyon, immediately north of supply well Otowi-1. This groundwater is characterized by a Ca^{2+}-Na^{+}-HCO_3^{-} ionic composition (see Figure 3-10). Groundwater collected from POI-4 is chemically similar to alluvial-Puye Formation groundwater (characterization well PAO-4) in lower Pueblo Canyon (compare Figures 3-10 and 3-14), confirming a hydraulic connection between the hydrogeologic media. Groundwater collected from both TW-1A and POI-4 are also similar in chemical composition and continuous saturation in the basalt between the two wells is likely.
- Characterization well POI-4 and monitor well TW-1A (ESH, 1997) contain elevated above background (Spring 9B) concentrations of boron, chloride, fluoride, sodium, nitrate, phosphate, and sulfate with respect to Spring 9B (ESH, 1997).
- Activities of tritium measured at POI-4 are 81 pCi/L, which is elevated above the range of rainfall and snowmelt (Adams et al., 1995) and background springs in the Los Alamos area (Blake et al., 1995). Activities of radionuclides (^{90}Sr, ^{238}Pu, $^{239, 240}Pu$) in groundwater samples collected at POI-4 are less than 1 pCi/L and are below the DOE derived concentration guidelines (DCGs) for drinking water systems.

Alluvial Groundwater in Lower Los Alamos Canyon

- Alluvial groundwater in lower Los Alamos Canyon is derived from several sources including: 1. storm-water flow in upper Los Alamos, Pueblo, Bayo, and Guaje Canyons; 2. discharges from the Bayo sewage treatment plant in Pueblo Canyon; 3. spring discharges in lower Los Alamos Canyon; potential underflow from Guaje and Bayo Canyons; 5. inflow from the Rio Grande; and 6. upward vertical movement of regional aquifer groundwater east of the confluence of Guaje and Los Alamos Canyons.
- Alluvial groundwater in lower Los Alamos Canyon (LLAO-2, LLAO-4, and LLAO-5) is characterized by a Ca^{2+}-Na^{+}-Cl^{-}-HCO_3^{-} ionic composition, with increasing concentrations of Cl^{-}, HCO_3^{-}, Ca^{2+}, and Na^{+} concentrations occurring east of LLAO-2 (Figure 3-14). This increase in major ion concentrations probably reflects mixing of regional aquifer groundwater (LLAO-5) (Figure 3-14).
- Activities of radionuclides (^{90}Sr, ^{238}Pu, $^{239, 240}Pu$) in groundwater samples collected in lower Los Alamos Canyon generally are less than 1 pCi/L and are below the DOE derived concentration guidelines (DCGs) for drinking water systems.

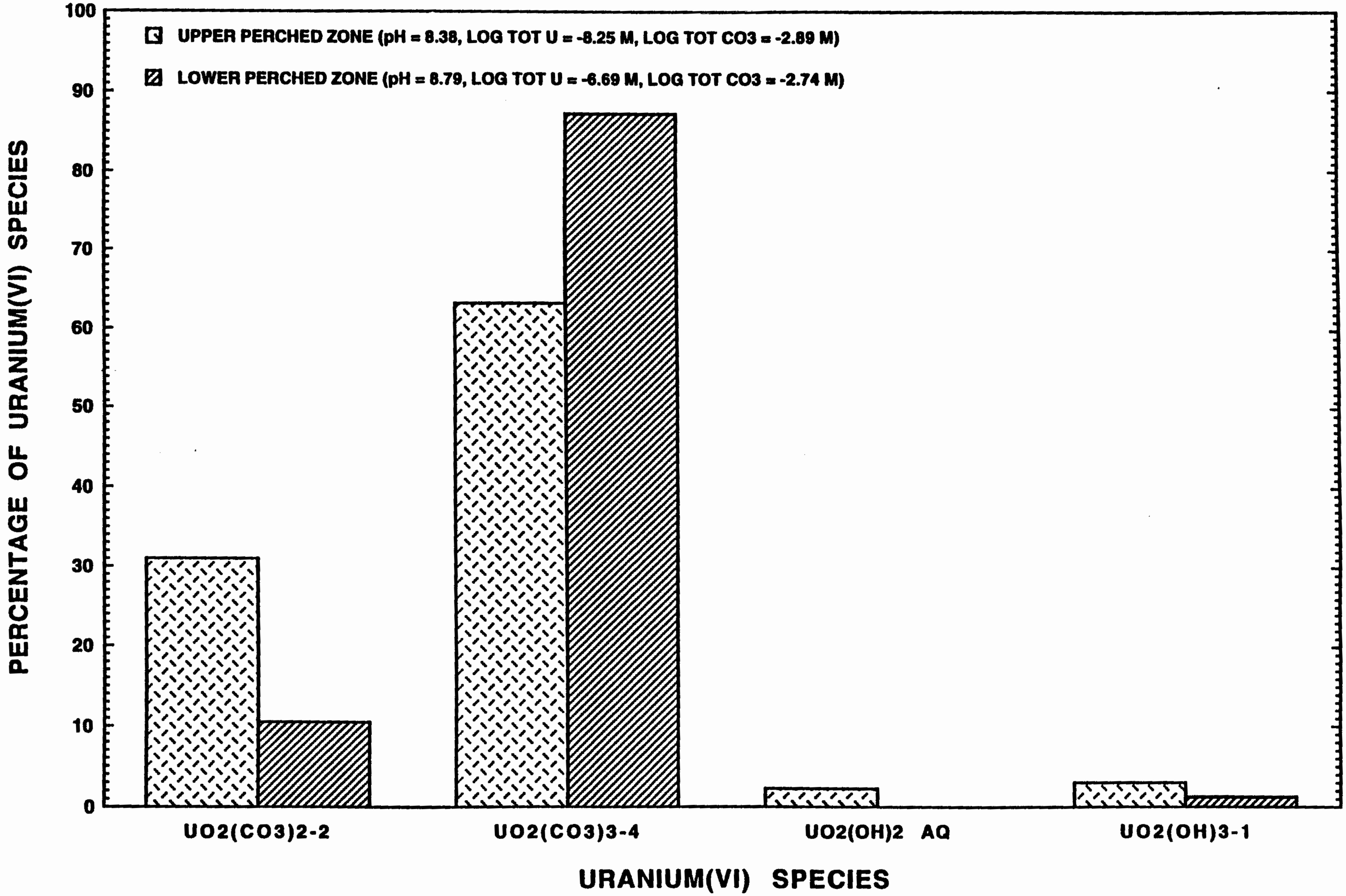
FIGURE 3-14 MAJOR ION AND NUTRIENT CHEMISTRIES OF ALLUVIAL GROUNDWATERS WITHIN LOS ALAMOS AND PUEBLO CANYONS.



Geochemical Modeling

- Geochemical modeling is used to assess what reactions or processes are important and to what extent will they occur; quantifying contaminant mobility and toxicity by considering contaminant speciation; and delineating flow paths and mixing of groundwaters. This knowledge is used to assess uncertainty in risk estimates, although the nature of the risk can be site specific within each canyon.
- Calculations of solute speciation, PCO_2, and solid phase saturation indices were made using the computer code MINTEQA2 (Allison et al., 1991). Solid-solution phase calculations were performed with the computer code MINTEQA2 (Allison et al., 1991) using analytical results obtained from filtered (less than 0.45 µm) alluvial, perched intermediate, and regional aquifer groundwater samples collected in 1994, 1995, 1996, and 1997. The purpose of the calculations was to assess the importance of precipitation reactions and to determine speciated forms of natural and anthropogenic solutes. The saturation index (SI) is a measure of the degree of undersaturation or oversaturation of a solid phase in water [$SI = \log_{10}$ {activity product/solubility product}; at equilibrium $SI = 0 \pm 0.5$].
- Calculations using MINTEQA2 suggest that dissolved strontium (^{90}Sr) in alluvial groundwater in upper Los Alamos Canyon is stable as Sr^{2+}.
- Alluvial groundwater in upper Los Alamos Canyon is predicted to be undersaturated with respect to solid strontium sulfate and carbonate phases and precipitation of these two minerals is unlikely.
- Results of geochemical modeling infer that rather than precipitating as a stoichiometrically-pure phase, Sr^{2+} probably undergoes cation exchange reactions with different adsorbents including solid organic matter, amorphous solids, and clay minerals. In addition to cation exchange, radioactive decay and hydrodynamic dispersion and mixing partially account for the decreased activity of ^{90}Sr observed along the groundwater flow path in the alluvium in upper Los Alamos Canyon.
- Results of geochemical modeling using MINTEQA2 suggest that alluvial groundwater at TA-2 approaches equilibrium with respect to amorphous $Cr(OH)_3$. The solubility of amorphous $Cr(OH)_3$ and lack of complete adsorption, however, could both account for the elevated above background concentrations of chromium (0.011 ppm) observed in groundwater at LAO-0.91 and LAO-1.
- To examine the speciation of uranium, MINTEQA2 (Allison et al. 1991), supplied with the Nuclear Energy Agency critically evaluated uranium database, was used to determine possible stable dissolved species of this solute. Calculations suggest that uranium [U(VI)] is stable mainly as $UO_2(CO_3)_2^{2-}$ with small percentages of $UO_2CO_3^0$ and $UO_2(CO_3)_3^{4-}$ between pH values of 6.8 and 7.6 (Longmire et al., 1996) typical of most groundwaters at LANL. At higher pH values (8.5-8.8) indicative of the basalt groundwaters, $UO_2(CO_3)_3^{4-}$ is predicted to be the dominant complex under oxidizing conditions (Figure 3-15). This complex is mobile and does not adsorb completely onto surfaces of reactive minerals or solid phases including $Fe(OH)_3$ and FeOOH (Ho and Miller 1986, Hsi and Langmuir 1985; Langmuir, 1997, Waite et al. 1994). The complex, $U(OH)_4^0$ is predicted to be the dominant species for uranium under reducing conditions within the basalt groundwaters. Uranium is less mobile under reducing conditions, forming low soluble solid phases including UO_2 and $USiO_4$.

FIGURE 3-15. CALCULATED DISTRIBUTION OF URANIUM(VI) SPECIES (MINTEQA2) IN THE UPPER AND LOWER PERCHED ZONES WITHIN BASALT, R-9 BOREHOLE.



- Although the groundwater flow rate in the alluvium in upper Los Alamos Canyon is substantial (274 m/yr, Gallaher, 1995), it is clear from this discussion and data presented by Longmire et al. (1996) and Longmire et al. (1997) that a complete flushing of ^{90}Sr, chromium, uranium, and other reactive solutes within the alluvium in upper Los Alamos Canyon has not occurred. Varying concentrations of contaminants remain in the sediments and in alluvial and perched-intermediate groundwaters (including vadose zones) in upper Los Alamos and DP Canyons. Trends in the data also suggest that residual releases may occur from the source inventories at former TA-1,TA-2, TA-21, and TA-41.
- Groundwater flow paths from the alluvium through the underlying vadose zones to perched intermediate systems are not well delineated. Tritium, chloride, uranium, and other solutes are detected in groundwater in basalt flows at depths up to 282 ft bgs in upper Los Alamos Canyon (borehole R-9). Chloride, tritium, and nitrate are detected within the Puye Formation at borehole R-9.
- Residual contamination remains in Pueblo Canyon from past discharges that occurred in Acid Canyon (^{239}Pu, ^{90}Sr, tritium) from operations at the former TA-45. The Bayo sewage treatment plant discharges treated sewage effluent to lower Pueblo Canyon, which provides recharge to the alluvium, Puye Formation, and basalts. The effluent contains nitrate, phosphate, boron, and other solutes at concentrations below their respect MCL values. This effluent is a component of both water discharging at Basalt Spring and alluvial groundwater in lower Los Alamos Canyon.
- Discharges from the Bayo sewage treatment plant are observed in alluvial groundwater in lower Los Alamos Canyon. Tritium occurs at activities less than 100 pCi/L in lower Los Alamos Canyon. Activities of ^{90}Sr, ^{241}Am, and plutonium isotopes are less than 5 pCi/L in this section of Los Alamos Canyon. Additional characterization wells installed in Los Alamos and Pueblo Canyons will greatly help in determining water chemistry and groundwater flow paths within and beneath the alluvium.
- The mobilities of strontium, uranium, chromium, americium, and plutonium have not been quantified with existing data. These contaminants have been identified in alluvial groundwater. In addition, uranium has been detected in borehole R-9 within two basalt groundwaters. It is recommeded that sorption constants (distribution coefficents) be determined using LANL-specific hydrogeologic materials for performing risk analysis.

3.2.1.4 Aggregate 1 FY98 Planned Activities

The planned hydrologic and geochemical investigations for Los Alamos and Pueblo Canyons (alluvial and perched groundwater and regional aquifer) for FY1998 consist of the following:

- Drill, log, sample, and install regional aquifer well R-7. R-7 will be located in upper Los Alamos Canyon, south of TA-21. It will provide water-quality and water-level measurements for the intermediate perched zones and the regional aquifer in an area of Los Alamos Canyon that is in close proximity to release sites of contaminated effluent (TA-2 and TA-21). R-7 is located between two existing boreholes (LADP-3 and LAOI(A)1.1) that penetrated the thickest known intermediate perched zone on the Pajarito Plateau. This perched zone occurs in the Guaje Pumice Bed at the base of the Bandelier Tuff and on top of the Puye Formation. Based on differences of tritium in LADP-3 and LAOI(A)-1.1, a recharge zone is hypothesized to lie between them. The location of R-7 was selected to identify the recharge zone. Drilling of R-7 will begin in September, 1998.

- Collect hydrologic and geochemical data for groundwater, vadose zone, and aquifer material from previously installed and planned characterization wells (LAO-B, LAO-0.3, LAO-0.6, LAO-0.8, LAO-0.91, LAO-1.6G, LAOI-1.1, LADP-3, LLAO-1, LLAO-2, LLAO-3, LLAO-4, LLAO-5, PAO-1, PAO-2, PAO-3, PAO-4, PAO-5N, PAO-5S, APCO-1, POI-4, and R-9),

- Prepare water table maps for the alluvium and perched intermediate zones and regional aquifer.

- Refine the hydrologic models (conceptual and analytical) for Los Alamos and Pueblo Canyons, including water balance and flow modeling.

- Assess distributions of ^{241}Am, ^{90}Sr, uranium, ^{238}Pu, and $^{239, 240}$Pu in alluvial and perched intermediate (if present) groundwaters,

- Characterize geochemical properties of aquifer material (alluvial and perched intermediate groundwater and the top of the regional aquifer) related to transport and natural attenuation,

- Quantify sorptive capacities of aquifer material,

- Perform geochemical modeling (speciation, mineral precipitation, and adsorption), and

- Provide hydrochemical data (speciation, sorption constants) for an initial pathway analysis and perform geochemical and solute-transport modeling, if sufficient and technically-defensible data are available.

- These data will be collected as part of the ER Canyons investigations for the next several years. Detail discussion of hydrologic and geochemical data collected as part of the canyons investigations are presented in the Los Alamos and Pueblo Canyons workplan.

- In Sandia Canyon, the planned FY98 activities include the drilling and installation of well R-12. This well will be located at the eastern boundary of the Laboratory. It is intended to provide water quality and water level data for perched intermediate zones and for the regional aquifer down gradient of Aggregate 1. It also serves as a water supply protection well for PM-1. R-12 drilling will begin in March, 1998.

3.2.2 Aggregate 2

Aggregate 2 is located in the east-central portion of the Laboratory and encompasses the technical areas where chemical and radioactive waste management is routine operations. The general boundaries of the aggregate are Pajarito Canyon on the south, Canada del Buey to the north, TAs-18 and -51 to the west, and the Laboratory boundary along State Road 4 to the east (Figure 3-16).

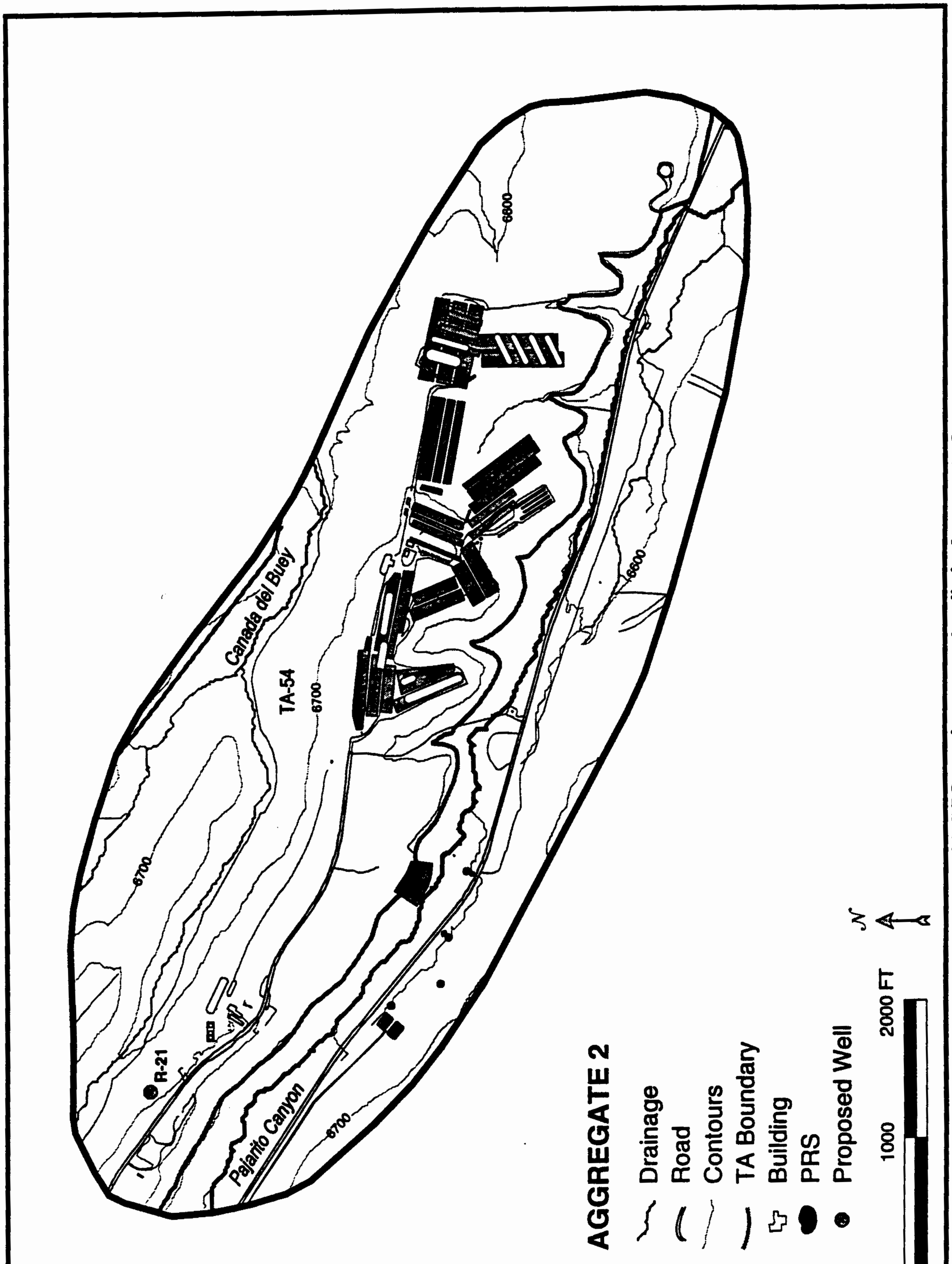


Figure 3-16. PRSs and proposed wells in Aggregate 2.

3.2.2.1 *Aggregate 2 FY97 Investigations*

TA-18

- Groundwater activities at TA-18 during FY 97 included drilling five additional alluvial wells for investigating possible VOC contamination near a septic system. Two quarters of validated data and three additional quarters of provisional data indicate no detections of VOCs.

- Two gaging stations have been added in Pajarito and Three Mile Canyons to determine surface water flows.

TA-54

- The "Performance Assessment and Composite Analysis for Los Alamos National Laboratory Material Disposal Area G" was completed in March. This report includes several studies reflecting our understanding of groundwater flow and transport beneath mesa top settings at the Laboratory. The report estimates dose to the public for a 1000-yr period beginning after assumed facility closure in 2044. The performance objectives evaluated include two limits associated with groundwater: a maximum effective dose equivalent of 25 mrem/yr resulting from external exposure and concentrations of radioactive material released into surface water, groundwater, soil, plants, and animals; and a maximum effective dose equivalent of 4 mrem/yr from drinking water. The analysis showed that MDA G is expected to meet these and other required performance objectives. The calculated dose for all pathways was 1×10^{-4} mrem/yr (compared to a 25 mrem/yr limit). The calculated dose for groundwater was 3.5×10^{-5} mrem/yr (compared to a 4 mrem/yr limit).

- The ER Project continued pore gas monitoring at TA-54. Waste Management personnel monitored subsurface moisture using neutron probe measurements.

3.2.2.2 *Aggregate 2 Conceptual Model Refinement*

The refinements to the conceptual model for Aggregate 2 are shown on Figure 3-17.

TA-18

The conceptual model for alluvial water in TA-18 was partially confirmed by the work completed during this year. The depth to alluvial groundwater in this area of the canyon was 1 to 10 feet. The alluvium was not fully penetrated, so the thickness of the saturated zone has not been confirmed. The quality of the alluvial water meets state standards.

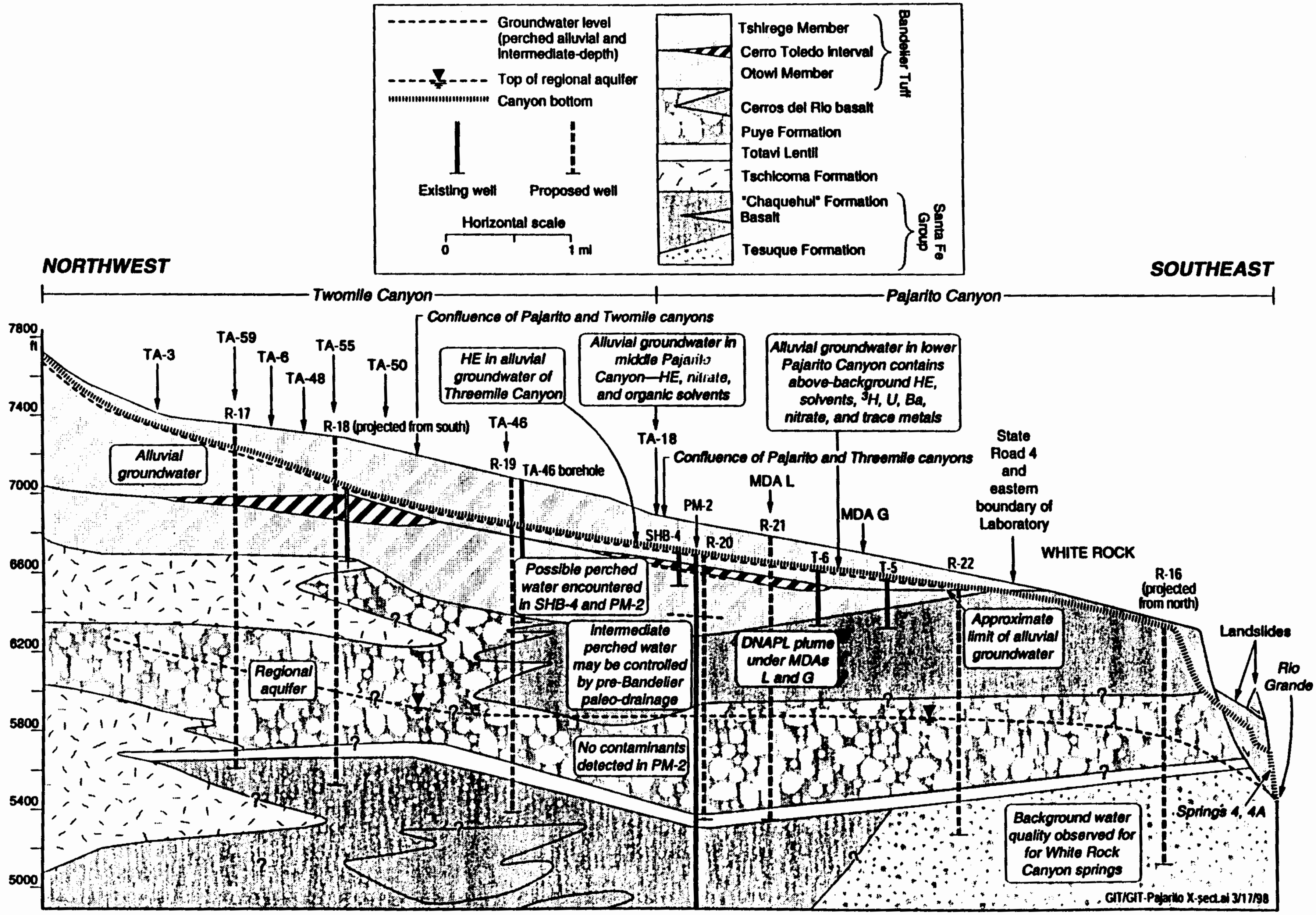


Figure 3-17. Schematic cross section showing conceptual model and proposed regional aquifer wells for Pajarito and Twomile canyons.

- Lateral diversion of flow could occur beneath the mesa at the Guaje Pumice Bed and within the underlying basalt.

- Pore water extracted from cores beneath the mesa has a high pH (about 9.8) and a high carbonate content. This has important implications for both mineral phases that precipitate on the rock matrix, and for the chemical speciation of radionuclides traveling with pore water. The pore water is over saturated with respect to calcite, which enhances the sorptive capacity of the tuff for the most important mobile sorbing radionuclides, Am and Np.

- Groundwater flow and transport modeling studies estimated the flux of radionuclides through the mesa towards the aquifer below. Due to high sorption capacities of the Bandelier Tuff and long travel times relative to their half-lives, most radionuclides are not predicted to penetrate the subsurface sufficiently to be considered in dose calculations. Only ^{14}C, ^{99}Tc, and ^{129}I were estimated to be of concern for the groundwater pathway over a 10,000 yr period.

3.2.2.3 Aggregate 2 FY98 Planned Activities

TA-18

- An additional background alluvial well will be drilled in Three Mile Canyon above TA-18. Water level and water quality measurements will be made at 15 alluvial wells over the next year. This information along with results from gaging stations in Pajarito and Three Mile Canyons above TA-18 and one in Pajarito Canyon below TA-18 will be used to evaluate the alluvial groundwater flow system in the area.

- A workplan for Pajarito Canyon is being prepared in FY98. Development of the workplan is coordinated with TA-18 investigations.

TA-54

Pore gas monitoring and neutron probe measurements will continue.

3.2.3 Aggregate 3

Aggregate 3 is located in the south central portion of the Laboratory and consist of Technical Area (TA)-49 on Frijoles Mesa. Aggregate 3 is bounded by Water Canyon on the north, State Road 4 on the south, TA-39 is the east boundary, and TA-16 is on the west (Figure 3-18).

3.2.3.1 Aggregate 3 FY97 Investigations

MDA AB (TA-49)

- Natural chloride and stable isotope tracers were used to examine vadose zone hydrology at boreholes 49-2-700-1 and TDBM-1 (Newman et al., 1997). Pore water chloride concentrations were measured with depth from core samples in both boreholes, and delta 18-O and delta deuterium were measured for borehole 49-2-700-1.

water in RFI
summary report on Vadose Zone
coming (like TA-21

TA-54

The following groundwater and geochemical conceptual model refinements resulted from studies supporting the MDA G Performance Assessment:

- Recharge through the mesa is very low. At the mesa surface, evapotranspiration consumes about 90% of precipitation on the mesa top, so little water is left for runoff or percolation. Mean annual calculated percolation beneath the surface is about one mm/yr.

- Moisture content in the top 4 to 5 meters of the mesa subsurface is about 8% to16% by volume and shows seasonal variation. Moisture content beneath depths of 4 to 5 m is very low: about 0.5% to 2% by volume.

- Evaporation within the mesa further decreases recharge and inhibits downward flow. A low moisture content zone near the base of Tshirege Unit 2 appears to result from drying by air movement through the tuff or through joints and surge bed deposits. This conclusion is supported by moisture content measurements and matric suction measurements on core samples. Chloride budget studies based on core sample pore water measurements as well as stable isotope analyses indicate that substantial evaporation occurs at these depths. Chloride budget results are that between 2000 and 17,000 years were required to accumulate chloride present in the portion of the mesa above the Tshirege Unit 1g/1v boundary. Little or no through flow of moisture would have occurred during this time interval. The differing values do indicate lateral heterogeneity within the mesa.

- Adsorption of neptunium and americium is enhanced under vadose zone conditions where sorbing phases including calcium carbonate are present. Conversely, decreased sorption of uranium and plutonium was observed from experimental batch sorption studies.

- Fractures play an important role in movement of air within the mesa, affecting the water balance through evaporation. Fractures in dry rock do not act as conduits for infiltration as the water is drawn from the fractures into the surrounding matrix too quickly. Low permeability fracture coatings can increase the depth of infiltration, but any breaks in fracture coating prevent deep infiltration from being effective. Low permeability fracture fill material prevents water from entering fractures. If water equivalent to four times the MDA G annual precipitation is applied to a coated fracture, an infiltration depth of 10 m can be achieved. Reactive minerals ($CaCO_3$ and $Fe(OH)_3$) are present within some fractures, enhancing the sorptive capacity of the Bandelier Tuff.

- High moisture contents at the vapor phase notch (the Tshirege Unit 1g/1v boundary) are probably the result of differences in tuff texture and mineralogy at this horizon. As high moisture content values are observed at this horizon throughout the Laboratory regardless of its relationship to other topographic features, the moisture contents are probably due to hydraulic property changes rather than to lateral movement of moisture.

- Recharge beneath canyon bottoms adjacent to the mesa is higher: estimated at perhaps 4.4 mm/yr beneath Cañada del Buey and between 20 and 100 mm/yr beneath Pajarito Canyon.

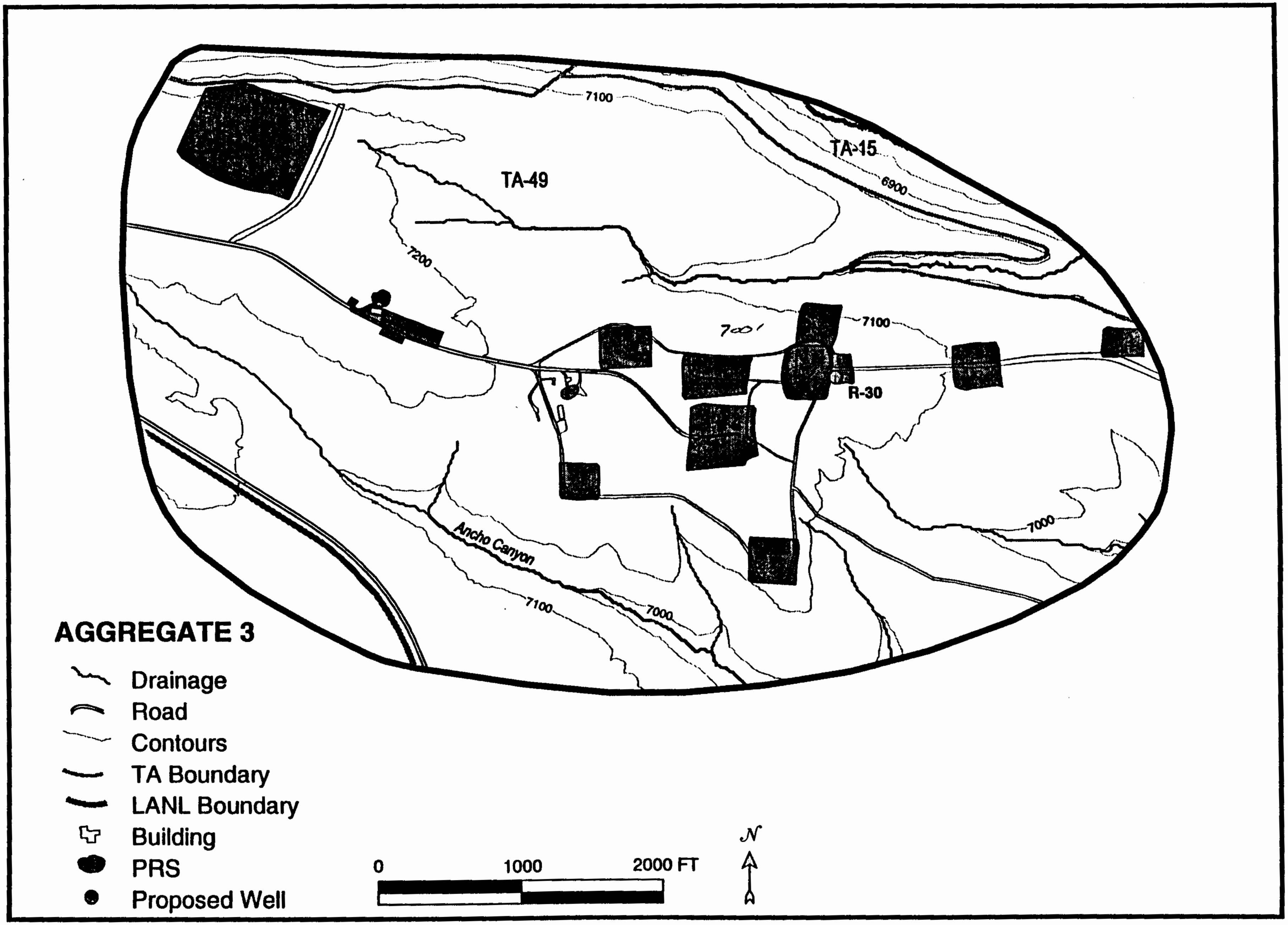


Figure 3-18. PRSs and proposed wells in Aggregate 3 .

- Air permeability measurements were made with downhole packers in borehole 49-2-700-1. Air permeability was measured at 49 measurement locations.

- Downhole anemometry measurements were made to measure air flow from different rock units in borehole 49-2-700-1.

- Borehole 49-2-700-1 was instrumented with psychrometers and platinum resistance temperature sensors to measure seasonal moisture and temperature fluctuations at 11 different depths. The data will be collected over a 6 month period. Early data qualitatively matches matric potential data collected from core samples.

3.2.3.2 Aggregate 3 Conceptual Model Refinement

The conceptual model refinements for Aggregate 3 are shown on Figure 3-19. Flux rates above the Qbt 1g/Qbt 1v contact appear to range from 0.01 to 0.2 cm/y. Below the contact flux rates appear to be higher, ranging from 0.24 to 1 cm/y. These rates may represent past conditions during the Holocene and late Pleistocene. Chloride-based pore-water ages in 49-2-700-1were about 7,000 y at the Qbt 1g/Qbt 1v contact and about 10,000 y near the bottom of the hole. A chloride-based pore-water age in TDBM-1 was about 5,000 y at 109 ft depth. Chloride bulges in profiles for both boreholes are consistent with removal of water from the mesa tens to hundreds of feet below the surface via vertical or horizontal fractures or through high-permeability zones that are exposed on the mesa sides. It appears that the part of the mesa that rises above the elevation of the canyon bottom is prone to higher rates of evaporative removal of pore waters that units below the elevation of the canyon bottom.

3.2.3.3 Aggregate 3 FY98 Planned Activities

Best Management Practice measures to prevent flow from the surface to the subsurface will be implemented at TA-49. Coreholes will be plugged and a surface cap will be installed over Pad 2.

3.2.4 Aggregate 4

Aggregate 4 includes TA-33 and TA-39, Ancho, Indio, Chaquehui canyons which are located in the southwest part of the Laboratory (Figure 3-20). Laboratory facilities and operations occurred on the mesa top at TA-33 and within a canyon setting at TA-39. Ancho and Chaquehui canyons are the principal watershed systems in this aggregate.

3.2.4.1 Aggregate 4 FY97 Investigations

There were no relevant investigation activities conducted at TA-33 or TA-39 during this period.

3.2.4.2 Aggregate 4 Conceptual Model Refinement

The conceptual model for Aggregate 4 is shown on Figure 3-21; however, no conceptual model changes stem from work in 1997.

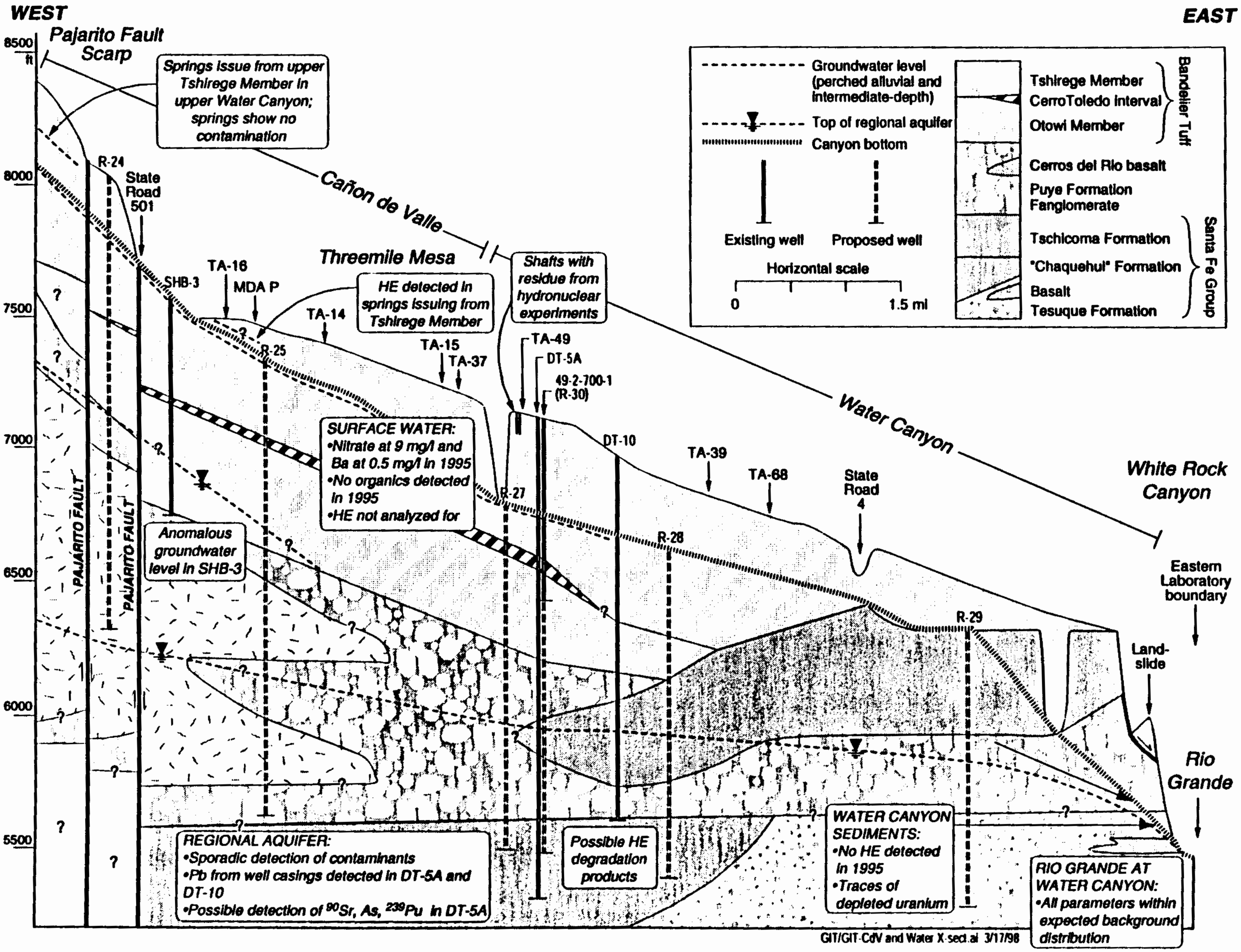


Figure 3-19. Schematic cross section showing conceptual model and proposed regional aquifer wells for Cañon de Valle and Water Canyon.

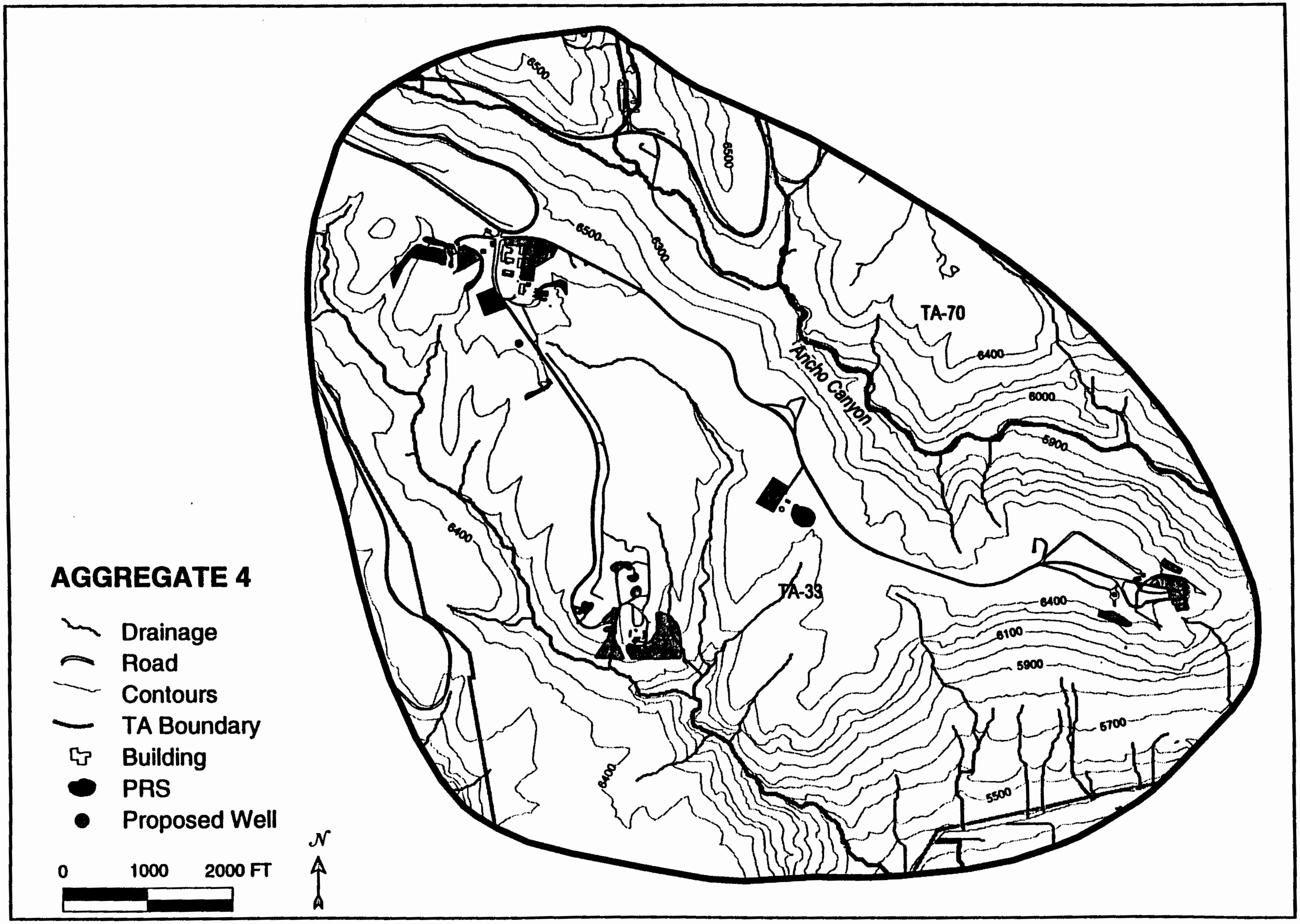


Figure 3-20. PRSs and proposed wells in Aggregate 4.

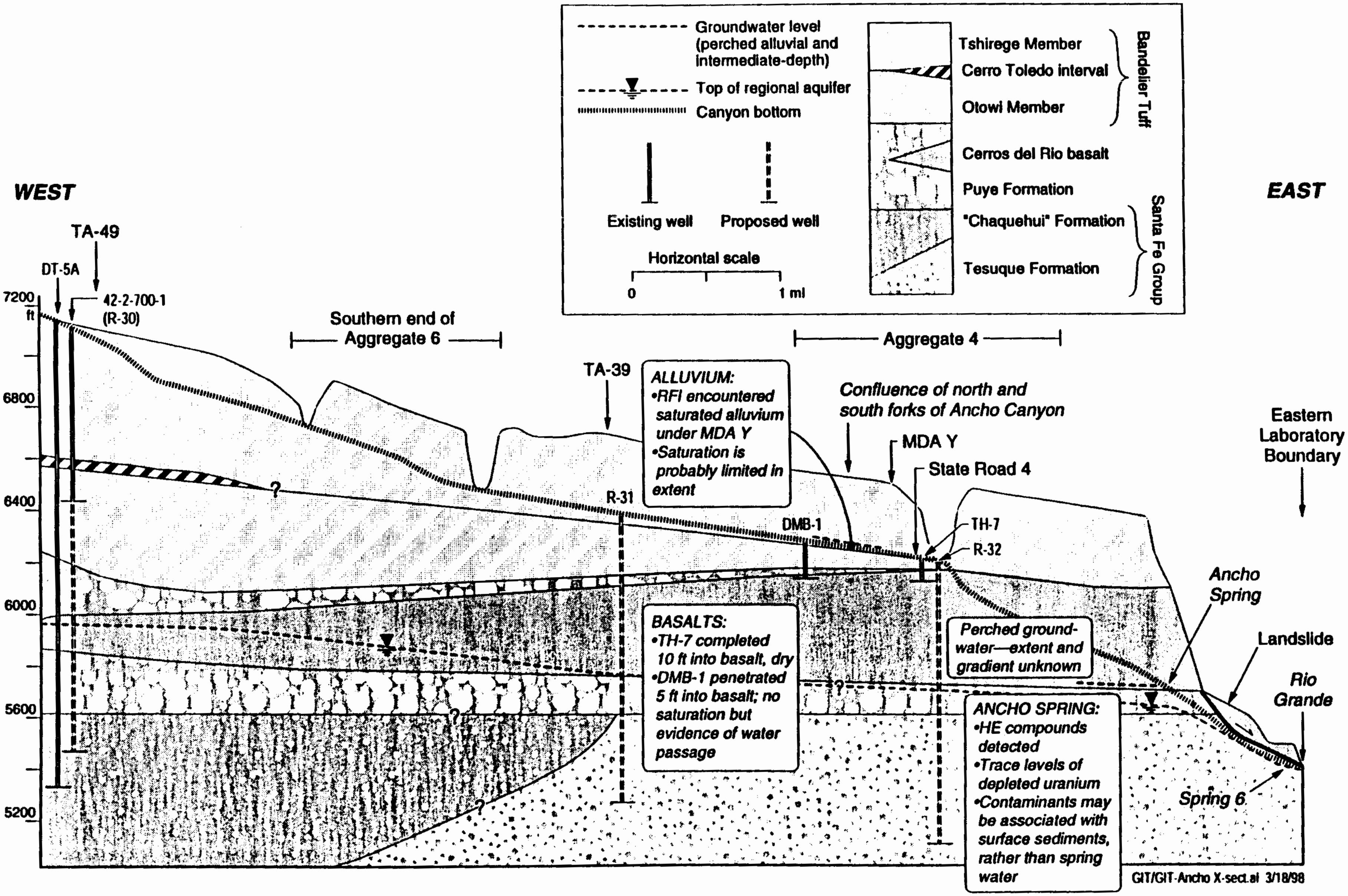


Figure 3-21. Schematic cross section showing conceptual model and proposed regional aquifer wells for Ancho Canyon.

3.2.4.3 Aggregate 4 FY98 Planned Activities

There are no activities planned in this Aggregate for FY 1998.

3.2.5 Aggregate 5

Aggregate 5 is bounded on the south by Water Canyon and on the north by the boundary of TA-9. Cañon de Valle is a tributary to Water Canyon; they join at the east end of TA-16 and form the eastern boundary of Aggregate 5. The western boundary of Aggregate 5 is formed by State Road 501 (Figure 3-22).

3.2.5.1 Aggregate 5 FY97 Investigations

TA-16

- Possible sources were evaluated for the springs in Cañon de Valle and branch canyons (SWSC, Burning Ground, and Martin Springs). The springs contain HE and Ba and discharge at about the Tshirege Unit 3/Unit 4 contact, where there is a lithologic transition between poorly welded Unit 4 overlies densely welded Unit 3. One part of this investigation was to determine whether a perched zone feeding the springs is present beneath the mesa. Such a perched zone could be supplied by recharge from several mesa top sources including the 90s line pond, the steam plant drainage, and the 260 outfall. Additional recharge might come from the Jemez Mountains. The 260 outfall has been turned off and is no longer a potential recharge source. The tracer study and drilling results described below suggest that recharge via preferential flow paths occurred in the outfall drainage.

- Monitoring stations were established at the three springs (SWSC, Burning Ground, and Martin Springs) in March 1997 to measure flow rates and collect periodic samples for analysis. Springs were sampled quarterly for chemistry and daily for bromide.

- A tracer test using bromide was carried out to evaluate whether discharge from the 260 outfall reached the springs. The bromide was released at the 260 outfall in April and breakthrough was observed in SWSC spring in July, after a period of 3 months. Breakthrough was also possibly observed in Burning Ground spring. The very small amounts of bromide measured at Burning Ground spring makes definite determination of breakthrough time difficult.
- Drilled 15 boreholes to depths of about 100 ft, passing through Tshirege Unit 4. Two of the boreholes were drilled to about 200 ft, passing into Tshirege Unit 2. All of the boreholes were essentially dry, although a wet surge bed was found in one hole. Traces of HE were found in cuttings from the holes. One of the two deeper holes was drilled near Martin Spring and found water at a depth about 20 ft below the spring elevation. After a few weeks, this small zone of saturation dried up.

Cañon De Valle

Five alluvial wells have been installed for monitoring of water levels and water quality. Well locations extend from the steam plant drainage downstream to below MDA P.

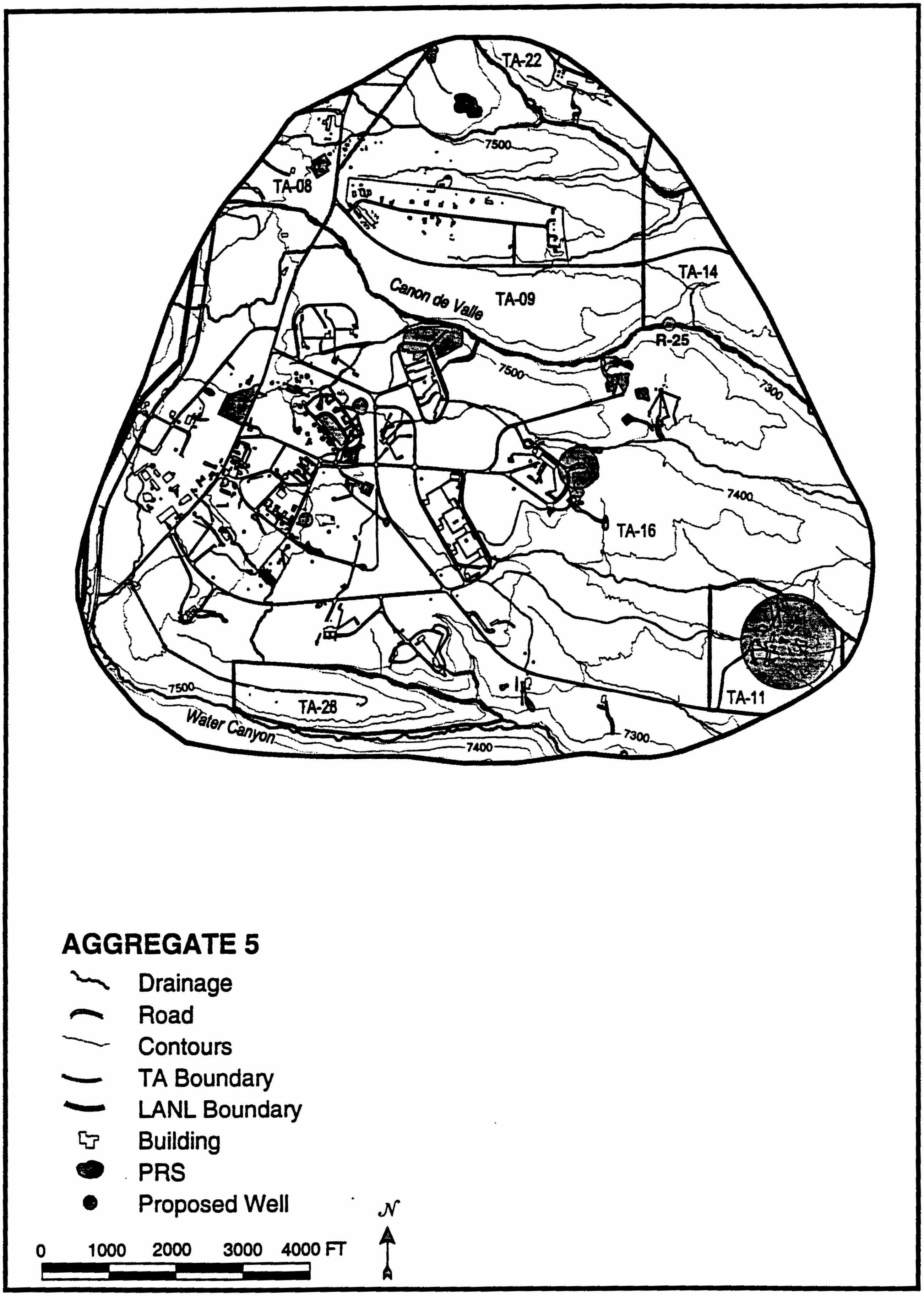


Figure 3-22. PRSs and proposed wells in Aggregate 5.

3.2.5.2 *Aggregate 5 Conceptual Model Refinements*

The conceptual model for Aggregate 5 is shown on Figure 3-19.

TA-16

- A perched zone located beneath the mesa at the Tshirege Unit 3/Unit 4 contact has been hypothesized as a source for springs in the area. If this perched zone exists, its extent may be limited to an area beneath the center of the mesa. Such a perched zone has not been found near the 260 outfall or the three springs discussed (SWSC, Burning Ground, and Martin Springs). Together with drilling results, the tracer study suggests that recharge occurred via preferential flow paths (rather than via a perched zone) in the 260 outfall drainage.

- Based on the tracer data, travel time between the 260 outfall and SWSC spring appears to be 3 months. If the suggestion of elevated bromide in Burning Ground spring is real then the travel time from the outfall to Burning Ground spring is about 6 months. The 260 outfall may have been a source of both water and HE for these springs.

Cañon de Valle

Based on the alluvial wells installed, the thickness of the alluvium is less that 10 feet (6-8 feet is commonly encountered). The alluvial groundwater is 6-8 feet thick and is perched on top of unit 3. Contaminants of concern exceed MCLs and include barium (3 ppm), RDX (0.1ppm) and HMX (0.05 ppm).

3.2.5.3 *Aggregate 5 FY98 Planned Activities*

- Two more deep (about 200 ft) holes will be drilled to determine whether a perched zone is present at the Tshirege Unit 3/Unit 4 contact. These wells will be drilled in mid-mesa positions (between Cañon de Valle and Water Canyon). Any permanent saturation will be monitored. The springs and alluvial wells will continue to be monitored for contaminants and bromide.

- Regional aquifer well R-25 will be drilled in 1998. The borehole will be located adjacent to Area P. The purposes of this borehole are 1) to provide reference stratigraphy for a large poorly-characterized southwest portion of the Laboratory; 2) provide critical information about the depth to the regional aquifer in this area; and 3) provide water quality and water level data for intermediate perched zones and the regional aquifer adjacent to MDA-P and other release sites. Drilling of this borehole is expected to begin in June or July, 1998.

3.2.6 Aggregate 6

Aggregate 6 is located in the south-central portion of the Laboratory and encompasses the technical areas where testing with High Explosives (HE) and Open Detonation/Open Burning are part of routine operations. The general boundaries of the aggregate are Water Canyon on the south, Potrillo Canyon on the north, the Rio Grande to the east, and the Laboratory boundary along the Jemez to the west (Figure 3-23).

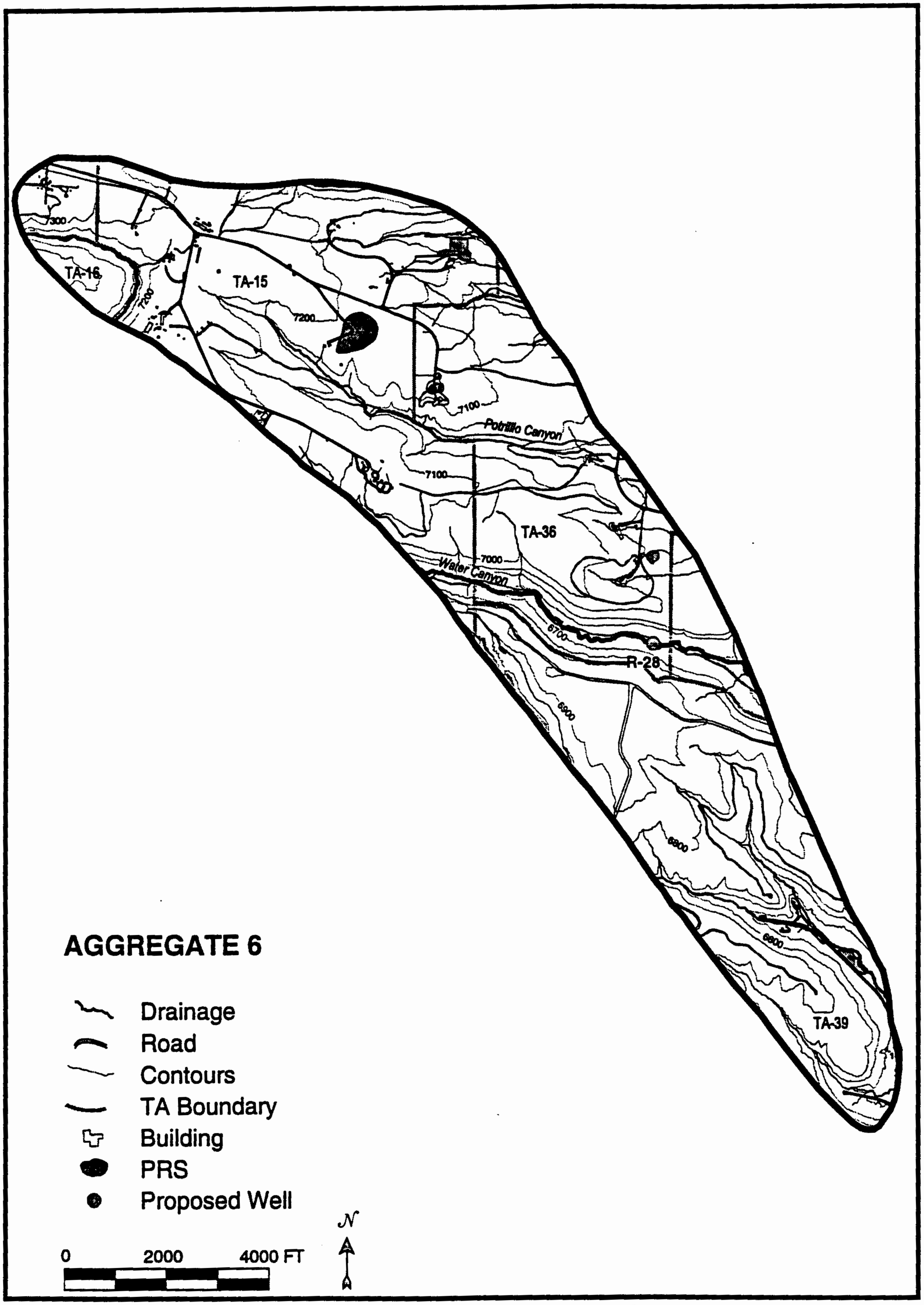


Figure 3-23. PRSs and proposed wells in Aggregate 6.

3.2.6.1 *Aggregate 6 FY97 Investigations*

- There were no new major subsurface field investigations conducted in Potrillo Canyon, Water Canyon, or Fence Canyon.
- Groundwater level measurements were performed in Water Canyon (WCO-1, -2, and -3) and Fence Canyon (FCO-1) during June, July, and September. Some water was found in Water Canyon alluvium (0.1 ft in WCO-2).
- A baseline human health and ecological risk assessment for Technical Area 14 was performed (LANL, 1997). The study concluded that exposure via the groundwater pathway was unlikely.

3.2.6.2 *Aggregate 6 Conceptual Model Refinement*

The conceptual model for Aggregate 6 is shown on Figure 3-19. Based on the above risk assessment, the TA-14 Open Burning / Open Detonation facility may not be a significant source of contaminants to groundwater. For the remainder of the aggregate, there are no refinements to the conceptual model.

3.2.6.3 *Aggregate 6 FY98 Planned Activities*

There are no activities planned for this time period.

3.2.7 Aggregate 7

The aggregate is located in the central portion of the Laboratory and contains both canyon bottom and mesa top waste disposal sites. The general boundaries of the aggregate include a portion of Pajarito Mesa within TA-35, TA-48, TA-50, TA-55, and the adjoining Mortandad Canyon drainage which include its major tributary, Ten Site Canyon (Figure 3-24).

3.2.7.1 *Aggregate 7 FY97 Investigations*

A work plan for Mortandad Canyon was prepared during FY1997 and delivered to NMED on September 29, 1997. The document provides detailed summaries of previous investigations conducted in Mortandad Canyon. Sampling and analysis plans (SAPs) for sediments, surface water, and groundwater are also presented in detail in the document.

3.2.7.2 *Aggregate 7 Conceptual Model Refinements*

- The conceptual model for Aggregate 7 is shown on Figure 3-25. The stratigraphy of the Bandelier Tuff and Cerro Toledo Interval were re-evaluated for Mortandad Canyon. Previous geologic descriptions assumed that the Cerro Toledo Interval was the alluvium within middle Mortandad Canyon. The paleotopography of the Guaje Pumice Bed was further defined beneath Mortandad Canyon.

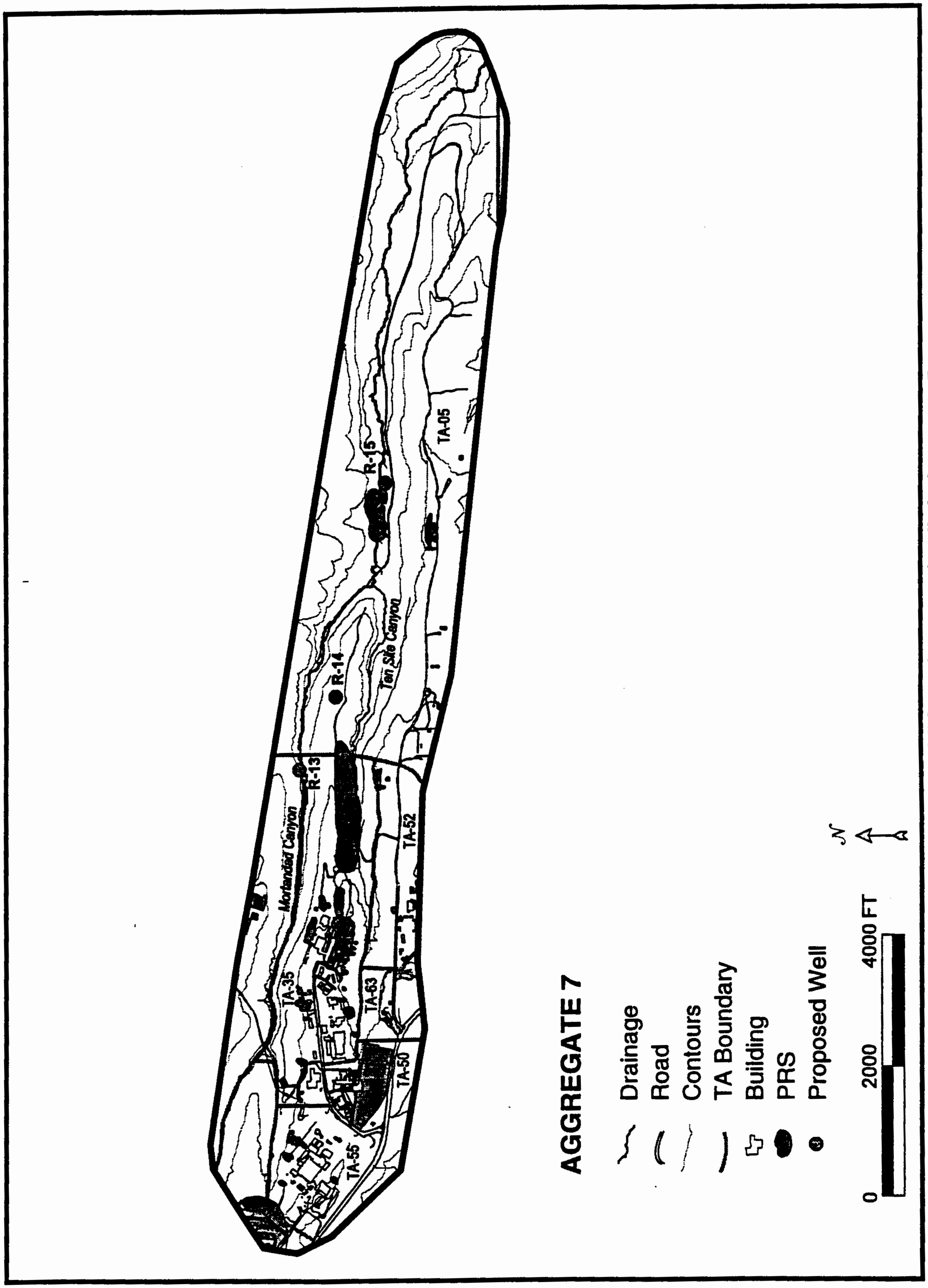


Figure 3-24. PRSs and proposed wells in Aggregate 7.

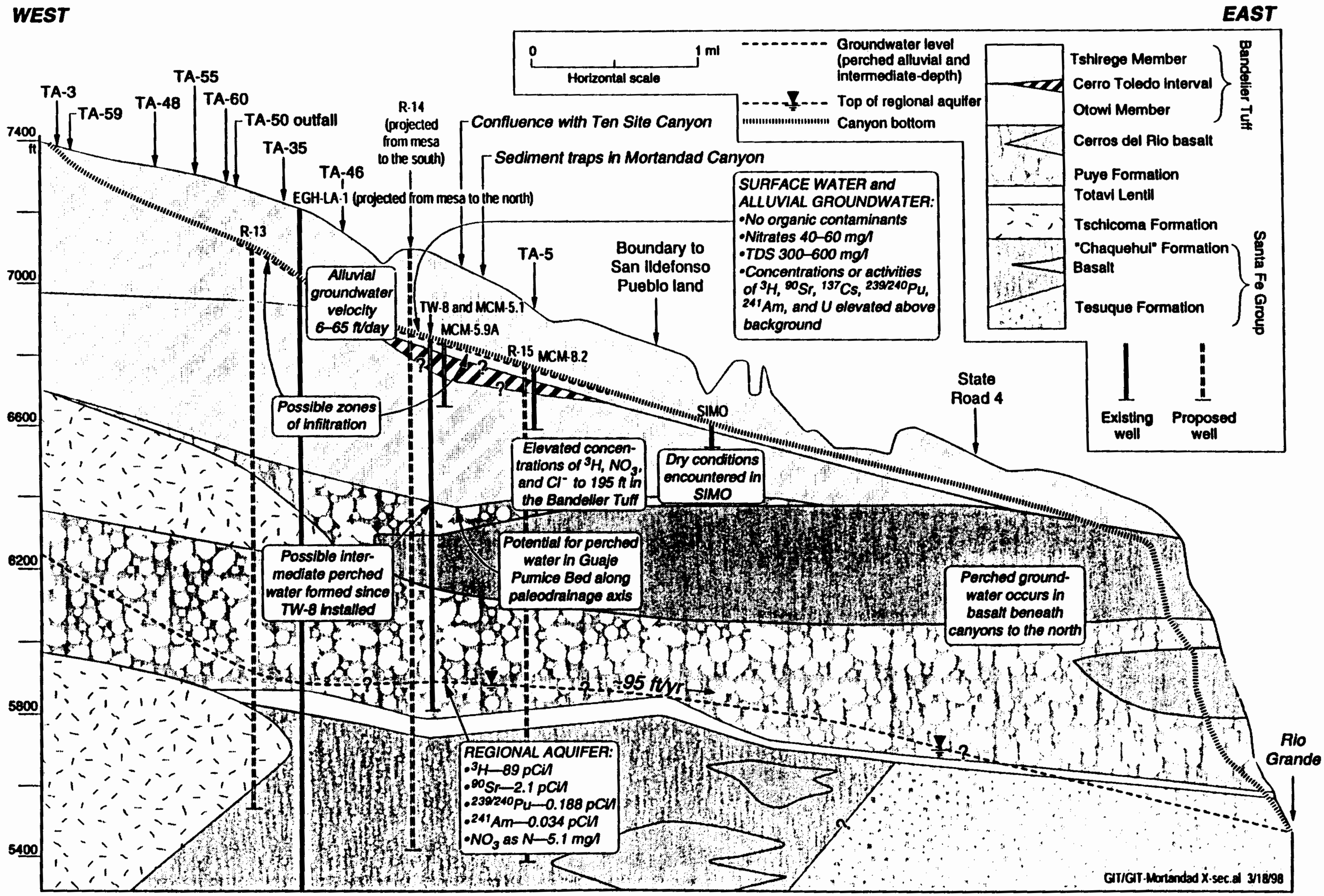


Figure 3-25. Schematic cross section showing conceptual model and proposed regional aquifer wells for Mortandad Canyon.

- Bicarbonate, chloride, nitrate, and sodium are the dominant solutes present in the TA-50 RLWTF discharge and alluvial groundwater in Mortandad Canyon. Activities of tritium in alluvial groundwater have ranged from 20,000 to 1,000,000 pCi/L since 1963. Distributions of tritium, nitrate, and chloride suggest that alluvial groundwater is hydrodynamically well mixed. Activities of tritium (100 nCi/L) were detected at depths of 180 ft bgs in corehole MCC-8.2. The vertical extent of the tritium plume(s) is not known in this borehole.

- Geochemical modeling was conducted to evaluate transport of strontium-90, americium-241, plutonium isotopes, and uranium. Results of speciation calculations suggest that uranium (VI) and plutonium (IV) are stable as anions of uranyl carbonate and plutonium carbonate capable of adsorbing onto calcium carbonate present in the alluvium. Americium (III) is predicted to be stable as americium carbonate complexes that strongly adsorb onto alluvial sediments. Strontium-90 is predicted to be stable as a divalent cation that can be partially removed from solution through cation exchange and mineral precipitation (strontium carbonate). Mineral precipitation is not an important attenuation process for uranium, americium, and plutonium. Adsorption processes are considered to be important for these actinides.
- Gallaher et al. (1997) suggest that Laboratory-derived plutonium and uranium activities in alluvial groundwater and sediments decrease along a short distance downstream of Laboratory outfalls. However, isotopic ratios determined from thermal ionization mass spectrometry (TIMS) suggest possible off-site transport of trace levels (fCi/g) of Laboratory-derived plutonium in stream sediments to distances approximately 2 mi (3.2 km) downstream of the Laboratory boundary to near State Road 4.

3.2.7.3 Aggregate 7 FY98 Planned Activities

Sediment reach sampling will start in the spring of FY1998, as detailed in the Mortandad Canyon work plan. Six alluvial and two Bandelier Tuff boreholes/characterization wells should be drilled in FY 1999. Three regional aquifer wells are scheduled for drilling in FY2000 (R-14) and FY2001 (R-13 and R-15).

GS 1.3
MCO 3
MCO
MCO 4B
TSCO 6A
MCO 7.2
MCO 6.8
MCO BP
MCO 8T4.
MCO 8T 7.5

3.2.8 Aggregate 8

Aggregate 8 encompasses the area north of Pueblo Canyon and includes Bayo Canyon, Barrancas Canyon, Rendija Canyon, and Guaje Canyon (Figure 3-26). These canyons are relatively little affected by Laboratory operations , but may be sources of recharge for groundwater in the northern portion of the Laboratory. Aggregate 8 includes former TA-10 and parts of TA-74 in Bayo Canyon and Barrancas Canyon, respectively. There are also potential release sites on Los Alamos County land in Rendija Canyon.

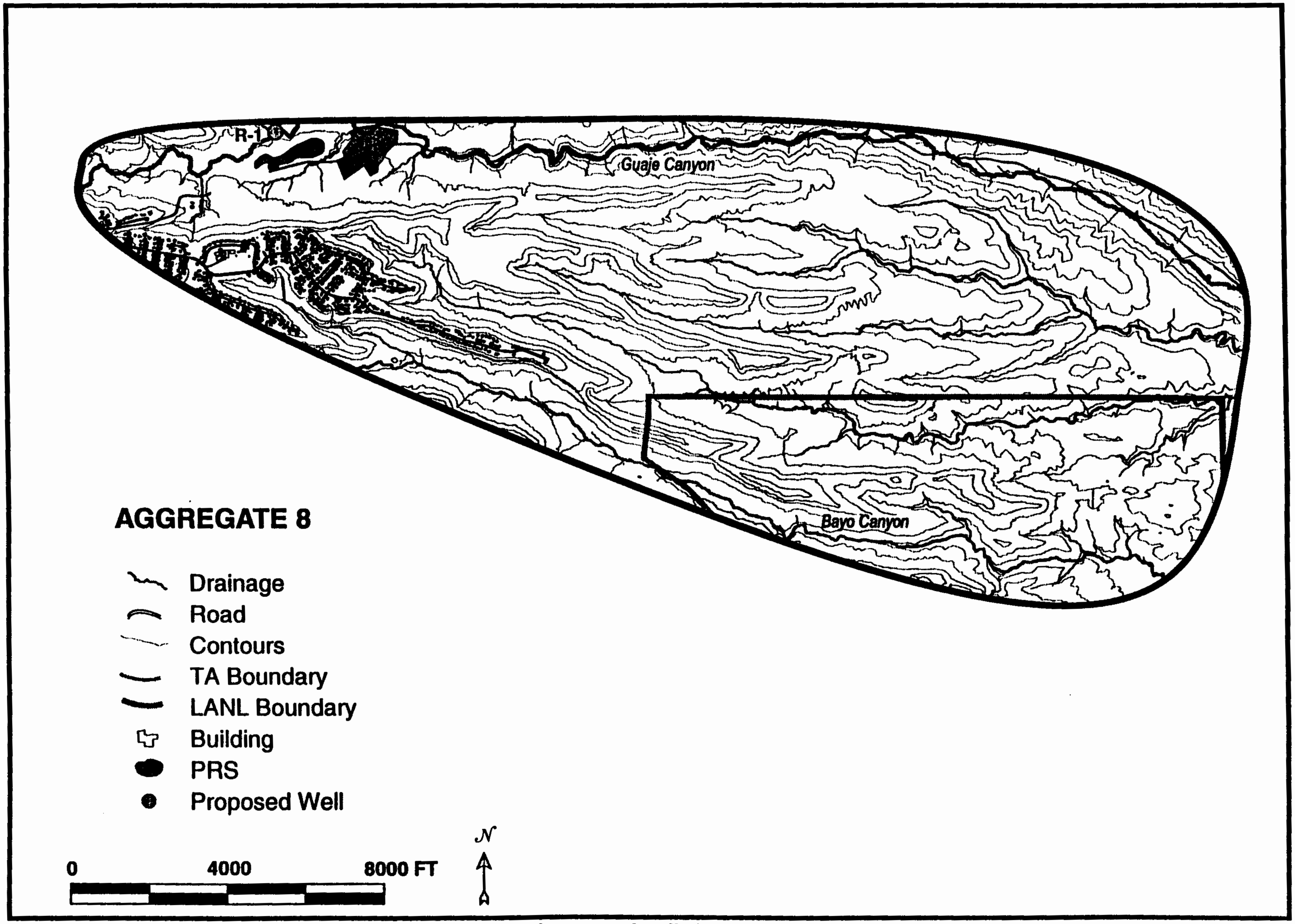


Figure 3-26. PRSs and proposed wells in Aggregate 8.

3.2.8.1 Aggregate 8 FY97 Investigations

- The Guaje Well Replacement Project will replace six of seven aging municipal water supply wells with four new high-capacity production wells. The existing Guaje well field is located on U.S. Forest Service lands in Guaje Canyon near the Rendija Canyon confluence. The existing wells were placed into service between 1950 and 1964. Individual well depths range from 1,500 to 2,000 feet below land surface. Once the new replacement wells are drilled, developed, tested, and equipped with new pumps, then the old wells will be abandoned in accordance with New Mexico State Engineer Office rules and regulations.

- The drilling contract for these four new wells was awarded to Beylik Drilling Company of Albuquerque, New Mexico, in June of 1997. Drilling activities began in mid-September of 1997. By December 31, 1997, two of the four wells had been drilled and completed. Sixteen-inch diameter production casing, screens, and filter packs were set in the first two wells (designated wells GR-2 and GR-3) to total depth of approximately 2,000 feet below land surface.

3.2.8.2 Aggregate 8 Conceptual Model Refinement

No conceptual model changes stem from the well replacement work in FY97. However, based on the testing completed to date in FY98, it appears that most of the water production comes from a limited zone which includes the upper Tesuque, Chaquehui, Totavi Lentil, and Puye Formation. Preliminary interpretation is that this confirms the Chaquehui may have important influence on flow in the regional aquifer. Preliminary analysis of the geological logs from wells GR-2 and GR-3 shows stratigraphy similar to the nearby original Guaje wells.

3.2.8.3 Aggregate 8 FY98 Planned Activities

Project activities remaining to be completed include the following: (1) drill and complete wells GR-1 and GR-4; final casing diameters and depths are similar to the first two wells; (2) swab and air-lift well development in all four wells; (3) pumping tests; (4) spinner logging; and (5) zonal water quality sampling in all four wells. Final project tasks include installation of well pumps, construction of well houses, and abandonment of existing wells.

4.0 SUMMARY OF FY98 PLANNED ACTIVITIES

The following is a summary of FY 98 activities described in sections 2.0 and 3.0 of this report:

4.1 Non-Field Activities

- Data Management:
  - Conduct data user needs assessment
  - Prepare implementation plan for central data repository

- Groundwater Modeling: Prepare report describing results of:
  - Development of a framework model
  - Translation of the hydrostratigraphic model into a finite-volume grid
  - Assignment of hydrologic properties to each stratigraphic unit

- Build FEHM flow model
  - Calibrate to observed head data
  - Sensitivity analysis and hypothesis testing concerning flow directions and locations of recharge

4.2 Field Activities

- Aggregate 9 – continue data collection per the 1997 program

- Aggregate 1
  - Los Alamos and Pueblo Canyons
  - Drill regional aquifer well R-7
  - Collect data from previously installed characterization wells
  - Prepare water table maps for the alluvium and perched intermediate zones
  - Refine conceptual and analytical hydrologic models
  - Assess radionuclide distributions in alluvial and perched zones
  - Characterize geochemical properties related to transport and natural attenuation
  - Quantify sorptive capacities of aquifer material
  - Perform geochemical modeling
  - Provide hydrochemical data for an initial pathway analysis
  - Drill six alluvial wells in Pueblo Canyon and sample at high flow and low flow

- Sandia Canyon – Install well R-12

- Aggregate 2
  - Drill background alluvial well in Three Mile Canyon above TA-18
  - Continue pore gas monitoring and neutron probe measurements at TA-54

- Aggregate 5
  - Drill two deep holes at the Tshirege Unit 3/Unit 4 contact
  - Drill regional aquifer well R-25

- Aggregate 8
  - Drill and complete wells GR-1 and GR-4

- Swab and air-lift development of all four wells
- Test pumping in all four wells and sample for zonal water quality
- Run spinner logs in all four wells

In addition to the planned activities, the following are proposed changes to the Hydrogeologic Workplan description of methods, procedures, and techniques for drilling and installing wells. These changes are based on experience gained during the drilling of R-9 and are intended to make the borehole drilling process more efficient and cost effective.

- During 1998, the Laboratory intends to implement a new drilling package by employing a Barber Dual Rotary drill rig. The rig should provide faster drilling and coring, and decrease the trip time by 20% to 50%.

- Improvements in placing temporary bentonite seals will be made by utilizing an improved pressure grouting system that deploys an inflatable packer and allows grout to be pressure injected below the packer, causing the grout to move up the annular space between the temporary casing and the borehole wall.

- Higher strength casing for use during well drilling will be purchased and used to increase depth of penetration for casing strings and decrease the possibility of casing separations.

- A multiple well completion system will be considered for R-9 and other future regional aquifer wells on a case-by-case basis, as compared to always using single completion construction, as previously described in the Hydrogeologic Workplan.

- The installation of a "companion" intermediate perched zone well(s) will be considered in proposing well completion plans for the regional aquifer wells, i.e. completion of any regional aquifer well (e.g. R-9) may also include the proposal to install an intermediate well(s) adjacent to the regional aquifer well as part of the completion strategy. These decisions will be made on a case-by-case basis.

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ANNUAL MEETING
REGARDING IMPLEMENTATION
OF LOS ALAMOS NATIONAL LABORATORY'S
HYDROGEOLOGIC WORKPLAN
Agenda
March 30, 1998
DOE LAAO, CONFERENCE ROOM

Ltdy Mtg in ~3 mo

8:30 Introductions (B. Koch)
8:45 Purpose of the Meeting (C. Nylander)
9:00 LANL approach to groundwater characterization (C. Nylander)
- Groundwater Protection Management Plan
- Hydrogeologic Workplan
- RFI Workplans

9:30 FY97Non-Field Activities
- Geologic Model Development (D.Broxton)
- Historical water quality data (B. Gallaher)

10:00 Break
10:15 FY97 Field Activities
- Aggregate 1 (D. Broxton)
    - R-9 findings, lessons learned, planned completion
    - Intermediate perched zones
- Aggregate 2 (D. Rogers)
    - Conceptual Model refinements from TA-54 Performance Assessment
- Aggregate 3 (B. Gallaher)
    - Conceptual Model refinements from TA-49 tracer studies
- Aggregate 5 (D. Rogers or Brent Newman)
    - Perched intermediate zone investigations
- Aggregate 7 (P. Longmire)
    - Mortandad Canyon characterization approach
- Aggregate 9 (B. Gallaher)
    - Conceptual Model refinements from 1997 field activities

12:00 Lunch
1:00 Proposed FY98 Non-Field Activities
- Data Management (C. Nylander/K. Mullen)
- Modeling (L. Winter/E. Keating)

2:00 Break
2:15 Proposed FY98 Field Activities (C. Nylander/D. Broxton)
- R-9 completion
- R-12
- R-25
- R-7

4:45 Summary of agreements and action items
5:00 Adjourn