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Los Alamos
NATIONAL LABORATORY
Los Alamos, NM 87545

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Produced by the Groundwater Investigations Focus Area for the Analysis and Assessment Focus Area

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Acronyms

2-D	two dimensional
3-D	three-dimensional
ER	environmental restoration
FIMAD	Facility for Information Management, Analysis and Display
FY	fiscal year
TA	technical area
TD	total depth
USGS	US Geological Survey

1.0 INTRODUCTION

Hydrogeologic studies seek to understand the relationship of the hydrologic systems of an area to its geologic framework, or the geologic controls of the hydrologic phenomena there (Stone 1999, 63990). Such studies are critical to the Los Alamos National Laboratory's (the Laboratory's) Environmental Restoration (ER) Project's efforts, but require adequate geologic and hydrologic maps. The Laboratory's three-dimensional (3-D) sitewide geologic model (Carey et al. 1999, 66782) compiles available geologic data in electronic form but is difficult to use in hard copy. Thus, a project was undertaken to produce a hydrogeologic atlas for the Laboratory area. Development was planned to occur in three stages: (1) construction of a preliminary atlas in 1999, (2) expansion of that version in 2000, and (3) annual updates (on request) thereafter.

The preliminary hydrogeologic atlas, consisting of 25 maps, was prepared in 1999 (Stone et al. 1999, 64039). The documentation for that version gave the overall purpose and scope of the atlas, described the source and quality of data used in its preparation, gave specifications and assumptions for the various types of maps presented, and discussed the availability of the atlas. Although much of that information applies to the expanded atlas as well, not all of it is repeated here. While those who already have the preliminary atlas may discard the maps from that version, they are advised to keep the original documentation for future reference. New atlas users are encouraged to refer to the original documentation for an introduction to the atlas, especially if they have not seen it previously.

This expanded version of the atlas consists of 45 sheets plus this documentation. (The illustrations that make up the new atlas maps are labeled as "sheets" rather than "maps," as in the preliminary version, because the final sheet is not a map; it gives a series of cross sections.) This updated documentation restates the purpose, scope, and availability of the atlas, but focuses on new features that were suggested in the peer review of the preliminary atlas or were deemed useful but could not readily be incorporated in that version, such as new subsurface maps, other new sheets, and changes to some of the maps in the preliminary atlas.

NB: Users of this atlas are urged to keep this documentation (as well as that of the preliminary version) with the atlas sheets for ready reference.

1.1 Purpose

Hydrologists, modelers, and environmental scientists at the Laboratory need various kinds of hydrogeologic information to perform their work. Maps that show the subsurface geology (structure, depth, and thickness of major units) are especially useful in predicting drilling conditions, describing hydrostratigraphic units, formulating conceptual hydrogeologic models, and discretizing numerical models. Maps that show water levels, areas of perched groundwater, and the geology at the regional piezometric surface help workers conceptualize the hydrologic system and identify data gaps. A geologic map and cross sections further characterize the geology of the Laboratory area.

The purpose of the atlas is threefold: (1) to synthesize (graphically, in one place) the considerable amount of previous hydrogeologic work available, (2) to present the information available in the 3-D sitewide geologic model (Carey et al. 1999, 66782) on traditional two-dimensional (2-D) paper sheets of a manageable size, and (3) to provide the basis for a single, sound hydrogeologic conceptual model for the Pajarito Plateau.

1.2 Scope

As was the case for the preliminary atlas, the scope of the expanded version is somewhat narrow. For one thing, this expanded version is restricted to the area covered by the Laboratory (Figure 1.2-1). Furthermore, it covers only the Tertiary and Quaternary geologic units normally encountered by drilling at the Laboratory. More specifically, it includes maps for only the major geologic units beneath the Pajarito Plateau (Figure 1.2-2). That is, while it includes maps for members of the Bandelier Tuff, it does not (with one exception) include maps for the various subunits within these members that are informally recognized at the Laboratory.

An effort was made to utilize only published data, supplemented where appropriate by the most recent unpublished data available. Geologic data used are those in the Laboratory's 1999 3-D sitewide geologic model (Carey et al. 1999, 66782). The sources of hydrologic data used include Purtymun (1995, 45344), the Laboratory's annual water-supply reports, and completion reports for the regional wells being installed under the Laboratory's hydrogeologic work plan (LANL 1998, 59599).

1.3 FY1999 Sitewide Geologic Model

The sitewide geologic model underwent a major revision in fiscal year (FY) 1999. This was done to better characterize deeper (pre-Bandelier) units, which could influence groundwater flow. More specifically, the revised model includes the two Tschicoma dacite/latite flows, whose source is north of the Laboratory, and three distinct sets of basalt flows, which interfinger with the Puye Formation and Santa Fe Group. In updating the Bandelier Tuff portion of the model, a new informal subunit (the unit 3/4 transition in the Tshirege Member) was added, as recent information suggests that this interval may play an important role in localizing saturation in the western portion of the Laboratory (LANL 1998, 59891).

Data from several sources were used to revise the model:

- new age dates for the basalts;
- drill-hole stratigraphy from new wells being installed under the hydrogeologic work plan (LANL 1998, 59599) and at Technical Area (TA) 16 (LANL 1998, 59891);
- new petrographic studies of sediments of the upper Santa Fe Group and Totavi Lentil;
- geologic map for the White Rock quadrangle (Dethier 1997, 49843);
- geologic map for the St. Peter's Dome area (Goff et al. 1990, 21574);
- geologic-mapping data for the Tschicoma Formation (Griggs 1964, 65649); and
- new high-precision geologic-mapping data (Gardner et al. 1998, 63496; 1999, 63492).

New contact surfaces were developed for all units in the model. The new age and petrographic data help support a preliminary pre-Puye paleogeographic model in which a major drainage system passes from north-northeast to south-southwest through the center of the Laboratory. The trend of the pre-Puye surface and of the base of the Los Alamos aquifer (within the upper Santa Fe Group) align with trends of the axial gravels of the Totavi Lentil and probably reflect the evolution of the ancestral Rio Grande (WoldeGabriel et al., in preparation). As data for these deeper units are limited, atlas-project geologists utilized this paleogeographic model to extrapolate contact surfaces between control points.

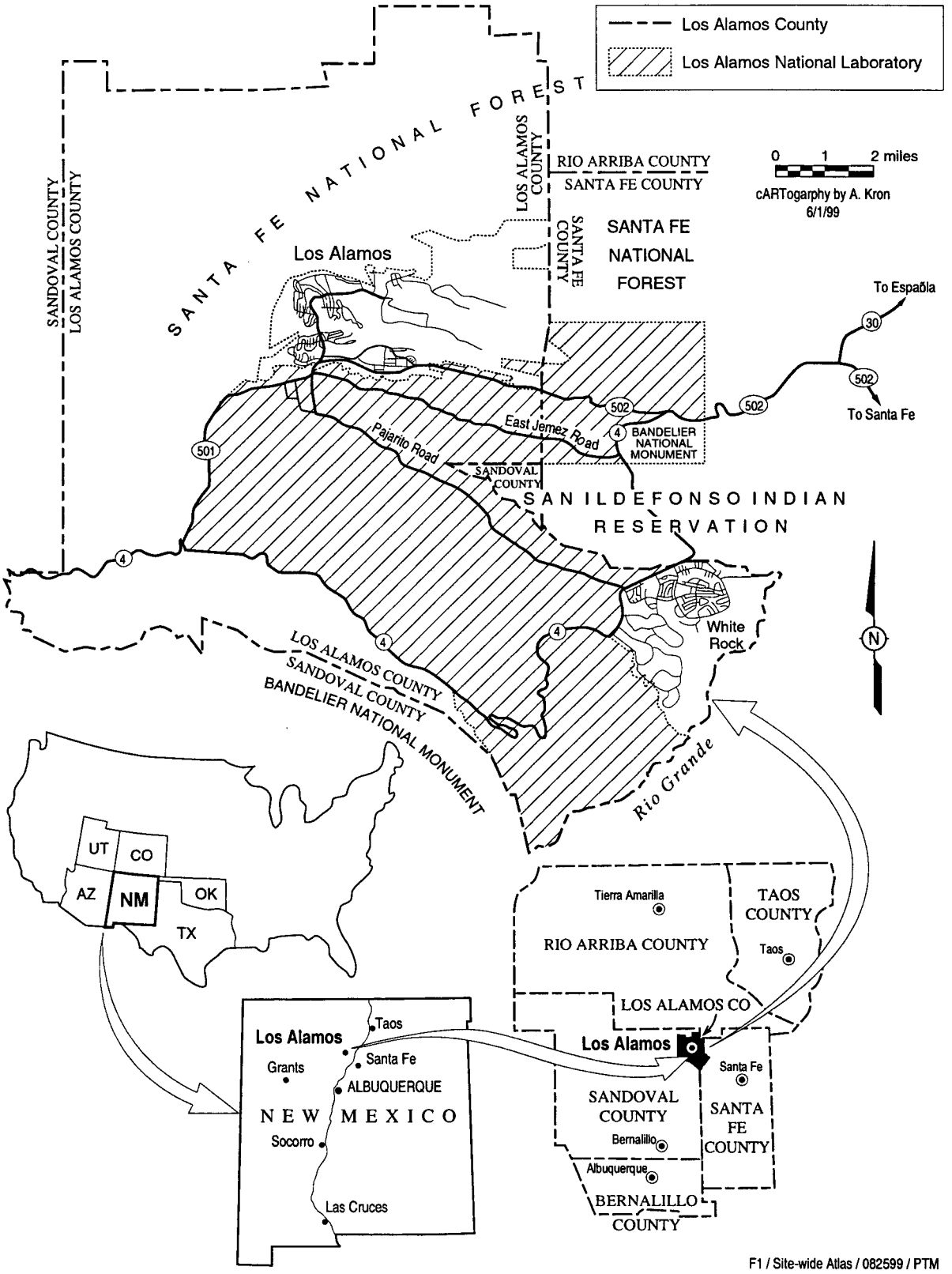

Figure 1.2-1. Location of Los Alamos National Laboratory

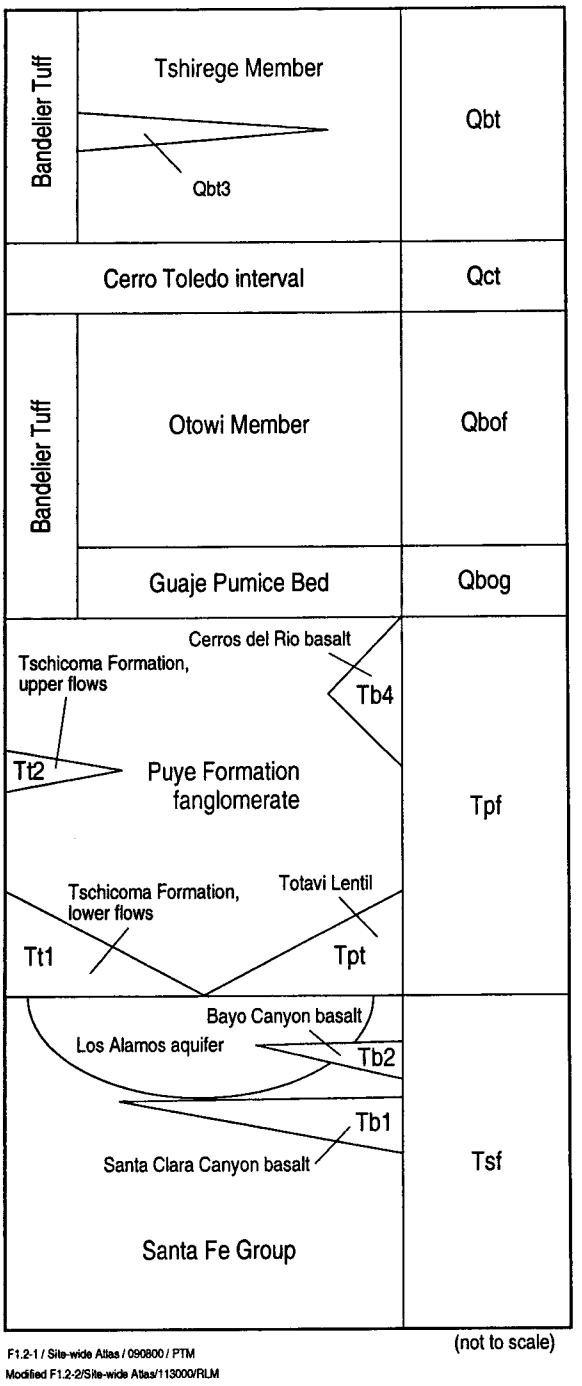

Figure 1.2-2. Geologic column showing units included in the expanded hydrogeologic atlas

Top and bottom surfaces for most pre-Bandelier flow units are based on sparse data (mainly the presence or absence of the units in area drill holes. The Cerros del Rio basalt is the exception, cropping out prominently in White Rock Canyon, east of the Laboratory. However, the geometry of these flows is not well controlled in the subsurface.

The FY1999 geologic model is a major improvement over previous versions. However, the spatial characterization of the deeper units is still poorly constrained and future revisions are inevitable. Likewise, the pre-Puye paleogeograhic model no doubt will be modified, as additional data become available.

2.0 NEW SUBSURFACE MAPS

Maps for seven other geologic units were added to the expanded atlas. These include the unit 3/4 transition of the Tshirege Member of the Bandelier Tuff, the Totavi Lentil of the Puye Formation, both upper and lower flows of the Tschicoma Formation, the Los Alamos aquifer (coarse, upper part of the Santa Fe Group), the Bayo Canyon basalt, and the Santa Clara Canyon basalt.

2.1 Tshirege Member, Unit 3/4 Transition (Qbt3)

Although a decision was made at the outset of work on the preliminary atlas to not include maps for the informal subunits recognized in the members of the Bandelier Tuff, a map has been added for the unit 3/4 transition in the Tshirege Member. This seems justified, as saturation is associated with that interval in some areas (LANL 1998, 59891).

2.2 Totavi Lentil (Tpt)

The Totavi Lentil is a coarse clastic subunit at the base of the Puye Formation. It was lumped with the Puye Formation in the preliminary hydrogeologic atlas because the lateral extent, continuity, and correlation of deposits ascribed to it across the Pajarito Plateau are uncertain. However, it is potentially significant hydrologically, so a separate set of subsurface maps for the Totavi Lentil is warranted. Consequently, maps for the Puye Formation in the expanded atlas do not include the Totavi Lentil. The 3-D geologic model, and thus the atlas, treats the Totavi as a laterally continuous layer, but as the name "lentil" implies, it probably is not.

2.3 Tschicoma Formation (Ttu, Ttl)

The volcanic rocks of the Tschicoma Formation interfinger with the Puye Formation beneath the western part of the Pajarito Plateau. In view of this relationship and the fact that few wells tap this unit, the Tschicoma Formation was lumped with the Puye Formation in the preliminary atlas. Two flow packages (upper and lower) are recognized within this unit. As they may be significant hydrologically, separate sets of subsurface maps for them are included in this expanded atlas.

2.4 Los Alamos Aquifer (Tsfuv)

Purtymun (1984, 6513) advanced the notion that the coarse clastics in the upper portion of the Tesuque Formation (uppermost unit in the Santa Fe Group in most of the Laboratory area) yielded more water to wells than other materials that constitute the regional aquifer. He eventually separated these deposits from the Tesuque Formation and proposed the name Chaquehui Formation for them, after exposures of material he believed to be correlative in Chaquehui Canyon (Purtymun 1995, 45344). However, this unit has since been rejected by geologists and hydrologists on several grounds. For one thing, it was not

named in accordance with US Geological Survey (USGS) rules for stratigraphic nomenclature and would be suitable only for informal usage at best. Furthermore, it is known only from drill cuttings and is difficult to distinguish from other units in the Santa Fe Group. More importantly, the material in the proposed type area differs from material originally assigned to the unit in wells. Finally, from an examination of hydrologic characteristics of the geologic units that make up the regional aquifer, as penetrated by supply and test wells on the Pajarito Plateau (Purtymun 1995, 45344), it is not clear that the stratigraphic interval to which the name was applied is really a better water producer than others screened in supply wells (for example, the Puye Formation).

Nonetheless, because the coarse clastic unit in the upper Santa Fe Group may be significant hydrologically, this expanded atlas includes a set of subsurface maps for it. Although the Chaquehui is not a valid stratigraphic unit, it may be treated as a hydrostratigraphic unit since its hydrologic characteristics seem to be the main basis for distinguishing it. The name "Chaquehui aquifer" was considered, in order to retain Purtymun's original geographic name for the material. However, this was rejected in view of the lack of any geologic connection between the aquifer material and that exposed in Chaquehui Canyon. Also, it seemed desirable to select a name that does not dredge up all the previous clamor over the Chaquehui. The name "Los Alamos aquifer" ultimately was selected to replace the Chaquehui for reference to the upper Santa Fe Group (Tsfuv). This seems fitting, inasmuch as the unit does supply water to the Laboratory and the Los Alamos townsite. It should be noted, however, that this is not the only unit making up the regional aquifer and supplying water to area wells.

2.5 Bayo Canyon Basalt (Tb2)

Two additional Tertiary basalts, predating the Cerros del Rio basalt, were added to the FY1999 geologic model. Inasmuch as saturation has been found in the Cerros del Rio basalt beneath the Laboratory, maps were added to the expanded atlas to cover all basaltic rocks reported in the Los Alamos area.

The Bayo Canyon basalt (Tb2) represents volcanic activity at 8 to 9.5 Ma. It is interbedded with the Los Alamos aquifer in the upper part of the Santa Fe Group at a stratigraphic position above that of the Santa Clara basalt (Tb1).

2.6 Santa Clara Canyon Basalt (Tb1)

The Santa Clara basalt (Tb1) represents volcanic activity at 11 to 13 Ma. As currently conceptualized, the Santa Clara consists of two distinct basalt bodies, one in the Guaje well field and the other in the vicinity of supply well O-1. This unit is interbedded with sediments of the upper Santa Fe Group, but below the Los Alamos aquifer and the position of the Bayo Canyon basalt (Tb2).

3.0 OTHER NEW SHEETS

In addition to the subsurface maps for additional geologic units, this expanded atlas contains two other new sheets. These are a geologic map and a sheet showing cross sections for selected areas on the Pajarito Plateau.

3.1 Geologic Map

The preliminary atlas lacked a geologic map, as none was available in electronic form for the entire Laboratory area. Rogers (1995, 54419) published a map for the members and subunits of the Bandelier Tuff that covered the entire Laboratory area. Although her map remains an invaluable resource, it is not

available in electronic form. Thus, the geologic map for this expanded atlas was constructed from the contact surfaces for units in the FY1999 geologic model. These surfaces were developed using data from numerous sources, including Rogers (1995, 54419). More specifically, the geologic map was built by the successive stacking of younger units on older units until the topographic-surface grid was intersected. This was accomplished using grid and polygon operations of ArcInfo software.

The color scheme used for the map does not follow standard practice (adopted by the USGS and others) in which specific colors are employed to signify specific geologic ages (yellow for Quaternary, green for Cretaceous, etc.). That scheme did not work for so many units within such a narrow time interval as are found on the Pajarito Plateau. However, the colors used in the atlas are the same as those employed in the Laboratory's sitewide geologic model.

3.2 Cross Sections

Constructing cross sections along any line, using the 3-D sitewide geologic model, is fairly easy. Eight geologic cross sections are presented in this expanded atlas: six aligned northwest-to-southeast more or less along major canyons and two aligned more or less perpendicular to those (northeast-to-southwest). In addition to the small index map on the cross-section sheet (Sheet 45), the lines of section are shown more clearly on the geologic map (Sheet 2). Although showing the piezometric surface on the various cross sections would have been desirable, that would not have been a trivial operation because that surface was in the 3-D model, whereas the sections were made by Stratamodel™.

4.0 CHANGES TO MAPS PREVIOUSLY PRESENTED

All maps presented in the preliminary atlas were changed for this expanded atlas. The biggest changes were required by a revision in the 3-D sitewide geologic model as described in Section 1.3, FY1999 Sitewide Geologic Model, above. Other changes were of two main types: the addition of data not previously shown or major modifications to the design used for maps in the preliminary atlas.

4.1 Addition of Data Not Previously Shown

Some maps merely were updated by adding geologic or water-level data obtained in new wells. Other maps were changed by adding things not previously shown. These additions include hydraulic conductivity and reported occurrences of intermediate-depth perched groundwater in wells.

4.1.1 Hydraulic Conductivity

Knowledge of the hydraulic properties of the geologic units beneath the Pajarito Plateau is critical to hydrogeologic studies at the Laboratory, especially flow and transport modeling. For example, hydraulic conductivity (K) is a key parameter in Darcy's law: $Q = -KIA$, where Q = discharge, I = hydraulic gradient, and A = cross-sectional area of saturated zone. Therefore, existing horizontal K values have been added to the thickness maps for each geologic unit in the atlas. This allows quick determination of transmissivity (T), should that parameter be needed: $T = Kb$, where "b" is thickness.

Table 4.1-1 summarizes the hydraulic-conductivity data used. Data came from aquifer tests reported by Purtymun (1995, 45344). In each well tested, the screened interval spans more than a single geologic unit. Units covered by testing were determined from Purtymun's well logs, the current geologic interpretation of those logs, and the screen or slot length he reported. Results of recent hydrologic

Table 4.1-1
Hydraulic-Conductivity (K) Data used in the Expanded Atlas

Well	Units Covered by Test*	K (gpd/ft^2)	Year of Test
Los Alamos Field			
LA-1B	Tsfu	9.3	1982
LA-2	Tsfu	3.5	1982
LA-3	Tsfu	3.3	1982
LA-4	Tsfu	5.7	1981
LA-5	Tsfu	3.0	1982
LA-6	Tsfu	9.1	1982
Guaje Field			
G-1	Tsfuv, Tb1, Tsfu	7.0	1982
G-1A	Tsfuv, Tb1, Tsfu	9.1	1982
G-2	Tsfuv, Tsfu	9.1	1982
G-3	Tsfuv, Tb1, Tsfu	5.3	1982
G-4	Tsfuv, Tb1, Tsfu	11.3	1982
G-5	Tsfuv, Tb1, Tsfu	8.7	1982
G-6	Tsfuv, Tb1, Tsfu	6.7	1982
Pajarito Field			
PM-1	Tsfuv, Tb2, Tsfu	31	1982
PM-2	Tpf, Tpt, Tsfuv, Tb2,	28	1982
PM-3	Tsfuv, Tb2, Tsfu	179	1982
PM-4	Tpf, Tpt, Tsfuv, Tb2	24	1982
PM-5	Tpf, Tpt, Tsfuv, Tb2, Tsfu	5.3	1982
Otowi Field			
O-1	Tsfu	4.7	1990
O-4	Tsfuv, Tb2, Tsfu	30	1990
Test Wells			
DT-5A	Tb4, Tpf, Tpt, Tsfuv	17	1960
DT-9	Tb4, Tpf, Tpt, Tsfuv	122	1960
DT-10	Tb4, Tpf, Tpt, Tsfuv	111	1960
TW-1	Tpt	4.0	1951
TW-2	Tpt	241	1951
TW-3	Tpt	120	1951
TW-4	Tt1	19	1951
TW-8	Tpf	25	1960

Source: Purtyman 1995, 45344; Carey et al. 1999, 67782.

*Units screened in well: Tb4 = Cerros del Rio Basalt; Tpf = Puye Formation, fanglomerate; Tt1 = Tschicoma Formation, upper flows; Tpt = Puye Formation, Totavi Lentil; Tsfuv = Los Alamos aquifer; Tb2 = Bayo Canyon basalt; Tb1 = Santa Clara Canyon basalt; Tsfu = Santa Fe Group, undifferentiated.

testing at the new regional characterization wells being installed under the hydrogeologic work plan (R-9i, R-15, R-19, R-22, R-31, and CDV-R-15-3) are not tabulated or plotted on the maps, as they are based on only cursory calculations and may be changed after test data have been subjected to more thorough analysis.

4.1.2 Occurrences of Intermediate-Depth Perched Groundwater

In addition to knowing the position of the regional water table, it also is useful in Laboratory hydrogeologic studies to know where perched groundwater can be expected. Although shallow perched water occurs locally in the alluvium along canyon bottoms, this saturation is mainly ephemeral and was not mapped. However, reported occurrences of intermediate-depth perched saturation in Laboratory wells were plotted on the map of the regional piezometric surface (Sheet 43).

A standard shaded area around wells where perched water has been observed depicts such occurrences. It should be noted that the actual extent of perched saturation likely varies through time and is not known at any of these locations. Thus, the symbol is merely for location purposes and the size of the shaded areas does not represent the actual extent of the perched saturation reported. Each occurrence (shaded area) is accompanied by a notation giving the depth to the perched water table and the geologic unit that contains the saturation.

Table 4.1-2 gives the intermediate-depth, perched-water observations used in the expanded atlas. The data came mainly from three sources: Purtymun (1995, 45344), canyon work plans, and completion reports for wells recently installed under the hydrogeologic work plan (LANL 1998, 59599).

4.2 Modifications of Preliminary Maps

Still other maps were modified by improving on the original design or making necessary corrections. This involved including outcrops and subsurface extent of units on the subsurface maps as appropriate, as well as correcting Rio Grande elevations and recontouring water-level data on the regional piezometric-surface map.

4.2.1 Inclusion of Outcrops and Subsurface Extent of Units

Subsurface maps in the preliminary atlas lacked edges or zero lines for geologic units. A concerted effort was made to make such boundaries more clear in this expanded atlas. This was mainly achieved by including outcrop areas as well as lines that show the subsurface extent of geologic units that are not pervasive beneath the Pajarito Plateau. Some units pinch out to the east, others to the west, some in both directions. A careful examination of a given map should reveal which is the case for that unit. For consistency and clarity, the outcrops are shown in the same color as on the geologic map (Sheet 2).

4.2.2 Revision of the Regional Piezometric-Surface Map

The regional piezometric-surface map was changed in three ways in the expanded atlas. First, as noted above, reported occurrences of intermediate-depth perched groundwater were added. Second, anomalous elevations for the Rio Grande incorporated on the preliminary piezometric-surface map have been corrected. (The anomalies apparently arose from using two different software programs for topographic-data sets in that part of the map: one for the river and another for topography.) The third change involved totally rethinking the contouring of available water-level data.

Table 4.1-2
Occurrences of Intermediate-Depth Perched Groundwater

Well	Perched Water Level Depth (ft)	Unit Containing Perched Saturation	Data Source
Pueblo Canyon			
TW-2A	120	Puye Formation	Purtymun 1995, 45344
O-1	183	Puye Formation	Purtymun 1995, 45344
TW-1A	180	Cerros del Rio basalt	Purtymun 1995, 45344
Los Alamos Canyon			
H-19	(20-ft interval)	Guaje Pumice bed	LANL 1995, 50290
LAO(A)	295	Guaje Pumice bed	LANL 1995, 50290
LADP-3	325	Guaje Pumice Bed	LANL 1995, 50290
O-4	253	Puye Formation	Purtymun 1995, 45344
R-9	137	Cerros del Rio basalt	Broxton et al. 2000, 66599
R-9	264	Cerros del Rio basalt	Broxton et al. 2000, 66599
R-9	524	Cerros del Rio basalt	Broxton et al. 2000, 66599
Sandia Canyon			
R-12	424	Cerros del Rio basalt	Broxton et al. 2000, 66601
PM-1	450	Cerros del Rio basalt	Purtymun 1995, 45344
Mortandad Canyon			
MCM-51	55	Tsankawi/Cerro Toledo	LANL 1997, 56835
MCM-5.9	105	Tsankawi/Cerro Toledo	LANL 1997, 56835
R-15	646	Cerros del Rio basalt	Longmire et al. 2000, 66602
Pajarito Canyon			
SHB-4	145	Cerro Toledo interval	LANL 1998, 59577
54-1016	592	Cerros del Rio basalt	LANL 1998, 59577
Ancho Canyon			
R-31	440	Cerros del Rio basalt	Marin 2000, 68082

Insufficient data (too few deep wells) hinder any confident mapping of the piezometric surface beneath the Laboratory. Furthermore, the few wells that are available have long screened intervals so water levels obtained from them are composite values. Even taking this into account, the placement of some contours on the preliminary version seems arbitrary.

Rather than move a few contours in a few places for the expanded atlas, the map of the regional piezometric surface was completely redrawn from scratch, using the most recent water levels available. Data used are given in Table 4.2-1. As for the preliminary atlas, data from the White Rock Canyon springs were not used in constructing the piezometric-surface map, as most of these springs are believed to yield water that has become perched above the regional zone of saturation (Stone 1996, 63989).

Table 4.2-1
Records of Wells used in Regional Piezometric-Surface Map

Well	Total Depth (ft)[a]	Unit at Total Depth[b]	Ground Surface Elevation (ft)[a]	Water Level Depth (ft)	Water Level Date (yr)	Water Level Elevation (ft)	Screen Length (ft)[c]	Data Source
CdV-R-15-3	1675	Tp	7257	1245	2000	6012	M	Environmental Restoration Project 2000, 67328
DT-5A	1821	Tsf	7144	1184	1996	5960	220	Purtymun 1995, 45344; McLin et al. 1998, 63506
DT-9	1501	Tsf	6935	1016	1997	5919	183	Purtymun 1995, 45344; McLin et al. 1998, 63506
DT-10	1409	Tsf	7020	1097	1997	5923	141	Purtymun 1995, 45344; McLin et al. 1998, 63506
G-1	2020	Tsf	5840	274	1997	5566	490	Purtymun 1995, 45344; McLin et al. 1998, 63506
G-1A	2071	Tsf	6014	309	1997	5705	563	Purtymun 1995, 45344; McLin et al. 1998, 63506
G-2	2006	Tsf	6056	358	1997	5698	425	Purtymun 1995, 45344; McLin et al. 1998, 63506
G-3	1997	Tsf	6139	375	1986	5764	400	Purtymun 1995, 45344; McLin et al. 1998, 63506
G-4	2002	Tsf	6229	375	1997	5854	360	Purtymun 1995, 45344; McLin et al. 1998, 63506
G-5	1997	Tsf	6306	459	1994	5847	400	Purtymun 1995, 45344; McLin et al. 1998, 63506
G-6	2005	Tsf	6422	581	1997	5841	810	Purtymun 1995, 45344; McLin et al. 1998, 63506
GR-1	2000	Tsf	6417	552	1998	5865	1233	McLin 2000, 68299
GR-2	2000	Tsf	6141	323	1998	5818	1415	McLin 2000, 68299
GR-3	2000	Tsf	6213	397	1998	5816	1390	McLin 2000, 68299
GR-4	2000	Tsf	6300	461	1998	5839	1325	McLin 2000, 68299
LA-1	1001	Tsf	5624	9	1996?	5615	805	Purtymun 1995, 45344; Map 24, Stone et al.1999, 64039
LA-1B	2256	Tsf	5622	+18	1996	5640	591	Purtymun 1995, 45344; McLin et al. 1998, 63506
LA-2	882	Tsf	5651	120	1996?	5531	760	Purtymun 1995, 45344; Map 24, Stone et al. 1999, 64039
LA-3	910	Tsf	5672	12	1996?	5560	760	Purtymun 1995, 45344; Map 24, Stone et al.1999, 64039
LA-4	2019	Tsf	5975	248	1996?	5727	350	Map 24, Stone et al.1999, 64039
LA-5	2024	Tsf	5840	148	1996?	5692	350	Map 24, Stone et al.1999, 64039

Table 4.2-1 (continued)

Well	Total Depth (ft)[a]	Unit at Total Depth[b]	Ground Surface Elevation (ft)[a]	Water Level Depth (ft)	Water Level Date (yr)	Water Level Elevation (ft)	Screen Length (ft)[c]	Data Source
LA-6	2030	Tsf	5770	88	1996?	5682	400	Purtymun 1995, 45344; Map 24, Stone et al.1999, 64039
O-1	2609	Tsf	6396	676	1997	5720	1460	Purtymun 1995, 45344; McLin et al. 1998, 63506
O-4	2806	Tsf	6627	762	1995	5865	1481	Purtymun 1995, 45344; McLin et al. 1998, 63506
PM-1	2501	Tsf	6520	760	1997	5760	1534	Purtymun 1995, 45344; McLin et al. 1998, 63506
PM-2	2600	Tsf	6715	870	1995	5845	1276	Purtymun 1995, 45344; McLin et al. 1998, 63506
PM-3	2552	Tsf	6640	779	1997	5861	1576	Purtymun 1995, 45344; McLin et al. 1998, 63506
PM-4	2220	Tsf	6920	1093	1997	5827	1594	Purtymun 1995, 45344; McLin et al. 1998, 63506
PM-5	3110	Tsf	7095	1254	1997	5841	1632	Purtymun 1995, 45344; McLin et al. 1998, 63506
R-9	771	Tsf	6384	688	1999	5696	65	Broxton et al. 2000, 66599
R-12	847	Tsf	6501	805	1998	5696	M	Broxton et al. 2000, 66601
R-15	1043	Tp	6818	964	1999	5854	62	Longmire et al. 2000, 66602
R-19	1902	Tp	7060	1156	2000	5904	M	Broxton et al. 2000, 66603
R-25	1942	Tp	7517	1285	2000	6232	M	LANL 1999, 68416
R-31	1078	Tp	6365	522	2000	5843	M	Marin 2000, 68082; Marin 2000, 68417
TW-1	642	Tp	6369	529	1997	5840	10	McLin et al. 1998, 63506
TW-2	834	Tp	6648	797	1996	5851	56	McLin et al. 1998, 63506
TW-3	814	Tp	6595	782	1997	5813	5	McLin et al. 1998, 63506
TW-4	1205	Ttu	7245	1176	1996	6069	10	McLin et al. 1998, 63506
TW-8	1065	Tp	6878	994	1997	5884	112	McLin et al. 1998, 63506

[a]Final, plugged-back depth.

[b]Tp = Puye Formation; Ttu = Tschicoma Formation, undifferentiated; Tsf = Santa Fe Group.

[c]Includes slotted pipe, perforations or louvers; M = multiple screened intervals of various lengths at various depths.

Note: Depths and elevations are rounded to nearest foot.

Some previous water-level maps for the Laboratory area are characterized by smooth contours that extend unswervingly through areas of known groundwater withdrawal and diverse water levels. This leaves anomalous values between contours. The piezometric-surface map presented in this version of the atlas (Sheet 43) attempts to better accommodate known water-level values. Thus, contours make broad swings around supply wells. This is especially obvious near the Pajarito and Guaje well fields. Nonetheless, because some isolated anomalous water levels don't contour easily, the map is still not ideal. Presumably, additional data from new wells will provide a basis for improving it.

A piezometric-surface grid was developed for the model from the digitized version of the hand-drawn water-level map. The approach to constructing the map showing geology at the regional piezometric surface was the same as that for constructing the geologic map (which is simply geology at the topographic surface). In the former case, however, the reference was the piezometric-surface grid rather than the topographic grid.

5.0 DISCUSSION

A few words of explanation are warranted on things that do not clearly fall under any of the headings above. For one thing, contours on some maps appear to branch (which is not allowed). In such cases, contours are merely merging at vertical boundaries.

Also, some values reported for structure and depth of units on the subsurface maps deserve clarification. It is fairly standard practice to use "less-than" (<) and "greater-than" (>) signs on subsurface maps. For example, a less-than (<) sign beside an elevation on a structure (elevation-of-top-of-unit) map usually indicates that the unit was not encountered before reaching total depth (TD) and its top presumably would be deeper or less than the elevation of TD. Similarly, greater-than (>) signs commonly accompany data on a depth (to-top-of-unit) map to indicate that the top of a unit lies below the well's TD.

However, some subsurface maps in this expanded atlas employ a reverse approach to such symbols because of the design philosophy of the 3-D geologic model upon which it is based. More specifically, the Laboratory's geologic model stresses projected noneroded surfaces for units. Thus, the elevation value for the top of a unit may be accompanied by a greater-than (>) sign, indicating that the well is in the outcrop area of the unit and the ideal (projected noneroded) top is at an elevation higher than that of the ground surface at the well. Similarly, values plotted for some wells on the depth maps may be preceded by a less-than (<) sign, indicating that the well is in the outcrop area for the unit and the depth-to-top of the ideal (projected noneroded) top is at a lesser depth than shown. These symbols may appear even if the model did not extend the outcrop area into the well locations.

Finally, although the atlas is not perfect, it is believed to be a good synthesis of existing information. As such, it is a useful tool for illustrating what is currently known and conceptualized of the hydrogeology of the Pajarito Plateau and the Laboratory. Its use should simplify planning of ER projects and result in a common thread in ER Project work plans.

The atlas has an unexpected secondary function of providing the perfect means for evaluating the sitewide geologic model. That is, persons familiar with this area's geology can review and critique the various sheets. Users of the atlas are not only invited but also expected to provide suggestions for the sitewide geologic model.

6.0 AVAILABILITY OF THE EXPANDED ATLAS

Hard copies of the expanded atlas are being distributed to those persons most actively involved in hydrogeologic work at the Laboratory (that is, those who drill wells, interpret hydrologic data, model groundwater systems, oversee environmental activities, etc.). As in the case of the preliminary atlas, this includes distribution of at least one copy to each Laboratory, US Department of Energy, New Mexico Environment Department, pueblo, and citizen group involved or interested in such studies, as well as the Los Alamos National Laboratory Research Library. Additional copies of part or all of the expanded atlas are available through the Laboratory's Facility for Information Management, Analysis, and Display (FIMAD).

To facilitate ordering separate parts of the expanded atlas, they are listed below by sheet number, abbreviated title, and FIMAD plot identification number:

1. Topography (109020)
2. Bedrock geology (109021)
3. Thickness of the Tshirege Member (109022)
4. Structure on top of Tshirege, unit 3/4 transition (109023)
5. Depth to top of the Tshirege, unit 3/4 transition (109024)
6. Thickness of the Tshirege, unit 3/4 transition (109025)
7. Structure on top of Cerro Toledo interval (109026)
8. Depth to top of Cerro Toledo interval (109027)
9. Thickness of the Cerro Toledo interval (109028)
10. Structure on top of ash flow, Otowi Member (109029)
11. Depth to top ash flow, Otowi Member (109030)
12. Thickness of the ash flow, Otowi Member (109031)
13. Structure on top of Guaje Pumice Bed (109032)
14. Depth to top of Guaje Pumice Bed (109033)
15. Thickness of the Guaje Pumice Bed (109034)
16. Structure on top of Cerros del Rio basalt (109035)
17. Depth to top of Cerros del Rio basalt (109036)
18. Thickness of the Cerros del Rio basalt (109037)
19. Structure on top of Puye Formation (109038)
20. Depth to top of Puye Formation (109039)
21. Thickness of the Puye Formation (109040)
22. Structure on top of Totavi Lentil (109041)
23. Depth to top of Totavi Lentil (109042)
24. Thickness of the Totavi Lentil (109043)
25. Structure on top of Tschicoma Formation, upper flows (109044)
26. Depth to top of Tschicoma Formation, upper flows (109045)
27. Thickness of the Tschicoma Formation, upper flows (109046)

28. Structure on top of Tschicoma Formation, lower flows (109047)
29. Depth to top of Tschicoma Formation, lower flows (109048)
30. Thickness of Tschicoma Formation, lower flows (109049)
31. Structure on top of Los Alamos aquifer (109050)
32. Depth to top of Los Alamos aquifer (109051)
33. Thickness of the Los Alamos aquifer (109052)
34. Structure on top of Santa Fe Group (109053)
35. Depth to top of Santa Fe Group (109054)
36. Partial thickness of the Santa Fe Group (109055)
37. Structure on top of Bayo Canyon basalt (109056)
38. Depth to top of Bayo Canyon basalt (109057)
39. Thickness of the Bayo Canyon basalt (109058)
40. Structure on top of Santa Clara Canyon basalt (109059)
41. Depth to top of Santa Clara Canyon basalt (109060)
42. Thickness of the Santa Clara Canyon basalt (109061)
43. Regional piezometric surface (109062)
44. Geology at the regional piezometric surface (109063)
45. Geologic cross sections (109064)

In accordance with the original project plan, complete sets of the atlas will not be prepared and distributed (or documented) beyond this version. Although the 3-D sitewide geologic model will be updated annually to incorporate data obtained from any new wells drilled, and thus updated atlas sheets can be prepared readily; they will only be made by FIMAD upon demand.

7.0 ACKNOWLEDGMENTS

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8.0 REFERENCES

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

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

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

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