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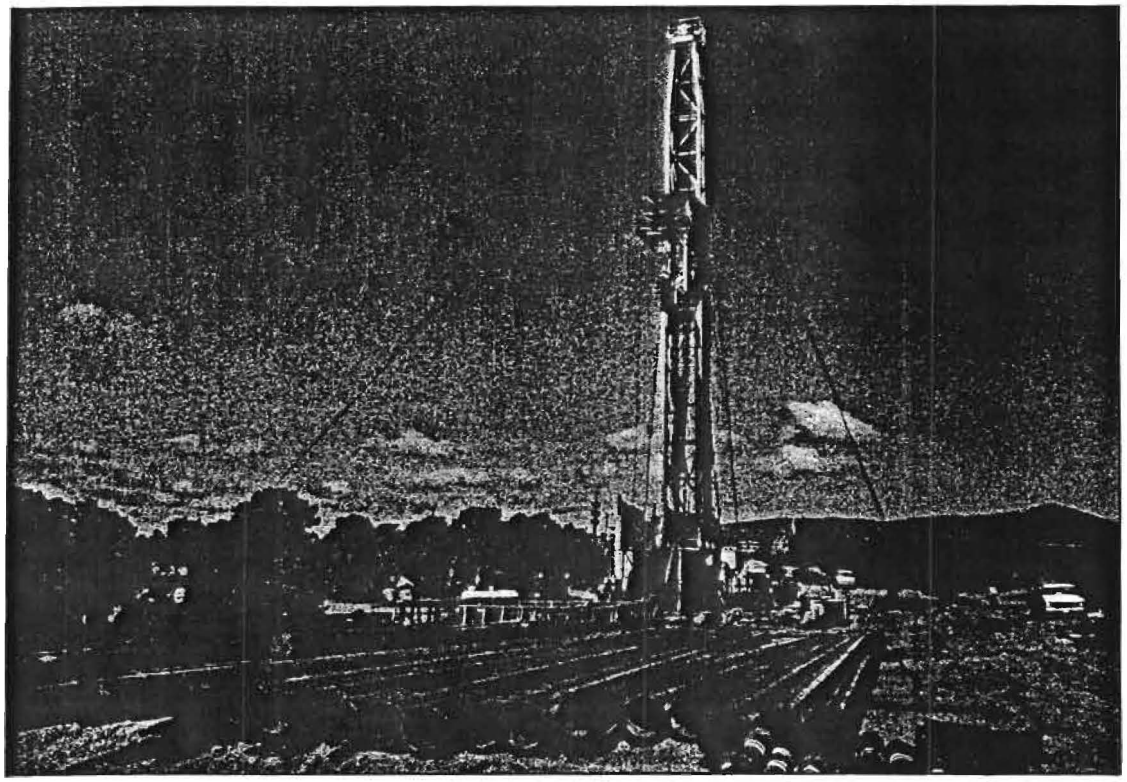
# Hydrologic Characteristics of the Main Aquifer in the Los Alamos Area:

## *Development of Ground Water Supplies*



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# Hydrologic Characteristics of the Main Aquifer in the Los Alamos Area: Development of Ground Water Supplies

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# HYDROLOGIC CHARACTERISTICS OF THE MAIN AQUIFER IN THE LOS ALAMOS AREA: DEVELOPMENT OF GROUND WATER SUPPLIES

by

W. D. Purtymun

## ABSTRACT

Deep wells completed into the main aquifer have furnished $40.5 \times 10^9$ gal. of water for the Los Alamos National Laboratory and for the communities of Los Alamos and White Rock from 1947 through 1982. The main aquifer is within the siltstones and sandstones of the Tesuque Formation along the Rio Grande, and it rises westward into the lower part of the Puye Conglomerate beneath the central and western part of the Pajarito Plateau. The Laboratory and communities of Los Alamos and White Rock are located on the Pajarito Plateau.

Supply, test, and stock wells have been used to collect hydrologic data from the aquifer beneath the Pajarito Plateau and to the east along the Rio Grande. Hydrologic characteristics of springs along the Rio Grande, which are in the discharge area from the main aquifer, are included to supplement the data from the wells. Hydrologic characteristics of the aquifer determined from tests and observations are the saturated thickness, pumping or production rates of the wells, drawdown, specific capacity, field coefficient of permeability, transmissivity, rate of water movement in the aquifer, production from wells and fields, water-level trends of the aquifer, rates of water-level decline, and production per foot of water-level decline.

Chemical quality of water in the aquifer varies according to the formations yielding water to the wells. Based on hydrologic characteristics of existing wells, suggested locations for four additional wells were made in areas to develop high-yield low-drawdown (1000-gpm/100-ft) supply wells. These locations are recommended in long-range planning for future water supply as the demand for water increases at the Laboratory and in the communities. A well to replace well G-4 in the Guaje Field is recommended to offset declining production in the field.

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## INTRODUCTION

The Los Alamos National Laboratory and the com-ınities of Los Alamos and White Rock are supplied by ıter pumped from deep wells in three well fields located Los Alamos Canyon, in Guaje Canyon, and on the jarito Plateau. Production from these wells is from the main aquifer of the Los Alamos area. The main aquifer is the only aquifer that is capable of municipal and industrial supply. In addition to the 18 supply wells that penetrate into the main aquifer, 10 test wells and 2 stock wells in the Los Alamos area are completed into the main aquifer.

## A. Purpose and Scope

Hydrologic data have been collected from 1947 through 1982 from supply and test wells. The data have been collected and published to ensure a continuing historical record to provide guidance for water management resources and long-range planning for the water supply sytem.[1-14] The purpose of this report is to evaluate this hydrologic data and to describe the hydrology of the main aquifer to provide support for long-range planning of locations for additional wells.

## B. Geography

The facilities of the Los Alamos National Laboratory and the communities of Los Alamos and White Rock are located on the Pajarito Plateau. The Pajarito Plateau forms an apron 8 to 16 miles wide and 30 to 40 miles long around the eastern flanks of the Sierra de los Valles (Fig. 1). The surface of the plateau slopes gently eastward from an altitude of about 7800 ft along the

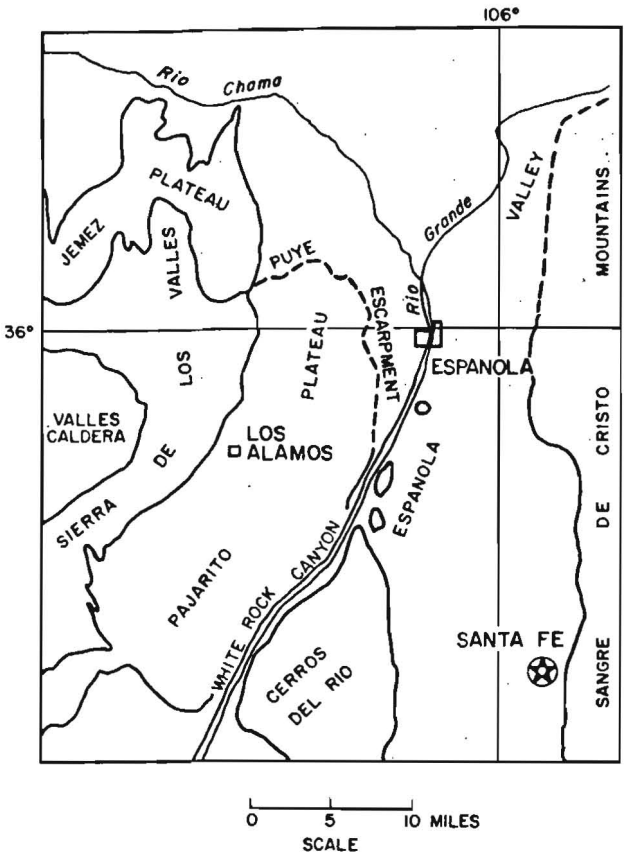


*Fig. 1. Topographic features in the Los Alamos area.*

flanks of the mountains to about 6200 ft along eastern edge, where it terminates along the Puye Esc ment and White Rock Canyon. The plateau is drainec southeast- and eastward-trending streams that have deep canyons into the surface of the plateau.

The Rio Grande lies to the east of the plateau. It dr from an altitude of about 5500 ft at Otowi (mouth of Alamos Canyon) to about 5360 ft at the junction Frijoles Canyon. North of Otowi the Rio Grande lie a broad valley, whereas to the south it is confined deep narrow canyon (White Rock Canyon).

The mountain peaks of the Sierra de Los Valles ris an altitude of about 11 500 ft near the head of S Clara Canyon and to an altitude of 10 200 ft near head of Frijoles Canyon. The crest of the north/so trending range of peaks and ridges forms a surface w divide. Streams originating on the eastern slopes Pajarito Plateau flow directly into the Rio Gra Streams on the western slopes follow a more circuit course and enter the Rio Grande 75 miles to the sou

The climate and vegetation change westward from Rio Grande to the crest of the Sierra de Los Valles, al with the change in altitude. The average precipita increases from about 10 in. along the Rio Grande t much as 30 in. along the crest of the mountains. average annual precipitation on the plateau is abou in. About 70% of the precipitation occurs in July August during summer thundershowers.

## C. Definitions of Terms

A few of the hydrologic terms are defined for convenience of the reader.

- Aquifer. A body of rocks or formations that cont sufficient permeable material to conduct ground w and to yield economically significant quantitie water to wells or springs.
- Saturated Thickness. The zone of complete satura which includes permeable and relatively imperme rock units.
- Pumping or Production Rate. Reported in gallons minute (gpm).
- Drawdown. The distance the water level in a we lowered by pumping (ft).
- Specific Capacity. The rate of discharge of a water per unit of drawdown (gpm/ft).
- Transmissivity. The rate at which water in an aquif transmitted through a unit width of the aquifer u unit hydraulic gradient (gpd/ft).

- Field Coefficient of Permeability. The rate of flow of water in gallons per day through 1 sq ft under a hydraulic gradient of 100% at prevailing temperature in the aquifer (gpd/ft$^2$).
- Rate of Movement in the Aquifer. Derived from the equation V = PI/p, where P = field coefficient of permeability in gpd/ft$^2$ (converted to ft$^3$), I = hydraulic gradient, and p = per cent porosity of saturated thickness ranging from 15% for fine sediments to 20% for sandstones and conglomerates.
- Production. Reported in gallons (gal.).

## II. GEOLOGY

Drainage areas or streams that head on the flanks of the mountains are cut into the rocks of the Tschicoma Formation. Canyons on the Pajarito Plateau are cut into and are underlain by the Bandelier Tuff. Along the eastern edge of the plateau, the channel is cut through the Puye Conglomerate into the Tesuque Formation, which floors the valley north of Otowi on the Rio Grande and forms the lower canyon walls along the Rio Grande in White Rock Canyon (Fig. 1). The basaltic rocks of Chino Mesa are in places interbedded in the sediments of the Puye Conglomerate.

The rock units described, from oldest to youngest, are the Tesuque Formation, Puye Conglomerate, and basaltic rock of Chino Mesa of the Santa Fe Group; the Tschicoma Formation and Bandelier Tuff of the volcanic rocks of the Jemez Mountains; and alluvium and soil of recent age. The generalized geology, stratigraphy, and structure are presented as a basis for understanding hydrology of the main aquifer. Detailed geology can be found in Refs. 15-19. The geologic nomenclature used in this report is from Griggs.[17]

The generalized stratigraphic relations are shown on the geologic cross-section through the Pajarito Plateau, Fig. 2. A diagrammatic section correlation of rock units between supply and test wells is shown in Fig. 3.

### A. Santa Fe Group

The Santa Fe Group, in ascending order, consists of the Tesuque Formation, Puye Conglomerate, and basaltic rocks of Chino Mesa (Fig. 2).

The Tesuque Formation is the oldest geologic formation to be considered in this report. It consists of a poorly to moderately cemented light-pink siltstone, silty sandstone, and a few lenses of pebbly conglomerate and clay. The sand-sized particles are dominantly quartz and feldspar; minor amounts of biotite, muscovite, and magnetite are also present. Rock fragments are rhyolite, gneiss, schist, limestone, and quartzite. Basalt flows are interbedded with the sediments of the Tesuque Formation. They generally are about 50 ft thick and contain interflow breccias of sediments.

The Tesuque Formation crops out along the Rio Grande and in lower Los Alamos and Guaje Canyons and underlies the Pajarito Plateau (Fig. 2).

Many individual beds in this formation are permeable and, where saturated, will yield water to a well. Some of the beds are relatively impermeable, and they restrict vertical and lateral movement of water within the formation. Beneath the Pajarito Plateau, coarse volcanic rock fragments of latite, basalt, rhyolite, tuff, and pumice predominate in the upper 1000 ft of the Tesuque Formation. These coarse sediments yield larger amounts of water to wells than do the finer sediments that predominate in the formation farther to the east along the Rio Grande.

The interbedded basalt flows in the Tesuque Formation may be fairly dense; when thin, they may be highly jointed and yield large amounts of water. Sediments of the interflow breccias between basalt flows are coarse and should yield water readily.

The Puye Conglomerate overlies the Tesuque Formation and consists of poorly to well-cemented detritus, which ranges in size from clay to large boulders (Fig. 2). The rocks that compose the conglomerate are latite, quartz latite, dacite, rhyolite, basalt, and pumice. Lenses and tongues of silt, clay, or pumice are common. The basal bed of the conglomerate is a slightly consolidated channel-fill deposit distinctive in composition, consisting of pegmatite gravel and boulders of quartzite, granite, gneiss, schist, and fragments of basalt and limestone.

The Puye Conglomerate crops out along the Rio Grande and thickens westward beneath the Pajarito Plateau. Along the western edge of the plateau, it interfingers in the subsurface with flow rocks of the Tschicoma Formation (Fig. 2). The Puye Conglomerate is highly permeable and, when saturated, it yields large amounts of water to wells.

The basaltic rocks of Chino Mesa consist of a series of basalt flows and interflow breccias. Individual flows generally are less than 50 ft thick; however, a series of flows may form a single thick-basalt unit. Interflow breccias of broken fragments of basalt and sediments may occur between individual flows.

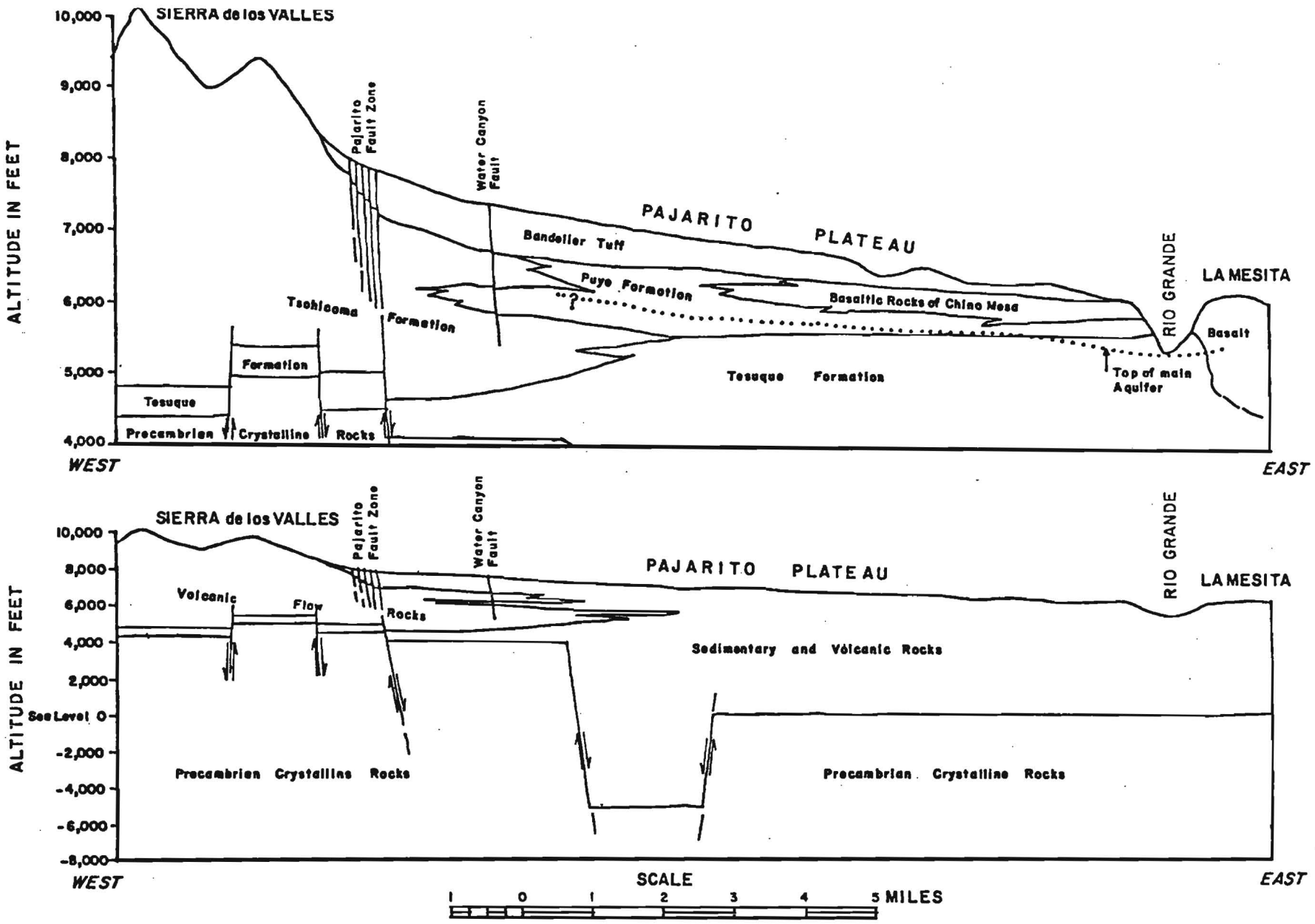


*Fig. 2. Geologic section showing stratigraphy and structure from the Sierra de los Valles across the Pajarito Plateau to the Rio Grande*

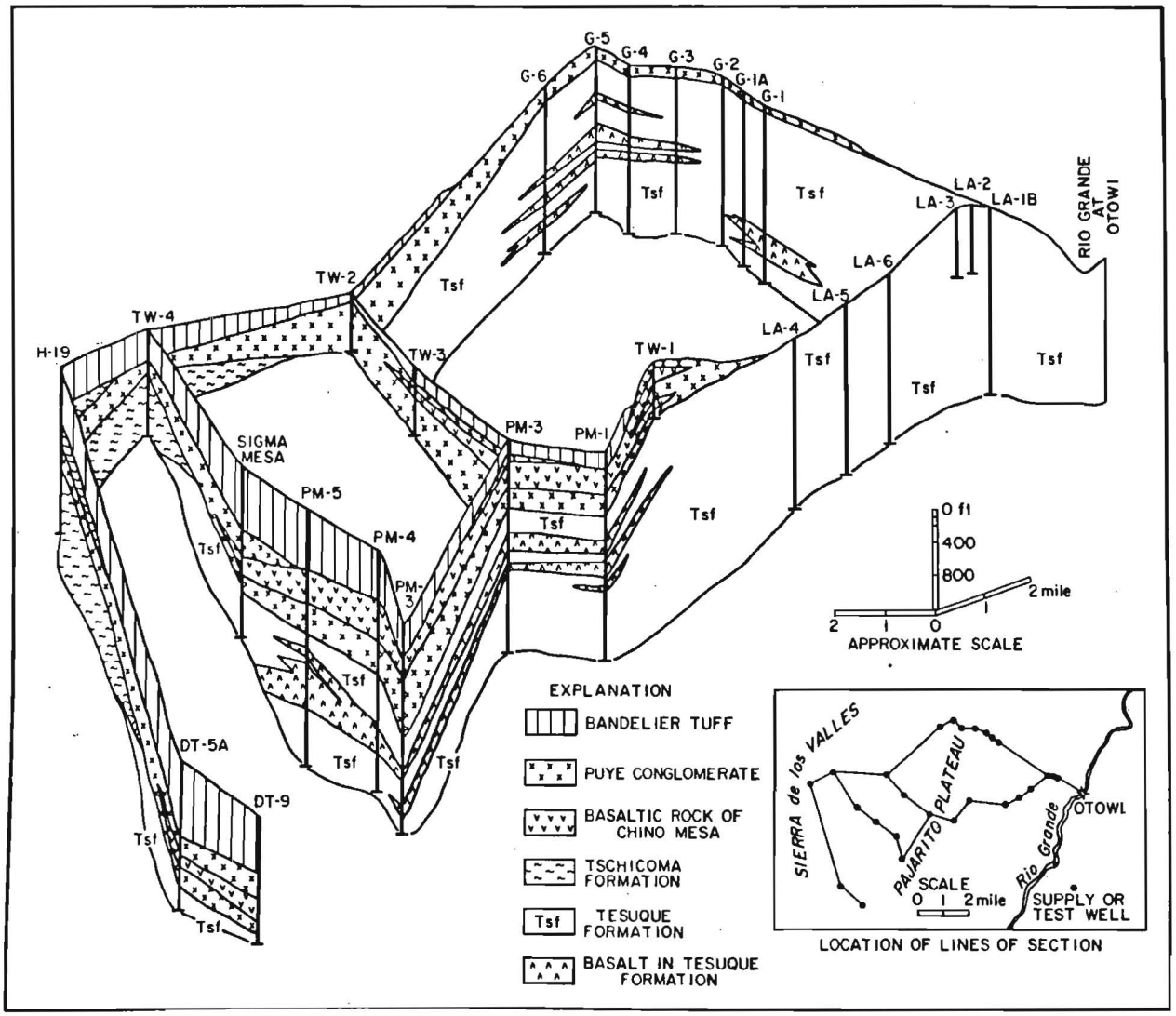


*Fig. 3. Diagrammatic section of geologic units in the Los Alamos area.*

A thick section of these rocks crops out along the Rio Grande in White Rock Canyon south of Los Alamos Canyon. The rocks thin westward beneath the Pajarito Plateau, where they interfinger in the subsurface with sediments of the Puye Conglomerate.

The basalt flows were extruded from centers east of the Rio Grande, and they flowed north, northwest, and west across the present course of the river. They form the eastern edge of a north/south-trending basin beneath the central part of the Pajarito Plateau (Fig. 3). The basin is filled with conglomerate that interfingers with the basalt; deposition of the conglomerate and emplacement of the basalts were contemporaneous. Thick sections of basalt into the subsurface and along the eastern margin of the Pajarito Plateau occur where the flows filled topographic lows in the Puye Conglomerate.

Thin basalt flows, separated by interflow breccias beneath the central part of the Pajarito Plateau, are permeable and when saturated, will yield water readily. Open joints and cavities in thick-basalt flows also yield water; however, along the Rio Grande (White Rock Canyon), steepening of the contours on the surface of the main aquifer indicates that thick-basalt flows form a barrier to movement of ground water (Fig. 4).

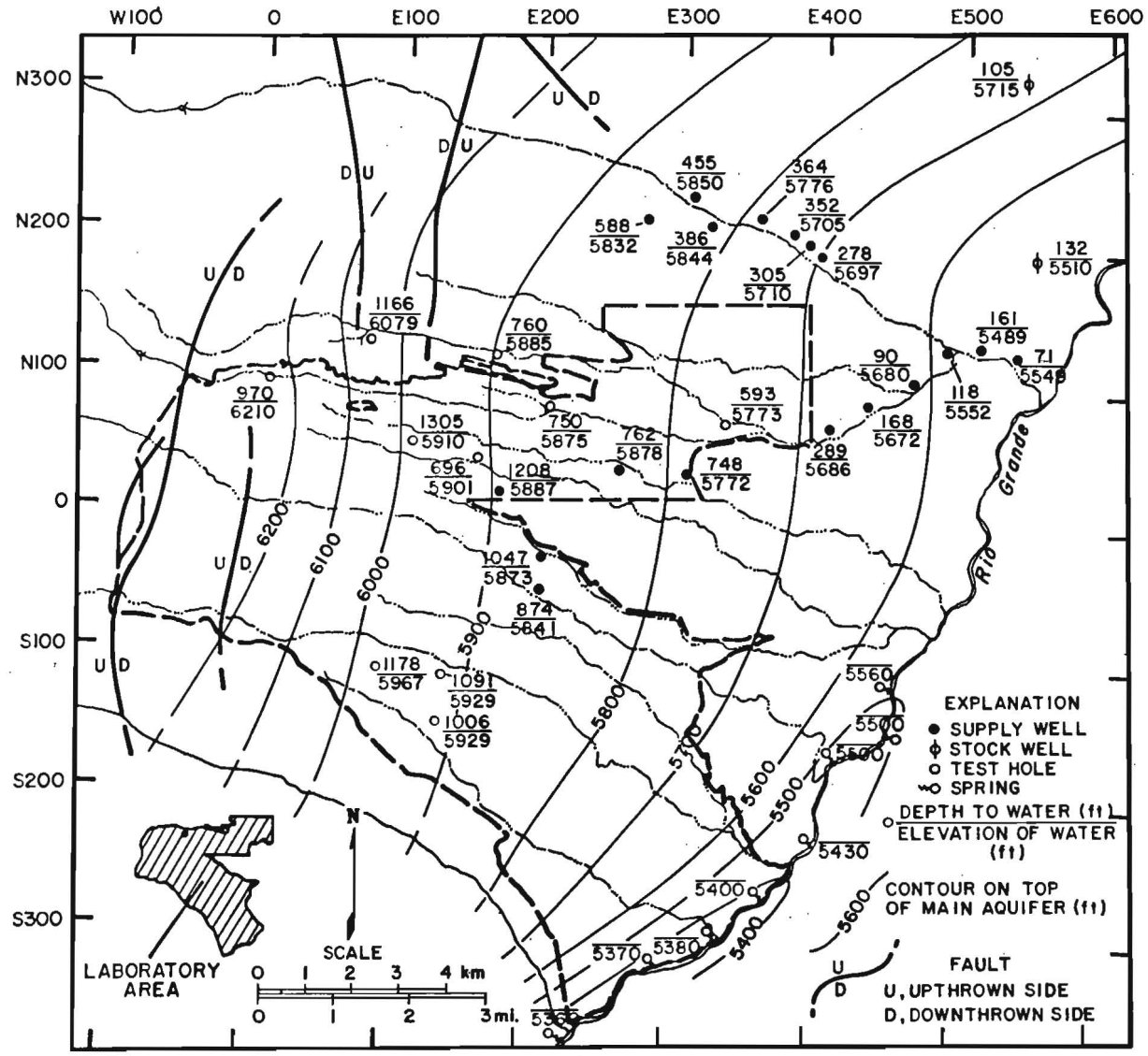


*Fig. 4. Generalized contours on the surface of the main aquifer.*

## B. Volcanic Rocks of the Jemez Mountains

Volcanic rocks of the Jemez Mountains, along the eastern flanks of the Sierra de los Valles and on the Pajarito Plateau, consist of the Tschicoma Formation and the younger Bandelier Tuff (Fig. 2).

The Tschicoma Formation consists of flow and pyroclastic rocks composed of latite, quartz latite, dacite, and andesite. Interflow breccias of broken fragments of flow rocks and sediments occur between flows.

The Tschicoma Formation forms the Sierra de los Valles west of the Pajarito Plateau and is present in the subsurface beneath the western part of the plateau, where it interfingers with the Puye Conglomerate (F and 3).

The Tschicoma Formation has low permeabilit thus retards and restricts the movement of ground Open joints and interflow breccias within the form which could yield appreciable amounts of wate limited.

The Bandelier Tuff consists of a series of ash fa ash flow tuff that is light grained and rhyolitic. Th contains quartz and sanidine crystals, pumice, and fragments of other igneous rock in a matrix of fir shards.

The tuff overlies the older rocks and forms the surface the Pajarito Plateau. The thickness ranges from about )00 ft along the western margin of the plateau, where it ɔs onto the Tschicoma Formation, to less than 50 ft ɔng the Rio Grande, where it overlies the Puye ɔnglomerate or the basaltic rocks of Chino Mesa (Fig.

The tuff is above the main ground-water body and ly in areas on the flanks of the Sierra de los Valles es it contain small amounts of perched water, which ;charges from springs.

### Alluvium and Soil

Alluvium from the Sierra de los Valles and the jarito Plateau has been deposited in the canyons of the ıteau. Near the heads of the canyons, bedrock com- ɔnly is exposed in the lower parts, but farther down the ıyons, alluvium may be several hundred feet wide and much as 80 ft thick.

Alluvial deposits in the canyons heading on the flanks the Sierra de los Valles contain cobbles and boulders h accompanying clay, silt, sand, and gravel derived m the Tschicoma Formation and Bandelier Tuff. posits in the canyons heading on the Pajarito Plateau ıtain clay, silt, sand, and gravel derived from the ndelier Tuff. The alluvium contains some water in the ;er canyons; however, the amount is insufficient for ter supply.

Clayey soil derived from weathering of the Bandelier ff covers most of the fingerlike mesas of the Pajarito teau.

### Structure

The Rio Grande depression is a structurally low area t constitutes the valley through which the Rio Grande vs.[20] The Pajarito Plateau is part of the depression, ıough it forms a topographic high area along the :tern margin of the valley.

The most prominent structural features of the Pajarito teau is the Pajarito fault zone, which trends north- d along the western edge of the plateau. It is a part of complex fault system that formed the Rio Grande ression. The fault zone consists of normal faults that downthrown to the east and that displace rocks of Bandelier Tuff, Puye Conglomerate, and Tschicoma mation (Fig. 2). The displacement, estimated from fault scarp, is from 400 to 500 ft. The amount of displacement decreases northward where, at a point north of Los Alamos, all visible traces of the fault disappear. The movement along the fault zone has been in small increments, which began before the deposition of the Bandelier Tuff and continued into post-Bandelier time. The displacement of the older rocks is greater than the displacement of the younger rocks. The major fault in this zone extends into and displaces the Precambrian rocks.

North of Los Alamos and east of the Pajarito fault zone, two normal faults cut the Bandelier Tuff, the Puye Formation, and the Tschicoma Formation. These faults, downthrown to the west, form a graben between them and the Pajarito fault zone. They are a part of the fault system that formed the Rio Grande depression.

Beneath the central part of the Pajarito Plateau, a north-trending depositional basin is formed in the Tesuque Formation. The basin is filled with volcanic debris of the Puye Conglomerate, overlain by the Bandelier Tuff. The eastern edge of the basin is formed by thick flows of basalt from Chino Mesa, 5 to 10 miles west of the Rio Grande (Fig. 2).

A gravity survey indicated that the deepest part of the Rio Grande depression (top of the Precambrian rocks) is in a north-trending trough near the center of the plateau. The bottom of this sediment-filled trough lies about 5000 ft below sea level (Fig. 2).[21]

## III. MAIN AQUIFER OF THE LOS ALAMOS AREA

The main aquifer of the Los Alamos area is the only aquifer capable of municipal and industrial water supply. The upper surface of the main aquifer rises westward from the Rio Grande through the Tesuque Formation into the lower part of the Puye Conglomerate, beneath the central and western parts of the plateau (Fig. 2).[22] The water in the aquifer moves from the major recharge area in the Valles Caldera eastward toward the Rio Grande, where a part is discharged into the river through seeps and springs (Fig. 4).

The major recharge area for the aquifer is the intermountain basin formed by the Valles Caldera. The upper parts of the sediments in the basin are lacustrine deposits of clay, sand, and gravels, which are underlain by volcanic debris resulting from collapse of the caldera.[23] The sediments and volcanics in the basin are highly permeable and are saturated. The saturated "basin fill" recharges the main aquifer in sediments of the

Tesuque Formation. Minor amounts of recharge may occur in the deep canyons containing perennial streams on the flanks of the mountains. The intermittent streams in the canyon, which are cut into the plateau, add little, if any, recharge to the main aquifer.

Radiometric methods to date the age of the water in the main aquifer (time in transit from recharge to discharge) have been made using tritium and carbon-14. Tritium concentrations in water from wells from the Los Alamos and Guaje well fields have been less than 0.5 tritium units. Based on a natural occurrence of eight tritium units in precipitation (before hydrogen bomb tests), the age of the water in the aquifer in the two well fields is greater than 50 yr. Carbon-14 analyses of water from a well in the Pajarito Field at the eastern edge of the well have indicated that the age of water in the main aquifer is about 1400 yr. The radiometric age of water in the main aquifer indicates a slow rate of movement from the recharge area in the Valles Caldera.

The gradient on the surface aquifer, beneath the Sierra de los Valles and the western part of the Pajarito Plateau in the Los Alamos area, is about 120 ft per mile in the Tschicoma Formation interbedded with the Puye Conglomerate. As water in the aquifer moves into the more permeable sediments of the Puye Conglomerate in the central part of the plateau, the gradient increases to 60 to 80 ft per mile. The gradient decreases to 80 to 100 ft per mile along the eastern edge of the plateau as the water in the aquifer moves into the less permeable sediments of the Tesuque Formation (Fig. 4). The depth to the aquifer ranges from about 1200 ft along the western edge of the plateau, decreasing to about 600 ft along the eastern edge.

The Rio Grande is the principal area for ground water discharges from the main aquifer. A gain in streamflow in the Rio Grande in a 26-mile reach from the gaging stations at Otowi to Cochiti was computed at about 25 cfs.[24] Further investigation indicated that the river gained flow from Otowi to the mouth of the Frijoles Canyon, a distance of about 11.5 miles. Below Frijoles Canyon the Rio Grande is a losing stream.[25] Water from the river is lost to underlying sediments. It is estimated that the 11.5-mile reach of the canyon below Otowi receives a discharge from the main aquifer of 4300 to 5500 acre-feet annually.[26]

The main aquifer extends to the south into Bandelier National Monument. The movement of water in the Monument trends more to the south than east, as in the Los Alamos area. The depth to water along the western edge of the Pajarito Plateau in the Monument ranges from 1000 to about 1200 ft, with a gradient of 60 t per mile. The Rio Grande above the mouth of F Canyon is a gaining stream, whereas below F Canyon the Rio Grande is a losing stream. Thu surface of the aquifer north of Frijoles Canyon is s above the river level, but the surface of the aquifer south is at an elevation below the river level.[25]

The main aquifer extends to the north of Los A beneath the Pajarito Plateau around the northw flanks of the Sierra de los Valles. Water movemen the east and northeast in the Puye Conglomerate a Tesuque Formation beneath the Pajarito Platea within the Tesuque Formation in the Española Va

The thickness of the main aquifer is unknown; ever, the Rio Grande depression contains over 15 of volcanic rocks and sediments that overlie the Pr brian crystalline rocks.[21] These volcanic rock sediments are potential aquifer.

The volcanic rocks and sediments that fill tl pression are apparently saturated. Water qualit deteriorate at increased depth. Most of the wells depression yield fresh [less than 1000 mg/ℓ tot solved solids (TDS)] to slightly saline water (1( 3000 mg/ℓ TDS).[27] The deepest well in the Los A area penetrated about 2250 ft of sediments i depression. The TDS concentrations from this w about 500 mg/ℓ. It is estimated that the water depression will be fresh to a depth of 6000 to 7 before the TDS will exceed 1000 mg/ℓ. Thus, th aquifer in the area has a saturated thickness of a 6000 ft before chemical quality may restrict the the aquifer for municipal and industrial supply.

## A. Supply, Test, and Stock Wells

The Los Alamos Field is composed of five pro wells (LA-1B, 2, 3, 4, and 5). One well (LA-6) standby to be used only in case of an emergency b the water contains excessive amounts of arseni field was constructed in 1946 and 1948. On (LA-1B) was added to the field in 1960 (Fig. 5).

The Guaje Field is composed of seven wells. Tl was constructed in 1950 and 1951. Well G-1 added to the field in 1954 and well G-6 was ad 1964.

The Pajarito Field is composed of wells PM-1, 3, which were constructed in 1965 and 1966; well added to the system in 1982; and well PM-5, con in 1982 but not added to the system until late 198

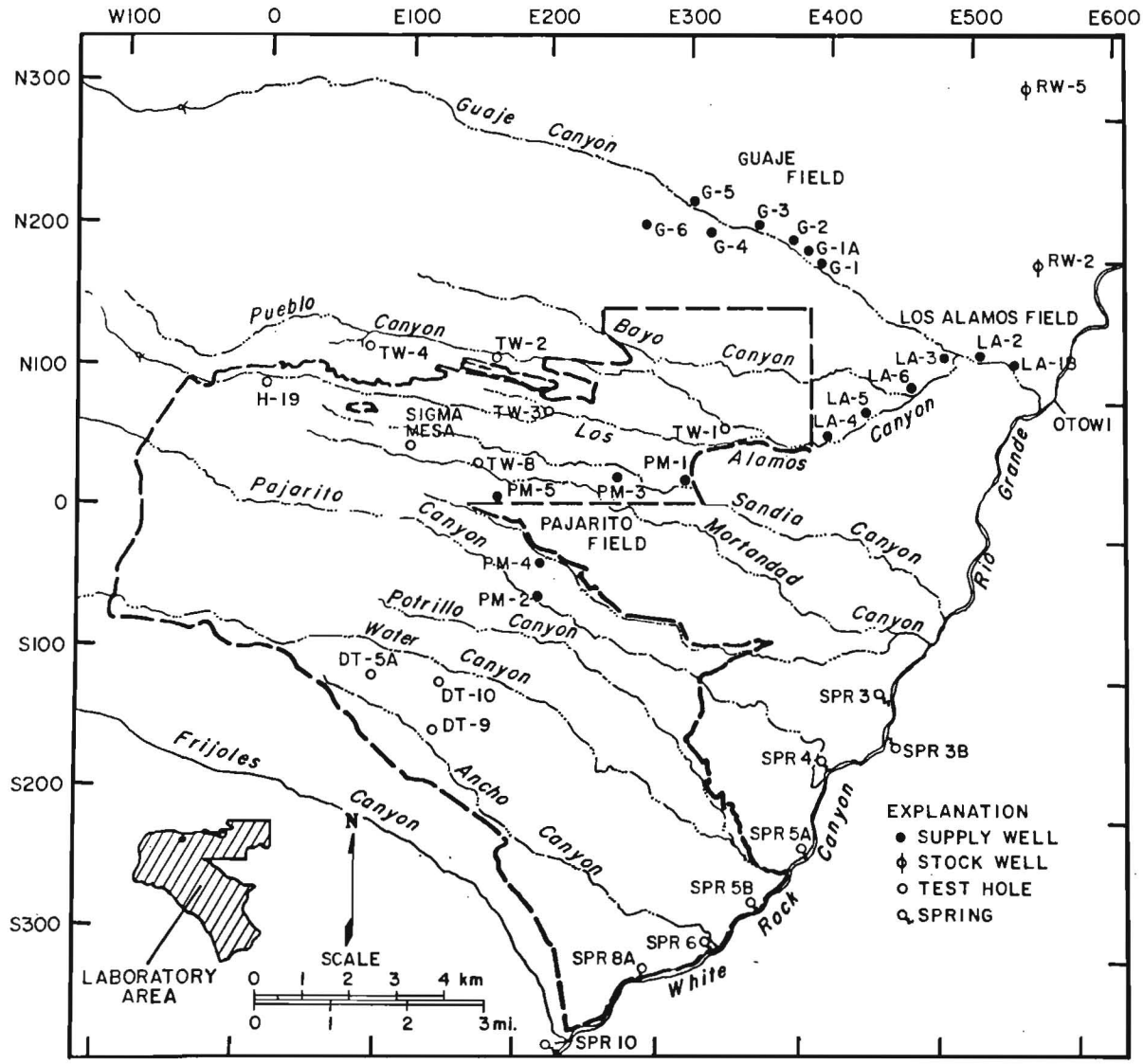


*Fig. 5. Location of supply, test, and stock wells and springs in the Los Alamos area.*

Construction and hydrologic data for the individual upply wells are presented in Appendix A.

Test wells TW-1, 2, 3, 4, and H-19 were drilled in 949 through 1950 to determine the geologic and ydrologic characteristics of formations underlying the ajarito Plateau. Test wells TW-1, 2, 3, and 4 are cased nd are used as part of a well net that monitors the main quifer.[28] Test well H-19 was abandoned uncased.

Test wells DT-5A, DT-9, and DT-10 were drilled in 960 to evaluate the geologic and hydrologic conditions f a test site.[29] Test well TW-8 was drilled in 1960 to determine the geologic and hydrologic condition beneath a canyon disposal area for treated liquid low-level radioactive effluents.[30] Sigma Mesa was a test hole drilled in 1979 to determine geologic and hydrologic conditions related to possible development of geothermal energy for use at the Laboratory. The hole was scheduled for a depth of 10 000 to 12 000 ft; however, construction problems (lost circulation) terminated the hole at a depth of 2292 ft.

Two stock wells, equipped with windmills located on San Ildefonso Pueblo, were drilled in 1954 and 1955.

Nothing is known about hydrologic characteristics of the main aquifer, except for original water levels and chemical quality.

Construction and hydrologic data for the individual test and stock wells are presented in Appendix B.

Eight springs in White Rock Canyon were used in construction of the contours on the surface of the main aquifer and aid in interpretation of chemical quality of water in the main aquifer.[25] Hydrologic data for the springs are presented in Appendix C.

## B. Production and Water-Level Fluctuations

Water from the wells in the Los Alamos Field is lifted vertically about 1800 ft through four booster stations into storage in the Laboratory and community areas. The water from the Guaje Field is lifted vertically about 1500 ft through four booster stations into storage. In the Pajarito Field, wells PM-1 and PM-3 supply the community of White Rock. The water is produced from the wells to storage. Wells PM-2, 4, and 5 can be used to supply White Rock, or their output can be lifted about 800 ft vertically into the Laboratory or community area through two booster stations.

The total production from well in the three wells fields from 1947 through 1982 has been 40 496 × $10^6$ gal. (Table I). Production from three test wells in the southern area of the Laboratory (DT-5A, DT-9, and DT-10) was measured during testing after completion in 1960.

The main aquifer beneath the western and central part of the Pajarito is under water table conditions, whereas along the eastern margin and Rio Grande it is under artesian conditions.[26] In 1946 a number of test holes were drilled along the Rio Grande, north of Otowi and in the lower part of Los Alamos Canyon, to determine if a water supply could be developed in this area.[31] Three test holes along the Rio Grande drilled to a depth of 475 to 495 ft were artesian, as were the four test holes ranging in depth from 375 to 475 ft in lower Los Alamos Canyon.[31]

Supply wells LA-1 (abandoned and replaced by LA-1B), LA-2, and LA-3, which were completed in late 1946 and 1947 and cased to a depth of 870 ft, also were artesian and flowed when completed.[32] Pumpage soon reduced the artesian pressure, and water levels were below the well head. Other wells in Los Alamos Field (LA-4, -5, and -6) probably encountered semiartesian conditions, as did some of the wells in Guaje Canyon (G-1, G-1A, and G-2) and in the Pajarito Field (PM and -3).

The hydrostatic pressures increased with depth. 1960 the water levels in the lower part of the Los Alan Field (LA-1, -2, and -3) ranged from 13 to 76 ft bel the well head. Well LA-1B, 150 ft northeast of ab doned well LA-1, was drilled to a depth of 2256 ft a was cased and gravel packed to 1750 ft. The well be flowing during development. The well flow increased about 100 gpm. The well was shut in and pressu measured over a 30-day period. Shut-in pressure was psi, which is equal to a head of water 34 ft above the l surface.[26] Pumpage in the first month reduced artesian pressure so that the water levels were below l surface. If the well is not pumped for several months, water level rises in the well; several times in the last yr, the well flowed for short periods of time bel artesian pressures were reduced by pumpage.

Months of heavy production generally occur in Ju July, and August and months of light production ar December, January, and February. The difference demand for periods of heavy-to-light production (s mer to winter) are mainly due to the use of water lawn and yard irrigation. As a result, the water level the wells fluctuate with production. The highest w level occurs during the winter and lowest water l occurs during the summer.

**1. Los Alamos Field.** The wells in the Alamos Field produced 14 503 × $10^6$ gal. of water f 1947 through 1982. This pumpage was 36% of the t pumpage from the three well fields (Table I).

Water levels in the individual wells have gene declined in response to the pumpage. The water-l declines from 1950 through 1982 in wells LA-2, -3 -5, and -6 have ranged from 7 ft in LA-6 to 72 f LA-2. The water-level decline in well LA-1B from 1 through 1982 has been 64 ft. In general, the lar amount of water-level decline has occurred in the lo part of the field (LA-1B, -2, and -3) and the least am of decline in the upper part of the field (LA-4, -5, and The average decline in the lower part of the field has l 52 ft from 1950 through 1982, whereas the lower has produced 35% of the water from the field. average water-level decline in the upper part of the has been 21 ft from 1950 through 1982, whereas upper field has produced 65% of the water from the (Table I).

TABLE I

PRODUCTION FROM THE LOS ALAMOS, GUAJE, AND PAJARITO WELL FIELDS
1947-82

| | Pumpage ($10^6$ gal.) | Percentage of Field | Percentage of Total |
|---|---|---|---|
| Los Alamos Field | | | |
| Well LA-1[a] | 154 | 1 | <1 |
| Well LA-1B | 1964 | 14 | 5 |
| Well LA-2 | 1305 | 9 | 3 |
| Well LA-3 | 1644 | 11 | 4 |
| Well LA-4 | 3503 | 24 | 9 |
| Well LA-5 | 3049 | 21 | 8 |
| Well LA-6[b] | 2884 | 20 | 7 |
| Total | 14 503 | 100 | ~36 |
| Guaje Field | | | |
| Well G-1 | 2402 | 16 | 6 |
| Well G-1A | 2937 | 20 | 7 |
| Well G-2 | 2520 | 17 | 6 |
| Well G-3 | 2040 | 13 | 5 |
| Well G-4 | 1217 | 8 | 3 |
| Well G-5 | 2790 | 19 | 7 |
| Well G-6 | 1077 | 7 | 3 |
| Total | 14 983 | 100 | 37 |
| Pajarito Field | | | |
| Well PM-1 | 1593 | 14 | 4 |
| Well PM-2 | 5863 | 53 | 14 |
| Well PM-3 | 3478 | 32 | 9 |
| Well PM-4 | 76 | 1 | <1 |
| Well PM-5 | --- | --- | --- |
| Total | 11 010 | 100 | ~27 |
| Total | 40 496 | --- | ~100 |

[a]Production 1946 to 1952 and 1955 to 1956 (well abandoned).
[b]Production from 1948 to 1976, well on standby production, pumped to wastes 1977 to 1982.

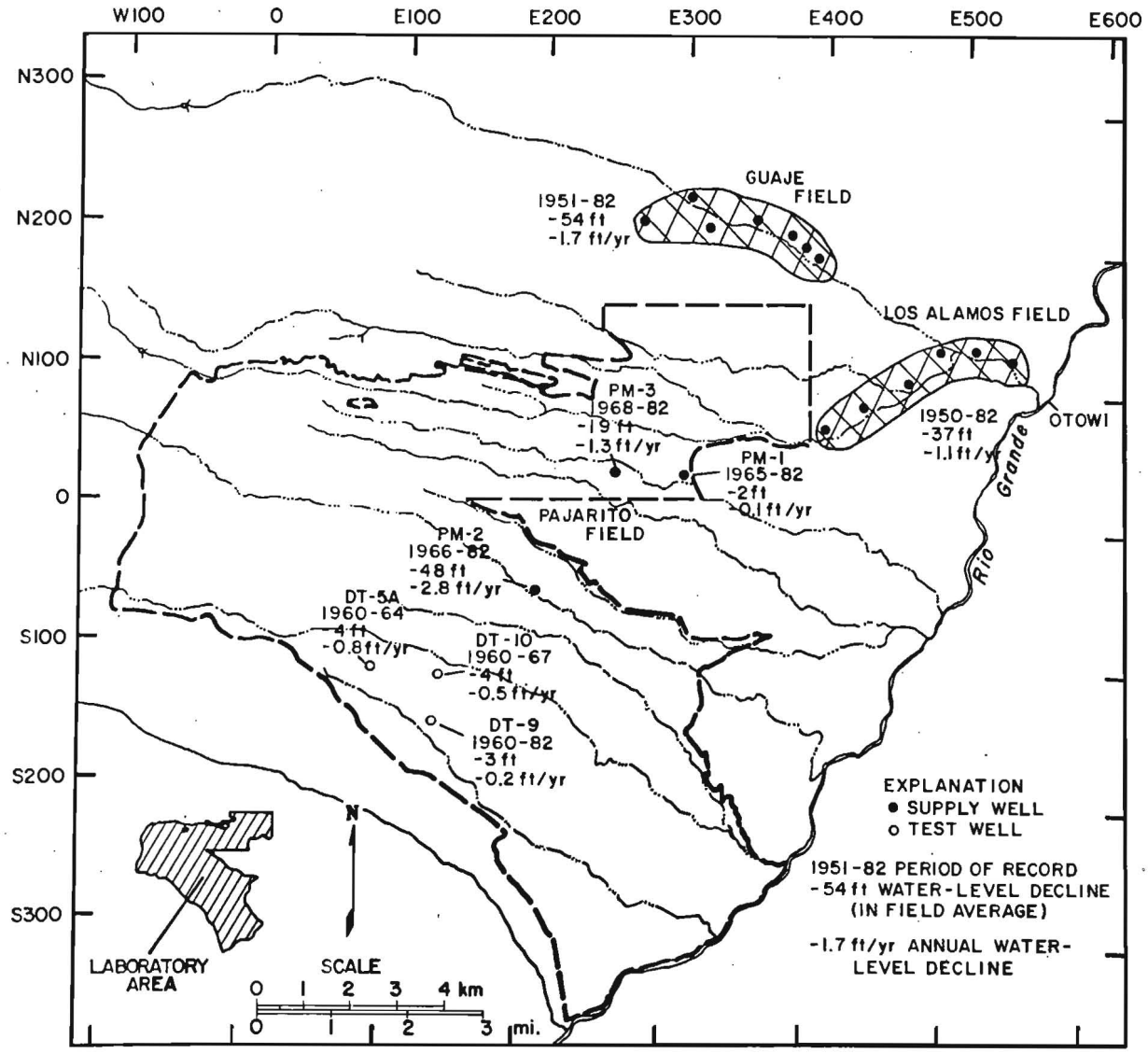


*Fig. 6. Water-level declines in well fields and supply and test wells.*

The average water-level decline in the Los Alamos Field from 1950 through 1982 has been 37 ft, with an average annual rate of decline of 1.1 ft/yr (Fig. 6). Production of 14 503 × $10^6$ gal. and a water-level decline of 37 ft equal the production of 392 × $10^6$ gal. of water per foot of water-level decline in the field (Fig. 7).

**2. Guaje Field.** The wells in the Guaje Field produced 14 983 × $10^6$ gal. of water from 1951 through 1982. This pumpage was 37% of the total pumpage from the three well fields (Table I).

Water levels in the individual wells have responde the amount of pumpage resulting in a general dec Water-level declines from 1951 through 1982 in v G-1, -1A, -2, -3, -4, and -5 have ranged from 29 to 9 The water level in well G-6 from 1964 through 1982 been 7 ft. The largest decline has been in the lower of the field (G-1, -1A, -2, and -3), where production been the greatest. The average decline has been abou ft, whereas about 66% of the total production from field has been from these wells. The average declin the upper field (G-4, -5, and -6) has been about 2

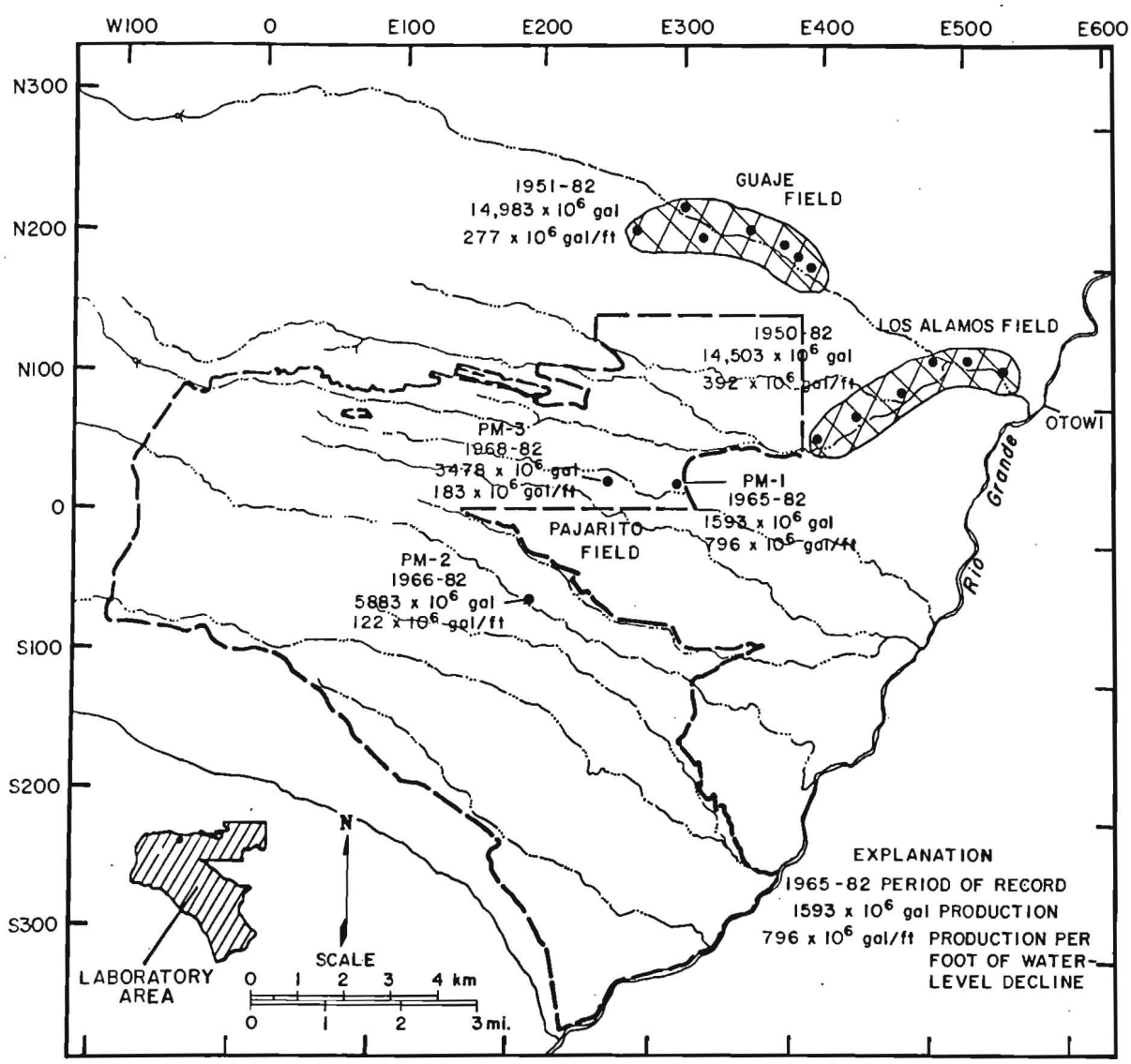


*Fig. 7. Water-level declines related to production from well fields and supply wells.*

/hile 34% of the total production has been from these /ells.

The larger amount of production from the lower field ; based on greater pumping rates. The declines are as nticipated for amount of pumpage and are not con- idered significant.

The average water-level decline in the Guaje Field for ıe period 1951 through 1982 has been 54 ft with an verage annual rate of decline of 1.7 ft/yr (Fig. 6). The roduction of 14 983 x $10^6$ gal. and a water-level decline f 54 ft equal the production of 277 x $10^6$ gal. of water er foot of water-level decline in the field (Fig. 7).

**3. Pajarito Field.** The well in the Pajarito Field produced 11 010 x $10^6$ gal. for the period 1965 through 1982. The pumpage was mainly from PM-1, -2, and -3, because production from PM-4 began in July 1982 and construction of the transmission system of PM-5 has not yet been completed. The pumpage from the field was 27% of the total pumpage from the three well fields (Table I). The water levels in the individual wells respond to the amount of pumpage, resulting in a general water-level decline.

The water level in well PM-1 declined 2 ft from 1965 through 1982 or at a rate of about 0.1 ft/yr (Fig. 6). The

pumpage during this period was about 1593 x $10^6$ gal. or 14% of the field total (Fig. 6 and Table I). The water level declined during production of 796 x $10^6$ gal./ft for the period 1965 through 1982. As the well PM-1 was pumped, the well continued to develop while allowing new water-bearing beds to contribute to the pumpage from the well. This is evident in the specific capacity, which increased each year from 15 gpm/ft in 1965 to 27 gpm/ft in 1982. This has resulted in the highest ratio in these wells of production to total water-level decline (Fig. 7).

The water level in well PM-2 declined 48 ft from 1966 through 1982, at a rate of 2.8 ft/yr (Fig. 6). The pumpage during this period was 5863 x $10^6$ gal., or about 53% of the field total. This is a high-yield well with a pumping rate of about 1400 gpm.

In the 18 years that well PM-2 was in operation, it produced 14% of the total production from all three well fields (Table I). The production during the period 1966 through 1982 was 5863 x $10^6$ gal. with a water-level decline of 42 ft. This equals the production of 122 x $10^6$ gal./ft of water-level decline (Fig. 7). Specific capacities varied slightly at about 23 gpm/ft but showed no significant trends for the period 1966 through 1982. There was little indication from the specific capacity that there was any further development of the well after it was placed in service.

The water level in well PM-3 declined 19 ft from 1968 through 1982, at a rate of 1.3 ft/yr (Fig. 6). The pumpage during this period was 3478 x $10^6$ gal. or about 32% of the field total (Table I).

PM-3 is a high-yield well with a pumping rate of 1400 gpm. In 15 yr of service, it has produced 9% of the total water produced at Los Alamos from 1947 through 1982 (Table I). The specific capacity of the well has increased from 48 gpm/ft in 1968 to about 61 gpm/ft in 1982. Based on specific capacity and production rates, this is the best well in the system. The water level has declined during production of 183 x $10^6$ gal./ft during the period 1968 through 1982 (Fig. 7).

Well PM-4 was completed in 1982 and was placed in production in July. The well produced 76 x $10^6$ gal. for the remaining 6 months of 1982. Water level, nonpumping and pumping, rose slightly as the well developed while it was pumped. The pumping cleaned out the drilling mud and fine silts, clays, and sands that were left in the gravel pack and water-bearing formations when the well was drilled. The specific capacity increased from 30.0 gpm/ft to 36.8 gpm/ft from July to December. It is also a high-yield well with a pumping rate of 147 and a high specific capacity. Based on productio and specific capacity, this is the second best well system.

Well PM-5 was completed in 1982 and has no equipped or connected to the system. Tests of th indicate that the pump will be rated at about 122 which will result in a drawdown of about 144 ft, specific capacity of about 8.5 gpm/ft of drawdow well will probably develop with pumpage when p production, resulting in a smaller drawdown greater specific capacity.

**4. Test Wells.** Test well DT-5A was pumpe 24-h period for testing early in 1960. The amo water produced was about 0.1 x $10^6$ gal. The wat recovered after the test and showed no effect pumpage. During the period 1960 through 1964 al test, the well was not equipped with a pump. Duri period the water level declined about 4 ft or at a 0.8 ft/yr (Fig. 6). The decline is under normal con (lack of recharge), not as the result of pumpage.

The test well DT-5A was equipped with a pu 1970. Since that time, the well has produced abou $10^6$ gal. for collection of samples for chemic radiochemical analyses. The well is pumped twice at about 5 gpm for about 2 days before samplin amount of water removed from the aquifer is sm if any decline occurred from pumpage, it wo insignificant and immeasurable from one pumping to the next (6 months later).

Test well DT-9 was pumped for a 24-h period 1960. The amount of water produced was abou $10^6$ gal. The water levels recovered after that and no effect of the pumpage. During the period 1 1982 after the test, the well was not equipped pump. Water was bailed out for sample collecti more than 500 gal. have been removed from t since 1960. The small amount of water removed fr well would not result in significant water-level cha the aquifer.

The well DT-9 is 0.75 mile south of well DT- 1.25 miles southeast of well DT-5A, so that th amount of water pumped from these wells will no the water level of well DT-9 (Fig. 2). Well DT equipped with a water stage recorder from 1960 and 1970 to 1982. A continuous water-level rec obtained from the recorder. Water-level data we piled into average annual measurements to il

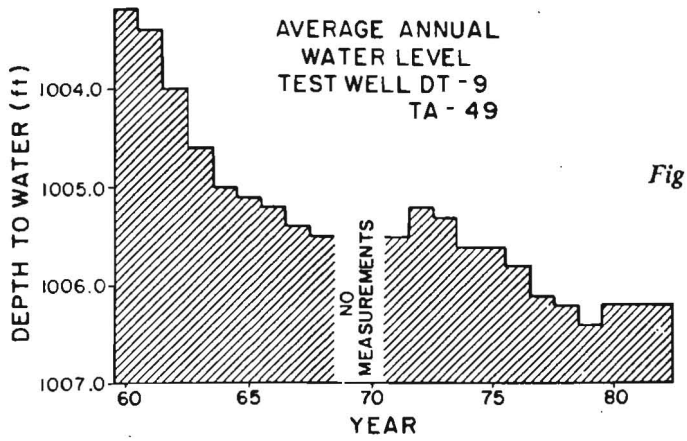


*Fig 8. Average annual water levels in Test Well DT-9, 1960 to 1968 and 1971 to 1982.*

water-level trends over a period of 22 yr. This reflects normal water-level fluctuations and trends for the region. The water level in the well declined from 1003 ft to 1006 ft from 1960 through 1982 (or at an average rate of about 0.1 ft/yr) (Fig. 8). The most rapid decline occurred from 1960 to 1968,when the decline was 2.3 ft or about 0.3 ft/yr (Fig. 8). The annual average water level rose 0.3 ft from 1971 to 1972, then declined 1.2 ft to 1979. Since 1979 the water level has remained about the same. The fluctuation of water levels reflects normal regional water-level trends. The decline in water levels shows deficient recharge, with only one period (1971) of recharge exceeding the normal discharge of the aquifer in White Rock Canyon.

The well and records from the water stage recorder were used in a special study, "Air Volume and Energy Transfer Through Test Holes and Atmospheric Pressure Effects on the Main Aquifer."[33] The main aquifer is very sensitive to atmospheric pressure changes, earth shocks, and probable earth tide effects. These effects (water-level fluctuation) were monitored by a continuous water stage record on well DT-9.

The possible earth tide effects are recorded by minor water-level fluctuations in which the gravitational pull of the moon elongates and compresses the aquifer. These effects, estimated from records by eliminating atmospheric effects, range from 0.01 to 0.03 ft of water-level fluctuation.

Water-level fluctuations are also recorded from earth shocks. In general, these are the result of strong earth motion. Records of the Alaskan earthquake of 1964 caused a water-level fluctuation of more than 1 ft in well DT-9. Small fluctuations have occurred, generally less than 0.10 ft, which are attributed to major earthquakes in Mexico or Central America. These water-level fluctuations are caused by expansion and compaction of the aquifer by surface waves of the earthquake.[33]

Test holes or wells in the Bandelier Tuff and Puye Conglomerate transfer air to and from the tuff and conglomerate in response to changes in atmospheric pressure. Test holes tend to "blow air" during barometric lows and to "suck air" during barometric highs. The air is transferred to and from the unsaturated zone above the main aquifer. The changes in atmospheric pressure also cause water-level fluctuations. During a storm in December 1967, a fluctuation of over 0.6 ft was recorded. Minor changes in atmospheric pressure also cause water-level fluctuations.

During a special study, October 10 through 14, 1964, four cycles of pressure changes were correlated with four cycles of water-level fluctuations. Increased atmospheric pressure caused water-level declines, and a decrease in pressure caused the water level to rise. The changes in water level, atmospheric pressure, and rates of air transfer from the test holes were correlated.[33]

The barometric efficiency of the aquifer can be expressed in terms of a column of water. The ratio of water-level changes to pressure changes expresses the barometric efficiency of the aquifer. During the four cycles of water-level and atmospheric pressure changes, the barometric efficiency of the aquifer ranged from 51 to 88%. The smaller pressure changes with smaller volumes of air transferred resulted in greater barometric efficiency.

The aquifer penetrated by DT-9 is not homogeneous but is made up of three different formations (conglomerate, basalts, and sandstones) with three different transmissibilities and probably three different pressure

heads (water pressures in each unit). The variations in barometric efficiency are the result of the combined different pressures within each formation.[33]

Test well DT-10 was equipped with a pump for a 24-h period for testing in early 1960. The amount of water produced was about 0.1 × $10^6$ gal. The water level recovered after the test and showed no measurable effect of the pumping. During the period 1960 to 1967, the water level declined about 4 ft or at an annual rate of 0.5 ft/yr. The well was not equipped with a pump during this period. Water-level decline was normal, not from pumpage, but because of lack of recharge to the aquifer.

It was not until 1979 that well DT-10 was equipped with a pump. The well is pumped twice a year at a rate of about 6 gpm for a period of 4 h. The amount of water produced during the past 4 yr is small (0.02 × $10^6$ gal.). Any resulting water decline caused by pumpage would be too small to measure from one pumping period to the next pumping period.

Test well TW-8 was bailed for testing in December 1960. The amount of water removed during the test was about 2.0 × $10^3$ gal. Recovery to the original water level was completed 8 min after the bailing ended.[33] The water-level decline from 1960 to 1965 was about 1 ft or about 0.2 ft/yr. This is a normal water-level decline.

In 1972 a pump was installed on TW-8. The well is pumped at about 6 gpm for a 2-h period twice a year. Thus, since 1972 about 0.03 × $10^6$ gal. of water have been pumped from the well for collection of samples.

## C. Hydrologic Characteristics

Hydrologic characteristics, pumping rates, specific capacities, transmissivities, and field coefficients of permeability were determined during aquifer tests or during periods of production from the wells or test holes (Fig. 9). The rock type or formation that forms the aquifer determines the hydrologic characteristics of the particular well or test hole (Table II). Wells in the Los Alamos and Guaje Fields are complete in the Tesuque Formations. Basalt flow occurs in the Tesuque Formation within the Guaje Field but is absent in the Los Alamos Field. Test well TW-4 is complete in the Tschicoma Formation. Supply wells in the Pajarito Field and test wells DT-5A, DT-9, and DT-10 are complete in the Puye Conglomerate and Tesuque Formation. Test wells TW-1, -2, -3, and -8 are complete in the Puye Conglomerate. Various thicknesses of saturation and different amounts of fines, such as silts, clays, and very fine sands in the various rock types, result in diffe hydrologic characteristics.

**1. Tesuque Formation.** The wells in the Alamos Field are completed in the fine sediments of Tesuque Formation. The sediments contain no in bedded basalts (Fig. 3). The saturated thickne penetrated by the wells range from 709 to 1700 ft an average of 1350 ft. At an average pumping rat 365 gpm, the average specific capacity is 4.5 gpm/f drawdown, an average drawdown of 91 ft. Based production characteristics of the well field, a drawd of >125 ft results in excessive sand produced with w which shortens the life of the pumps.

The field coefficient of permeability ranges from 3. 9.3 gpd/ft$^2$ with an average of 5.6 gpd/ft$^2$. Transmissi of the aquifer ranges from 2.5 × $10^3$ to 15.7 × $10^3$ gp with an average 8.4 × $10^3$ gpd/ft (Fig. 9). The rat movement of water in the aquifer, based on hydrol characteristics and gradient on the top of the n aquifer in the Los Alamos Field, is estimated at 20 f within the upper 1350 ft of the aquifer (Fig. 10).

**2. Tesuque Formation with Interbed Basalts.** All wells in the Guaje Well Field penetr the sediments with interbedded basalts, except one G-2 (Fig. 3). The saturated thickness of the aq ranged from 942 to 1722 ft with an average of 141 At an average pumping rate of 376 gpm, the ave specific capacity was 5.8 gpm/ft of drawdown o average drawdown of 65 ft.

The field coefficient of permeability ranged from 5. 11.3 gpd/ft$^2$ with an average of 8.2 gpd/ft$^2$. The ave transmissivity of the aquifer in the Guaje Field is 11 $10^3$ gpd/ft.

The rate of movement of water in the upper 1410 the aquifer of sediments and basalts in the Guaje Fie estimated at 35 ft/yr (Fig. 10).

**3. Tschicoma Formation.** Test well TW-4 completed into a brecciated zone within the Tschic Formation. The saturated thickness was about 40 ft, the specific capacity was low at 0.6 gpm/ft duri pumping rate of 2.8 gpm. The transmissivity low w 0.75 × $10^3$ gpd/ft and the field coefficient of permeal averaged 19 gpd/ft$^2$. The rate of movement of wat the 40 ft of the aquifer in the brecciated zone is estim at 50 ft/yr (Fig. 10).

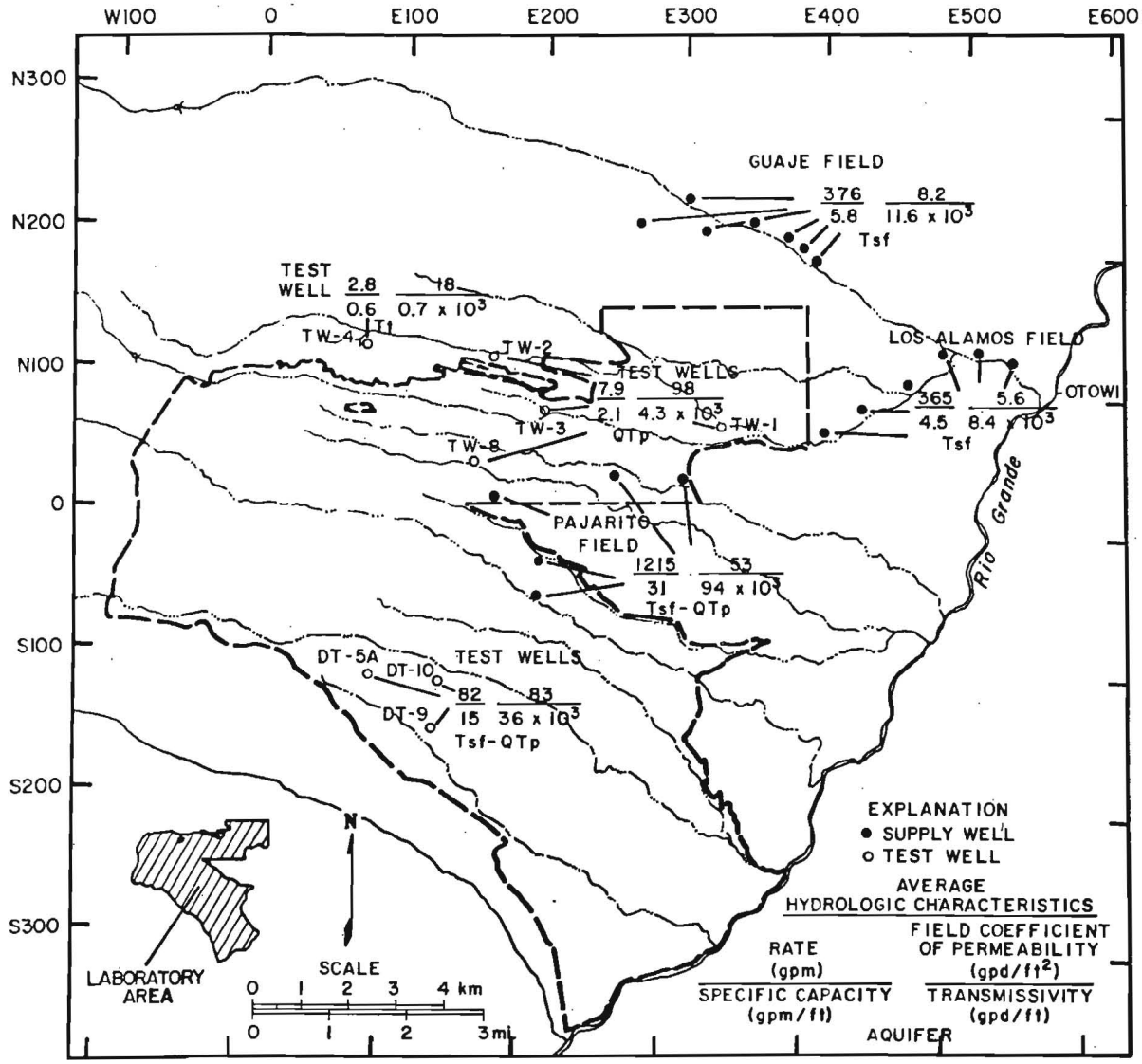


*Fig. 9. Hydrologic characteristics of the main aquifer.*

Test well H-19 encountered water in the lower part of ıe Puye Conglomerate underlain by a massive flow of 'schicoma Formation would yield very little water to the 'ell. Tests indicated that the saturated section of the schicoma Formation (joints and brecciated zone beveen the flows) was relatively impermeable and was not source of water supply.[17]

**4. Tesuque Formation and Puye Conlomerate.** The well in the Pajarito Field and test wells T-5A, DT-9, and DT-10 penetrated the main aquifer in e lower part of the Puye Conglomerate and the :suque Formation. The Pajarito Field and test wells are located on the Pajarito Plateau. Beneath the plateau, the Tesuque Formation contains interbedded basalt flows.

The saturated thickness of the Puye Conglomerate in the Pajarito Field ranged from 50 to 535 ft with an average thickness of 270 ft, although the saturated thickness of the underlying Tesuque Formation ranged from 890 to 1700 ft with an average thickness of 1470 ft. At an average pumping rate of 1215 gpm, the average specific capacity is 31 gpm/ft of drawdown or an average drawdown of 40 ft (Fig. 9).

The field coefficient of permeability of the combined Puye Conglomerate and Tesuque Formation is 53 gpd/ft$^2$ with an average transmissivity of 94 × 10$^3$ gpd/ft.

TABLE II

AVERAGE HYDROLOGIC CHARACTERISTICS OF THE MAIN AQUIFER IN THE LOS ALAMOS AREA

| | Saturated Thickness (ft) | Rate (gpm) | Specific Capacity (gpm/ft) | Field Coefficient of Permeability (gpd/ft$^2$) | Transmissivity ($10^3$ gpd/ft) |
|---|---|---|---|---|---|
| Los Alamos Field (Tesuque Formation) | 1350 | 365 | 4.5 | 5.6 | 8.4 |
| Guaje Field (Tesuque Formation and interbedded basalt) | 1410 | 376 | 5.8 | 8.2 | 11.6 |
| Pajarito Field (Tesuque Formation and Puye Conglomerate) | 1740 | 1215 | 31 | 53 | 94 |
| Test Hole TW-4 (Tschicoma Formation) | 40 | 2.8 | 0.6 | 18 | 0.7 |
| Test Holes DT-5A, -9, and -10 (Tesuque Formation and Puye Conglomerate) | 490 | 82 | 15 | 83 | 36 |
| Test Holes TW-1, -2, -3, and 8 (Puye Conglomerate) | 60 | 7.9 | 2.1 | 98 | 4.3 |

Rate of movement of water in the combined thickness of 1740 ft of Puye Conglomerate and Tesuque Formation is 95 ft/yr (Fig. 10).

The saturated thickness of the Puye Conglomerate in the three test wells (DT-5A, -9, and -10) ranged from 310 to 355 ft with an average of 340 ft. The saturated underlying Tesuque Formation ranged from 15 to 290 ft with an average of 150 ft. At a pumping rate of 82 gpm, the average specific capacity was 15 gpm/ft of drawdown or about 5.5 ft of drawdown (Fig. 9).

The average field coefficient of permeability of the Puye Conglomerate and Tesuque Formation penetrated by the test holes was 83 gpd/ft$^2$, where the average transmissivity was 36 × $10^3$ gpd/ft. The rate of movement of water in the 490 ft of aquifer penetrated by test hole was 345 ft/yr (Fig. 10).

**5. Puye Conglomerate.** Test wells on plateau that are complete within the main aquifer in Puye Conglomerate are TW-1, -2, -3, and -8 (Fig. The saturated thickness of the conglomerate ranges fr 29 to 97 ft with an average of 60 ft. At an aver pumping rate of 7.9 gpm, the specific capacity is gpm/ft of drawdown or an average drawdown of 17 The average field coefficient of permeability is about gpd/ft$^2$ with an average transmissivity of 4.3 × $10^3$ gp (Fig. 9). The rate of movement of water in the P Conglomerate with an average thickness of 60 ft is ab 250 ft/yr (Fig. 10).

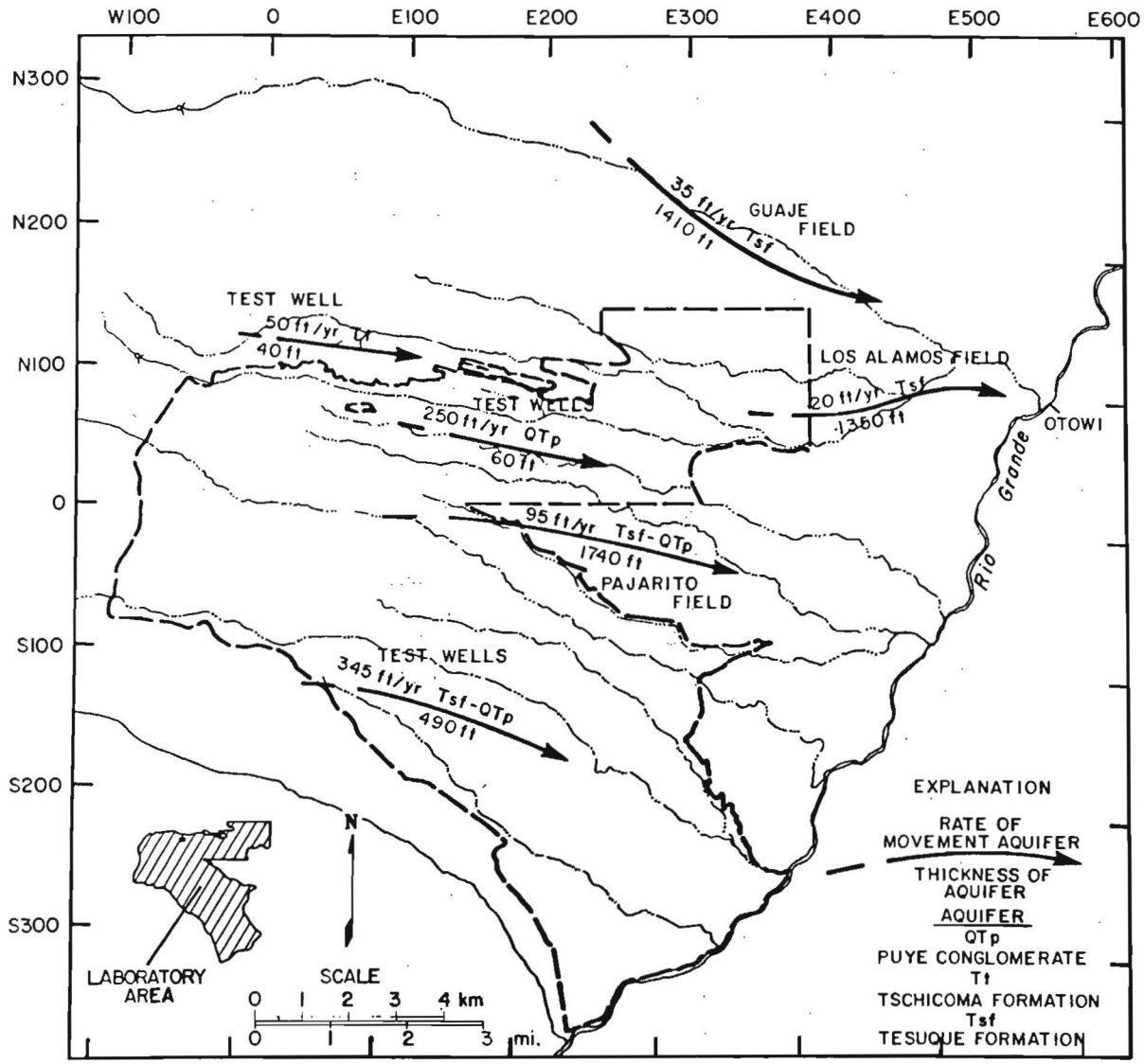


*Fig. 10. Rate of movement of water in the main aquifer.*

## D. Quality of Water

The quality of water is monitored from the supply well to determine if the water meets the Federal primary, secondary, and radiochemical standards for municipal supplies.[34,35] The water is collected at the well heads after a period of pumping so that the water sampled represents what is in the aquifer adjacent to the well. Quality of water from a well depends on the depth of well, the lithology of the aquifer, and yields from individual beds within the aquifer. The quality of water from th individual wells varies because of local aquifer conditior within the same aquifer.

Primary drinking water standards relate directly to th safety of drinking water supplies.[34] Ten primary sta dards are compared with maximum concentrations fro the wells (Table III), whereas detailed analyses fro individual wells are presented in Appendix D (Table III The maximum concentrations from wells are within th standards with the exception of fluoride of 2.6 mg/

## TABLE III

## CHEMICAL AND RADIOCHEMICAL QUALITY OF WATER FROM SUPPLY WELLS

| Chemical | Units | Maximum Concentration Supply Well | Standards |
|---|---|---|---|
| **Chemical Standards[a]** | | | |
| **Primary** | | | |
| Ag | mg/ℓ | <0.0005 | 0.05 |
| As | mg/ℓ | 0.048 | 0.05 |
| Ba | mg/ℓ | 0.09 | 1.0 |
| Cd | mg/ℓ | <0.001 | 0.01 |
| Cr | mg/ℓ | 0.022 | 0.05 |
| F | mg/ℓ | 2.6 | 2.0 |
| Hg | mg/ℓ | <0.0002 | 0.002 |
| $NO_3$ | mg/ℓ | 7.6 | 45 |
| Pb | mg/ℓ | 0.005 | 0.05 |
| Se | mg/ℓ | <0.003 | 0.01 |
| **Chemical Standards[b]** | | | |
| **Secondary** | | | |
| Cl | mg/ℓ | 16 | 250 |
| Cu | mg/ℓ | 0.013 | 1.0 |
| Fe | mg/ℓ | 0.325 | 0.3 |
| Mn | mg/ℓ | 0.008 | 0.05 |
| $SO_4$ | mg/ℓ | 27 | 250 |
| Zn | mg/ℓ | 0.12 | 5.0 |
| TDS | mg/ℓ | 408 | 500 |
| pH | — | 8.1 | 6.5 - 8.5 |
| **Radiochemical Standards[a]** | | | |
| $^{137}Cs$ | $10^{-9}$ μCi/mℓ | 40 ± 60 | 200 |
| $^{238}Pu$ | $10^{-9}$ μCi/mℓ | 0.018 ± 0.024 | 7.5 |
| $^{239}Pu$ | $10^{-9}$ μCi/mℓ | 0.010 ± 0.010 | 7.5 |
| Gross Alpha | $10^{-9}$ μCi/mℓ | 11 ± 6.0 | 15 |
| $^{3}H$ | $10^{-6}$ μCi/mℓ | 4.2 ± 0.6 | 20 |
| Total U | $10^{-9}$ μg/ℓ | 7.0 ± 1.4 | 1800 |

[a]Reference 34.
[b]Reference 35.

from well LA-1B in the Los Alamos Field. Mixing water with that from other wells in the field reduces the fluoride concentrations to acceptable limits within the distribution system.

Secondary standards are not related to the safety of drinking water but, instead, refer to the aesthetic quality.[35] Listed are eight constituents from the wells that are below the secondary standards (Table III). Secondary constituents from individual wells are listed in Appendix E.

Radiochemical standards relate to the safety of drinking water.[34] Radioactivity in the water from the wells occurs naturally in the aquifer. Gross alpha activity from the water from well PM-4 ($20 \pm 8.0 \times 10^{-9}$ μCi/mℓ) is above the standard ($15 \times 10^{-9}$ μCi/mℓ). Further analyses indicated gross alpha was $0.0 \pm 0.8 \times 10^{-9}$ μCi/mℓ. Analyses were performed for $^{226}$Ra. It was $0.03 \times 10^{-9}$ μCi/mℓ, much less than the $5 \times 10^{-9}$ μCi/mℓ drinking water standard. The high gross alpha reported initially probably reflects contamination of the sample after collection. All other radioactive concentrations were below the standards (Table III). Radiochemical analyses from individual wells are listed in Appendix F.

Water from well LA-6, Los Alamos Field, is not used for municipal supply because the arsenic concentration in the water exceeds the primary standards. The water cannot be mixed with other water from the well field to reduce the arsenic concentrations in the distribution system to a level below the standards.[36]

Routine analyses determine whether water quality deteriorates with continued production. Some of these analyses, along with some of the primary and secondary constituents, are used to discuss the quality of water from the well fields, supply wells, and test wells (Fig. 11).

**1. Los Alamos Field.** Predominate chemical constituents in water from the Los Alamos Field are sodium-bicarbonate (Fig. 12). The water from the well field is very soft with total hardness ranging from 16 to 28 mg/ℓ. (Hardness classification: soft, 1 to 60 mg/ℓ; moderately hard, 61 to 120 mg/ℓ; hard, 121 to 180 mg/ℓ; and very hard, >180 mg/ℓ.)[37]

The TDS range from 70 to 514 mg/ℓ. The high 514 mg/ℓ occurs in water from well LA-1B. The maximum concentration of chloride is about 15 mg/ℓ, but fluorides range from 0.4 to 2.5 mg/ℓ. Dilution in the distribution system reduces the fluoride from well LA-1B (2.5 mg/ℓ) to levels below the standards for municipal use.

The arsenic-bearing water at well LA-6 is from a dec source and is circulated upward through a permeab fault zone that crosses or lies adjacent to the well. Tl high arsenic concentration in water from the well (ran 0.141 to 0.203 mg/ℓ) precludes using this water for tl municipal supply. It was calculated that the arsenic lev from the well would have to be at a concentration 0.100 mg/ℓ or less, at a pumping rate of 300 gpm, order to dilute it enough by pumpage from the oth wells in the field to lower it to an acceptable level in tl distribution system.[36]

**2. Guaje Field.** Water from wells in the upper pa of the Guaje Field (G-5 and -6) is a calcium bicarbona type changing downgradient to a calcium sodiu bicarbonate type at well G-4 to a sodium bicarbona water in the lower part of the well field (G-1, -1A, -2, ar -3). The transition from one type of water to another the field is probably because the basalts in the upper pa of the field yield more water than those in the lower fie (Fig. 12). The water from the field is soft, with hardne ranging from 24 to 54 mg/ℓ. The hardness of the wat decreases from the upper part of the field into the low part of the field. The TDS range from 134 to 220 mg/ The chloride concentrations in water from the wells a about 2 mg/ℓ, but fluoride concentrations are 0.8 mg/ or less.

**3. Pajarito Field.** Water from wells PM-1 and contains calcium bicarbonate. As a result, the water hard, with a hardness of about 90 mg/ℓ. The w penetrated a thickness of saturated basalt in the sec ments of the Tesuque Formation, which may ha caused the high concentration of calcium ar magnesium resulting in the hard water. The gener chemical quality of the water from the two wells similar, with TDS of 212 and 216 mg/ℓ in PM-1 and - respectively. Chlorides are 4 and 10 mg/ℓ and fluorid are about 0.4 mg/ℓ in water from each well.

The water from wells PM-2, -4, and -5 is similar quality, being a sodium bicarbonate water (Fig. 12). Tl water is soft, ranging from 36 to 52 mg/ℓ, but the TI range from 140 to 211 mg/ℓ. Chlorides are low at mg/ℓ or less; fluorides are 0.3 mg/ℓ.

**4. Test Wells.** Water from TW-1, -2, and -3 is calcium bicarbonate water. The water quality is n exactly the same at each of the wells. Water from TW

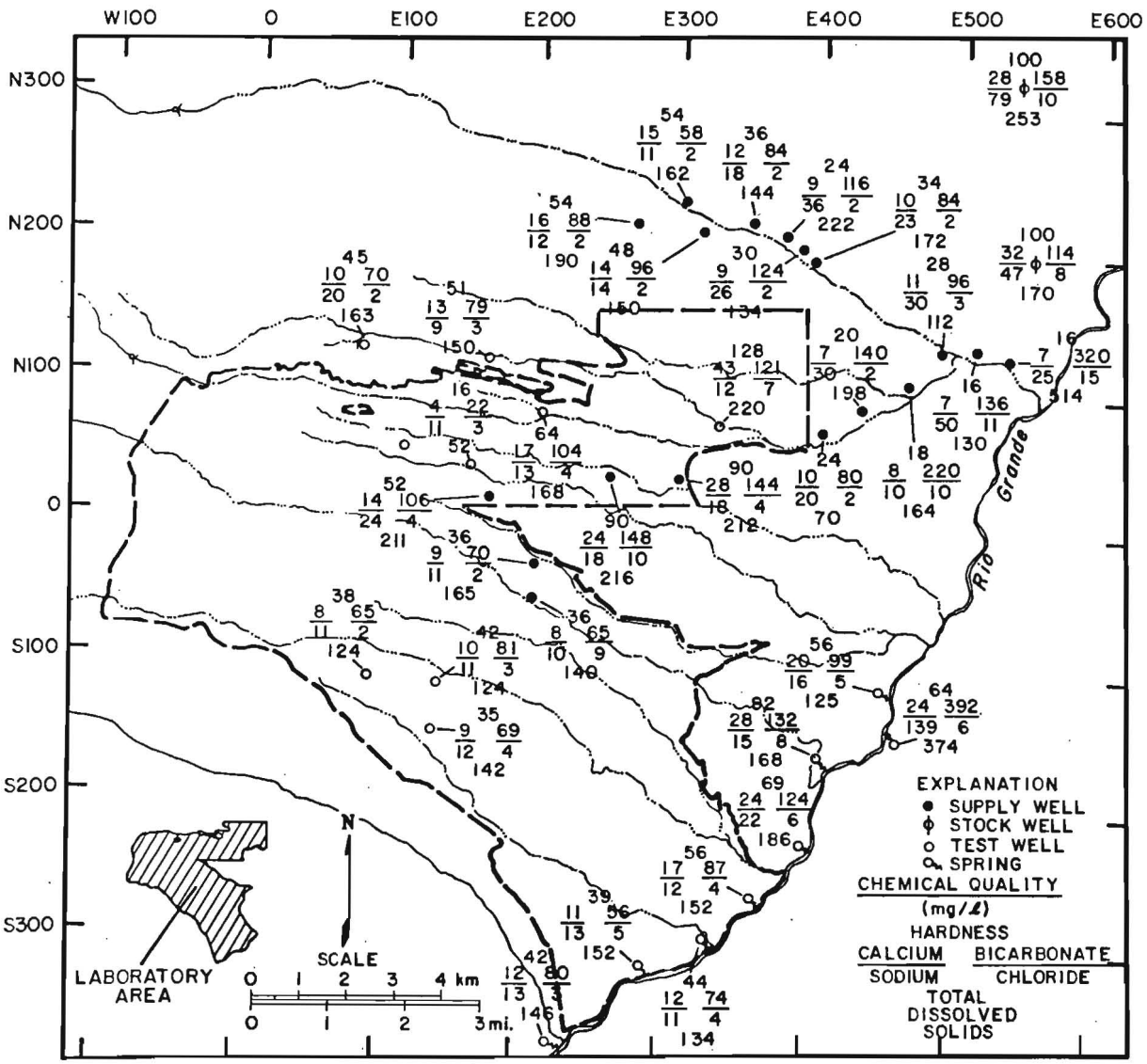


*Fig. 11. Chemical quality of water from supply, test, and stock wells.*

is hard at 128 mg/ℓ, and TDS are 220 mg/ℓ, where chloride is 7 mg/ℓ and fluoride is 0.4 mg/ℓ. Water from TW-2 is soft at 51 mg/ℓ, and TDS are 150 mg/ℓ, where chloride is 3 mg/ℓ and fluoride is 0.5 mg/ℓ. Water from TW-3 is moderately hard at 64 mg/ℓ, and TDS are 168 mg/ℓ, where chloride is 4 mg/ℓ and fluoride is 0.4 mg/ℓ.

Water from TW-4 and -8 is a sodium bicarbonate water, which is different in chemical quality (Fig. 12). Water from TW-4 is soft at 45 mg/ℓ with TDS of 163 mg/ℓ. The chlorides are about 2 mg/ℓ, where fluorides are <0.4 mg/ℓ. Water from TW-8 is soft at 16 mg/ℓ with TDS of 52 mg/ℓ. Chlorides are about 3 mg where fluorides are 0.2 mg/ℓ.

Water from DT-5A, -9, and -10 is of a sodi bicarbonate type. The quality of water is quite sim from all three test wells. The water is soft, ranging fr 35 to 42 mg/ℓ. The concentrations of TDS range fr 124 to 142 mg/ℓ with chloride concentrations of 4 m or less and fluoride of 0.3 mg/ℓ or less.

**5. Stock Wells.** Water from the stock wells RV and -5 is similar in chemical quality and is a sodi

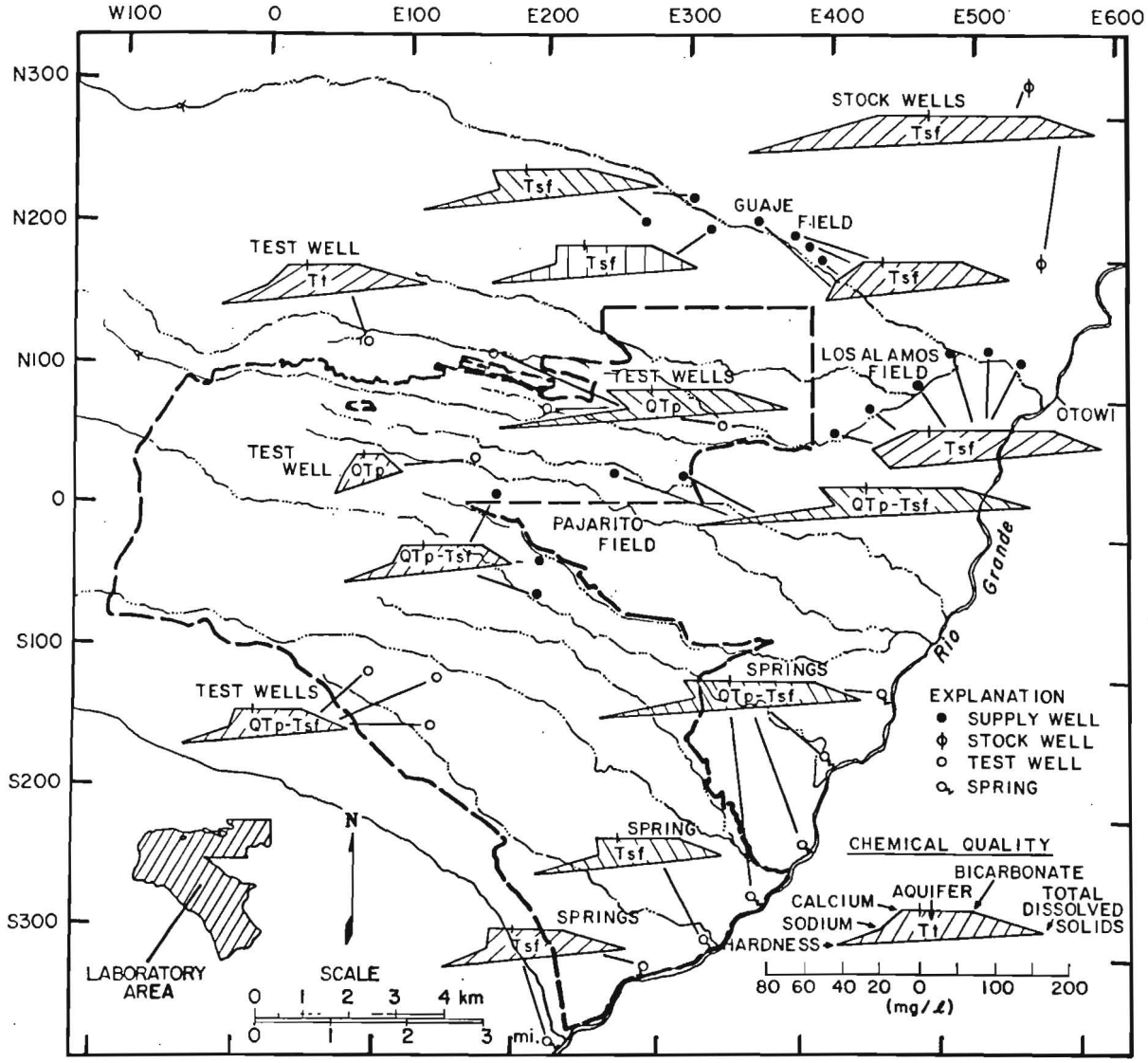


*Fig. 12. Graphic comparison of chemical constituents in water from supply, test, and stock wells.*

bicarbonate type water (Fig. 12). There is a large amount of calcium and magnesium in the water, which results in a moderately hard water with a hardness of 100 mg/ℓ. The TDS are 170 and 253 mg/ℓ, where chlorides are 10 mg/ℓ or less. The fluoride concentrations are 0.2 mg/ℓ or less.

**6. Springs.** The quality of water from the springs varies; however, it is combined in four groups for the purpose of this report. The springs discharge from the main aquifer.

The water from Spring 3B is a sodium bicarbon type with TDS of about 610 mg/ℓ. The water moderately hard at 64 mg/ℓ, where chlorides are 6 m and fluorides are 0.6 mg/ℓ. The spring discharges fr basalts in the Tesuque Formation along a fault or di The quality of water is different from that of any ot spring in this area of White Rock Canyon.

The quality of water from the spring changes fror calcium bicarbonate to a sodium bicarbonate wa south between Spring 5A to Spring 8A in White R

Canyon (Fig. 12). The spring discharge is from the main aquifer.

Water from Springs 3, -4, -5A, and -5B is of the calcium bicarbonate type, and water quality varies. Water from Spring 3 is soft with a hardness of 56 mg/ℓ; the TDS are 125 mg/ℓ, where chlorides are 5 mg/ℓ and fluorides are 0.4 mg/ℓ. Water from Spring 4 is moderately hard at 92 mg/ℓ; the TDS are 168 mg/ℓ, where chlorides are 8 mg/ℓ and fluorides are 0.5 mg/ℓ. Water from Spring 5A is moderately hard at 69 mg/ℓ; the TDS are 186 mg/ℓ, where chlorides are 6 mg/ℓ and fluorides are 0.3 mg/ℓ. Water from Spring 5B is soft at 56 mg/ℓ; the TDS are 152 mg/ℓ, where chlorides are 4 mg/ℓ and fluorides are 0.5 mg/ℓ.

The water from Spring 6 is transitional from a calcium bicarbonate water to a sodium bicarbonate water (Fig. 12). The concentrations of calcium and sodium are almost equal at 12 mg/ℓ and 11 mg/ℓ, respectively. The water is soft at 44 mg/ℓ, where the TDS are 134 mg/ℓ. The chlorides are low at 4 mg/ℓ, as are the fluorides at 0.3 mg/ℓ.

Water from Springs 8A and 10 is a sodium bicarbonate water. The water chemical quality from these springs is similar. The water is soft with hardnesses of 39 and 42 mg/ℓ, respectively. The TDS of water from Spring 8A are 152 mg/ℓ and those from Spring 10 are 146 mg/ℓ. The chloride concentrations are 5 mg/ℓ or less, and fluoride concentrations are 0.4 mg/ℓ.

## IV. DEVELOPMENT OF ADDITIONAL WATER SUPPLY

The main aquifer extends from the Rio Grande westward beneath the Pajarito Plateau and rises stratigraphically through the Tesuque Formation into the lower part of the Puye Conglomerate. The Puye Conglomerate becomes an important part of the main aquifer. The conglomerate attains its greatest thickness in the north/south-trending basin beneath the central part of the plateau. The coarse volcanic debris within the conglomerate yields water readily to wells and, in part, allows the development of high-yield, low-drawdown wells in this area. The Tesuque Formation beneath the Pajarito Plateau is saturated and is the main source of water supply for municipal and industrial use. The sediments of the Tesuque Formation become coarser westward from the Rio Grande; the upper bed becomes younger with the westward dip. This coarse sediment aids in the development of high-yield wells in this area.[38]

The locations of future wells in this area must chosen carefully, because wells placed too far west encounter flow rock of the Tschicoma Formation, wl does not yield water readily. Wells placed too far to east encounter vast thicknesses of basalt, which will only constitute difficult drilling but may also not y water readily (Fig. 2).[39]

### A. Los Alamos Field

The Los Alamos Field is composed of five produ wells in lower Los Alamos Canyon (Fig. 5). The well two booster stations and transmission lines are on Ildefonso Pueblo land. The combined production from the field in 1982 was about 2050 gpm,[13] and booster stations are equipped to handle 2300 gpm. Tl to reach full capacity of the system an additional gpm could be developed.

The Los Alamos Field was developed in 1946 thro 1948, but one well (LA-1B) was added in 1960. Of six original wells in the field, only four (LA-2, -3, -4, -5) are still in use. Well LA-1 was abandoned whe yield declined, owing to partial filling of the well with sand and sediments. Well LA-6 is on standby emergency use only because arsenic concentration the water are above standards for municipal use. Of four original wells (1946-1948) in service, the comb pumping rate has declined from 1935 gpm in 195 1562 gpm in 1982. The specific capacity has declined from 4.3 gpm/ft to 2.5 gpm/ft indicating over the past 30 yr, some wells have deteriorated. Sc openings are corroded and gravel pack material is f with fine sand, silts, or clay. To ensure contir production from the field, future plans should inc additional wells to offset production decline in the c wells.

The present location of the field is on Pueblo lan an area where only low- to moderate-yield wells (30 500 gpm) can be developed. The present spacing betv wells in the Los Alamos field restricts any future locations in that field, because any closer spacing w result in interference between wells, thus causing r water-level decline in this section of the field.

Location and development of additional wells fo Los Alamos Field should be west of the present fie lower Pueblo Canyon (Fig. 13). This is in an area w high yield and low drawdown (1000 gpm with less 100 ft of drawdown) can be developed. In this area lower part of the Puye Conglomerate is saturated an

coarser sediments in the upper part of the Tesuque Formation are within the main aquifer. Two wells could be developed in this area that could use the existing Los Alamos Field transmission and booster system (Fig. 13). Combined production rates from the two wells should be at least 2000 gpm or about the output of the five presently producing wells in the field.

The anticipated geologic section of wells drilled in the lower Pueblo Canyon area is presented in Table IV. The pilot hole should be at least 2500 ft deep. This wo allow about 1800 ft of saturated thickness for devel ment of the well.

The water quality should be similar to that of sup well PM-1. The water will probably have a hardnes about 90 mg/ℓ, a TDS concentration of 212 mg/ℓ, chloride and fluoride concentrations of 4 mg/ℓ and mg/ℓ, respectively.

TABLE IV

ANTICIPATED GEOLOGIC LOG OF A SUPPLY WELL IN LOWER PUEBLO CANYON

Elevation: 6400 to 6600 ft above sea-level datum
Depth of Pilot Hole: 2500 ft
Hydrologic Data:
Depth to water: 600 to 750 ft
Yield: Estimated 1000 gpm
Drawdown: Estimated 100 ft or less
Aquifer: Puye Conglomerate and Tesuque Formation

| Stratigraphic Unit | Thickness (ft) | Depth (ft) |
|---|---|---|
| Alluvium | | |
| Gravel and boulders | 20 | 20 |
| Puye Conglomerate | | |
| Conglomerate | 60 | 80 |
| Basaltic rocks of Chino Mesa | | |
| Basalts and interflow breccia, may contain perched water, at a depth of 210 to 260 ft | 205 | 285 |
| Puye Conglomerate | | |
| Conglomerate | 165 | 450 |
| Basaltic rocks of Chino Mesa | | |
| Basalts and interflow breccias | 100 | 550 |
| Puye Conglomerate | | |
| Conglomerate | 250 | 800 |
| Tesuque Formation | | |
| Siltstone, sandstone, and conglomerate with occasional basalt flow in upper 1200 ft of formation | 1700 | 2500 |

## B. Guaje Field

The Guaje Field is composed of seven produc wells. The combined production of the field in 1982 2630 gpm. The booster stations and transmission l can handle 2700 gpm; thus, to reach full capacity, additional 70 gpm could be developed in the field.

The Guaje Field was developed in 1950 through 1 with one well (G-1A) added in 1954 and another (G-6) added in 1964. The five wells in the field in 1 through 1951 had a combined production rate of 2 gpm in 1952 and an average specific capacity of gpm/ft. The pumping rate had declined to 1847 gpm, the average specific capacity declined to 5.0 gpm/ 1982. The wells deteriorated because of age, corrosio the screen openings, the well filling with sedime gravel pack filled with fine sediments, and mainly, damage to screen sections of the wells, especially v G-4 and G-5.[6] The yield from the wells will continu decline with time because of deterioration of the cas screen, and gravel pack. To ensure continued produc from the field and maximum use of existing booster distribution systems, one replacement well should considered and other wells should be rehabilitated.[11]

A replacement well should be considered, becaus present, the spacing of existing wells in the Guaje Fie adequate with minor interference occurring when wells are pumped. An additional well in the field w cause excessive drawdown because of the proximit other wells. An additional well in the field should nc located northwest or west of the existing wells becau the outcrop of Tschicoma Formation in these area well that is finished in or near the outcrop of Tschic would not yield an appreciable amount of water bec the rocks are relatively impermeable and they for barrier to east and southeast movement of ground w in the main aquifer. Land ownership will not pe locating a well southeast of well G-1 in Guaje Ca (Fig. 5).

A replacement well should be considered for well G-4. Maximum yield from the well was 434 gpm with a specific capacity of 3.0 gpm/ft of drawdown in 1954. In 1982 the yield had declined to 297 gpm with a specific capacity of 1.5 gpm/ft of drawdown. At times, the well produces a lot of sand with the pumpage.

Well G-4 was completed at a depth of 1930 ft in 1951. In November 1953 the well was filled with sediments to about 1129 ft. Attempts to remove the sediments from the well were abandoned at a depth of 1486 ft because the bailer would stick and gravel pack was being bailed from the well. The presence of gravel pack indicated that the casing was ruptured. In October 1954 the well was opened to 1386 ft. About 110 ft of the 360 ft of screen buried below the 1380-ft level reduced the yield of the well because sediment continued to accumulate. In 1968 the well had filled with sediments to a depth of 765 ft. When sediments were being removed from the well, a large amount of gravel pack was present, so it was cleaned only to a depth of 798 ft. The well was filled with sediments to a depth of 750 ft in 1975. At this time, the sediments were cleaned out to a depth of 1750 ft. A video log of the hole was made with a television camera, which indicated minor breaks in the screen above the depth of 1230 ft with major breaks in sections of the screen below a depth of 1230 ft. A slotted liner was set from 1214 to 1750 ft; however, after the well was back in operation, pumpage sometimes contained a large amount of sand. In 1981 the hole was opened only to a depth of 1150 ft. Only 22 ft of sediments were cleaned out of the well because the bailer tended to stick in the well. Well G-4 should be replaced because of the damaged screen. The well will continue to deteriorate with sand accumulation until the yield will be insufficient to continue economical operation. It can be replaced with a well that should produce at least 500 gpm with less than 100 ft of drawdown.

The replacement well should be located at least 150 ft south of well G-4; however, a distance of 300 to 500 ft would be preferable because drilling would be less likely to affect the cavities caused by pumpage of sand from G-4. The pilot hole should be at least 2000 ft deep. This would allow a saturated section of about 1600 ft to develop the well. The stratigraphic section penetrated by the replacement well should be similar to those penetrated by well G-4 (Table V). The water quality should also be similar to that of well G-4. The TDS should be about 150 mg/ℓ, with soft water at 48 mg/ℓ. Chloride should be less than 5 mg/ℓ and fluorides should be about 0.2 mg/ℓ.

TABLE V

ANTICIPATED GEOLOGIC LOG OF A SUPPI WELL NEAR WELL G-4 IN GUAJE CANYOI

Elevation: 6230 ft above sea-level datum
Depth of Pilot Hole: 2000 ft
Hydrologic Data:
Depth To Water: 400 ft
Yield: Estimated 500 gpm
Drawdown: Estimated 100 ft or less
Aquifer: Tesuque Formation

| Stratigraphic Unit | Thickness (ft) | Dept (ft) |
|---|---|---|
| Alluvium | | |
| Gravels and boulders | 15 | 15 |
| Puye Conglomerate | | |
| Conglomerate | 105 | 120 |
| Tesuque Formation | | |
| Siltstone and sandstone | 380 | 500 |
| Basalt and interflow breccia | 30 | 530 |
| Siltstone and sandstone | 330 | 860 |
| Basalt and interflow breccia | 75 | 935 |
| Siltstone and sandstone | 30 | 965 |
| Basalt and interflow breccia | 20 | 980 |
| Siltstone and sandstone | 130 | 1110 |
| Basalt and interflow breccia | 40 | 1150 |
| Siltstone and sandstone | 850 | 2000 |

Well G-3 had a pumping rate of 410 gpm an specific capacity of 8.6 gpm/ft of drawdown in 19 The pumping rate has declined to 240 gpm, wit specific capacity of 2.1 gpm/ft of drawdown in 19 Television logs of the well indicate that the casing screens are in good condition. The well should rehabilitated by some method (acid, shock, jet screens with high pressure, or swabbing) to try increase the yield of the well.

Well G-5 is missing large sections of the screen be a depth of 700 ft. As the well continues to be a g producer with little drawdown (520 gpm with spe capacity of 9.5 gpm/ft), no attempt should be mad repair or rehabilitate the well. A replacement well sh

be considered in the future for this well if yield and specific capacity decline.

## C. Pajarito Field

The Pajarito Field is composed of four producing wells. One well that was just completed should be added to the system in late 1983. The four wells can produce about 4800 gpm and when the fifth well is added to the system, the production should be about 6000 gpm. These wells are high-yield wells in an area capable of developing wells with pumping rates >1000 gpm. The development of additional wells in the field is not imminent; however, if additional wells are to be developed, locations should be in areas where high yield and low drawdown can be expected.

The Pajarito Field north and west of PM-2, -4, or -5 cannot be expanded and still remain in the area where high-yield wells can be developed. Also, space is unavailable in Sandia Canyon for additional wells, if space is maintained between wells to reduce interference or overlapping of drawdown. Adding wells in lower Pueblo Canyon has already been discussed.

The suggested location for additional wells in the Pajarito Field is to the southwest of well PM-2 (Fig. 13). The locations are chosen for maximum spacing between wells to minimize the interference between wells when they are pumping and to align the wells at right angles to the movement of ground water in the main aquifer, which is west to east.

One additional well could be located about 3500 ft southwest of PM-2 at an elevation of about 6850 ft, with a second well located about 7000 ft southwest of PM-2 at an elevation of about 6800 ft. The quality of water at these locations should be similar to that of PM-2. The TDS should be about 140 mg/ℓ with a chloride value of 9 mg/ℓ and fluoride value of 0.3 mg/ℓ. The water is soft with hardness of 36 mg/ℓ.

The pilot hole at these locations should be at least 2800 ft, which would result in a saturated section of about 1800 ft to develop a high-yield well. The anticipated geologic section at the two locations is shown in Table VI.

## D. Drilling Conditions

Cable tool and rotary methods of drilling have been used to construct water supply wells in the Los Alamos area. The cable tool and rotary method has been used to drill the upper section of unsaturated material (alluvium Bandelier Tuff, Puye Conglomerate, and Basaltic Rock: of Chino Mesa) above the main aquifer. Rotary drillin has been used to complete the well in the saturate sediments and volcanic rocks within the main aquifer the lower part of the Puye Conglomerate, and th Tesuque Formation.

The alluvium or soil at most sites is thin. The alluviun (Guaje or Pueblo Canyons) may cover large, very har boulders of latite, rhyolite, or quartz latite.

The Bandelier Tuff is a soft, friable, porous, an permeable rock. The drilling should progress easily. A thick section of tuff may cause major circulation prob lems if it is drilled with the rotary using drilling mud as cutting carrier. Drilling by cable tool should cause n lost circulation problems; using air foam as a cuttin carrier with the rotary should reduce the lost circulatio problem and should allow the upper section of the hole t be cased above the main aquifer. The wall of th borehole in the Bandelier Tuff holds up well when it i drilled by either cable tool or rotary.

The Puye Conglomerate contains numerous latit rhyolite, and quartz latite boulders that are quite har The formation is slightly consolidated to consolidate Drilling will be slow, and in some cases, circulation c drilling fluid when using the rotary method may b difficult.

The basaltic rocks of Chino Mesa are hard an contain joints and small cavities. Drilling these rocks wi be slow and difficult, and if rotary methods are use circulation may be difficult to maintain. Using air foa as a cutting carrier through the basalts reduces th circulation problem. For completion of the well, it wi probably be necessary to set a surface string of casin through these basalts. The pilot hole in basalts is likely t become crooked because when the hard rocks are drille the bits are deflected by joints and interflow breccia between flows of different hardnesses.

The Tesuque Formation of siltstones and sandston is drilled easily by rotary-methods using mud as cuttings carrier. The interbedded basalts in the sedimen are hard to drill and will, in most cases, cause problen in maintaining the circulation using a mud rotary. Tl formation is completely saturated at most of the loc tions (Guaje Canyon is the exception). If sufficie penetration of the aquifer is made and a high head water can be maintained in the drill hole, rever circulation using air down a drop line in the drill ste has been successful in maintaining circulation at depth

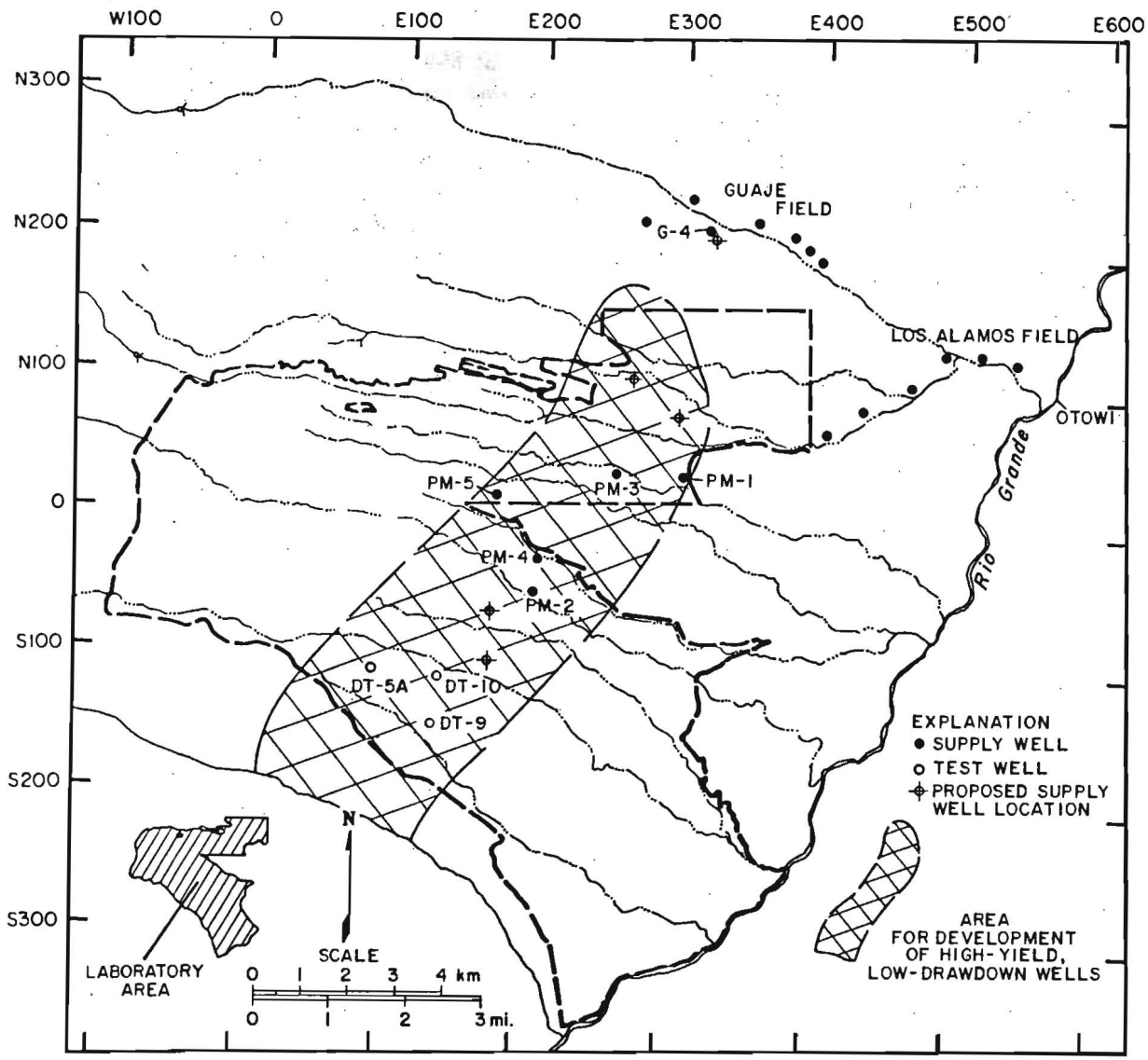


*Fig. 13. Proposed locations for additional supply wells and area for development of high-yield, low-drawdown wells.*

he Tesuque Formation when the sediments contain nterbedded basalts.

## E. Geology and Geophysical Logs

The depth at which a supply well will be completed is letermined from geologic and geophysical logs. During lrilling of the pilot hole, cuttings should be caught at 5-t-depth intervals when using a cable tool or at 10-ft-depth intervals when using a rotary. Cuttings are thei described by a geologist and a geologic log is prepared The geologic log is used to correlate and compare rocl units with hydrologic characteristics of geophysical logs

Geophysical logs to be run in the pilot hole are (1 Compensated Neutron-Formation Density, (2) Dual In duction—SFL with Linear Correlation Log, (3) Micrc log, and (4) Temperature Log. These logs, along with th geologic log, will aid in determining the water-bearin

TABLE VI

ANTICIPATED GEOLOGIC LOG OF SUPPLY WELLS ON THE PAJARITO PLATEAU SOUTH OF WELL PM-2

Elevation: ~6850 ft
Depth of Pilot Hole: 2850 ft
Hydrologic Data:
Depth to Water: 950 ft
Yield: Estimated 1000 gpm
Drawdown: Estimated 100 ft or less
Aquifer: Puye Conglomerate and Tesuque Formation

| Stratigraphic Unit | Thickness (ft) | Depth (ft) |
|---|---|---|
| Bandelier Tuff | | |
| Ashflow tuff and pumice | 650 | 650 |
| Basaltic rocks of Chino Mesa | | |
| Basalt and interflow breccia | 350 | 1000 |
| Puye Conglomerate | | |
| Conglomerate | 650 | 1650 |
| Tesuque Formation | | |
| Sandstone and conglomerate | 400 | 2050 |
| Basalt and interflow breccia | 50 | 2100 |
| Sandstone and siltstone | 200 | 2300 |
| Basalt and interflow breccia | 100 | 2400 |
| Siltstone and sandstone | 450 | 2850 |

characteristics of the Puye Conglomerate and Tesuque Formation within the main aquifer.

## F. Well Construction

Well construction should provide for a surface string of blank casing, adequately cemented, to seal out water encountered in the alluvium (Pueblo and Guaje Canyon). It will also be necessary to seal out, with casing, any water encountered above the main aquifer. Samples of water encountered above the main aquifer should be obtained for chemical and radiochemical analyses, where possible, if drilling with cable tool or air rotary.

Most of the water-bearing beds of the Tesuq Formation contain fine sediments so poorly consolidat that a gravel pack around the casing and screen secti of the well will be required to reduce the entry of fi material into the well. Perforated pipe or screen shou be placed through the entire saturated section of the w except in the upper 200 to 250 ft of the saturated sectio The pump intake is usually set 200 to 250 ft below t top of the aquifer. Blank pipe should be set through t section to prevent "cavitation" of the pump bowls order to obtain the maximum efficiency of the pump.

Two gage lines (2-in. i.d.) attached outside the casi should extend from the surface and enter the casing 200 to 250 ft below the top of the main aquifer or ne the top of the screen section. One gage line houses the line and continuously monitors the water levels; t second gage line is used for the water-level measureme equipment or well-surveying instruments.

## V. SUMMARY AND CONCLUSIONS

The main aquifer of the Los Alamos area is the on aquifer capable of municipal and industrial water suppl The main aquifer extends from the Rio Grande westwa beneath the Pajarito Plateau and rises westward stra graphically through the Tesuque Formation into t lower part of the Puye Conglomerate. The water in t aquifer moves eastward toward the Rio Grande, where discharges through a series of springs and seeps. T depth of the main aquifer varies from about 1200 along the western margin of the plateau to about 600 at the confluence of Pueblo and Los Alamos Canyon At the Rio Grande, some wells encountered water in t aquifer under artesian pressures. The main aquif extends north and south of the Los Alamos area and estimated to be over 6000 ft thick.

The Puye Conglomerate is highly permeable an where it is saturated beneath the Pajarito Plateau, w yield large amounts of water to wells. The Tesuq Formation is composed of siltstones, sandstones, a some conglomerate. Many of the individual beds in t Tesuque Formation are highly permeable and, whe saturated, will yield water to a well. Beneath the Pajari Plateau, coarse volcanic rock fragments are in the upp 1000 ft of the Tesuque Formation, and they yield mo water to wells than do the finer sediments, whi predominate in the formation farther to the east alo the Rio Grande.

In the Los Alamos area,18 supply wells, 10 test wells, and 2 stock wells are supplied by the main aquifer. Hydrologic characteristics of the main aquifer were determined from some of these wells. The hydrologic characteristics reflect the permeability and thickness of the formations.

The Los Alamos Field is completed in siltstones and sandstones of the Tesuque Formation. With a saturated thickness of about 1350 ft, the average specific capacity is about 4.5 gpm/ft of drawdown at a pumping rate of 365 gpm. The average transmissivity is 8.4 x $10^3$ gpd/ft with a field coefficient of permeability of 5.6 gpd/$ft^2$. The average rate of movement in the upper 1350 ft of aquifer in the Los Alamos Field is about 20 ft/yr. The production from the field in 1947 to 1982 has been 14.5 x $10^9$ gal. or about 36% of the total water pumped for use at Los Alamos. This has resulted in an average water-level decline in the field of 37 ft or about 1.1 ft/yr. The average production per foot of water-level decline has been 392 x $10^6$ gal./ft.

The Guaje Field is completed in siltstones and sandstones with some interbedded basalt flows and breccias of the Tesuque Formation. The average saturated thickness of 1410 ft has an average specific capacity of 5.8 gpm/ft of drawdown at a pumping rate of 376 gpm. The average transmissivity is 11.6 x $10^3$ gpd/ft with a field coefficient of permeability of 8.2 gpd/$ft^2$. The average rate of movement is about 35 ft/yr. The production in 1951 through 1982 from the field has been 14.9 x $10^9$ gal. or about 37% of total water pumped for use at Los Alamos. This has resulted in an average water-level decline in the field of 54 ft or about 1.7 ft/yr. The average production per foot of water-level decline has been 277 x $10^6$ gal./ft.

The Pajarito Field is completed in siltstones, sandstones, and conglomerates that are interbedded with basalt and basalt breccias of the Puye Conglomerate and Tesuque Formation. The lower part of the Puye Conglomerate is also saturated within the field. The average saturated thickness of 1740 ft has an average specific capacity of 31 gpm/ft of drawdown at a pumping rate of 1215 gpm. The average transmissivity is 94 x $10^3$ gpd/ft with an average field coefficient of permeability of 53 gpd/$ft^2$. The average rate of movement in the 1740 ft of Puye Conglomerate and Tesuque Formation is 95 ft/yr. Production from the field from 1965 to 1982 has been 11.0 x $10^9$ gal. or about 27% of the total water pumped at Los Alamos.

There are five wells in the field, but most of the production has been from three wells: PM-1, -2, and -3. Well PM-4 was placed in service in July 1982, and well PM-5 was completed but had not been connected to the transmission line by the end of 1982. The production from well PM-1 has been about 1.6 x $10^9$ gal. from 196[illegible] to 1982 resulting in a water-level decline of 2 ft. The average production per foot of water-level decline has been 796 x $10^6$ gal./ft. The production from well PM-2 has been 5.9 x $10^9$ gal. from 1966 to 1982. This well has produced the most water of the individual wells (14% of the total water pumped at Los Alamos in 1950 through 1982). The water level declined 48 ft from 1966 to 198[illegible] or about 2.8 ft/yr. The average production per foot of water-level decline has been 122 x $10^9$ gal./ft. The production of well PM-3 has been 3.5 x $10^9$ gal. from 1968 to 1982. This has resulted in a water-level decline of 19 ft with an average production of 183 x $10^6$ gal./ft of drawdown.

Test well TW-4 is completed into a brecciated zone in the Tschicoma Formation. At a pumping rate of 2.[illegible] gpm, the specific capacity is 0.6 gpm/ft of drawdown. The 40-ft zone of saturation has a transmissivity of 0.7 x $10^3$ gpd/ft and a field coefficient of permeability of 1[illegible] gpd/$ft^2$. The rate of movement in the brecciated zone is about 50 ft/yr.

Test wells DT-5A, -9, and -10 penetrated a saturated thickness of 345 ft at the Tesuque Formation and lower part of the Puye Conglomerate. The test well had an average specific capacity of 15 gpm/ft of drawdown at a pumping rate of 82 gpm. The average transmissivity is 36 x $10^3$ gpd/ft with an average field coefficient of permeability of 83 gpd/$ft^2$. The amount of pumpage from these test wells is low, thereby causing no significant change in water levels; however, water-level decline in well DT-5A from 1960 to 1964 was 4 ft and in well DT-10 it was 4 ft from 1960 to 1967. At well DT-9, the average annual water levels were recorded from 1960 to 1968 and 1970 to 1982. The most rapid decline occurred from 1960 to 1968, about 2.3 ft. The water level rose about 0.3 ft from 1971 to 1972, then declined about 1 ft to 1979. Since 1979 the water level has remained about the same. The water-level declines reflect decreases in recharge resulting in natural water-level declines.

Test Wells TW-1, -2, -3, and -8 penetrated a 60[illegible] saturated section in the lower part of the Puye Conglomerate. At a pumping rate of 8 gpm, the average specific capacity is 2.1 gpm/ft of drawdown. The average

transmissivity is $4.3 \times 10^3$ gpd/ft with an average field coefficient of permeability of 98 gpd/ft$^2$. The average rate of water movement in the 60-ft saturated section of the aquifer is about 250 ft/yr.

Based on hydrologic characteristics of the wells, high-yield and low-drawdown (1000 gpm/100 ft) wells can be developed near the center of the Pajarito Plateau in a northeast-trending zone. Two high-yield and low-drawdown wells can be developed in lower Pueblo Canyon as replacement wells or wells to supplement production from the Los Alamos Field. Two high-yield and low-drawdown wells can be located on the Pajarito Plateau southwest of well PM-2 to supplement the production from the Pajarito Field to meet future increased demand.

A replacement well for well G-4 in the Guaje Field should be considered to offset decline in production in the field as well efficiency declines in the field. The well could be constructed to produce 500 gpm with less than 100 ft of drawdown.

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## APPENDIX A

### CONSTRUCTION AND HYDROLOGIC DATA FOR WELLS IN LOS ALAMOS, GUAJE, AND PAJARITO FIELDS

| | Los Alamos Field | | | | | | |
|---|---|---|---|---|---|---|---|
| | LA-1[a] | LA-1B | LA-2 | LA-3 | LA-4 | LA-5 | LA-6 |
| Date of Completion (yr) | 1946 | 1960 | 1946 | 1947 | 1948 | 1948 | 1948 |
| Elevation of LSD (ft) | 5625 | 5620 | 5650 | 5670 | 5975 | 5840 | 5770 |
| Construction | | | | | | | |
| Depth drilled (ft) | 1001 | 2256 | 882 | 910 | 2019 | 2084 | 7030 |
| Depth completed (ft) | 870 | 1750 | 870 | 870 | 1965 | 1750 | 1790 |
| Diameter (in.) [b] | 10 | 12 (650 ft) 10 | 10 | 10 | 12 (754 ft) 10 | 12 (630 ft) 10 | 12 (597 ft) 10 |
| Water Levels | | | | | | | |
| Date | 1982 | 1982 | 1982 | 1982 | 1981 | 1982 | 1982 |
| Depth below LSD (ft) | 40 | 71 | 161 | 118 | 289 | 168 | 90 |
| Elevation (ft) | 5585 | 5549 | 5489 | 5552 | 5686 | 5672 | 5680 |
| Water-Level Fluctuations | | | | | | | |
| Period | 1950-1982 | 1960-1982 | 1950-1982 | 1950-1982 | 1950-1981 | 1950-1982 | 1950-1982 |
| Change (ft) | −79 | −64 | −72 | −21 | −11 | −45 | −7 |
| Annual rate (ft/yr) | −2.4 | −2.8 | −2.2 | −0.6 | −0.3 | −1.4 | −0.2 |
| Aquifer | | | | | | | |
| Formation | Tsf | Tsf | Tsf | Tsf | Tsf | Tsf | Tsf |
| Saturated thickness (ft) | 830 | 1679 | 709 | 752 | 1676 | 1582 | 1700 |
| Yield | | | | | | | |
| Date | 1950 | 1982 | 1982 | 1982 | 1981 | 1982 | 1981 |
| Rate (gpm) | 366 | 486 | 269 | 247 | 579 | 467 | 580 |
| Drawdown (ft) | 293 | 109 | 187 | 128 | 104 | 136 | 57 |
| Specific capacity (gpm/ft) | 0.8 | 4.5 | 1.4 | 1.9 | 5.6 | 3.4 | 10.2 |
| Transmissivity (gpd/ft) | --- | 15 700 | 2500 | 2500 | 9600 | 4800 | 15 500 |
| Field coefficient of permeability (gpd/ft$^2$) | --- | 9.3 | 3.5 | 3.3 | 5.7 | 3.0 | 9.1 |
| Production | | | | | | | |
| Period (yr) | 1947-1956 | 1960-1982 | 1947-1982 | 1948-1982 | 1948-1982 | 1948-1982 | 1948-1975 |
| Pumpage ($10^6$ gal.) | 353 | 1964 | 1305 | 1644 | 3503 | 3049 | 2884 |

APPENDIX A (cont)

| | Los Alamos Field | | | | | | |
|---|---|---|---|---|---|---|---|
| | LA-1[a] | LA-1B | LA-2 | LA-3 | LA-4 | LA-5 | LA-6 |
| Quality of Water | | | | | | | |
| Date | 1952 | 2-28-80 | 2-28-80 | 2-28-0 | 2-28-80 | 2-28-80 | 2-28-80 |
| Chemical (mg/ℓ) | | | | | | | |
| $SiO_2$ | 29 | 40 | 26 | 24 | 30 | 36 | 26 |
| Ca | 7 | 7 | 7 | 1 | 10 | 7 | 8 |
| Mg | 1 | 0.4 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 |
| Na | 80 | 25 | 50 | 30 | 20 | 30 | 10 |
| $CO_3$ | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| $HCO_3$ | 177 | 320 | 136 | 96 | 80 | 140 | 220 |
| $SO_4$ | 20 | 37 | 13 | 7 | 3 | 5 | 22 |
| Cl | 18 | 15 | 11 | 3 | 2 | 2 | 10 |
| F | 1.3 | 2.5 | 1.2 | 0.5 | 0.4 | 0.9 | 1.6 |
| $NO_3$ | 1.8 | 2.3 | 2.5 | 2.4 | 2.0 | 2.3 | 2.3 |
| TDS | --- | 514 | 130 | 112 | 70 | 198 | 364 |
| Hardness | 22 | 16 | 16 | 28 | 24 | 20 | 18 |
| Specific conductance (μmho) | 385 | 330 | 270 | 550 | 200 | 200 | 300 |
| pH | --- | 8.4 | 8.5 | 8.4 | 8.5 | 8.7 | 8.7 |
| Radiochemical | | | | | | | |
| Total uranium (μg/ℓ) | --- | 5.7 ± 1.2 | 4.5 ± 1.0 | 3.5 ± 0.8 | 0.9 ± 0.8 | 4.8 ± 0.8 | 3.1 ± 0.8 |
| Temperature (°F) | 63 | 83 | 75 | 67 | 83 | 77 | 84 |

APPENDIX A (cont)

| | Guaje Field | | | | | | |
|---|---|---|---|---|---|---|---|
| | G-1 | G-1A | G-2 | G-3 | G-4 | G-5 | G-6 |
| Date of Completion (yr) | 1950 | 1954 | 1951 | 1951 | 1951 | 1951 | 1964 |
| Elevation of LSD (ft) | 5975 | 6015 | 6055 | 6140 | 6230 | 6305 | 6420 |
| Construction | | | | | | | |
| Depth drilled (ft) | 2100 | 2071 | 2006 | 1996 | 2002 | 1997 | 2005 |
| Depth completed (ft) | 2000 | 1519 | 1996 | 1792 | 1930 | 1840 | 1530 |
| Diameter (in.)[b] | 10 (490 ft) 10 | 12 (8663 ft) 10 | 12 (8600 ft) 10 | 12 (8695 ft) 10 | 12 (8720 ft) 10 | 12 (8739 ft) 10 | 12 |
| Water Levels | | | | | | | |
| Depth below LSD (ft) | 278 | 305 | 352 | 364 | 386 | 455 | 588 |
| Elevation (ft) | 5697 | 5710 | 5703 | 5776 | 5844 | 5850 | 5832 |
| Water-Level Fluctuations | | | | | | | |
| Period (yr) | 1951-1982 | 1955-1982 | 1951-1982 | 1951-1982 | 1951-1982 | 1951-1982 | 1964-1982 |
| Change (ft) | -83 | -40 | -93 | -83 | -29 | -41 | -7 |
| Annual rate (ft/yr) | -2.6 | -1.4 | -2.9 | -2.6 | -0.9 | -1.3 | -0.4 |
| Aquifer | | | | | | | |
| Formation | Tsf | Tsf | Tsf | Tsf | Tsf | Tsf | Tsf |
| Saturated thickness (ft) | 1722 | 1214 | 1644 | 1428 | 1544 | 1385 | 942 |
| Yield | | | | | | | |
| Date | 1982 | 1982 | 1982 | 1982 | 1982 | 1982 | 1982 |
| Rate (gpm) | 313 | 505 | 476 | 239 | 297 | 522 | 281 |
| Drawdown (ft) | 165 | 42 | 47 | 112 | 192 | 55 | 81 |
| Specific capacity (gpm/ft) | 1.9 | 12.0 | 10.1 | 2.1 | 1.5 | 9.5 | 3.5 |
| Transmissivity (gpd/ft) | 12 000 | 11 000 | 15 000 | 7500 | 17 500 | 12 000 | 6300 |
| Coefficient of permeability (gpd/ft$^2$) | 7.0 | 9.1 | 9.1 | 5.3 | 11.3 | 8.7 | 6.7 |
| Production | | | | | | | |
| Period (yr) | 1950-1982 | 1954-1982 | 1951-1982 | 1951-1982 | 1951-1982 | 1951-1982 | 1952-1982 |
| Pumpage ($10^6$ gal.) | 2386 | 2921 | 2504 | 2084 | 1202 | 2774 | 1062 |

APPENDIX A (cont)

| | Guaje Field | | | | | | |
|---|---|---|---|---|---|---|---|
| | G-1 | G-1A | G-2 | G-3 | G-4 | G-5 | G-6 |
| Quality of water | | | | | | | |
| Date | 2-28-80 | 2-28-80 | 2-28-80 | 2-28-80 | 2-28-80 | 2-28-80 | 2-24-80 |
| Chemical (mg/ℓ) | | | | | | | |
| $SiO_2$ | 86 | 78 | 78 | 54 | 52 | 64 | 70 |
| Ca | 10 | 9 | 9 | 12 | 14 | 15 | 16 |
| Mg | 0.5 | 0.5 | 0.6 | 1.5 | 2.5 | 3.7 | 3.6 |
| Na | 23 | 26 | 36 | 18 | 14 | 11 | 12 |
| $CO_3$ | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| $HCO_3$ | 84 | 124 | 116 | 84 | 96 | 88 | 88 |
| $SO_4$ | 4 | 4 | 4 | 4 | 3 | 4 | 3 |
| Cl | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| F | 0.5 | 0.5 | 0.8 | 0.3 | 0.2 | 0.2 | 0.2 |
| $NO_3$ | 2.1 | 2.1 | 1.9 | 2.5 | 2.7 | 2.9 | 1.8 |
| TDS | 172 | 134 | 222 | 144 | 150 | 162 | 190 |
| Hardness | 34 | 30 | 24 | 36 | 48 | 54 | 54 |
| Specific conductance (μmho) | 130 | 200 | 200 | 300 | 160 | 130 | 200 |
| pH | 8.3 | 8.4 | 8.5 | 8.3 | 8.2 | 8.2 | 7.9 |
| Radiochemical | | | | | | | |
| Total uranium (μg/ℓ) | 1.0 + 0.8 | 0.7 + 0.8 | 0.9 + 0.8 | 0.8 + 0.8 | 1.0 + 0.8 | 0.8 + 0.8 | 2.4 + 0.8 |
| Temperature (°F) | 78 | 84 | 85 | 82 | 79 | 78 | 83 |

APPENDIX A (cont)

| | Pajarito Field | | | | |
|---|---|---|---|---|---|
| | PM-1 | PM-2 | PM-3 | PM-4 | PM-5 |
| Date of Completion | 1965 | 1965 | 1966 | 1981 | 1982 |
| Elevation of LSD (ft) | 6520 | 6715 | 6640 | 6920 | 7095 |
| Construction | | | | | |
| Depth drilled (ft) | 2501 | 2600 | 2552 | 2920 | 3120 |
| Depth completed (ft) | 2499 | 2300 | 2552 | 2875 | 3093 |
| Diameter (in.)[b] | 12 | 14 | 14 | 16 | 16 |
| Water Levels | | | | | |
| Date | 1982 | 1982 | 1982 | 1982 | 1982 |
| Depth below LSD (ft) | 748 | 874 | 762 | 1047 | 1208 |
| Elevation (ft) | 5772 | 5841 | 5878 | 5873 | 5887 |
| Water-Level Fluctuations | | | | | |
| Period (yr) | 1965-1982 | 1966-1982 | 1968-1982 | 1981-1982 | --- |
| Change (ft) | −2 | −48 | −19 | 5 | --- |
| Annual rate (ft/yr) | −0.1 | −2.8 | −1.3 | --- | --- |
| Aquifer | | | | | |
| Formation | QTp-Tsf | QTp-Tsf | QTp-Tsf | QTp-Tsf | QTp-Tsf |
| Saturated thickness (ft) | 1751 | 1426 | 1790 | 1828 | 1885 |
| Yield | | | | | |
| Date | 1982 | 1982 | 1982 | 1982 | 1982 |
| Rate (gpm) | 589 | 1386 | 1402 | 1473 | 1225 |
| Drawdown (ft) | 22 | 60 | 23 | 40 | 144 |
| Specific capacity (gpm/ft) | 26.8 | 23.1 | 60.9 | 36.8 | 8.5 |
| Transmissivity (gpd/ft) | 55 000 | 40 000 | 320 000 | 44 000 | 10 000 |
| Field coefficient of permeability (gpd/ft$^2$) | 31 | 28 | 179 | 24 | 5.3 |
| Production | | | | | |
| Period (yr) | 1965-1982 | 1966-1982 | 1968-1982 | 1982 | --- |
| Pumpage ($10^6$ gal.) | 1593 | 5863 | 3478 | 76 | --- |
| Quality of Water | | | | | |
| Date | 3-18-81 | 3-18-81 | 3-18-81 | 8-3-81 | 8-4-81 |
| Chemical (mg/ℓ) | | | | | |
| $SiO_2$ | 77 | 81 | 88 | 87 | 86 |
| Ca | 28 | 8 | 24 | 9 | 14 |
| Mg | 6.9 | 3.1 | 8.4 | 3 | 4 |
| Na | 18 | 10 | 18 | 11 | 24 |
| $CO_3$ | 0 | 0 | 0 | 0 | 0 |
| $HCO_3$ | 144 | 65 | 148 | 70 | 106 |
| $SO_4$ | 5 | 3 | 7 | 4 | 10 |
| Cl | 4 | 9 | 10 | 2 | 4 |
| F | 0.3 | 0.3 | 0.4 | 0.3 | 0.3 |
| $NO_3$ | 2.0 | <0.1 | 1.8 | 2 | 8 |
| TDS | 212 | 140 | 216 | 165 | 211 |
| Hard | 90 | 36 | 90 | 36 | 52 |
| Specific conductance (μmho) | 260 | 130 | 250 | 120 | 190 |
| pH | 8.0 | 7.8 | 8.3 | 8.2 | 8.2 |
| Radiochemical | | | | | |
| Total uranium (μg/ℓ) | 2.4 ± 0.8 | 0.0 ± 0.8 | 1.0 ± 0.8 | 0.8 ± 0.8 | 2.2 ± 0.4 |
| Temperature (°F) | 71 | 69 | 71 | 69 | 73 |

[a]Well was abandoned in 1956; data were not used in the average hydrologic characteristics. It is located 150 ft SW of well LA-1B.

[b]Wells have two different diameter sizes of casing; i.e., 12 (650 ft) 10 reads: 12-in. diameter to 650 ft, then 10-in. diameter to completed depth of well.

Note: QTp = Puye Conglomerate; Tsf = Tesuque Formation.

## APPENDIX B

### CONSTRUCTION AND HYDROLOGIC DATA FOR TEST AND STOCK WELLS

| | Test Wells | | | | |
|---|---|---|---|---|---|
| | TW-1 | TW-2 | TW-3 | TW-4 | TW-5A |
| Date of Completion | 1950 | 1949 | 1949 | 1950 | 1960 |
| Elevation of LSD (ft) | 6370 | 6645 | 6625 | 7245 | 7145 |
| Construction | | | | | |
| Depth drilled (ft) | 642 | 789 | 815 | 1205 | 1821 |
| Depth completed (ft) | 642 | 789 | 815 | 1205 | 1821 |
| Diameter (in.) | 8 | 8 | 10 | 6 | 8 |
| Water levels | | | | | |
| Date | 1951 | 1951 | 1951 | 1951 | 1964 |
| Depth below LSD (ft) | 593 | 760 | 750 | 1166 | 1178 |
| Elevation (ft) | 5773 | 5885 | 5875 | 6079 | 5967 |
| Water-Level Fluctuations | | | | | |
| Period | — | — | — | — | 1960-1964 |
| Changes (ft) | — | — | — | — | –4 |
| Annual rate (ft/yr) | — | — | — | — | –0.8 |
| Aquifer | | | | | |
| Formations | QTp | QTp | QTp | Tt | QTp-Tsf |
| Saturated thickness (ft) | 49 | 29 | 65 | 39 | 643 |
| Yield | | | | | |
| Date | 1951 | 1951 | 1951 | 1951 | 1960 |
| Rate (gpm) | 2.4 | 6.7 | 6.6 | 2.8 | 81 |
| Drawdown (ft) | 38.9 | 7.5 | 15.0 | 4.8 | 14.2 |
| Specific capacity (gpm/ft) | <0.1 | 1.0 | 0.5 | 0.6 | 5.7 |
| Transmissivity (gpd/ft) | 200 | 7000 | 7800 | 750 | 11 000 |
| Field coefficient of permeability (gpd/ft$^2$) | 4 | 241 | 120 | 19 | 17 |
| Quality of Water | | | | | |
| Date | 2-28-81 | 9-17-81 | 3-31-81 | 6-8-65 | 9-16-81 |
| Chemical (mg/ℓ) | | | | | |
| $SiO_2$ | 49 | 79 | 84 | — | 72 |
| Ca | 43 | 13 | 17 | 10 | 8 |
| Mg | 7.7 | 3.8 | 6.0 | 5 | 2.5 |
| Na | 12 | 9 | 13 | 20 | 11 |
| $CO_3$ | 0 | 0 | 0 | 0 | 0 |
| $HCO_3$ | 121 | 79 | 104 | 70 | 65 |
| $SO_4$ | 3 | 3 | 3 | — | 1 |
| Cl | 7 | 3 | 4 | 2 | 2 |
| F | 0.4 | 0.5 | 0.4 | <0.4 | 0.2 |
| $NO_3$ | 2.4 | 6.2 | 4.1 | 0.4 | 3.9 |
| TDS | 220 | 150 | 168 | 163 | 124 |
| Hardness | 128 | 51 | 64 | 45 | 38 |
| Specific conductance (μmho) | 320 | 150 | 190 | 150 | 120 |
| pH | 8.0 | 8.0 | 7.9 | 7.9 | 7.9 |
| Radiochemical | | | | | |
| Total uranium (μg/ℓ) | 6.1 ± 1.2 | 0.1 ± 0.8 | 0.7 ± 0.8 | 0.5 ± 0.5 | 0.0 ± 0.8 |
| Temperature (°F) | 70 | 71 | 74 | 70 | 70 |

APPENDIX B (cont)

| | Test Wells | | | | | Stock Wells | |
|---|---|---|---|---|---|---|---|
| | TW-8 | DT-9 | DT-10 | Sigma Mesa | H-19 | RW-2 | RW-5 |
| Date of Completion | 1960 | 1960 | 1960 | 1979 | 1949 | 1954 | 1955 |
| Elevation of LSD (ft) | 6870 | 6935 | 7020 | 7215 | 7180 | 5642 | 5820 |
| Construction | | | | | | | |
| Depth drilled (ft) | 1065 | 1501 | 1409 | 2292 | 2000 | 161 | 132 |
| Depth completed (ft) | 1065 | 1501 | 1408 | — | 2000 [a] | 161 | 132 |
| Diameter (in.) | 8 | 12 | 12 | — | — | — | — |
| Water Levels | | | | | | | |
| Date | 1965 | 1982 | 1967 | 1979 | 1949 | 1954 | 1955 |
| Depth below LSD (ft) | 969 | 1006 | 1091 | 1305 [b] | 970 | 132 | 105 |
| Elevation (ft) | 5901 | 5929 | 5929 | 5910 | 6210 | 5510 | 5715 |
| Water-Level Fluctuations | | | | | | | |
| Period | 1960-1965 | 1960-1982 | 1960-1967 | — | — | — | — |
| Change (ft) | −1 | −3 | −4 | — | — | — | — |
| Annual rate (ft/yr) | −0.2 | −0.2 | −0.5 | — | — | — | — |
| Aquifer | | | | | | | |
| Formations | QTp | QTp-Tsf | QTp-Tsf | QTp-Tsf | Tt-QTp | Tsf | Tsf |
| Saturated thickness (ft) | 97 | 498 | 324 | 987 | 1030 | — | — |
| Yield | | | | | | | |
| Date | 1960 | 1960 | 1960 | — | — | — | — |
| Rate (gpm) | 16 | 88 | 78 | — | — | — | — |
| Drawdown (ft) | 8.0 | 4.0 | 4.9 | — | — | — | — |
| Specific capacity (gpm/ft) | 2 | 22 | 16 | — | — | — | — |
| Transmissivity (gpd/ft) | 2400 | 61 000 | 36 100 | — | — | — | — |
| Field coefficient of permeability (gpd/ft$^2$) | 25 | 122 | 111 | — | — | — | — |
| Quality of Water | | | | | | | |
| Date | 4-6-81 | 4-10-81 | 4-2-81 | — | — | 12-7-67 | 12-7-67 |
| Chemical (mg/ℓ) | | | | | | | |
| $SiO_2$ | 50 | 72 | 58 | — | — | — | — |
| Ca | 4 | 9 | 10 | — | — | 32 | 28 |
| Mg | 0.9 | 3.1 | 3.5 | — | — | 5 | 7 |
| Na | 11 | 12 | 11 | — | — | 47 | 79 |
| $CO_3$ | 7 | 0 | 0 | — | — | 0 | 0 |
| $HCO_3$ | 22 | 69 | 81 | — | — | 114 | 158 |
| $SO_4$ | <1 | 2 | 1 | — | — | — | — |
| Cl | 3 | 4 | 3 | — | — | 8 | 10 |
| F | 0.2 | <0.2 | 0.3 | — | — | 0.1 | 0.2 |
| $NO_3$ | 4.4 | 4.3 | <0.4 | — | — | 0.9 | 3.1 |
| TDS | 52 | 142 | 124 | — | — | 170 | 253 |
| Hardness | 16 | 35 | 42 | — | — | 100 | 100 |
| Specific conductance (μmho) | 90 | 150 | 130 | — | — | 200 | 270 |
| pH | 9.8 | 8.0 | 8.3 | — | — | 8.1 | 7.6 |
| Radiochemical | | | | | | | |
| Total uranium (μg/ℓ) | 0.0 ± 0.8 | 0.8 ± 0.8 | 0.8 ± 0.8 | — | — | 1.8 ± 0.4 | 2.3 ± 0.8 |
| Temperature (°F) | 67 | 70 | 67 | — | — | 67 | 66 |

[a] Hole abandoned.

[b] Water level interpreted from geophysical logs.

Note: Tsf = Tesuque Formation; QTp = Puye Conglomerate; and Tt = Tschicoma Formation.

## APPENDIX C

## HYDROLOGIC DATA FOR SPRINGS IN WHITE ROCK CANYON

| | Spring 3 | Spring 3B | Spring 4 | Spring 5A | Spring 5B | Spring 6 | Spring 8A | Spring 10 |
|---|---|---|---|---|---|---|---|---|
| Elevation of LSD (ft) | 5560 | 5500 | 5500 | 5430 | 5400 | 5380 | 5370 | 5360 |
| Aquifer | QTp | Tsf | QTp | Tsf | Tsf | Tsf | Tsf | Tsf |
| Discharge at Rio Grande (gpm) | 20 | 30 | 80 | 30 | 10 | 60 | 30 | 20 |
| Quality of Water | | | | | | | | |
| Date | 10-13-81 | 10-13-81 | 10-13-81 | 10-13-81 | 10-14-81 | 10-14-81 | 10-14-81 | 10-15-81 |
| Chemical (mg/ℓ) | | | | | | | | |
| $SiO_2$ | 52 | 46 | 60 | 60 | 64 | 74 | 75 | 69 |
| Ca | 20 | 24 | 28 | 24 | 17 | 12 | 11 | 12 |
| Mg | 1.6 | 2.0 | 5.7 | 2.7 | 4.4 | 3.6 | 2.8 | 3.2 |
| Na | 16 | 139 | 15 | 22 | 12 | 11 | 13 | 13 |
| $CO_3$ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| $HCO_3$ | 99 | 392 | 132 | 124 | 87 | 74 | 56 | 80 |
| $SO_4$ | 4 | 4 | 6 | 7 | 2 | 2 | 3 | 3 |
| Cl | 5 | 6 | 8 | 6 | 4 | 4 | 5 | 4 |
| F | 0.4 | 0.6 | 0.5 | 0.3 | 0.5 | 0.3 | 0.4 | 0.4 |
| $NO_3$ | 2.6 | 8.4 | <0.4 | 1.7 | 2.0 | <0.4 | <0.4 | 1.7 |
| TDS | 125 | 374 | 168 | 186 | 152 | 134 | 152 | 146 |
| Hardness | 56 | 64 | 92 | 69 | 56 | 44 | 39 | 42 |
| Specific conductance (μmho) | 210 | 610 | 220 | 240 | 150 | 140 | 130 | 120 |
| pH | 8.1 | 7.5 | 7.0 | 7.4 | 7.4 | 7.0 | 9.0 | 7.8 |
| Radiochemical | | | | | | | | |
| Total uranium (μg/ℓ) | 2.3 ± 0.8 | 19 ± 4.0 | 1.5 ± 0.8 | 2.2 ± 0.8 | 1.9 ± 0.8 | 1.0 ± 0.8 | 1.7 ± 0.8 | 1.7 ± 0.8 |
| Temperature (°F) | 72 | 68 | 66 | 70 | 61 | 73 | 72 | 66 |

Note: Tsf = Tesuque Formation and QTp = Puye Conglomerate.

## APPENDIX D

## CHEMICAL QUALITY OF WATER FROM MUNICIPAL SUPPLY AND DISTRIBUTION

| | Primary Chemical Quality Required for Municipal Use (Concentrations in mg/ℓ) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Ag | As | Ba | Cd | Cr | F | Hg | $NO_3$ | Pb | Se |
| **Los Alamos Field** | | | | | | | | | | |
| Well LA-1B | <0.0005 | 0.039 | 0.06 | <0.001 | 0.022 | 2.6 | <0.0002 | 1.2 | <0.003 | <0.003 |
| Well LA-2 | <0.0005 | 0.013 | 0.09 | <0.001 | 0.020 | 1.9 | <0.0002 | 1.8 | <0.003 | <0.003 |
| Well LA-3 | <0.0005 | 0.009 | 0.06 | <0.001 | 0.010 | 0.7 | <0.0002 | 1.7 | <0.003 | <0.003 |
| Well LA-5 | <0.0005 | 0.032 | 0.07 | <0.001 | 0.010 | 1.0 | <0.0002 | 1.4 | <0.003 | <0.003 |
| **Guaje Field** | | | | | | | | | | |
| Well G-1 | <0.0005 | <0.005 | 0.06 | <0.001 | 0.008 | 0.4 | <0.0002 | 1.2 | <0.003 | <0.003 |
| Well G-1A | <0.0005 | 0.009 | 0.04 | <0.001 | 0.006 | 0.5 | <0.0002 | 1.2 | <0.003 | <0.003 |
| Well G-2 | <0.0005 | 0.048 | 0.03 | <0.001 | 0.011 | 1.0 | <0.0002 | 0.9 | <0.003 | <0.003 |
| Well G-3 | <0.0005 | 0.018 | 0.02 | <0.001 | 0.005 | 0.4 | <0.0002 | 1.0 | 0.004 | <0.003 |
| Well G-4 | <0.0005 | <0.005 | 0.02 | <0.001 | 0.004 | 0.3 | <0.0002 | 1.5 | <0.003 | <0.003 |
| Well G-5 | <0.0005 | <0.005 | 0.02 | <0.001 | 0.002 | 0.3 | <0.0002 | 3.0 | <0.003 | <0.003 |
| Well G-6 | <0.0005 | <0.005 | 0.02 | <0.001 | 0.005 | 0.3 | <0.0002 | 0.6 | <0.003 | <0.003 |
| **Pajarito Field** | | | | | | | | | | |
| Well PM-1 | <0.0005 | <0.005 | 0.09 | <0.001 | 0.010 | 0.3 | <0.0002 | 1.1 | <0.003 | <0.003 |
| Well PM-2 | <0.0005 | <0.005 | 0.02 | <0.001 | 0.004 | 0.2 | <0.0002 | 0.4 | <0.003 | <0.003 |
| Well PM-3 | <0.0005 | <0.005 | 0.05 | <0.001 | 0.003 | 0.3 | <0.0002 | 0.7 | 0.005 | <0.003 |
| Well PM-4 | <0.0005 | <0.005 | 0.04 | <0.001 | 0.006 | 0.3 | <0.0002 | 7.6 | <0.003 | <0.003 |
| Well PM-5 | <0.0005 | <0.005 | 0.04 | <0.001 | 0.002 | 0.4 | <0.0002 | 3.0 | <0.003 | <0.003 |
| Los Alamos Well LA-6 | <0.0005 | 0.185 | | <0.001 | 0.014 | 2.3 | <0.0002 | 0.4 | 0.006 | <0.003 |
| USEPA Maximum Contaminant Level | 0.05 | 0.05 | 1.0 | 0.01 | 0.05 | 2.0 | 0.002 | 45 | 0.05 | 0.01 |

APPENDIX E

SECONDARY CHEMICAL QUALITY FOR MUNICIPAL USE
(concentrations in mg/ℓ)

| | Cl | Cu | Fe | Mn | $SO_4$ | Zn | TDS | pH |
|---|---|---|---|---|---|---|---|---|
| Los Alamos Field | | | | | | | | |
| Well LA-1B | 16 | 0.003 | 0.028 | <0.002 | 27 | <0.01 | 408 | 7.9 |
| Well LA-2 | 16 | 0.006 | 0.100 | 0.008 | 12 | <0.01 | 204 | 8.5 |
| Well LA-3 | 4 | <0.002 | 0.007 | <0.002 | 5 | <0.01 | 162 | 8.3 |
| Well LA-5 | 2 | <0.002 | <0.005 | <0.002 | 3 | <0.01 | 170 | 8.6 |
| Guaje Field | | | | | | | | |
| Well G-1 | 3 | 0.003 | 0.007 | 0.010 | <2 | 0.02 | 162 | 7.9 |
| Well G-1A | 3 | 0.013 | 0.006 | <0.002 | <2 | 0.02 | 152 | 8.3 |
| Well G-2 | 3 | <0.002 | 0.010 | <0.002 | 2 | <0.01 | 168 | 8.3 |
| Well G-3 | 3 | 0.010 | 0.018 | <0.002 | <2 | 0.12 | 120 | 8.3 |
| Well G-4 | 3 | 0.012 | 0.062 | 0.002 | 3 | 0.09 | 126 | 8.2 |
| Well G-5 | 3 | <0.002 | 0.012 | 0.002 | 4 | <0.01 | 160 | 8.3 |
| Well G-6 | 3 | <0.002 | <0.005 | <0.002 | 2 | <0.01 | 134 | 7.6 |
| Pajarito Field | | | | | | | | |
| Well PM-1 | 6 | <0.002 | <0.005 | <0.002 | 2 | <0.01 | 188 | 7.6 |
| Well PM-2 | 2 | 0.003 | <0.005 | <0.002 | 2 | 0.04 | 134 | 8.0 |
| Well PM-3 | 8 | 0.001 | <0.005 | <0.002 | 3 | 0.01 | 203 | 8.0 |
| Well PM-4 | 2 | <0.002 | 0.020 | 0.003 | 4 | <0.01 | 169 | 8.2 |
| Well PM-5 | 3 | <0.002 | 0.050 | 0.005 | 10 | <0.01 | 211 | 8.2 |
| Water Canyon Gallery | <1 | <0.002 | 0.325 | <0.002 | 2 | 0.02 | 114 | 7.5 |
| Los Alamos Well LA-6 | 4 | 0.011 | 0.908 | <0.002 | 2 | 0.07 | 222 | 8.6 |
| Secondary Standards | 250 | 1.0 | 0.3 | 0.05 | 250 | 5.0 | 500 | 6.5 - 8.5 |

## APPENDIX F

### RADIOCHEMICAL QUALITY OF WATER FROM MUNICIPAL SUPPLY AND DISTRIBUTION

| Station | 1982 Date | Radiochemical | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | $^{137}Cs$ ($10^{-9}$ μCi/mℓ) | $^{238}Pu$ ($10^{-9}$ μCi/mℓ) | $^{239}Pu$ ($10^{-9}$ μCi/mℓ) | Gross Alpha ($10^{-}$ μCi/mℓ) | Gross Beta ($10^{-9}$ μCi/mℓ) | $^{3}H$ ($10^{-6}$ μCi/mℓ) | Total U (μg/ℓ) |
| **Los Alamos Field** | | | | | | | | |
| Well LA-1B | 3-30 | −50 ± 80 | −0.004 ± 0.014 | −0.004 ± 0.012 | 11 ± 6.0 | 6.4 ± 2.4 | --- | 5.0 ± 1.0 |
| Well LA-2 | 3-30 | 19 ± 40 | 0.009 ± 0.020 | −0.019 ± 0.000 | 9.0 ± 4.0 | 4.1 ± 1.8 | 0.3 ± 0.6 | 3.9 ± 0.8 |
| Well LA-3 | 3-30 | −80 ± 40 | 0.004 ± 0.012 | −0.012 ± 0.008 | 1.5 ± 1.4 | 6.5 ± 2.0 | 1.2 ± 0.6 | 4.6 ± 1.0 |
| Well LA-5 | 3-30 | −10 ± 34 | −0.005 ± 0.010 | −0.010 ± 0.010 | 3.3 ± 2.0 | 3.8 ± 1.8 | 0.9 ± 0.6 | 7.0 ± 1.4 |
| **Guaje Field** | | | | | | | | |
| Well G-1 | 3-30 | 40 ± 60 | −0.006 ± 0.012 | −0.012 ± 0.012 | 0.1 ± 1.2 | 2.4 ± 1.6 | 3.4 ± 0.6 | 0.9 ± 0.8 |
| Well G-1A | 3-30 | −2 ± 80 | 0.007 ± 0.030 | −0.007 ± 0.020 | 0.3 ± 1.0 | 28 ± 6.0 | 1.8 ± 0.6 | 1.0 ± 0.8 |
| Well G-2 | 3-30 | −7 ± 38 | 0.005 ± 0.016 | −0.014 ± 0.012 | 0.8 ± 1.2 | 0.8 ± 1.4 | 0.3 ± 0.6 | 0.9 ± 0.8 |
| Well G-3 | 3-30 | −40 ± 40 | 0.004 ± 0.014 | −0.013 ± 0.000 | 1.0 ± 1.2 | 2.1 ± 1.6 | 4.1 ± 0.6 | 1.6 ± 0.8 |
| Well G-4 | 3-30 | 40 ± 60 | 0.014 ± 0.038 | 0.010 ± 0.600 | 1.1 ± 1.2 | 1.2 ± 1.4 | 0.2 ± 0.6 | 1.0 ± 0.8 |
| Well G-5 | 3-30 | −40 ± 80 | −0.005 ± 0.000 | −0.016 ± 0.010 | 1.0 ± 1.0 | 3.8 ± 1.6 | 0.7 ± 0.6 | 1.3 ± 0.4 |
| Well G-6 | 3-30 | 19 ± 40 | 0.009 ± 0.026 | −0.009 ± 0.038 | 5.9 ± 2.4 | 7.7 ± 2.2 | 0.8 ± 0.6 | 1.7 ± 0.8 |
| **Pajarito Field** | | | | | | | | |
| Well PM-1 | 3-30 | −50 ± 40 | −0.010 ± 0.020 | −0.050 ± 0.100 | 0.7 ± 1.4 | 8.1 ± 2.4 | 0.5 ± 0.6 | 1.8 ± 0.8 |
| Well PM-2 | 3-30 | 20 ± 40 | 0.010 ± 0.040 | −0.020 ± 0.040 | 1.1 ± 1.2 | 1.9 ± 1.6 | 0.3 ± 0.6 | 0.0 ± 0.8 |
| Well PM-3 | 3-30 | 30 ± 20 | −0.014 ± 0.014 | −0.005 ± 0.014 | 1.0 ± 1.4 | 13 ± 3.2 | 4.2 ± 0.6 | 1.6 ± 0.8 |
| Well PM-4 | 8-3 | 10 ± 48 | 0.012 ± 0.020 | −0.012 ± 0.034 | 0.0 ± 0.8 | 18 ± 4.0 | 0.5 ± 0.6 | 0.8 ± 0.8 |
| Well PM-5 | 8-4 | 36 ± 34 | 0.018 ± 0.024 | 0.004 ± 0.024 | 3.9 ± 2.2 | 3.2 ± 1.6 | 0.4 ± 0.6 | 2.2 ± 0.4 |
| **Los Alamos Field** | | | | | | | | |
| Well LA-6 | 3-30 | −30 ± 40 | −0.005 ± 0.000 | −0.015 ± 0.030 | 2.9 ± 2.2 | 4.0 ± 1.8 | 0.5 ± 0.6 | 3.8 ± 0.8 |



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