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HYDROGEOLOGY OF THE RIO GRANDE VALLEY AND ADJACENT INTERMONTANE AREAS OF SOUTHERN NEW MEXICO

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CONTENTS

Page

ILLUSTRATIONS

Tables

Page

Figures

Plates

ABSTRACT

The area of investigation in Southern New Mexico is a 3,600 square mile region extending from Caballo Reservoir on the north to the New Mexico-Texas-Chihuahua line on the south and from the Luna-Dona Ana County line on the west to the Organ-San Andres Mountain chain on the east. The main physiographic features are the entrenched valley of the Rio Grande, which crosses the area from northwest to southeast, and two large intermontane basins, the Jornada del Muerto and the Mesilla Bolson.

Previous ground-water investigations in the area (e.g. Conover, 1954) have been primarily concerned with the hydrology of surface water and shallow ground-water supplies in and immediately adjacent to the Rio Grande Valley. Emphasis of this report is on the relationship of geology to the hydrologic system over a much broader region.

The basic geomorphic setting is one of mountain uplifts alternating with broad structural basins. The Rio Grande crosses the area in a valley as much as 8 miles in width entrenched from 250 to 500 feet below ancient basin floors. Many of the mountains in the area consist of fault blocks with a general north-south trend. Other mountain types include broad domal uplifts and igneous intrusive and extrusive bodies.

The primary hydrologic role played by consolidated rocks, both in upland areas and where buried beneath the basin fill, is that of a barrier to the movement of ground water. Bedrock units, particularly where gypsiferous, also serve as a primary source of many of the dissolved solids locally found in ground-and surface-water supplies. The consolidated rocks are subdivided into four major hydrogeologic units: (1) igneous intrusive and metamorphic rocks of Precambrian and Tertiary age, (2) carbonate rocks and other clastic sedimentary rocks of Paleozoic, late Mesozoic and early Tertiary age, (3) Tertiary acid to intermediate volcanic and associated sedimentary rocks, and (4) late Cenozoic basalts.

The Santa Fe Group basin fill of Miocene to middle Pleistocene age and the Rio Grande Valley fill of late Quaternary age constitute the two major ground-water reservoirs in the area of study.

The Santa Fe Group is a rock-stratigraphic unit, locally exceeding 3,500 feet in thickness, that partly fills intermontane basins along and adjacent to the Rio Grande Valley. It merges laterally to the west with basin-fill deposits currently designated the "Gila Conglomerate". Studies of lithologic variations in the basin fill, carried out in conjunction with geomorphic and time-stratigraphic investigations, demonstrate that environments of Santa Fe Group deposition included both closed-and open-basin systems. The former type, the classic bolson environment (piedmont alluvial slopes grading to basin floors containing ephemeral lakes), prevailed during early stages of basin filling, while later stages were characterized by

coalescence of basin floors and development of a regional system of through drainage. Thus, deposition of the Santa Fe Group in Southern New Mexico generally fits Bryan's (1938) concept of basin filling in the type region of the Santa Fe Group of Central and Northern New Mexico.

Hydraulic properties of the basin fill and chemical quality of the ground water reflect the variety of environments of deposition in both closed and open basins. The lacustrine facies of the basin fill is the least favorable zone in terms of quantity and quality of ground-water production, while the fluvial facies, representing deposits of the ancestral Rio Grande, is the most favorable. The alluvial facies, deposited in a piedmont-slope sedimentation environment, represents a transitional unit, with hydraulic properties ranging from excellent to poor. Coefficients of transmissibility in better aquifer zones within the Santa Fe Group range from 30,000 to 80,000 gpd/feet, with developed zones commonly ranging from 300 to 500 feet in thickness.

The other important aquifer in the study area is the thin layer of late Quaternary gravel and sand comprising the fill of the inner Rio Grande Valley. These fluvial deposits are no more than 80 feet thick. In the segment of the river valley extending from Fort Selden to Caballo Dam, they constitute the main source of ground water. In the Mesilla Valley the late Quaternary valley fill forms a complex aquifer system with underlying sand and gravel of the Upper Santa Fe Group. This valley aquifer system, because of excellent capacity for recharge, transmission and storage, is capable of supplying ground water in large quantities for agricultural, municipal and industrial use. There is a potential for further industrial development in certain parts of the Rio Grande Valley, because of the local availability of large quantities of good-quality ground water.

The distribution of aquifers in the basins east and west of the Rio Grande Valley is not completely known because in many places wells are widely spaced (plate 1). However, on the basis of the present investigation, it would seem that there are few aquifers capable of production of sufficient water for profitable irrigation. Ground-water development in basin areas is hampered by the relatively great depth of the water table, which often exceeds 250 feet in areas away from the inner Rio Grande Valley.

The ground-water table contour map (plate 1) shows many of the facets of the geohydrology of the region. Of particular interest is the northwestward movement of ground water in the Jornada del Muerto. This interpretation of the flow pattern differs markedly from previous interpretations. Troughs in the ground-water table, which probably represent very permeable zones of Santa Fe Group aquifers, have been delineated east of Las Cruces, east of Anthony and northwest of Anapra. An unexplained ground-water mound is present in the area of Kilbourne, Hunt's and Phillip's Holes on the La Mesa plain. The Fillmore Gap area represents a region where there may be ground-water communication with the Hueco Bolson.

INTRODUCTION

Purpose and Scope of the Investigation

The authors of this report believe that it is important to delineate and describe the basic geological framework of a given area as a first step in understanding the hydrology of that area. The initial geologic study is mandatory, because (a) geological conditions control the occurrence and movement of water and (b) it is a logical prelude to later geohydrological studies. Consequently, the purpose of this report is to set forth the known facts about the hydrogeology of the Rio Grande Valley and adjacent intermontane basins of Southern New Mexico.

Although the area is one of great importance to the present economy and growth potential of New Mexico, its hydrogeology has received but little attention during the last fifteen years. C. S. Conover's excellent report (1954) is the only comprehensive hydrological investigation dealing with the region, and it does not concern itself extensively with hydrogeology. Rather, the report is primarily an analysis of the surface-subsurface water supply relationships, particularly in the valley of the Rio Grande.

Fortunately, since the late 1940's, when Conover did his field work, hundreds of wells have been drilled. While it is true that most of these wells have been located in the Rio Grande Valley, informative wells have been drilled in other parts of the Mesilla Bolson, in the Jornada del Muerto, and in other portions of the region. As a consequence, the authors had access to a wealth of hitherto unstudied geological information, and the opportunity to better understand the complexities of the geologic framework.

Because of a comparatively limited budget, little quantitative geohydrology was possible. For example, no aquifer tests were conducted during the course of the investigation, and pumping tests were monitored only when the well owner assumed the expense of the test.

This hydrogeologic study encompasses a region of some 3,600 square miles stretching from Caballo Reservoir on the north to the New Mexico-Texas-Chihuahua line on the south and from the Luna-Dona Ana County line on the west to the Franklin-Organ-San Andres Mountain chain on the east (figs. 1, 3, 4, and plate 1). In a region of this size, the distribution of subsurface data is not uniform, and portions of the investigation are, of necessity, much more detailed than others. For example, the well spacing is close in the Rio Grande Valley, where there is extensive farming, but in ranching areas, like La Mesa, the wells are widely spaced.

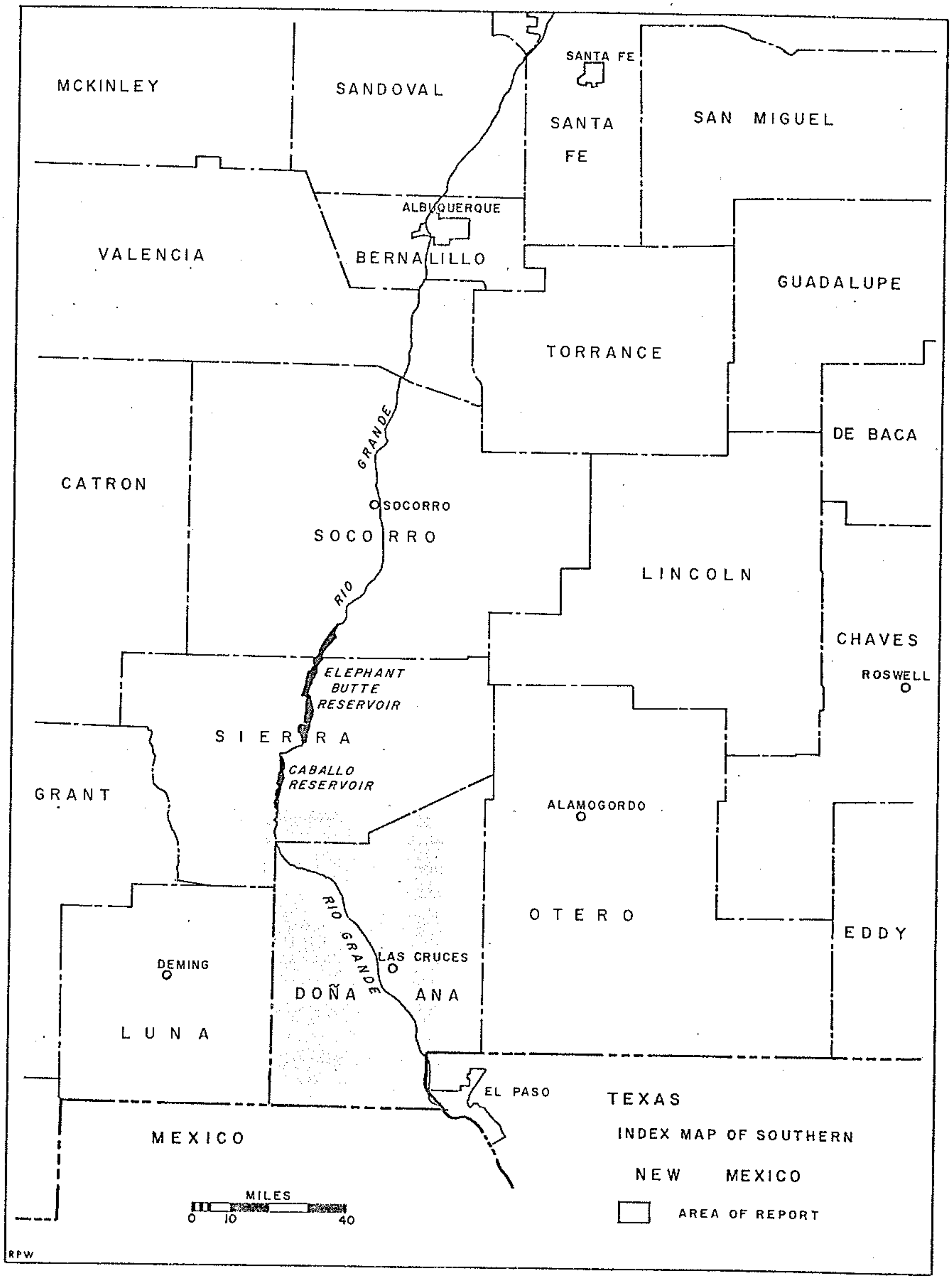
MCKINLEY
SANDOVAL
SANTA FE
SANTA FE
SAN MIGUEL
VALENCIA
ALBUQUERQUE
BERNALILLO
GUADALUPE
TORRANCE
DE BACA
CATRON
RIO GRANDE
SOCORRO
SOCORRO
LINCOLN
CHAVES
ROSWELL
ELEPHANT BUTTE RESERVOIR
SIERRA
CABALLO RESERVOIR
GRANT
ALAMOGORDO
OTERO
EDDY
DEMING
LAS CRUCES
DOÑA ANA
LUNA
EL PASO
TEXAS
MEXICO
INDEX MAP OF SOUTHERN NEW MEXICO
AREA OF REPORT
MILES
0 10 40
RPW

FIGURE I.

In 1964, the Water Resources Research Act was passed by the United States Congress, and the Water Resources Research Institute of New Mexico, under the direction of H. R. Stucky, was established soon thereafter. The present investigation was among the first to be funded by the Institute. The field and laboratory work was begun in February, 1965, and terminated in August, 1968.

The Principal Investigator, W. E. King, Professor of Geology at New Mexico State University, spent one quarter of his time through each academic year and three full months each summer on the investigation. He was responsible for supervision of the investigation and is accountable for many of the conclusions. Andrew M. Taylor served as a graduate assistant on the project from its inception through August, 1967, and did much of the well logging and surface geology. Richard P. Wilson spent one year as a student assistant and is largely responsible for the drafting as well as much of the thought expressed in the water table contour map (plate 1).

John W. Hawley, Areal Geologist with the Soil Conservation Service of the United States Department of Agriculture, suggested the investigation and has cooperated in the study throughout. The section on geology and its relationship to the hydrologic system as well as many of the fundamental conclusions of the investigation are the results of his work.

Location and General Geographic Features

The area of investigation, except for a small portion of Sierra County, is entirely in Dona Ana County, New Mexico. The county is an extremely large one with diverse terrain, vegetation and land use.

The largest amount of irrigated cropland, 88,191 acres in 1966, according to the Elephant Butte Irrigation District records, lies in the Rio Grande Valley, which extends from the northwest corner to the southeast corner of the area studied. Elevation of the valley floor ranges from about 4,125 feet at Caballo Dam to 3,725 feet at El Paso. The valley agriculture depends upon surface water from Elephant Butte Reservoir, supplemented with ground water from hundreds of wells. The major crops are cotton and forage crops, but recently a trend to vegetable production has been established. The chief vegetable crop, at the time of writing, is lettuce. This development is most interesting, because lettuce needs water of better chemical quality than cotton to flourish. A number of valley farmers are now seeking high quality water.

To the west of the Mesilla Valley segment of the Rio Grande Valley stretch the extensive plains of the Mesilla Bolson. On the broad floor of this basin, which is designated La Mesa, all but several sections of the land is devoted to the grazing of livestock. The region is sparsely settled, but a number of wells have been drilled for livestock and domestic use. From time to time, there have been attempts to establish irrigated farms on La Mesa, but, to the best of the authors' knowledge, none of these ventures have had a high economic return. The mountains in the region, the East and West Potrillos, Mount Riley and the Aden hills, are generally low. The most striking physiographic features are the scattered extinct volcanoes and the extensive lava flows (fig. 3 and plate 1).

North of the Mesilla Bolson and west of the Rio Grande Valley is, again, a region primarily devoted to ranching. Prominent features of the landscape are the Sierra de las Uvas and the Robledo Mountains. The Nutt-Hockett irrigation basin lies just to the west of the region of this investigation, but livestock raising is the major land use.

East of the Rio Grande Valley in the southern Jornada del Muerto, the area is likewise primarily one of ranching activity. The United States Department of Agriculture maintains the Jornada Range Station in the area, and New Mexico State University operates a ranch near the Dona Ana Mountains. There is some irrigated farming in the Jornada near the center of the basin (sec. 36, T20S, R2E) where wells yield fairly large quantities of water. However, the irrigated areas comprise at the most only small portions of this vast region. In the same general area of the Jornada del Muerto (sections 30 and 31, T20S, R2E) the two water supply wells for the Apollo Test Facility of the National Aeronautics and Space Administration provide adequate quantities of water.

Along U. S. Highway 70 in the Southern Jornada del Muerto, there are several housing subdivisions that rely upon ground water. In addition, there are small business establishments, such as gasoline stations, grocery stores and automotive repair garages, that have wells. It seems likely that the strip of land bordering Highway 70 will be a developing commercial area of the future, but the chances are not bright that there will be much irrigation farming there for reasons stated in the section of this paper on geology and its relation to the hydrologic system.

Prominent features of the Southern Jornada del Muerto are the Dona Ana Mountains, the Tonuco-Selden Hills uplift, and, along the eastern boundary, the San Andres and Organ Mountains. The summit of Organ Needle, with an elevation of 9,012 feet, is the highest point in the county.

South of the Jornada del Muerto, or south of a line from the Central Dona Ana Mountains to Tortugas Mountain to the Central Organ Mountains, there is a portion of the Mesilla Bolson that lies east of the Rio Grande Valley. Prominent features of the area are the

Tortugas Mountain and Bishop's Cap uplifts. The region is bordered on the east by the Southern Organ Mountains and the Northern Franklin Mountains. Although there is a small farming development in Fillmore Pass between the Franklin Mountains and Bishop's Cap, this region is primarily utilized for livestock production.

Population, Industry and Resources

The dominant population center of the area of investigation is Las Cruces with an estimated population of 47,000, based upon utilities services. Other population centers are, for the most part, congregated in the Rio Grande Valley. Taken from north to south, some of the most prominent are Arrey, Derry, Garfield, Salem, Rincon, Hatch, Radium Springs, Dona Ana, Las Cruces, Mesilla, Mesquite, San Miguel, La Mesa, Vado, Berino, Anthony, La Union and Anapra. The University community at New Mexico State in University Park, has 7,350 students, 3,000 of whom are resident students. The University operates its own water system. The only population center of any appreciable size outside of the Rio Grande Valley is Organ, which lies in San Augustin Pass of the Organ Mountains (sometimes called the San Augustin Mountains in that area).

All of the population centers mentioned above are dependent upon ground-water supply for domestic and industrial purposes.

While the area under review in this report is not one of heavily concentrated industry, there is a pumpage of ground water for a variety of commercial uses, such as several canneries for the processing of locally grown produce, a newly constructed completely automated egg production plant near Chamberino, the Apollo Test Facility of NASA in the Jornada del Muerto, and the Hanes Corporation knitting mill south of Las Cruces.

Finally, there are sporadic mining endeavors in the region. Should certain mineral prices improve at any time this mining activity could expand rapidly.

Although the industrial growth of the area has not been large, the potential for growth appears to be very bright as the population pressures of the nation become more intense. The water resources, particularly those of the Rio Grande Valley, are adequate to support many kinds of industry. With sufficient water, an extremely favorable climate, and an inviting labor market, the region is destined to continue to be one of the major growth areas of New Mexico and the Southwest.

Climate1/

At present two general kinds of climate occur in the study area (fig. 1). The climate is arid (Thornthwaite, 1941) in basin areas along both sides of the Rio Grande Valley, in the valley itself, and in the closed basin north of Highway 70. The climates of the highest mountains, the Organs and San Andres, are considered to be semiarid. The Dona Ana and Robledo Mountains are ranges of lower elevation and may be arid in part.

Precipitation

Precipitation patterns in the study area are controlled mainly by the inland location and by the north-south orientation of the mountain ranges. In summer, moist air from the Gulf of Mexico dominates the region. Surface heating and lifting of the moist Gulf air as it moves upslope causes thundershowers that are usually short but commonly intense. In the winter, general eastward circulation of moist air from the Pacific Ocean is dominant. Nearly all of the precipitation falls in the form of rain. Some light snow falls on the average of two years out of three, but it usually melts as soon as it accumulates on the ground. Prolonged rains are not common.

Precipitation in the valley at University Park is slightly over 8 inches annually. These values are similar to those of Fort Fillmore, located just south of University Park, and Fort Selden to the north, as shown in a tabulation below. In the closed basin area north of Highway 70 in the Southern Jornada del Muerto, precipitation is nearly 9 inches, according to Jornada Experimental Range records. More than half of the moisture normally falls during July, August and September. The yearly precipitation varies widely. The highest recorded annual precipitation at University Park was 19.60 inches in 1941, and the lowest was 3.62 inches in 1964. A 6.49-inch rain that fell in a 24-hour period on August 29-30, 1935, was one of the heaviest 24-hour rainfalls recorded in New Mexico.

Precipitation increases markedly towards the Organ Mountains which are the highest mountains in the area. There is no official weather station there, but unofficial records were obtained from Boyd's Ranch at an elevation of 6,200 feet (personal communication, R.E. Boyd) in the Organ Mountains. Precipitation over the 10-year period from 1948 to 1957 for Boyd's Ranch and University Park are summarized in a table below. Precipitation in the mountains is nearly double that in

1/ Summarized from a statement on the climate of the Las Cruces area prepared by Leland H. Gile, Soil Scientist, Soil Conservation Service.

the valley. Maximum precipitation occurs in the summer in both the mountains and the valley. Both stations show a slight secondary maximum in the winter.

Temperature

Summer temperatures in the desert, as shown in the table below, are warm. Daytime readings reach 90° F or higher during an average of 101 days a year. Winters are mild. The average daily minimum in January (the coolest month) is 25° F; the average daily maximum is 57°F. The lowest recorded temperature is -10°F, on January 11, 1962. The average annual temperature at University Park is 60°F, and the daily temperature range generally exceeds 30°F. The desert areas normally experience more than 80 percent of the possible sunshine.

Wind

Dust storms are most common during the spring months. Winds are highest during March and April, when they average 7.3 to 7.6 m.p.h. respectively, as compared to a yearly average of 5.9 m.p.h.

Hourly wind speeds during the dusty season show far greater contrast than the monthly averages. Windiest periods occur in the afternoons. In March, for example, winds at the El Paso Airport Station at 2:00 p.m. were 25 m.p.h. or greater for 15 percent of the time, as compared to only one percent for August and September at the same time of day. High winds and the dry spring season combine to cause an abundance of blowing dust. Wind direction is variable during the year, but in the spring it is dominantly from the west.

Humidity and Evaporation

Humidities in the desert are low. At University Park, the average is somewhat less than 50 percent for the year and ranges from about 60 percent in the early morning to less than 30 percent during warmer hours of spring and early summer. Evaporation from a free-water surface, as recorded in an evaporation pan, averages about 97 inches a year, which is more than ten times the average precipitation at University Park. Evaporation is greatest during late spring and summer. In the mountains, humidity is undoubtedly somewhat higher and evaporation lower than in the desert.

The following tables in this discussion were compiled from U.S. Weather Bureau Climatological Summaries (1932, 1965, 1962-1967) and from Hardy, Overpeck and Wilson (1939).

Average Monthly and Annual Precipitation (in inches)
at Several Stations in the Project Area

Station, Years, and Elevation	Jan.	Feb.	Mar.	Apr.	May	June	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Ann.
Ft. Fillmore (1852-1860) 3,880	.07	.49	.17	.11	.16	.45	1.80	1.60	1.48	.54	.71	.10	7.68
Ft. Selden (1866-1876) 3,980	.30	.22	.18	.13	.18	.59	1.99	1.91	1.32	.54	.25	.54	8.17
University Park (1892-1966) 3,881	.36	.41	.36	.21	.30	.59	1.47	1.70	1.2	.71	.44	.49	8.26
Jornada Exp. Range (1914-1966) 4,265	.46	.37	.33	.20	.38	.49	1.75	1.68	1.45	.91	.40	.57	8.94

Comparison of Precipitation (in inches)
at University Park and Boyd's Ranch

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
						University Park							
1948	.18	1.43	.16	.07	.04	.86	.07	.46	.39	.37	0	1.13	5.16
1949	1.85	.46	.07	.06	.79	.15	1.14	.73	2.37	.88	T	.51	9.01
1950	.11	.48	T	T	.06	.25	2.41	.51	1.15	.38	0	0	5.34
1951	.31	.38	.16	.42	.02	0	1.47	.96	0	.74	.08	.51	5.05
1952	T	.72	.71	.56	.16	1.07	1.11	1.22	.37	0	.19	.12	6.23
1953	0	.68	.41	.03	T	.28	1.31	.33	T	.57	T	.20	3.81
1954	.07	.30	.10	0	.82	.26	.72	1.34	.96	1.25	0	T	5.82
1955	.66	0	.39	0	.15	.08	3.17	.59	.01	2.10	.11	T	7.26
1956	.18	1.04	0	.02	T	.52	.86	1.35	.09	.28	T	.44	4.78
1957	.32	1.48	.53	.02	.34	T	.81	2.66	.50	1.82	.85	T	9.33
Av.	.37	.70	.25	.12	.24	.35	1.31	1.02	.58	.84	.12	.29	6.18
						Boyd's Ranch							
1948	2.50	.85	0	.32	1.01	1.85	.90	2.18	.88	.30	0	0	10.79
1949	1.50	1.49	0	.32	1.00	.30	3.76	.94	1.68	1.62	0	1.20	13.81
1950	.35	1.50	0	0	.11	0	8.43	.85	1.29	.49	0	0	13.02
1951	.75	.55	.43	1.04	0	0	.77	1.65	.30	1.05	.74	.43	7.71
1952	.34	1.12	.90	.67	1.73	1.67	2.07	2.88	.38	0	.59	.60	12.95
1953	0	1.31	.16	.65	.04	.58	3.63	.61	.30	.90	0	.56	8.74
1954	.29	0	.08	0	.60	.32	2.95	1.64	2.89	1.90	0	0	10.67
1955	1.45	0	1.28	0	.06	.22	4.67	1.67	0	5.76	.20	0	15.31
1956	.58	.12	0	0	.03	.73	2.43	2.67	.38	.08	0	.60	7.62
1957	.44	1.28	.80	.35	.31	0	3.29	2.02	.19	4.66	.95	0	14.29
Av.	.82	.82	.37	.34	.49	.57	3.29	1.71	.83	1.68	.25	.34	11.49

Daily Temperature Data (degrees F) at University Park, 1892-1960
and Jornada Experimental Range, 1914-1960

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Ann.
University Park													
Average	41.5	45.7	51.6	59.1	67.1	76.5	79.4	77.6	71.0	61.2	48.9	41.6	60.1
Av. daily min.	25.5	29.1	34.4	41.6	49.2	59.0	65.1	63.6	56.2	44.2	31.2	26.1	43.8
Lowest	-8	2	12	20	27	36	42	44	30	22	5	1	-8
Av. daily max.	57.4	62.2	68.7	76.6	85.0	93.9	93.6	91.6	86.8	77.5	65.5	57.1	76.3
Highest	78	86	90	94	103	107	109	103	102	93	83	78	109
Jornada Experimental Range													
Average	39.1	44.1	49.4	57.5	65.7	75.6	79.0	77.4	71.1	59.9	46.4	39.1	58.7
Av. daily min.	21.7	26.1	31.0	38.8	46.5	56.5	63.5	61.8	54.3	42.0	27.9	22.2	41.0
Lowest	-20	3	5	15	24	31	45	44	30	20	0	-4	-20
Av. daily max.	56.1	62.0	68.0	76.1	84.9	94.8	94.5	92.8	87.9	77.6	64.9	56.1	76.3
Highest	79	85	88	94	104	109	110	105	102	94	88	74	110

Review of Previous Investigations

C. S. Slichter (1905) conducted the first ground-water investigation in the region. Of particular interest to the present study is the fact that he determined the thickness of alluvium overlying bedrock in the El Paso narrows to be about 86 feet. In addition, his report contains geologic and hydrologic data from a number of auger hole tests in the vicinity of Mesilla Park and pumping tests of 12 irrigation wells in the Las Cruces and Berino areas.

W. T. Lee (1907) presented data on wells and discussed the quantity, source and discharge of ground water in the Mesilla Valley.

In 1935, K. C. Dunham published a report on the geology of the Organ Mountains and the general geology of Dona Ana County. He recognized that the bulk of the basin fill was correlative with the Santa Fe Formation of northern and central New Mexico.

C. V. Theis (1936) made a reconnaissance survey of the area surrounding Las Cruces for municipal water supplies.

In 1938, Kirk Bryan discussed the general hydrogeology of the Rio Grande Depression in Colorado, New Mexico and West Texas. He devoted considerable attention to hydrogeologic description of types of intermontane basins. Bryan emphasized the following points:

1. Most of the sediments in the Jornada and La Mesa Bolsons are part of the Santa Fe Formation.

2. The Santa Fe contains sediments laid down in three environments of deposition and in two types of basins. Closed basins are characterized by peripheral alluvial-fan deposits grading from bordering mountains toward central basin floors where fine-grained lake and playa deposits occur. Open-ended basins are characterized by coarse axial stream (fluvial) deposits flanked by, and intertonguing with, alluvial-fan deposits derived from bordering mountain uplifts.

3. An ancestral upper Rio Grande emptied into the Mesilla Bolson prior to development of the present through-flowing river system.

A. N. Sayre and Penn Livingston (1945) analyzed the geology and ground-water resources of the El Paso area. Included in the report is a measured section of the Santa Fe sediments near Anapra, New Mexico.

C. S. Conover (1954) conducted a thorough investigation of the ground-water conditions in the Rincon and Mesilla Valleys and adjacent areas and presented a map showing water table contours and depth to water. The following is a brief summary of some of his more-important conclusions:

1. Ground water flows from La Mesa toward the valley rather than following a possible former course of the Rio Grande toward Mexico.

2. The ground water level rises during the irrigation season to a high level in late August and declines during the nonirrigation season to its lowest level in February or March. The water table slopes down the valley at an average rate of 4.5 feet to the mile, roughly paralleling that of the valley floor.

3. Discharge of ground water in the valley is essentially by seepage to the drains and parts of the river and by transpiration by plants.

4. As water pumped from wells in the Mesilla Valley is not an additional or new supply, but rather water that is normally intercepted by the drains of the valley, continuing records should be kept of the amount of water pumped, of water-level measurements, and of the location and performance of the irrigation wells.

Frank Kottlowski (1953, 1958, 1960) reported on the general geology and geomorphology of the El Paso-Las Cruces area. He formally extended Santa Fe Group terminology into southern New Mexico.

Personnel of the United States Geological Survey (Leggat, Lowry, and Hood, 1962), in cooperation with the City of El Paso, discussed the ground water conditions of the Mesilla Valley, Texas. The report contains descriptions of the shallow, medium and deep aquifers, recharge and discharge, aquifer tests and calculations regarding the quantity of fresh water in storage.

E. R. Leggat (1962) published a study regarding the development of ground water in the El Paso District from 1955 to 1960.

R. V. Ruhe (1962, 1964, 1967) defined the geomorphic features of the Las Cruces area, and demonstrated that the Mesilla Valley is a relatively young geologic feature that has been cut since middle Pleistocene time.

Gene C. Doty (1962) of the United States Geological Survey evaluated the water-supply development of the Apollo Test Facility of NASA. The report includes data on lithology, transmissibility data and water-quality analyses.

John W. Hawley (1965) wrote a paper on the geomorphic surfaces along the Rio Grande Valley from El Paso to Caballo Reservoir. The origin of the younger basin- and valley-fill deposits is discussed, and the geomorphic evolution of the valley since mid-Pleistocene time is traced.

John W. Hawley and Leland H. Gile (1966) of the Soil Conservation Service, published a guidebook on the landscape evolution and soil genesis in the Rio Grande region, southern New Mexico.

W. S. Strain (1966) postulated that a large lake (Lake Cabeza de Vaca) or series of lakes existed in the southern New Mexico, west Texas, northern Chihuahua region in early Pleistocene time. He further established the age of Santa Fe Group sediments exposed in the walls of the El Paso Valley as being early to middle Pleistocene in age.

Hawley and others (Hawley and Kottlowski; and Hawley, Kottlowski, Strain, Seager, King and Le Mone; 1969) have recently presented two papers on the Late Cenozoic Geology of the south-central New Mexico border region. In these reports, the Santa Fe Group is more precisely defined in terms of position, lithology and age, and the Quaternary geologic evolution of the region is discussed. The Santa Fe Group comprises the fill of the present intermontane basin system. It post-dates a major mid-Tertiary interval of volcanic activity and predates initial entrenchment of the present Rio Grande Valley in middle Pleistocene time. The Kirk Bryan (1938) model of Late Cenozoic basin filling is generally substantiated. Mention is made of an early to mid-Pleistocene "fluvial" sand and gravel facies of the Upper Santa Fe Group, which forms the uppermost layer of sediments below the floors of the Mesilla and Jornada basins. The concept of an ancestral braided distributary stream system, with a shifting locus of deposition, and radiating out from a more confined channel system located to the north of Hatch is suggested as a possibility to explain the widespread occurrence of the sand and gravel unit. Such a system could have developed where an ancestral river emptied into the closed basin region of southwestern New Mexico, western Trans-Pecos, Texas, and northern Chihuahua. Subsequently, the upper Rio Grande became integrated with an ancestral lower Rio Grande and through drainage to the Gulf of Mexico developed. Since mid-Pleistocene time, alternating episodes of entrenchment, stability, and minor aggradation of the river valley floor have taken place due to shifts of climate and base level on a regional and local scale. Episodes of major valley entrenchment probably correlate with Pleistocene glacial-pluvial substages when river discharge was greater, and local sediment production less, than during interpluvial substages.

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While the assistance of all persons named above, and many others too numerous to mention, is appreciated, it is clear that the authors assume total responsibility for errors of fact or judgment.

System of Numbering Wells in New Mexico

All wells that are mentioned in this report are identified by the location-number system used by the United States Geological Survey and the New Mexico State Engineer for numbering water wells in New Mexico. The number is a description of the geographic location of the well, based upon the common United States Land Survey subdivision of the nearest 10-acre tract, when the well can be located that accurately. The location number consists of a series of digits corresponding to the township, range, section and tract within a section, in that order, as illustrated in figure 2. If a given well has not been located closely enough to be placed within a particular section or tract, a zero is used for that part of the location number.

Ordinarily the range number portion of the location number stands alone if it is east, and a W is added to the number if the range is west of the principal meridian. Since the area of this report spans the principal meridian, we have, for convenience in reading, added the E or the W to every range location.

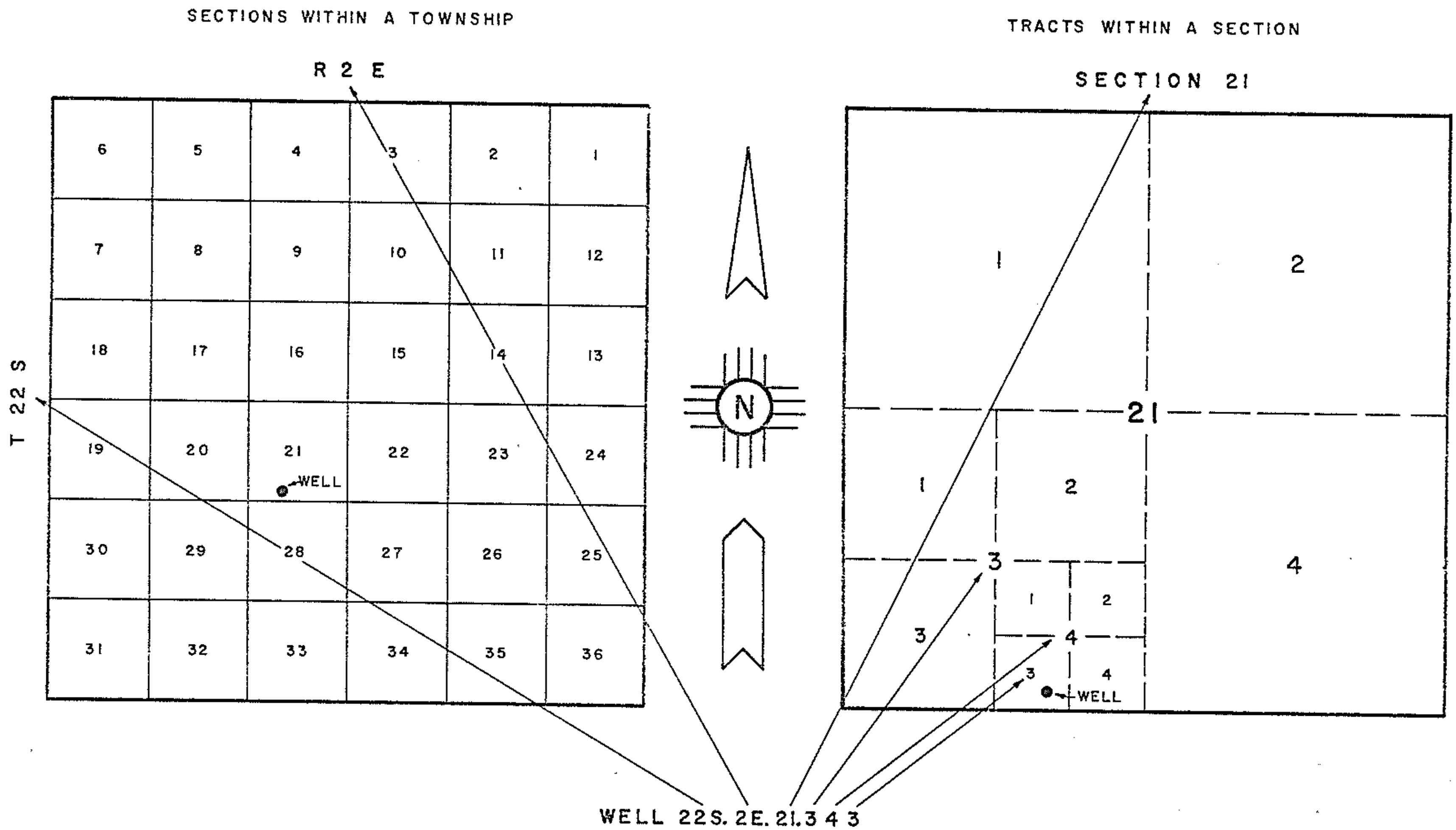

FIGURE 2. SYSTEM OF WELL NUMBERING

GEOLOGY AND ITS RELATIONSHIP TO THE HYDROLOGIC SYSTEM

GEOMORPHIC FEATURES

Introduction

The area under discussion (figures 1 and 3, plate 1) is located in the Mexican Highland section of the Basin and Range physiographic province (Fenneman, 1931; Thornbury, 1965). It includes a number of mountain uplifts, parts of four major intermontane basins, and the valley of the Rio Grande. The area is bounded on the west by the Mimbres River Basin, the Goodsight Mountains, and the Hillsboro-Animas Uplift. The San Andres-Organ-Franklin Mountain chain forms the eastern boundary. The intermontane basins discussed extend south into northern Chihuahua and north into central New Mexico.

The geomorphology of the region has been discussed in detail by Ruhe (1962, 1964, 1967), Kottlowski (1958), Kelley and Silver (1952), and Hawley (1965; Hawley and Gile, 1966; Hawley and Kottlowski, 1969). The succeeding discussion will emphasize features considered to be of hydrogeologic significance.

Mountains

With some major exceptions, the mountains in the Rio Grande region of southern New Mexico consist of fault block uplifts with a general north-south trend (Kottlowski, 1958). Other mountain types include broad domal uplifts and remnants of igneous intrusive bodies. Only the low-lying West Potrillo Mountains (maximum elevation - 5,473'), located in southwest Dona Ana County, reflect the primary form of the basaltic volcanic cones and flows that underlie that particular upland area.

The highest peak in the region, Organ Needle (elevation 9,012') is part of the jagged crest of a mass of Tertiary intrusive rocks (monzonites) that comprises the central Organ Mountains. The San Andres Range and the Franklin and southern Organ Mountains generally have the form of strongly tilted fault blocks, which are bounded on the west by dip slopes on Paleozoic to Tertiary beds (dominantly marine carbonate rocks), and on the east by escarpments that cut across Paleozoic strata into Precambrian rocks. Alluvial-fan and pediment gravels on the upper piedmont slopes of the western Hueco and Tularosa Basins are cut by faults that are closely aligned with the east-facing escarpments.

The Caballo Mountains, which extend into the north-central part of the area of investigation, are very similar in form to the San Andres-Franklin Range, with the exception that they consist of several east-tilted fault blocks.

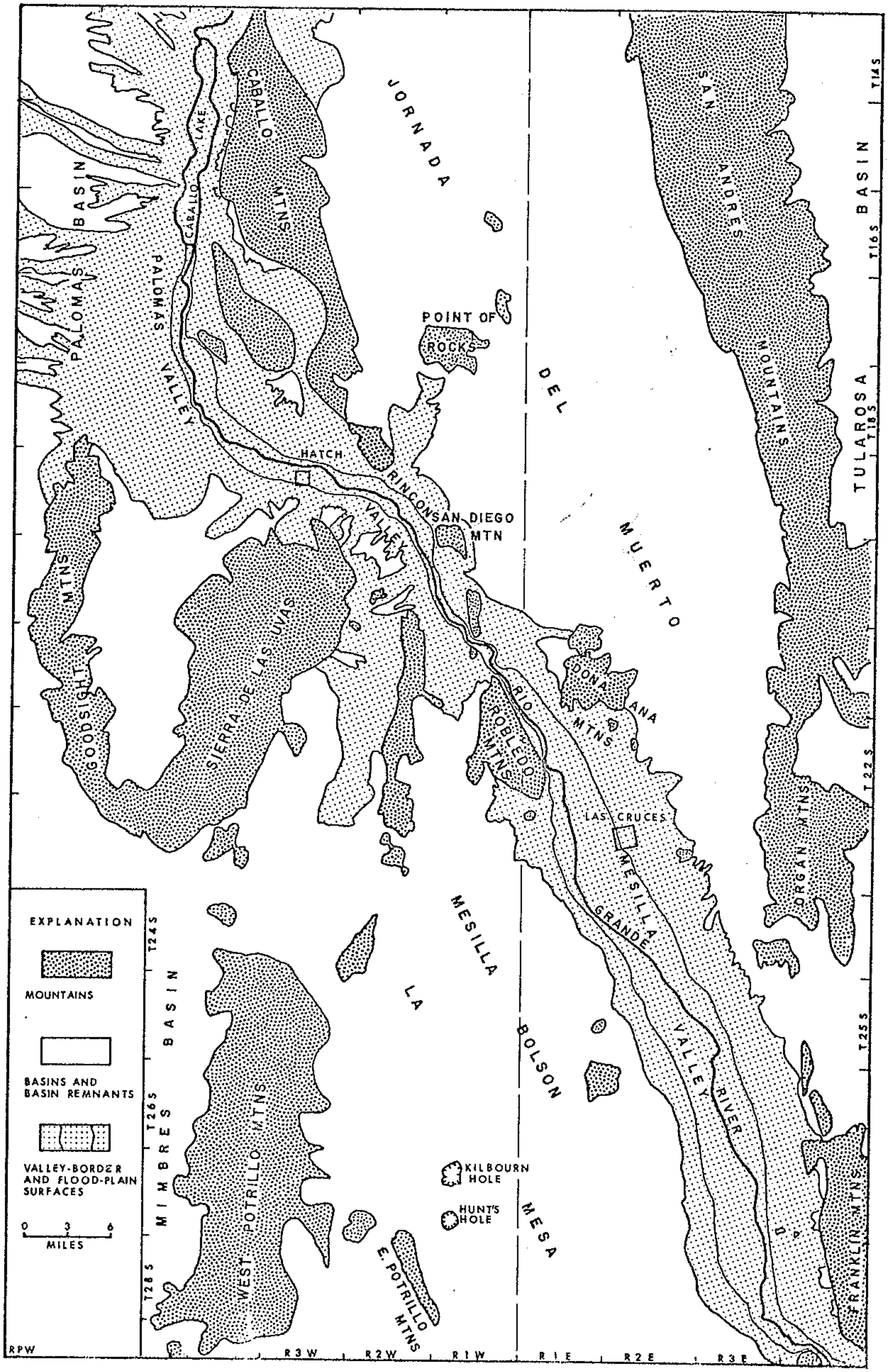

FIGURE 3. PHYSIOGRAPHIC MAP OF THE REPORT AREA

The Robledo Mountains also consist of a tilted fault-block uplift, but in this case, the mountains have the form of a wedge-shaped horst that is bounded on the east and west by faults and is tilted gently to the south. The peaks and high ridges of the Robledo, Caballo, San Andres, and Franklin Mountains are in most cases underlain by thick-bedded carbonate rocks of Paleozoic age.

The two other major upland areas, the Dona Ana Mountains and the Sierra de Las Uvas, are domal uplifts composed mainly of Tertiary igneous rocks. Monzonite intrusive rocks form the high peaks of the Dona Ana Mountains, and thick basaltic andesite flows and rhyolitic welded tuffs hold up high mesas, cuestas, and buttes in the Sierra de Las Uvas. The west flanks of the Uvas uplift make up the east limb of a large north-plunging syncline. The Tertiary volcanics cropping out in the nose and west limb of this syncline form the arcuate Goodsight Mountains.

A number of small, isolated, upland areas occur throughout the region. These are often aligned along definite trends, and they appear to be associated with buried extensions of major positive structures. Small fault-block uplifts include the Rincon Hills, Tonuco-Selden Hills Uplift, Tortugas Mountain, and Bishop's Cap. Small peaks formed by erosional remnants of Tertiary igneous intrusive bodies include Goat Mountain, Picacho Peak, Vado Hill, Mount Riley, and Cerro de Muleros. The Aden, Sleeping Lady, and Rough and Ready Hills consist of a belt of small peaks, ridges, buttes, and elongated mesas underlain by Tertiary volcanic rocks. The hills appear to be remnants of a former cover of andesites, basalts, rhyolite tuffs, and associated sedimentary rocks that had been disrupted by a combination of erosion, faulting, and warping. Point of Rocks between the southern Caballo and San Andres Ranges is another group of hills of this type.

Basins

The major intermontane basins in the area of investigation (figure 3) represent structurally depressed units that have been displaced downward with respect to the mountain uplifts. Relative displacement of mountains and basins has been achieved by block faulting, warping, and a combination of these two processes.

The basins include the southeastern Mimbres Basin and Mesilla Bolson (Hill, 1900), which are separated by the Rough and Ready-Sleeping Lady-Aden Hills and the west Potrillo Mountains; and the southern Jornada del Muerto and Palomas Basins, which are separated by the Caballo Mountains and the Sierra de Las Uvas. The Goodsight Mountains and the Sierra de Las Uvas separate the Mimbres Basin from the southern Palomas Basin. There is no distinct, positive surface boundary between the Mesilla Bolson and the Jornada del Muerto but, for the purposes of this report, the two basins are separated along a line extending eastward from the northern Robledo Mountains to the central Dona Ana Mountains and then to the central Organ Mountains via Tortugas Mountain.

Only a portion of each of the four basins is included in the area of study. Each basin is highly elongated in a north-south direction and can be subdivided into two or more distinct sub-basins in terms of surface-water hydrology. Each basin has two basic landscape components: basin floor and piedmont slope. The basin floors generally have a slight gradient to the south (less than 0.5 percent) and are nearly level transversely; they range in width from less than 1 mile to more than 20 miles; and they are locally marked by shallow, closed depressions of either linear or circular shape. The piedmont slopes, which gradually rise from the basin floors to the abrupt break in slope at the mountain fronts (gradients from less than 1 percent to about 10 percent) include two basic types of surfaces: constructional, alluvial-fan, and coalescent fan surfaces; and erosional surfaces, cut both on hard rocks adjacent to the mountain fronts (pediments) and on older basin fill deposits.

The range in age of the basin surfaces is considerable. Large areas of the basin floors of the Mesilla Bolson and the southern Jornada del Muerto are remnants of a middle Pleistocene basin landscape that formed prior to initial cutting of the Rio Grande Valley. A few remnants of this landscape are also preserved in the southern Palomas basin, which is now largely occupied by the valleys of the Rio Grande and tributary arroyos. In early to middle Pleistocene times, these basin floors were the sites of aggrading channels of the ancestral Rio Grande, which emptied into lake basins in what is now northern Chihuahua and westernmost Trans-Pecos Texas. Subsequent to valley entrenchment, only the basin-floor areas adjacent to piedmont slopes and the scattered closed depressions that are subject to periodic flooding have been sites of active sedimentation.

In contrast to the basin floors, large areas of the piedmont slopes have been the sites of repeated cycles of erosion and deposition in middle and late Quaternary time (Gile and Hawley, 1966). Remnants of the piedmont slope component of the ancient basin landscape are preserved only in dissected areas near the mountain fronts and adjacent to the deeply entrenched valleys of the Rio Grande and tributary arroyos.

Formal geomorphic surface names have been given to parts of the basin landscape that pre-date initial cutting of the present valley system. The basin floors underlain by sand and rounded gravel deposits of mixed composition and mid-Pleistocene age have been designated the La Mesa surface (Ruhe, 1964, 1967; Hawley and Kottlowski, 1969). A piedmont-slope surface of roughly equivalent age has been named the Dona Ana surface (Ruhe, 1964, 1967), and a slightly younger piedmont-slope and basin-floor surface has been designated the Jornada surface (Ruhe, 1964, 1967; Hawley and Gile, 1966; Hawley and Kottlowski, 1969). In the Rincon to Caballo Reservoir area, the names "Jornada", "Palomas", and "Rincon", have been applied to a complex of basin surfaces ranging from early (?) to middle Pleistocene in age (Kelley and Silver, 1952; Kottlowski, 1953; Hawley, 1965). Late Quaternary piedmont-slope and basin-floor surfaces include the late Pleistocene Jornada II and Petts Tank surfaces and the Holocene Organ surface (Hawley and Gile, 1966; Ruhe, 1967; Gile and Hawley, 1968).

Valley of the Rio Grande

The evolution of the basically erosional Rio Grande Valley system in southern New Mexico has been discussed in considerable detail by Kottlowski (1958), Ruhe (1962, 1964, 1967), Hawley (1965), Metcalf (1967), and Hawley and Kottlowski (1969).

The morphology of the Rio Grande Valley, which crosses the area from northwest to southeast, reflects (1) the nature of the materials in which the valley is cut, (2) the control exerted by deep-seated structural movements, and (3) the cyclic nature of valley incision since integration of the upper and lower Rio Grande systems and development of through drainage to the Gulf of Mexico in mid-Pleistocene time.

The present flood-plain surface ranges from about 250 to 500 feet below the ancient basin surfaces. Evidence of former cycles of valley entrenchment and aggradation is preserved in the form of rock-defended river terraces and valley-slope remnants of geomorphic surfaces that were graded to former, higher river base levels. These relict surfaces extend into the drainage basins of tributary arroyos. Levels of ancestral flood-plain stability can be reconstructed at elevations of about 130 feet, 70 feet, and less than 30 feet above the present valley floor. The two higher levels, listed in order of decreasing age and elevation, correspond with the Tortugas and Picacho valley-slope surfaces of mid-to-late Pleistocene age (Dunham, 1935; Kottlowski, 1953, 1960; Ruhe, 1962, 1964, 1967; Hawley, 1965; Hawley and Kottlowski, 1969). The Leasburg and Fillmore (Fort Selden Group) surfaces comprise latest Pleistocene and Holocene terraces and valley slopes associated with local base levels no more than 30 feet above the present flood-plain surface (Ruhe, 1962, 1967; Hawley, 1965; Hawley and Kottlowski, 1969). Maximum entrenchment of the ancestral Rio Grande occurred in latest Pleistocene time (probably between 11,000 and 22,000 years ago). This stage of valley cutting is represented by an erosion surface, cut in basin fill and older rocks, about 80 feet below the present valley floor (Hawley, 1965; Hawley and Kottlowski, 1969; Davie and Spiegel, 1967).

Local evidence of fault movements and downwarping along the Rio Grande valley margins in Quaternary time indicates that the general valley position is structurally controlled and that some of the relief between the basin surfaces and valley floors is a product of tectonic movements (Ruhe, 1964; Hawley and Kottlowski, 1969). However, the major valley border surfaces in the study area can be correlated with similar stepped sequences of geomorphic surfaces up and down the Rio Grande Valley (Ruhe, 1964; Hawley, 1965). It thus appears that the geomorphic development of the valley system since mid-Pleistocene time has been basically controlled by the hydrology of the Upper Rio Grande system. Marked changes in river and arroyo discharge, erosion and sediment production, and character of vegetative cover have periodically occurred that are related to the waxing and waning of Quaternary glacial-pluvial stages (Hawley and Gile, 1966; Metcalf, 1967; Schumm, 1965).

The Rio Grande erosional valley is wide where it is cut into the poorly-consolidated fills of the intermontane basins and narrow where it crosses the rock cores of mountain uplifts. The valley has been subdivided into five major segments in the Caballo-El Paso reach (Hawley, 1965). The northern segment, the Palomas Valley, comprises the river valley and the valleys of major tributary arroyos (such as Placitas, Thurman, Crow, Green, and Berenda) from Caballo Reservoir to the town of Hatch. Rincon Valley designates the area between Hatch and Selden Canyon and includes the valley of Rincon Arroyo and several other arroyo valleys heading in the Sierra de Las Uvas. Selden Canyon extends from the valley constriction southwest of San Diego Mountain to the Radium Springs-Fort Selden area. Mesilla Valley, the major valley area, extends about 50 miles from Fort Selden to northwest El Paso. El Paso Canyon, the final valley constriction, is located in the southeastern corner of the studied area at the Texas, New Mexico, and Chihuahua boundary juncture.

The present flood-plain ranges in width from about one-quarter of a mile in narrower canyon areas to 5 miles in parts of the Mesilla Valley. The gradient of the flood-plain is about 4.5 feet per mile in the Caballo Dam-El Paso reach. The gradient of the present, straightened river channel approaches the flood-plain slope, but the sinuous channel characteristic of the reach prior to the 1860's had a gradient as low as one and one-half feet per mile (U. S. Reclamation Service, 1914). Maximum river discharge since Elephant Butte Dam closed in 1915, has been generally less than 8,000 cubic feet per second. However, in 1904 and 1905 peak discharges in the San Marcial-El Paso reach attained magnitudes ranging from about 24,000 cubic feet per second (El Paso, 6/12/1905) to 50,000 cubic feet per second (San Marcial, 10/11/1904; Surface Water Branch, USGS, 1961, 1965).

Soils

Soils form an integral part of the landscape discussed above. The soil surveys of the early part of the century (Nelson and Holmes, 1914; Sweet and Poulson, 1930) have been updated during the past two decades by relatively detailed surveys of the Soil Conservation Service. Soil maps covering large parts of Dona Ana County and a new soil associations map for New Mexico (Maker and Dregne, 1968) are available for inspection at the Las Cruces and University Park offices of the SCS and at the Agricultural Experiment Station, NMSU. Published soil maps and other significant information on soil-geomorphic relationships are included in reports by Gile and others (Gile, 1961, 1966, 1967; Gile, Peterson and Grossman, 1965, 1966; Gile and Grossman, 1968; Gile and Hawley, 1966, 1968) and by Buffington and Herbel (1963). Publication of additional soil maps is scheduled for the near future.

The two great soil resource areas include (1) the Rio Grande flood-plain, and the Holocene fan surfaces that form the lower parts of valley slopes, and (2) the extensive, undissected plains in basins adjacent to the river valley. The former area is under intensive cultivation, while the latter area is primarily utilized as rangeland.

Soils of the flood-plain and adjacent Holocene slopes are associated with very young, constructional geomorphic surfaces. The soils show little profile development. They primarily reflect the composition of recently deposited alluvium and the addition of small amounts of organic matter, and calcium and sodium salts. Dominant great groups in these areas are Torrifluvents, Torripsamments and Torriorthents in the new soil survey classification system (Soil Survey Staff, 1960, 1967).

Soils of the basin surfaces reflect the great age range of geomorphic surfaces and variations in geologic parent materials, as well as orographic and topographic effects. Soils associated with Holocene basin surfaces are weakly developed compared to soils of older basin surfaces. Torrifluvents, Torripsamments, Torriorthents, weak Calciorthids and weak Haplargids are the dominant great groups. Soils associated with Pleistocene basin surfaces have much stronger horizons of clay or carbonate accumulation, or both, with the strongest horizons of accumulation generally being associated with soils of the older Pleistocene landscapes. Haplargids, Paleargids, Calciorthids and Paleorthids are dominant great groups. The Paleorthids and Paleargids with indurated horizons of carbonate accumulation within 40 inches of the ground surface are particularly important from a hydrologic standpoint. Shallow horizons plugged with carbonate inhibit deep movement of soil moisture, thereby retaining the limited amounts of water for plant use (Bailey, 1967) and preventing downward percolation into the thick interzone of unsaturated basin fill.

ROCKS AND UNCONSOLIDATED DEPOSITS: STRATIGRAPHY, LITHOLOGY, AND WATER-BEARING CHARACTERISTICS

Consolidated Rocks

The primary hydrologic role played by consolidated rocks in the area of study is that of a barrier to the movement of water. The consolidated rocks also serve as the source of many of the dissolved solids found in the ground and surface waters of the area. The geohydrologic properties of various bedrock units that occur in the area have been summarized by Dinwiddie (1967), and Titus (1967). On the geologic map (fig. 4) the consolidated rocks are subdivided into four groups on the basis of both geologic and water bearing characteristics: (1) Precambrian and Tertiary metamorphic and igneous intrusive rocks; (2) Paleozoic, Mesozoic, and early Tertiary sedimentary rocks, (3) Tertiary volcanics and associated sedimentary rocks, and

R — Valley-fill alluvium; Late Quaternary; clay to gravel, less than 80 feet thick.

B — Olivine basalt flows and volcanic cones; Quaternary, generally post date the Santa Fe Group.

BF — Basin-fill surface. Santa Fe Group, with discontinuous overlay (generally less than 25 feet thick) of younger alluvial, eolian and minor lacustrine deposits.

SF — Santa Fe Group basin fill; Miocene to Middle-Pleistocene; clay to gravel, locally as much as 4,000 feet thick. Also discontinuous overlay (generally less than 100 feet thick) younger valley slope deposits.

V — Volcanic rocks, and associated clastic sedimentary rocks, undifferentiated; Middle Tertiary.

S — Sedimentary rocks, undifferentiated; Paleozoic, Cretaceous and Early Tertiary.

I — Intrusive rocks, undifferentiated, and associated metamorphics; Precambrian and Tertiary.

• • • • • Santa Fe - Gila Group Boundary.

Faults involving significant displacements of Basin Fill.

GEOLOGIC MAP LEGEND

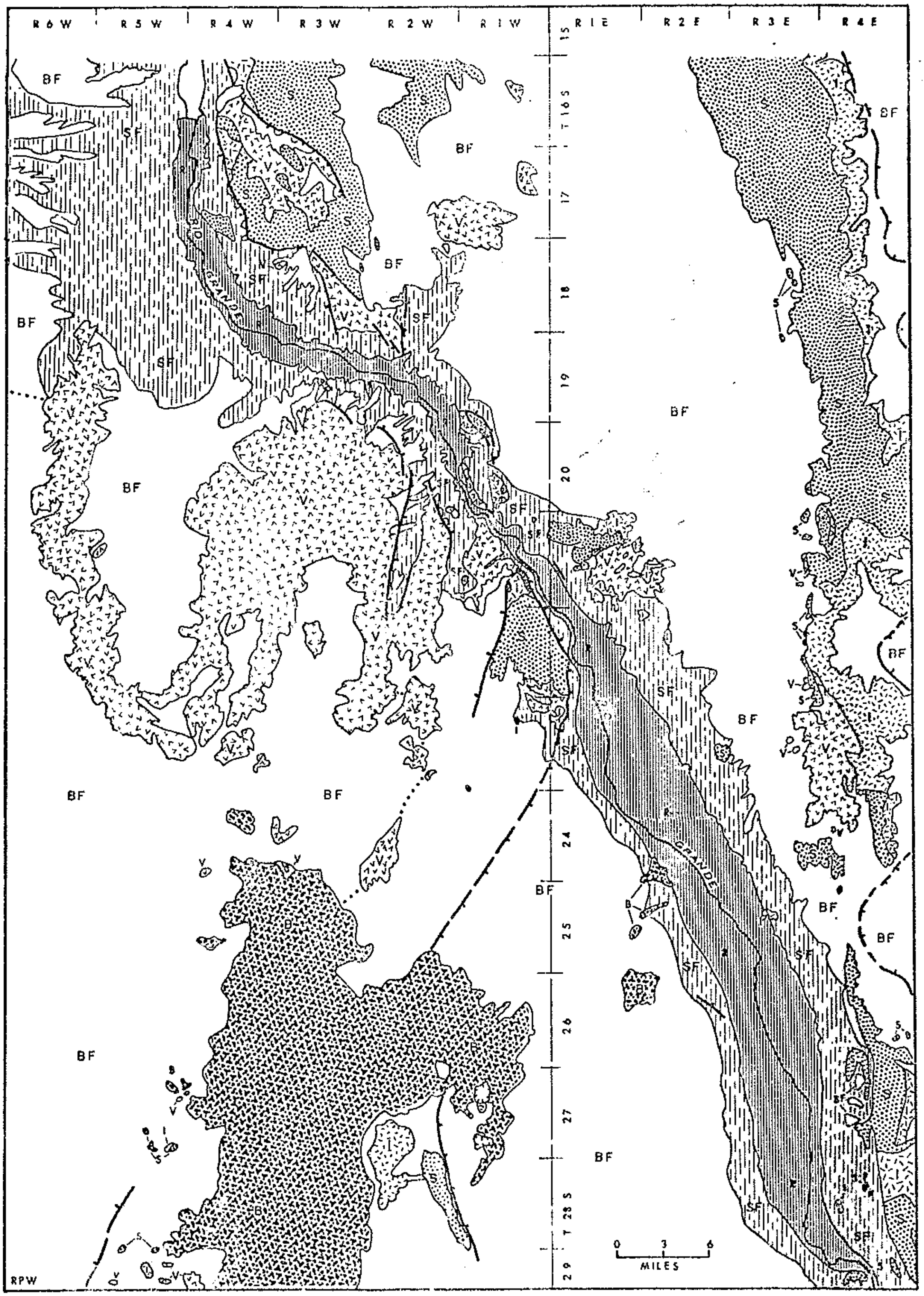

FIGURE 4. GENERALIZED GEOLOGIC MAP OF THE REPORT AREA

(4) late Cenozoic basalts. Groups (1), (2), and (3) comprise the bedrock exposed in the mountain uplifts and buried by fills of variable thickness in the intermontane basins (Dunham, 1935; Kelley and Silver, 1952; Kottlowski, 1953, 1960; Kottlowski et al., 1956; Dane and Bachman, 1962). These rocks will be discussed in the following paragraphs. The late Cenozoic olivine basalts are either interbedded with or cover the basin-fill deposits and will be described in the section dealing with those materials.

Igneous Intrusive and Metamorphic Rocks

Deep-seated igneous intrusive bodies of granitic to porphyritic texture and of Precambrian and Tertiary age make up the cores of the San Andres-Organ-Franklin Mountain chain, and the Dona Ana and Caballo Mountains. Smaller uplifts with igneous intrusive centers include the Tonuco (San Diego Mountain) Uplift, Goat Mountain, Vado Hill, Picacho Peak, Cerro de Muleros and Mount Riley. The Precambrian intrusives are intimately associated with complexes of metamorphic rocks.

All the rocks in the intrusive-metamorphic group are very effective barriers to ground-water movement, and yield only small quantities of water in local weathered or fractured zones. Quality of water derived from intrusive-metamorphic terrains is usually good, but may be exceptionally poor in mineralized areas.

Sedimentary Rocks of Paleozoic to Early Tertiary Age

For the purposes of this report, the sedimentary rocks of Paleozoic, Cretaceous and early Tertiary age are discussed as one hydrogeologic unit. All these rocks are well consolidated and have been locally subjected to tectonic deformation. The rocks of Palezoic age are dominantly limestones and dolomites, with the exception of a basal Cambro-Ordovician quartzite to quartzite conglomerate, a Devonian shale sequence, and intertongueing bodies of gypsum and red-bed sandstone to siltstone in the upper Pennsylvanian to Permian part of the section. Paleozoic rocks make up the bulk of the bedrock in the San Andres, Franklin, Caballo and Robledo Mountains. Relatively complete stratigraphic sections ranging from Cambro-Ordovician to Permian in age are exposed in each of the uplifts. Cretaceous rocks include shales and limestones that crop out in the southern Franklin, Cerro de Muleros, and East Potrillo uplifts, and shales to sandstones exposed along the flanks of the Caballo and San Andres Mountains. The early Tertiary sedimentary rocks consist of conglomerates, sandstones and minor shales which crop out in a few areas along the eastern flanks of the Caballo Mountains and the western flanks of the San Andres and Organ Mountains.

Primary porosity is low in all the rock units. The major effective porosity is along joints, fissures, and faults. Solution cavities in carbonate and gypsiferous rocks appear to be uncommon in this area. Yields from the very few wells penetrating the sedimentary rocks are very low, rarely exceeding a few gallons per minute. Two Apollo Project test wells (Doty 1963, wells D and G; table 1, 20.3E.12.332 and

20.3E.15.442) respectively penetrated about 1150 and 350 feet of rocks below the water table, which are interpreted as Cretaceous and early Tertiary shales, sandstones and conglomerates. Although the wells were regarded as "dry" holes, enough water for stock or domestic purposes might be available and the term "damp holes" (Lehr,1968) would be a more accurate designation. Large water yields have been reported from the Torpedo-Bennett fault zone along the northwest base of the Organ Mountains (Dunham, 1935). Water produced from the sedimentary rock group often has a high content of dissolved solids, particularly in areas of hydrothermal mineralization or where gypsum is present.

Tertiary Volcanic and Sedimentary Rocks

The third major bedrock group comprises Tertiary volcanics and thick sequences of interbedded clastic sedimentary rocks.

These rocks are mainly of Oligocene to Miocene age. They comprise the major bedrock units in the Sierra de las Uvas, Goodsight, Dona Ana and southern Organ Mountains, and the Rincon, Selden, Rough and Ready, Sleeping Lady and Aden Hills.

There is a great range in consolidation of these materials. Rhyolite, andesite-latite, and basaltic andesite flows, and rhyolitic welded tuffs are generally very hard and dense; on the other hand non-welded tuffs of rhyolitic to andesitic composition and the interbedded sedimentary rocks are moderately well to very poorly consolidated. These rocks are generally of very low permeability. Even the poorly consolidated volcanics and associated sediments consist of well-graded mixtures including a wide range of particle sizes (from boulders to clay); thus the primary porosity of these materials is very low. As is the case with the older rocks, effective porosity is provided by fractures. Since the joints, faults and fissures in the bedrock tend to be sites of mineralization, water in zones of intense fracturing often has a high content of dissolved solids and commonly is nonpotable. Two Apollo Project test wells were also drilled into Tertiary volcanics (Doty, 1963, wells C and H; table 1, 21.3E.4.211 and 20.3E.16.233), Well C, which penetrated about 550 feet of rhyolite and interbedded sediments below the water table, produced less than 40 gallons per minute; while well H, which penetrated about 1150 feet of andesitic volcanics, was regarded as a "dry (damp) hole".

Discussion

A very important point that should be considered here is the influence of the various bedrock units exposed in the mountain uplifts on the textural and geochemical characteristics of the basin fills. The latter type of deposits will be discussed in detail in the next section, but it should be noted here that the types of material deposited in the basins, particularly in the piedmont-slope areas, directly reflect the way the different bedrock lithologies behave as they are affected by the various agents of weathering, entrainment, and transport.

For example, monzonite and other granitic textured rocks generally break down into fragments ranging in size from very coarse sand to clay during weathering and transportation to the ultimate site of deposition. Limestones, and calcareous sandstones and siltstones (such as those cropping out in the San Andres, Caballo, Robledo, and Franklin Mountains) tend to break down either into gravel or fine sand to silt-sized particles. The more massive, very hard rocks, such as metaquartzites and some rhyolites (for example the Soledad Rhyolite in the southern Organ Mountains) tend to break down into gravel-sized clasts. The shape and the size of the gravel is in great part controlled by spacing of fractures in the bedrock outcrop. Poorly-consolidated tuffs and tuffaceous sedimentary rocks of middle Tertiary age, older shales and mudstones, and the clayey B horizons of some upland soils have been source materials for much of the fine-grained material in the basin fills. Of particular importance to the geochemistry of ground water, are the prominent gypsite beds occurring in the upper Pennsylvanian and/or Permian section in parts of the San Andres and Franklin Mountains. These rocks have been the source beds for locally thick secondary gypsum deposits in the fills of adjacent basin areas.

Unconsolidated to Moderately Consolidated Deposits

Introduction

This category of geologic materials includes the two major water bearing units in the region: The Santa Fe Group basin fill of Miocene (?) to middle Pleistocene age, and the Rio Grande and tributary arroyo valley fills of Late Quaternary age. The stratigraphy and general composition of these units has been described by Hawley and others (1969). This section of the report will emphasize the hydrogeology of the basin and valley fills at places where semi-quantitative information is available in the form of well data. Table 3 (separate appendix) of this report contains a number of sample and driller's logs, that include specific notations on the stratigraphic and lithologic units penetrated by water wells and oil tests.

Basin Fill - The Santa Fe Group and the Gila Conglomerate

The Santa Fe Group is a rock-stratigraphic unit comprising a complex sequence of unconsolidated to moderately consolidated sedimentary deposits, and some basalts, that partly fill the intermontane basins along and adjacent to the Rio Grande Depression from the San Luis Valley of Colorado to the lower El Paso Valley of Texas and Chihuahua. The lower limit of the Santa Fe Group in the area of investigation is placed above the volcanic and associated sedimentary rocks of middle Tertiary age, which are well exposed in the Rincon Valley-Selden Canyon area. The upper limit of the Group is the surface of the youngest basin-fill deposits pre-dating initial entrenchment of the present Rio Grande Valley system in middle Pleistocene time. The Jornada, La Mesa, Dona Ana, and Palomas geomorphic surfaces and associated soils commonly mark the upper boundary of the Santa Fe Group in southern New Mexico.

Studies of lithologic variations in the basin-fill deposits (both in outcrop and in subsurface), carried out in conjunction with investigations of basin geomorphology and basin-fill stratigraphy, demonstrate that Santa Fe Group deposition occurred in both closed and open intermontane basin environments (Bryan, 1938; Spiegel, 1962; Strain, 1966; Lambert, 1968; Hawley et al., 1969). The former type, the classic bolson environment (Tolman, 1907; Thornbury, 1968), prevailed during early stages of basin filling; while later stages were marked by coalescence of the floors of contiguous basins and development of a regional system of through drainage (the ancestral Rio Grande system of Bryan, 1938; Spiegel, 1962). Locally derived piedmont-slope alluvium, characterized by wide textural variation and including alluvial-fan, coalescent fan, and pediment deposits, was a typical facies in both closed and open basin environments. In closed systems, piedmont-slope alluvium graded into or intertongued with fine-grained, lacustrine and alluvial, basin-floor deposits. In open systems, the basin-floor facies included medium-to coarse-grained fluvial deposits; with fine-grained materials making up a relatively small proportion of the basin-fill sequence.

By arbitrary decision, the boundary with the Santa Fe Group's southwestern New Mexico analog, the Gila Conglomerate, has been placed along the eastern drainage divide of the Mimbres Basin (Dane and Bachman, 1965; Hawley et al., 1969). Therefore, the older fills of the Mimbres-Mason Draw Basin (figures 3 and 4), an area subjected to only cursory study in this investigation, are classified as Gila Conglomerate.

The Santa Fe Group is the major ground-water reservoir in the region. Aquifers in the Santa Fe produce most of the water used in metropolitan and industrial centers, as well as a significant proportion of ground water used to supplement surface irrigation supplies (Conover, 1954; Leggat et al., 1963; Dinwiddie et al., 1966; Dinwiddie, 1967). From the preceding discussion, however, it can be seen that the Group is not a single hydrologic unit. Water-bearing properties of the basin fill and quality of the ground water reflect the variety of depositional environments in both open and closed basin systems. Thus the Santa Fe Group includes a number of aquifers as well as major zones that are relatively impermeable. Obviously, the quantity of water needed for a particular purpose at a certain place determines an individual's concept of what an aquifer is. Highly productive domestic and stock wells are often referred to as "dry hole" when considered as producers of water for irrigation or industrial uses.

The Santa Fe Group in the Palomas Basin

Much of the upper Santa Fe Group fill of the Palomas Basin has been removed during cyclic stages of valley entrenchment by the Rio Grande and its tributaries since middle Pleistocene time. The only extensive remants of the original or slightly-modified basin-fill surface are preserved north of Caballo Dam and in the undissected Uvas-Goodsight Basin (Nutt-Hockett Basin of State Engineer Reports).

Subsurface information (Kelley and Silver, 1952; Davie and Spiegel, 1967) shows that as much as 1,165 feet of Santa Fe sediments were deposited in Palomas Basin in late Cenozoic time. The basin is asymmetric with its axis located in the eastern part of the basin at the foot of the Caballo structural block. Piedmont slopes rising to the Animas-Hillsboro Uplift on the west are long and gentle, while slopes rising to the Caballo Mountains are short and steep. Studies in the Animas creek area (T. 15S., R. 4-6W) northwest of Caballo Dam, by Davie and Spiegel (1967, p. 9) show that the Santa Fe Group is composed of three facies: (1) an alluvial-fan facies composed of gravel to clay derived from bordering uplands on the east and west; (2) "a clay facies, possibly representing the distal...beds of alluvial-fan facies"; and (3) "an axial-river facies (in this report designated the fluvial facies) consisting of well-sorted sand and gravel containing well-rounded quartzite pebbles, probably derived from northern New Mexico and Colorado". Geologic studies in areas to the south (Strain, 1966; Hawley et al., 1969) indicate that the clay facies (which also includes beds of silt and sand) was deposited in large part in playa-and/or perennial-lake basins.

Near Caballo Reservoir the exposed sections of Santa Fe deposits are generally medium to very coarse-grained, reflecting alluvial-fan (extensive) and fluvial (limited) environments of deposition. The clay and fluvial facies occur mainly in subsurface, in the central parts of the basin (Davie and Spiegel, 1967, plate 3).

In the Hatch area, at the south end of the basin, the clay and fluvial facies are well exposed in valley walls. West of Hatch, a 400-foot section of silt, bentonitic clay, sand, and sandstone is exposed below a high-level basin-floor remnant correlated with the older parts of the La Mesa geomorphic subsurface (Hawley and Kottlowski, 1965, p. 25).

The fluvial facies in the Palomas Basin, as well as in basins to the south and east, typically occupies a position in central areas immediately below the ancient basin floors and crops out on the slopes of the Rio Grande Valley. This lithologic unit is primarily composed of cross-bedded clean sand and gravel which locally may be cemented with calcite. The gravel fraction consists of subangular to rounded pebble to cobble gravel of obvious local origin, and of rounded to well-rounded pebbles (and some cobbles) of rock types foreign to the local drainage basin. The latter types include hard siliceous rocks such as quartzite, quartz, chert, granite, and obsidian; and coarse fragments of basalt scoria and rhyolite pumice.

Water-well tests near Hatch indicate that the clay facies of the Santa Fe Group extends as much as 2,000 feet below the valley floor. In the Palomas Valley segment south of Caballo Dam, the fluvial facies is above the water table and the major basin-fill facies in the zone of saturation consists of clay, which does not yield significant quantities of water to wells. Ground water production is from the Late Quaternary valley-fill aquifer. The north to south change from relatively coarse-grained to fine-grained facies in the saturated part of the Santa Fe Group is apparently due to large-scale structural movements. This point will be discussed further in the next section.

The Uvas-Goodsight (or Nutt-Hockett) ground-water basin at the extreme south end of the Palomas Basin is just outside the area discussed in this report. In this sub-basin, which is currently being studied by the State Engineer, large quantities of ground water are produced from a coarse-grained alluvial facies of the Santa Fe Group.

The Santa Fe Group in the Southern Jornada del Muerto Basin and Selden Canyon

Reconnaissance studies in the southern Caballo Mountains - northern Sierra de Las Uvas area by Seager and Hawley (unpublished data) indicate that the Rio Grande Valley between Caballo Dam and the village of Rincon crosses an unwarped and faulted basin-fill area extending from the Southwestern Hills (Kelley and Silver, 1952) and southern Caballo Mountains to the Sierra de Las Uvas and Tonuco-Selden Canyon uplifts. This positive trend marks the very poorly defined boundary between the Jornada del Muerto and southern Palomas Basins. In addition to the clay facies, an intertongueing and underlying fanglomerate facies is upwarped in this area. This gravelly unit usually has a fine-grained compact matrix and yields very small quantities of water to wells. The fluvial facies of the Santa Fe Group, which is the major water producer in the Mesilla Valley area, appears to be entirely above the water table in most parts of the Rincon Valley, excluding the eastern slopes betweem the Rincon Hills and San Diego (Tonuco) Mountain. In Selden Canyon, south of Rincon Valley, tectonic uplift has raised the lower fanglomerate facies of the Santa Fe Group above the water table and Late Quaternary valley fills rest directly on andesitic to rhyolitic volcanics.

The main part of the structural basin that forms the southern Jornada del Muerto lies east of a line extending through the crests of the southern Caballo Mountains, Rincon Hills, Tonuco Uplift, Selden Hills, Dona Ana Mountains, Goat Mountain, and Tortugas Mountain. Point of Rocks and the Dona Ana-Sierra County line mark the northern limit of the basin; and a line extending from Tortugas Mountain to the Fillmore Canyon area of the central Organ Mountains forms the approximate southern boundary of the Jornada basin system.

The central Jornada del Muerto Basin, which occupies the area north of Point of Rocks and between the Caballo-Fra Cristobal and San Andres Mountains, is also a distinct structural unit. It is north of the area of investigation and will only be briefly discussed. This basin segment was not subjected to the intense down-faulting, relative to the adjacent uplifts, that was so prominent in parts of the Jornada del Muerto to the south and north during the period of Santa Fe Group deposition. Thus basin-fill deposits are relatively thin, and Tertiary and late Cretaceous bedrock crops out or is only shallowly buried along the axis of the basin. There is no surface or shallow subsurface evidence that an ancestral Rio Grande ever flowed through the central Jornada del Muerto Basin between the San Marcial Basalt Flow and Point of Rocks (Kelley and Silver, 1952; Hawley et al., 1969).

The basin south of Point of Rocks contrasts markedly with the area to the north. North of the Dona Ana Mountains the basin floor, which ranges up to 12 miles in width, is a constructional plain underlain by as much as 350 feet of fluvial-facies sand and gravel that rests in turn on a thick clay to fan-gravel sequence. Studies of samples from a group of seismic shot holes drilled in an 8 mile line from the northwest corner of Section 21, T16S, R1E to the northeast corner of Section 33, T18S, R2E demonstrate that the fill in that area is more than 325 feet thick. Unconfirmed reports on the results of seismic testing and deeper drilling indicate that the fill is at least 1,000 feet thick. Southeast of San Diego Mountain, a lower Santa Fe Group sequence of gypsiferous silt and clay over partly consolidated, gravelly fan alluvium is more than 3,100 feet thick (measured section by Hawley and Seager in Hawley et al., 1969; Seager, 1969). This sequence underlies more than 200 feet of sand and gravel of the fluvial facies. Vertebrate fossils recovered from the fluvial facies near San Diego Mountain indicate that the ancestral Rio Grande was established in the area in early to mid-Pleistocene time. There is no evidence of a Pliocene Rio Grande in the region.

The broad piedmont slope rising to the San Andres Mountains and the narrower slopes rising to the Dona Ana Mountains consist mainly of coalescent alluvial-fan surfaces, which locally bear evidence of as much as 30 feet of deposition in mid-to late Quaternary time (post-Santa Fe deposition). Underlying fan alluvium of the upper Santa Fe Group appears to intertongue with pebbly sand to clay of the fluvial facies that is partly impregnated with gypsum. The zone of facies change occurs approximately below the break in slope at the piedmont slope-basin floor juncture. Still older fan deposits definitely predate the fluvial facies and appear to interfinger, below the present basin floors, with extensive fine-grained deposits that may be partly of lacustrine origin.

In the northwest part of the southern Jornada basin (the area between the Dona Ana Mountains and Point of Rocks), the lowermost part of the fluvial sand and gravel facies probably extends into the zone of saturation. Elsewhere in the basin the fluvial facies is usually above the water table, and the zone of saturation is either in older alluvial-fan deposits or in the fine-grained units of the clay facies.

The only large ground-water development in the southern Jornada del Muerto Basin is located in Section 36 , T20S, R2E, and Sections 30 and 31, T20S, R3E on the lower slopes of the large alluvial fan spreading out from the mouth of Bear Canyon in the San Andres Mountains. There are four water wells in the area capable of producing from 500 to 1500 gallons per minute. The western two wells are used for irrigation, while the eastern two are production wells for the NASA Apollo Test Site located five miles to the east. Doty (1963) has reported on the water-supply development for the Apollo Site. The two Apollo wells each penetrate over 1,000 feet of unconsolidated Santa Fe Group fan alluvium that contains thick, very gravelly zones (limestone, sandstone, chert, and some rhyolite clasts). The static water level in the area ranges from 300 to 350 feet below the ground surface, and the coefficient of transmissibility for the 400 to 500 feet of saturated sediments tested ranges from 48,000 to 80,000 gallons per day per foot.

Moderate amounts of ground water are produced at the southern end of the Jornada Basin along Highway 70 between Interstate 25 and the village of Organ. The relatively large quantity of subsurface hydrogeologic information available for this area (including drillers log, notes on well cuttings, geophysical data and water-table configuration) is summarized in figure 5, a cross-section extending from La Mesa, west of the Mesilla Valley, to San Augustine Peak, east of Organ.

Ground water production in the Highway 70 area is again from the alluvial-fan facies of the Santa Fe Group. Basin fill in the area was deposited in an environment of coalescing alluvial fans that spread out from several canyons in the central and northern Organ Mountains. The fan deposits are fine textured in comparison with the coarse fan gravels that were penetrated by the Apollo wells. Intergranular spaces between coarser clasts are often plugged with compact well-graded mixtures of fine sand, silt, and clay. Common lithologic types noted in well cuttings include primarily monzonite-derived sand and very-fine pebble gravel, originally from the northern Organ Mountains, and some andesite pebble gravel derived from outcrops on the flanks of the northern Organs, mixed with pebbles of rhyolite and andesite derived from the Fillmore Canyon area of the central part of the mountains (Dunham, 1935). The Fillmore Canyon watershed was the primary source for much of the fan alluvium in the Santa Fe Group in a 45 square mile area including the southwest part of T22S, R3E; the southeast part of T22S, R2E; the northeast part of T23S, R2E; and the northwest part of T23S, R3E.

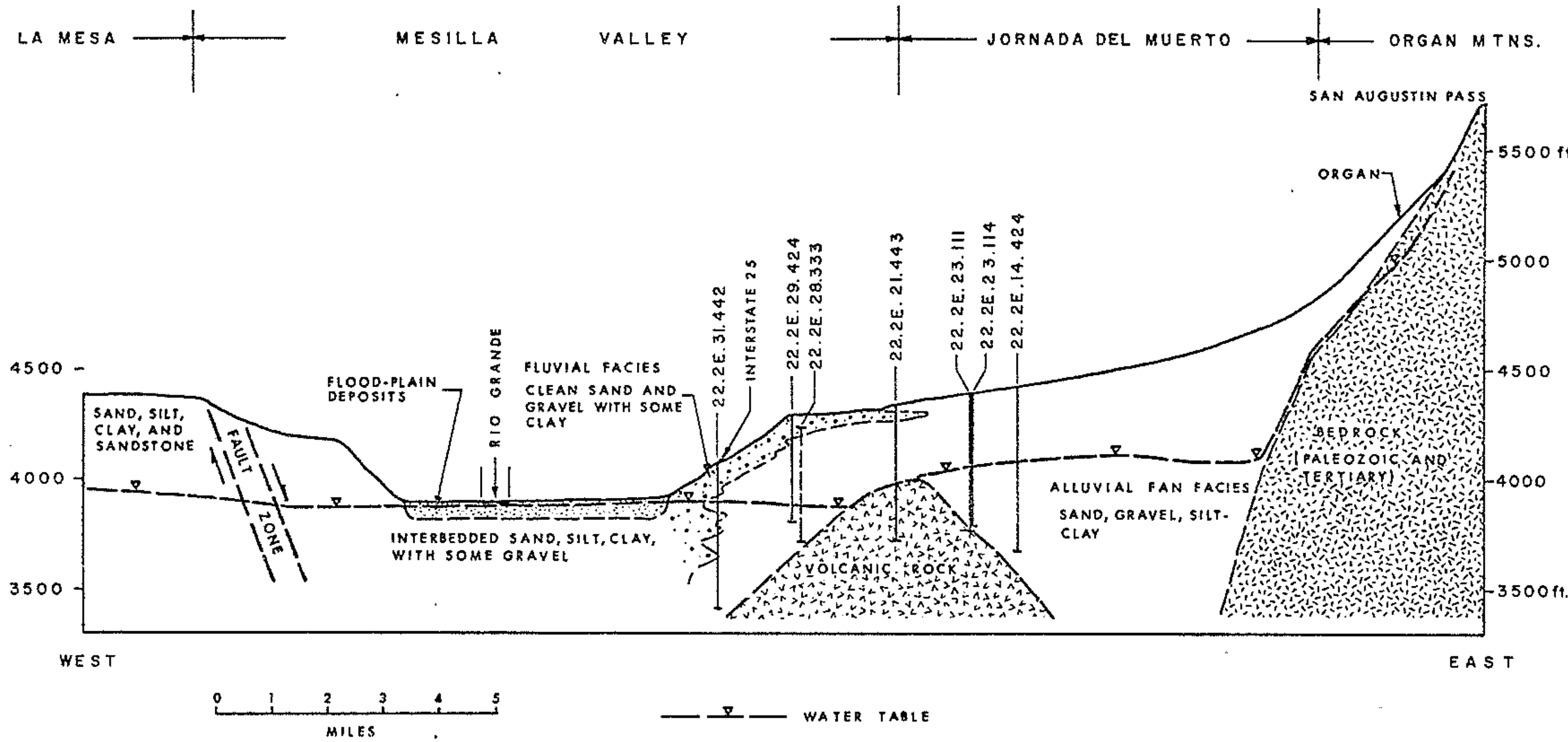

FIGURE 5. HYDROLOGIC CROSS SECTION NEAR HIGHWAY 70

The major bedrock unit in Fillmore Canyon is the Soledad Rhyolite (Dunham, 1935). Ruhe (1962, 1964, 1967) has noted the widespread occurrence of Soledad Rhyolite clasts, derived originally from Fillmore Canyon and other watersheds in the southern Organ Mountains, in surficial fan gravels of the area. He used this information to map out ancient drainage and sediment distribution patterns. Andrew Taylor (1967, and table 4, this report) has noted the occurrence of several other distinctive volcanic rock types in Fillmore Canyon, and he has shown that these types, along with the Soledad rhyolite, can be used locally as indicators of the source and depositional environment of certain basin-fill deposits found in the subsurface in the Las Cruces area. This point will be elaborated upon in a later section of this report.

Production from wells along Highway 70 ranges from about 20 to 250 gallons per minute depending on the thickness of saturated materials penetrated and the type of well construction. Specific capacities of wells are less than 5 gallons per minute per foot of drawdown. Depth to the water table, as shown on figure 5 and plate 1, ranges from about 300 feet to 575 feet, and the maximum thickness of saturated basin fill penetrated by any well is about 400 feet (tables 1 and 3).

South of the Dona Ana Mountains there is no distinct surface divide between the southernmost part of the Jornada del Muerto Basin and the northeastern Mesilla Bolson. Surface and subsurface studies between the Dona Anas and Tortugas Mountain demonstrate that the two basins aggraded as a single unit during at least the final 200 to 300 feet of basin filling. However, subsurface information from wells and gravity surveys1/ demonstrate that the southern Jornada is a well-defined structural basin separated from the Mesilla Bolson by a buried bedrock high extending from the Dona Ana Mountains to Tortugas Mountain (refer to logs of wells 22.2E.15.143, 22.2E.21.444, 22.2E.23.111 and 22.2E.29.444 in table 3). Samples recovered from these four different wells indicate that Tertiary volcanic rocks make up the high. The geologic cross section along Highway 70 (figure 5) shows the general position of this barrier and illustrates the marked effect it has on the water-table configuration. The hydrologic effects of the barrier will be further discussed.

East of the bedrock high the basin fill thickens markedly, and a gravity survey by Bear Creek Exploration Company2/ indicates that the depth to bedrock is about 2,500 feet along a belt about 2.5 miles

1/ Bear Creek Exploration Company, Kerr-McGee Corporation, and Mobil Oil Company officials, personal communications

2/ Robert Stuart, personal communication, 1964.

west of Organ and extending several miles north of Highway 70. Test drilling in Section 14 (424) T22S, R2E demonstrates that the Santa Fe Group basin fill is at least 770 feet thick.

No wells have been drilled on the main part of the Fillmore Canyon fan between Tortugas Mountain and Highway 70. A test well drilled in 1966, halfway between Tortugas Mountain and the Organ Mountain front (23.3E.20.222) possibly penetrated dense volcanic rock[3/] at 285 feet after penetrating about 10 feet of younger basin alluvium and 275 feet of Santa Fe Group fan gravel. If bedrock was actually encountered, the deep basin shown in figure 5 ends rather abruptly within an area not more than 6 miles south of Highway 70.

The Santa Fe Group in the Mesilla Bolson

The quantity of water produced from the Santa Fe Group basin fill in the Mesilla Bolson is many times greater than the combined production from all other basins discussed. Average daily pumpage from basin-fill aquifers in the City of El Paso's Canutillo well field exceeds 10 million gallons per day, and Las Cruces City wells completed in the Santa Fe Group produce on an average more than 8 million gallons per day (Dinwiddie et al., 1966). Many of the supplemental irrigation wells in the Mesilla Valley tap not only the Late Quaternary valley fill (which will be discussed later) but also the Upper Santa Fe Group. All irrigation wells located on the Mesilla Valley slopes are finished in the basin fill.

Because the wells drilled in the Santa Fe Group are primarily concentrated in the area of the Mesilla Bolson occupied by the Mesilla Valley, most of the succeeding discussion will be concerned with that area.

The Santa Fe Group exposed in side slopes of the Mesilla Valley consists of two facies that in various places intertongue with or are gradational with each other. In the northern and southern parts of the valley that are opposite the Dona Ana, Robledo, and Franklin Mountains, the alluvial-fan facies is the dominant Santa Fe facies cropping out in the valley slopes and the walls of the deep tributary arroyo valleys. Essentially continuous outcrops of the fluvial sand and gravel facies occur in two valley-border areas: (1) the east valley slope, between the villages of Dona Ana and Berino, that ascends to scattered remnants of Jornada and La Mesa geomorphic surfaces; and (2) the west valley slope, between Picacho Peak and the Cerro de Muleros, that ascends to the main part of the Mesilla Bolson floor and the La Mesa geomorphic surface. (Refer to geologic maps by Kottlowski, 1953, 1960 and Ruhe, 1967, as well as to section descriptions in Ruhe, 1962, and Sayre and Livingston, 1945). Due to the general unconsolidated nature of the Upper Santa Fe beds, exposures are poor, particularly on the lower slopes.

3/ This "rock" could be a large rhyolite boulder. Further test drilling is planned in the area in 1969.

Intertonguing of the two facies can locally be observed in the walls of the deep valleys of several arroyos that extend from the Organ Mountains across the northeastern part of the Mesilla Bolson and into the Mesilla Valley (Hawley and Kottlowski, 1969) figure 3. Figure 5 shows diagrammatically the intertonguing relationships between the fluvial facies and the alluvial fan facies along Highway 70 east of Las Cruces. The results of surface mapping along Alameda Arroyo, and the sample and drillers' logs of four key wells (22.2E.21.444, 22.2E.28.3334, 22.2E.29.424, 22.2E.31.444) were used in construction of the part of the cross section extending from the crest of the buried bedrock high to the Mesilla Valley floor.

Distinct lithologic differences between the mixed-rounded gravels of the fluvial facies and the more angular, locally-derived gravels of the fan facies enabled Taylor (1967) to distinguish the two facies in the basin fill penetrated by City Wells 23 and 24. The distinctive suite of volcanic rock clasts derived from Fillmore Canyon in the Organ Mountains, mentioned previously (table 4), appeared in the fan facies in both city wells at depths considerably below the top of the intervening buried bedrock high shown in figure 5. This observation indicates that the buried uplift is locally breached in the area east of Interstate 25, between Highway 70 and Tortugas Mountain, and that it is not a continuous barrier to water movement in the Santa Fe Group basin fill. Taylor's (1967) detailed studies of the gravel lithologies in cuttings from City Wells 23 and 24 (22.2E.31.444, 23.2E.16.133) also enabled the writers to determine that the ground water production of the east Las Cruces well field comes from a zone of the Santa Fe Group characterized by intertonguing of sand and gravel (with only minor amounts of silt and clay) of the alluvial-fan and fluvial facies. These wells, which are 650 feet deep (up to 430 feet of saturated fill), are capable of producing large quantities (in the order of 1000 GPM) of good quality water (table 2).

The comments made in the previous paragraphs also generally apply to the New Mexico State University Campus area. The University has its own independent water supply system tapping both the fan-facies (23.2E.22.331) and the fluvial facies (23.2E.28.331). Well 22.331 is one of the few wells in the area whose hydraulic capabilities have been adequately tested. Records of a step-drawdown well-performance test[1/] show a relatively low coefficient of transmissibility of about 6,000 gallons per day per foot (about 150 feet of saturated basin fill tested), which is probably a near maximum figure for wells tapping only the alluvial-fan facies on the east side of the Mesilla Bolson.

A small area of domestic ground water production from the alluvial-fan facies, located 2 miles southeast of the State University, is of particular interest because of the high temperature

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1/ Mr. Stuart Meerscheidt, Butte Pump Co., June, 1962, personal communication.

of water (90° to 110° F) produced from a zone about 350 to 450 feet below the surface (Sec. 34, T23S, R2E). A high geothermal gradient associated with a fault zone bounding the Tortugas Mountain block may the cause of this temperature anomaly. The geochemistry of thermal waters in the area is currently being studied by K. Summers of the New Mexico Institute of Mining and Technology.

A final area of interest in the Mesilla Bolson east of the Rio Grande Valley proper is Fillmore Pass. The pass is a 4-mile wide gap between the Bishop Cap outlier of the Organ Mountains and the Franklin Mountains that connects the Mesilla and Hueco Bolsons. Results of test drilling in Fillmore Pass, reported by Knowles and Kennedy (1956, 1958), indicate that unconsolidated basin fill is locally as much as 970 feet thick and that no bedrock barrier exists in the area which would impede the flow of ground water between the two bolsons. Strain (1966, p. 11) suggested that, after initial coalescence of basin fill through the pass, the Mesilla and Hueco Bolsons "continued to aggrade with a common level" during at least the last 500 feet of basin filling. The present floor of the pass represents the constructional La Mesa surface formed on Middle Pleistocene sand and gravel of the Santa Fe Group fluvial facies. The thickness of this facies is not definitely known; but according to Thomas Cliett, geologist for the El Paso Water Utilities Board (personal communication, 1968) it could be as much as 400 feet.

In the part of the Mesilla Bolson occupied by the Mesilla Valley, subsurface information on the nature of the Santa Fe Group below the Rio Grande flood plain is incomplete because the majority of the wells penetrate less than 300 feet below the valley floor. Deep drilling in the New Mexico part of the valley area has been confined to a few scattered test holes that are no more than 620 feet deep. However, a number of wells have been drilled to depths exceeding 1000 feet in the Texas part of the Valley, some of which have completely penetrated the Santa Fe Group (Leggat, et al., 1963).

The Late Quaternary river-valley fill, which will be discussed in a later section, appears to be no more than 80 feet thick. Many shallow irrigation wells extend through the valley fill and into the uppermost beds of the underlying Santa Fe Group basin fill. Because there is no legal requirement in this part of New Mexico for submission of well logs or well construction data to the State Engineer, it has been impossible to determine from the information available the relative amounts of water produced from the two units.

The Santa Fe strata penetrated below the valley fill in the New Mexico part of the valley generally consist of alternating layers of fine to coarse sand, and clay to sandy clay (table 3, 25.3E.32.421). However, wells on the east side of the valley near Las Cruces also encounter some beds of gravel in the upper 200 to 300 feet of basin fill (table 3, well 24.2E.9.132). Earlier workers assumed that the Santa Fe Group below the Mesilla Valley floor was nongravelly, and erroneously attributed some deep gravel-bearing strata to post-Santa Fe valley-fill deposits (Conover, 1954; Leggat et al., 1963).

The basin-fill facies classification used up to this point does not adequately characterize the sequence of alternating medium- and fine-grained beds described in the preceding paragraph. This sequence comprises a large part of the "sub valley" Santa Fe section and extends to depths as much as 600 feet below the surface in the area south of Las Cruces. The alternating sand and clay unit extends southward into Texas, where Leggat and others (1963) refer to it as the "medium (Santa Fe Group) aquifer". Well cuttings from the sand to sand and gravel zones are identical to cuttings from the fluvial facies elsewhere in the area. Samples from the clay to sandy clay beds appear identical to clay facies material from the Palomas and Rincon Valleys.

W. S. Strain (1966, in press) has postulated that a large lake, Lake Cabeza de Vaca, periodically occupied the floor of Hueco Bolson in early Pleistocene time, prior to the extension of ancestral Rio Grande deposits into that basin. He also considers it likely that higher stands of this lake extended into the Mesilla Bolson via basins in northern Chihuahua, the El Paso narrows, and possibly Fillmore Pass, and that clayey beds exposed in the lower parts of the southern Mesilla Valley walls might represent lacustrine strata. With this hypothesis in mind, it appears quite possible that the alternating clay and sand sequence represents basin-fill deposition in a deltaic area near the mouth of the ancestral Rio Grande, with the lithologic variations being controlled by rising and falling levels of ancient Lake Cabeza de Vaca.

Deep wells drilled for the City of El Paso south of Anthony, Texas-New Mexico, in the east half of T27S, R3E, (projected township and range lines) have encountered a very thick unit of clean, well-sorted fine to medium sand ($<$1mm maximum grain size) between 600 and 1300 feet below the flood plain surface (Leggat et al., 1963). Several wells have penetrated below this unit, which has been designated the "deep (Santa Fe Group) aquifer", one into a tongue of Lower Santa Fe fanglomerate, and one into pre-Santa Fe volcanic rock and underlying older Tertiary sedimentary deposits. The resistivity curves on electric logs for City of El Paso test wells show the striking contrast between the upper, alternating sand and clay unit and the lower, thick sand unit, as well as the general improvement in water quality with depth (Leggat et al., 1963).

The origin and distribution of the very thick sand unit comprising the deep aquifer is an important and unsolved hydrogeologic question. As the sand has been encountered only in the subsurface, sedimentary structures cannot be observed. In the Anthony-Canutillo area, the unit is about 450 to 1150 feet below the elevation of the bedrock lip in El Paso Canyon (Slichter, 1905). One possible hypothesis is that the unit is a fluvial to deltaic facies of ancestral Rio Grande alluvium deposited in a subsiding structural basin, now occupied in part by the lower Mesilla Valley. How far the unit extends up the valley and to the west is unknown. Mr. Thomas Cliett, Geologist for El Pasó Water Utilities, is working on the problem at the present time.

The aquifers described above can produce very large quantitites of water, if care is taken in installation of properly-sized, gravel pack and well screen combinations. Wells completed in the Santa Fe Group (medium and deep aquifers) in the Texas section of the southern Mesilla Valley commonly produce between 1,000 and 3,000 gallons per minute (Leggat et al., 1963). Measured coefficients of transmissibility range from 34,000 to 73,000 gpd/ft and average about 50,000. Permeabilities range from 128 to 150 gpd/ft^2 and average about 140. Local flowing wells and very low measured storage coefficient values demonstrate that artesian ground water conditions exist. This might be expected because of the presence of thick clay beds in the upper 500 to 600 feet of the Santa Fe section.

Wells drilled in the Anapra, New Mexico, section of the Lower Mesilla Valley (Leggat et al., 1963; and wells 28.3E.34.331 and 29.3E.3.243) have encountered Tertiary intrusive bedrock at relatively shallow depths (less than 300 feet), and have thus demonstrated that the Santa Fe Group abruptly wedges out at the south end of the valley. Ground water quality deteriorates at all depths in the extreme southern portion of the valley.

The Santa Fe Group appears to extend westward under the floor of the Mesilla Bolson (La Mesa geomorphic surface) without any appreciable decrease in thickness between the Las Cruces Municipal Airport area, north of Highway 70, and the International Boundary. The basin fill definitely wedges out against the East Potrillo Mountains, Mount Riley, and the Aden-Sleeping Lady Hills. To the north Santa Fe Group fluvial and older fanglomerate facies extend through the Corralitos sub-basin (T22S., R1-2W) between the Rough and Ready Hills and the Robledo Mountains into the Selden Canyon area. To the south the Santa Fe Group extends an unknown distance into the Lake Palomas Basin (Reeves, 1965) of northern Chihuahua, but probably at least 75 miles. Outcrops of the fluvial facies (sand and rounded-gravel unit) have been examined in caliche borrow pits below the La Mesa surface along Chihuahua State Highway 10, 20 miles south of the International Boundary and due south of T29S, R1W and 1E. The fine-grained (in part lacustrine) facies of the Santa Fe Group should be expected in the subsurface below the extensive bolson plains of northern Chihuahua.

No more than 60 wells have been drilled in the 725 square mile area of the Mesilla Bolson west of the Rio Grande. Most of these are stock wells, on which no logs have been kept. Logs of 8 railroad wells (Conover, 1954), one test well for a radar site, and 3 oil tests provide the only relatively good subsurface information for the area. Well cuttings from two of the three oil tests in the area were available for study by the authors, and have provided a limited amount of information on the subsurface geology. Unfortunately, the physical properties of the basin-fill deposits were not of primary interest to the well owners. Thus, the size and quality of the sample sets available left something to be desired from the standpoint of obtaining the maximum information on hydrogeologic properties of the Santa Fe Group.

The Picacho Oil and Gas Syndicate Test Well (Conover, 1954, Kottlowski, et al., 1956) is the northernmost deep well in the bolson. This wildcat, drilled in Section 36, T22S, R2E, penetrated only 165 feet of Santa Fe basin fill (fluvial, clay, and fanglomerate facies), which in turn rested on a sequence of andesitic volcanics and early Tertiary sedimentary rocks at least 2175 feet thick. The hole ended in Permian sedimentary rocks at 3,196 feet.

The driller and electric logs of a "dry test hole" at the Radar Site (well 23.1W.31.440) located 4.5 miles southwest of the Picacho oil test, indicate that basin-fill sediments extend to a depth of at least 440 feet in the immediate area of the well. Surface outcrops of two basalt "necks" near the well site, as well as flow (?) rocks reported in the upper part of the section penetrated, demonstrate that Quaternary volcanics locally intrude and possibly intertongue with the Upper Santa Fe Group near the Radar Site.

The northernmost of two recently drilled oil tests (Boles-Federal No. 1) is located in the north-central part of the bolson, about 4 miles west of Mesilla Dam. This well, drilled in 1962, appears to have penetrated 3790 feet of sandy to gravelly Santa Fe Group basin-fill, with some interbedded clays, before encountering Tertiary volcanic rocks. Drillers records are not clear as to whether or not the well finished in Paleozoic carbonate rocks at about 5180 feet.

The best subsurface information on the basin-fill and underlying volcanics is provided by an oil test well (S.H. Weaver - Federal 1, table 3, 26.1E.35.332) located about 12 miles west of Anthony. A relatively good sample set and an electric log (partial penetration) are available for this well. Study of well cuttings and the electric log indicates that medium- and fine-grained beds comprise the bulk of the Santa Fe Group at the site. Gravelly to conglomerate beds are also present at the very top and base of the fill sequence, which extends to about 2020 feet and rests on Tertiary volcanics and associated sedimentary rocks. The well finished in Tertiary rocks at 6600 feet. The interpretation of this subsurface data was difficult because electric logging was not done below 2432 feet. It is possible that the above interpretation may be incorrect and that Santa Fe beds may extend below 2020 feet.

Wells drilled at former watering stops along the two Southern Pacific Railroad rights-of-way west and northwest of Anapra provide the only subsurface information for the southern half of the bolson (Conover, 1954). The wells penetrated 950 feet of basin-fill at Lanark (Sec. 11, T27S, R1E), 1330 feet at Strauss (Sec. 24, T28S, R2E), and 565 feet at Noria (Sec. 8, T29S, R1E). In each area the fill consisted of alternating layers of sand and clay. Gravel-sized materials reported in some drillers' logs probably represent calcareous concretions that formed in place after sediment deposition.

The general textural trend for the upper 1330 feet of bolson fill,revealed from the well logs discussed above, is one of progressive decrease in average grain size from north to south. Coarse gravelly zones are uncommon even beneath the northern part of the Mesilla Bolson floor.

The West Potrillo Mountains and Quaternary Volcanism in the Mesilla Area

Olivine basalt flows and cinder cones are prominent surface features in the Mesilla Bolson-Potrillo area southwest of Las Cruces (figure 3). Flows cover an area of at least 350 square miles. The West Potrillo Mountains form the largest single volcanic field and include at least 85 cinder cones (Hawley and Kottlowski, 1969). Six smaller volcanic centers occur on the Mesilla Bolson floor (La Mesa geomorphic surface) between the Potrillo Mountains and the Mesilla Valley. The oldest basalts, such as at the Radar Site (Sec. 31, T23S, R1W) appear to intertongue with basin-floor sediments of the Upper Santa Fe Group. However, the bulk of the basalts east of the West Potrillo field, and perhaps in that field as well, postdate development of the La Mesa geomorphic surface in middle Pleistocene time (Ruhe, 1962; Hawley and Kottlowski, 1969; DeHon, 1965; Kottlowski, 1960). Two basalt flows that spilled into the Mesilla Valley during an early stage of valley entrenchment are preserved in the west-central part of the valley near San Miguel and Santo Tomas. The minimum age of the youngest group of flows, the Aden or Qb3 basalt of Kottlowski (1960) is definitely established. Remains of a ground sloth in a lava tunnel on Aden Volcano date the youngest eruption at greater than 11,000 years before the present (Simons and Alexander, 1964). Potassium-argon dating of La Mesa basalts has been attempted, but there are still problems in obtaining accurate dates (Hawley and Kottlowski, 1969). In all cases the Quaternary basalts of the central Mesilla Bolson appear to be thin and well above the water table.

Three huge, rimmed depressions of volcanic origin occur near the western edge of Mesilla Bolson, respectively 26, 29 and 39 miles south-southwest of Las Cruces (plate 1). From north to south, they are Kilbourne Hole, Hunt's Hole, and Potrillo Maar. These explosion features, termed maare by DeHon (1965), formed after initial extrusion of basalts on the La Mesa geomorphic surface. The largest of the three, Kilbourne Hole, is about two miles in diameter. Its floor is about 280 feet below, and its rim as much as 170 feet above the La Mesa surface. Excellent exposures in the southeast wall of the "Hole" show a thick section of rim ejecta resting on a thin basalt flow which in turn rests on Santa Fe Group beds ranging from sands (with scattered rounded, siliceous pebbles) to clayey silts. A strong soil profile, with a prominent indurated horizon of carbonate accumulation (caliche) was developed in the uppermost part of the Santa Fe section. It marks the buried La Mesa surface.

A fourth large depression, Phillips Hole, located 3 miles east of Hunt's Hole, is also from 1 to 2 miles in diameter, but it is shallower than the above three features and does not have a rim. DeHon (1965, p. 208) states that "Phillips Hole may be a maar which, lacking a buried basalt to control erosion, has engulfed the rim deposits by backwasting". The four depressions discussed above, while postdating the La Mesa geomorphic surface, may not all be of the same age. They may each represent a distinct set of volcanic eruptions. The maare-forming events may have been spread over a long span of middle to late Pleistocene time.

As mentioned in the previous section on geomorphic features, the West Potrillo Mountains, which bound the west-central part of the Mesilla Bolson, form a mountain upland that is unique in the region discussed. That is, the relief in all the other mountains flanking the Rio Grande Valley and adjacent basins is the result of differential uplift of certain segments of the earth's crust relative to adjoining segments. A considerable part of the relief of the West Potrillos is due to constructional processes -- the piling up of volcanic ejecta around vents to form cinder cones and the simple building up of layer upon layer of olivine basalt flows in Quaternary time. Due to the fact that there has been no subsurface geologic or geophysical logging of wells in the central part of the Potrillo volcanic field, it is not known whether the basalts are underlain by a thick section of basin-fill deposits or by Tertiary and older bedrock units. Isolated exposures of middle Tertiary volcanic rocks and older sedimentary rocks on the flanks of the West Potrillo Mountains do indicate that the latter alternative is probably more likely to be the case.

<u>Rio Grande Valley-Fill Deposits</u>

Three major alluvial fill sequences that postdate deposition of the Santa Fe Group basin fill are present in the Rio Grande Valley. The youngest of the three, comprising the late Quaternary flood plain and channel deposits of the Rio Grande and interfingering of alluvial-fan deposits of tributary arroyos, is the only group of valley-fill deposits that makes up an important aquifer unit (table 3). This is due to the fact that the older valley fills, associated with constructional parts of the Tortugas and Picacho surfaces (Hawley and Kottlowski, 1969), appear in all cases to be above the water table.

In latest Pleistocene time, probably during the last major Wisconsinan glacial-pluvial substage (between 22,000 and 13,000 years ago) when the discharge of the ancestral Rio Grande was considerably greater than present, the floor of the river valley was eroded down to a level about 80 feet below the present flood-plain surface (Kottlowski, 1959; Hawley, 1965; Davie and Spiegel, 1967). Subsequent to the time of maximum degradation, a thick channel gravel and sand deposit was laid down on the erosion surface, which appears in most cases to have been cut into ancient basin-fill of the Santa Fe Group, or in the case of El Paso and Selden Canyon areas, locally into older rocks. Carbon 14 dating of Holocene valley fills (Hawley and Gile, 1966; A. L. Metcalf, U.T.E.P. Biology Dept., personal communication, October 1968) in the Mesilla and Palomas Valleys indicates that early back filling of the inner valley was relatively fast, with aggradation of the valley floor being essentially completed by 10,000 years B.P. (before present). The upper group of flood-plain deposits are finer grained than the basal gravelly unit and consist mainly of sand to clay. The carbon 14 dating indicates that at least one halt in valley aggradation, perhaps accompanied by minor valley cutting and back filling, also occurred some time between 5,000 and 10,000 years ago.

As mentioned in the section on the Santa Fe Group in the Mesilla Valley, the shallower wells in valley floor areas (generally less than 200 feet deep) are commonly finished in both the younger valley fill and the underlying Santa Fe beds. A good example of this practice is the "shallow aquifer" of Leggat and others (1963) in the Mesilla Valley south of the 32nd parallel. This aquifer designation includes both late Quaternary flood-plain deposits and middle Pleistocene and older basin fill. Furthermore, it appears to be a meaningful hydrologic unit in a large part of the Mesilla Valley area because in terms of physical aquifer characteristics and water quality patterns, the profound geologic unconformity about 80 feet below the flood-plain surface often does not seem to play an important role.

In general, the quantity of water production from wells penetrating the shallow valley and basin-fill deposits is not a problem. Wells developed in buried channel gravel and sand deposits below the river flood plain are capable of producing 1,000 to 3,000 gallons of water per minute. Specific capacities are usually high, often ranging from 70 to 100 gallons per minute per foot of drawdown, with coefficients of transmissibility commonly in the 100,000 to 150,00 gallons per day per foot range (Conover, 1954; Leggat et al., 1963).

Quality of ground water in the shallow deposits tends to vary from place to place and at a single point it often varies with depth (Leggat et al., 1963; Conover, 1954; current studies by the U. S.

Geological Survey in cooperation with the State Engineer Office). While quantitative studies of water quality are beyond the scope of this report, it appears that two major geologic features associated with flood-plain depositional environments are important in influencing the quality of water stored and moving through the valley fill deposits. First, the Late Quaternary valley fill contains local lenses of concentrated organic matter ranging in size from microscopic particles to large fragments of rotten wood. Such materials probably represent deposition in ancient ox-bow lake and slough environments. Besides organic compounds, hydrogen sulfide and iron concentrations are often common features of these zones and have a deleterious effect on ground water quality. Second, concentrations of soluble salts were locally built up in poorly drained, fine-textured, flood-plain sediments. While this phenomenon is particularly noticeable at the present time due to irrigation practices since inception of the Elephant Butte Irrigation Project, it is also a natural geologic process that has taken place during the progressive filling of the valley in latest Quaternary time. With local exceptions, the salt problem seems to progressively increase as one moves southward in the Mesilla Valley (Conover, 1954; Leggat et al., 1963). Apparent upward movement of deep circulating ground water and discharge by evapotranspiration at the extreme southern end of the valley is a probable cause for the very poor quality of the ground water in that area, both in the younger valley fill and the Santa Fe Group as well.

In the Palomas and Rincon Valleys and in Selden Canyon, the Late Quaternary valley fill for all practical purposes is the only source for reliable supplies of ground water of relatively good quality. As mentioned previously, the Santa Fe Group in those areas is clayey or otherwise very compact and impermeable. The same can be said for the older Tertiary volcanic and sedimentary rocks that locally underlie the valley fill alluvium in Selden Canyon. As in the Mesilla Valley the Late Quaternary fill generally grades upward from very gravelly at the base to sandy at the top, and it rarely exceeds 80 feet in thickness (Refer to table 3) 1/.

1/ Contributions by J. W. Hawley (p. 19-47) approved for publication by the Director, Information Division, Soil Conservation Service, U. S. D. A.

GEOHYDROLOGY

Introduction

Surface water and ground water in Dona Ana County are closely related to each other, particularly in the river valley of the Rio Grande, where withdrawals from wells can be considered to be an alternative method of diversion of water from the Rio Grande.

As precipitation heavy enough to fully satisfy the soil moisture capacity occurs only rarely, recharge to ground water usually occurs principally by the infiltration of surface runoff into rills and arroyo channels during summer storms. Areas with sandy soils and dunes, however, may permit more direct recharge from precipitation more frequently. Although the amount of water recharged per unit of surface area is small in Dona Ana County (perhaps 1 or 2 percent of the annual precipitation), it is generally sufficient to cause movement of ground water toward the Rio Grande valley rather than away from it (see water level contours on pl. 1). Thus, the Rio Grande valley is generally a natural discharge area, although in some reaches the transmissivity of the recent alluvium is large enough to permit the river to recharge the adjacent watercourse aquifer. This water is conveyed downstream in the aquifer system to be consumed by vegetation or returned to the river or artificial drains, along with "new water" moving into the valley from adjacent portions of the Santa Fe group. Thus, the Rio Grande locally loses water to the adjacent aquifer, but the valley as a whole gains ground water. An excess of natural evapotranspiration and beneficial consumptive use over ground water inflow to the valley causes general depletion of the Rio Grande in Dona Ana County.

Early attempts to irrigate crops in Mesilla valley by ground water (Vernon and Lester, 1903, Vernon, Lester, and McLallen, 1904; Vernon, Lovett, and Scott, 1905; Fleming, 1909; Fleming and Stoneking, 1909, 1911) were premature because of the lack of cheap and convenient energy sources, the low efficiency of pumps available at the time, and the relatively greater maturity of techniques of management of surface water resources. However, within two decades after the construction of Elephant Butte Dam, the turbine pump for wells became more reliable and efficient, and large reserves of oil and natural gas for pump power were made available in New Mexico and adjacent portions of Texas. In another decade, electric power became generally available at attractive rates. In the early 1950's, when a severe drought depleted the surface storage available for irrigation, a few enterprising farmers drilled irrigation wells as a substitute for the greatly diminished surface irrigation supplies. The wells were so successful that 1,682 wells had been drilled by 1955 (Spiegel, 1958, pt. II, p. 11) and the Elephant Butte Irrigation District had become a project utilizing for firm irrigation supplies both surface water impounded in Elephant Butte Reservoir and ground water in storage under irrigated project lands.

With the end of the severe drought in 1958, surface water from Elephant Butte Dam was again available for full-irrigation supply. The surface-water supply was welcomed to leach out salts accumulated locally from ground-water irrigation, and because assessments are levied for project water whether or not the surface supply is available for use by the farmer.

A hydrograph of average water levels in 39 observation wells in Mesilla valley (figure 6) illustrates the effects of changes in relative amounts of irrigation water used from surface and underground sources. Prior to 1951, water levels rose markedly in summer in response to return flow from surface irrigation. Minimum and maximum seasonal levels were controlled by the drains and amount of water supplied, respectively. From 1952 to 1957, water levels lowered in summer in response to net withdrawals from wells, and some residual annual lowering remained from previous pumping. From 1958 on, water levels returned to nearly the pre-1957 cycle, but some effects of supplemental pumping are apparent each year.

Surface Water

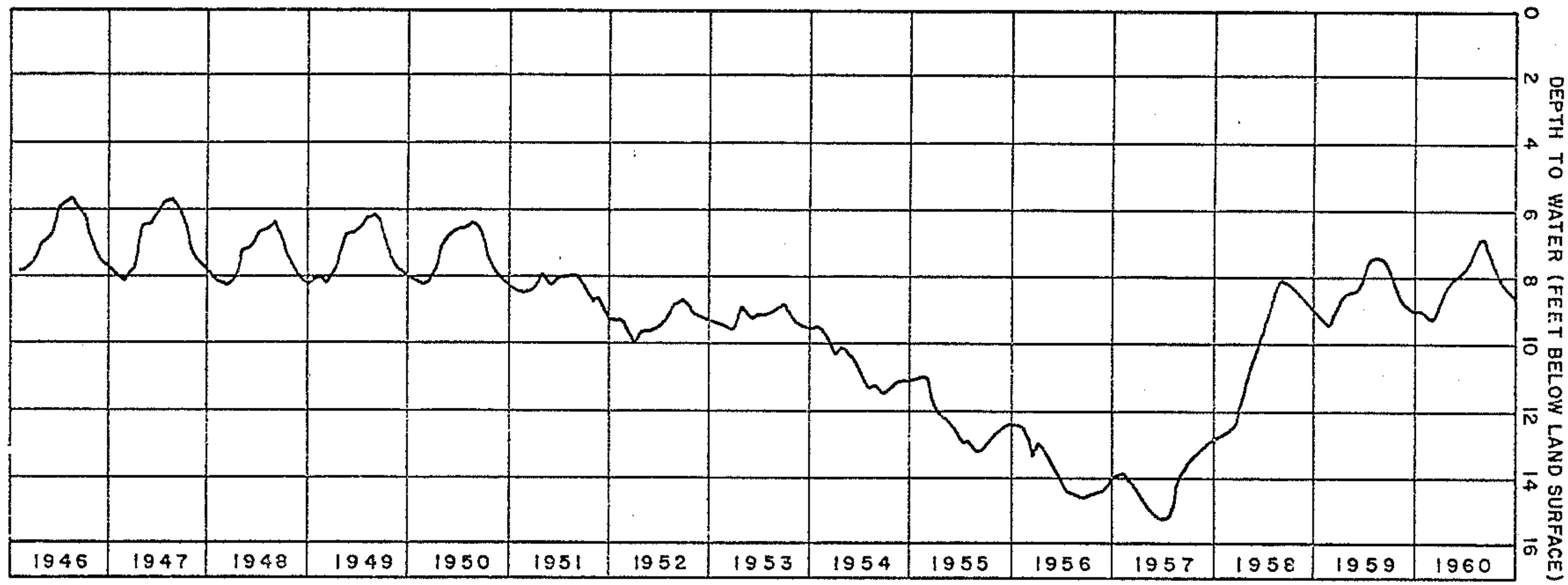
The principal stream of the investigation area is the Rio Grande, the discharge of which is regulated by releases from Elephant Butte Dam. Conover (1954), Spiegel (1958) and Taylor (1967) have examined the relationships of the surface-subsurface water supply of the Rio Grande Valley in some detail.

The arroyos that are tributary to the Rio Grande are characterized by ephemeral flow. No well-documented figures are available for the total quantities of water delivered by these tributaries. The arroyos of the Southwestern Palomas Basin and those of the Eastern Mesilla Bolson drain to the Rio Grande, although there is some internal drainage on La Mesa and the basin to the west. An example of internal drainage is Mason Draw in T22,23 and 24S,R3W, which leads to a playa in Section 18, T24S,R3W. In conjunction with volcanic rocks of low permeability in the area, Mason Draw has contributed to an interesting ground water mound at the southern end of its basin (pl.1).

The Southern Jornada del Muerto north of U. S. Highway 70 is a region of internal drainage with numerous playas. The largest of these is Isaack Lake in Section 27, T21S, R2E, which is occasionally flooded by summer storm runoff from adjacent piedmont slopes. South of Highway 70, the intermittent streams from the Organ Mountains flow westward to the Rio Grande.

The Ground-Water Reservoir

Nearly all of the economically exploitable ground water in the investigation area is in unconsolidated to partly consolidated Tertiary and Quaternary sedimentary deposits. Where saturated, these basin-and



AVERAGE DEPTH TO WATER IN 39 WELLS IN MESILLA VALLEY 1946-1960

FIGURE 6. MODIFIED FROM SPIEGEL (1958). DATA FROM BUREAU OF RECLAMATION.

valley-fill deposits, and a few volcanic rocks, are called the ground-water reservoir. The zones in the ground-water reservoir that yield significant quantities of water to wells are called aquifers. While some of the consolidated rocks of the region do contribute water to wells, most of these rocks have much lower porosity and permeability than the fill deposits and do not yield significant amounts of water, comparatively.

Because of the structural, depositional, erosional and igneous features of the area, the thickness of the prime basin-and valley-fill ground-water reservoir is highly variable. The area is extensively faulted and has a history of abundant extrusive and intrusive igneous activity. The maximum basin-fill reservoir thickness is perhaps as much as 3,465 feet in the Mesilla Bolson in well 24.1E.7.440, and the minimum is no reservoir footage in well 22.2E.21.444 located in the Southern Jornada del Muerto. The latter well yielded no water at all from impermeable igneous rock at total depth (table 1).

Ground-Water Occurrence

Water in the aquifers is contained in the interstices or pore spaces between granular rock particles and chemical precipitates in the zone of saturation. Porosity and permeability of the deposits depend upon the size and shape of the particles and the degree of sorting, as well as compaction and cementation of the rock materials. In general, well-sorted sediment has the highest porosity, and coarse-grained sediment has the greatest permeability. Well-sorted medium-grained sediments, as are often encountered in the medium and deep Santa Fe aquifers, may have high porosity and sufficient permeability for large production with proper well development. Aquifers containing abundant clay will have high porosity but very low permeability due to the platy shape of the clay particles which causes a limited size of pore spaces.

The upper surface of the saturated zone of an unconfined aquifer is known as the water table. Water in a well completed in unconfined sediments will stand at the level of the water table when the well is not being pumped. Fluctuations in the level of the water table are caused by changes in storage of ground water.

Addition of water to the aquifer is known as recharge, while the process of removal of water from storage is known as storage depletion. Movement of water out of the aquifer is called discharge.

Ground water moves in the direction of least hydraulic head from areas of recharge to areas of discharge. This movement can be easily visualized on a water table contour map, because the movement is, in general, perpendicular to the contour lines.

Recharge and Discharge

Most natural recharge to the aquifers in the area of investigation is from infiltration of channel runoff from precipitation in the area. In the inner valley of the Rio Grande artificial recharge from surface irrigation water released from Elephant Butte Reservoir exceeds the natural recharge but creates local circulation to drains and certain reaches of the river.

The surface alluvium of the Rio Grande floodplain locally permits a high rate of recharge to the underlying shallow aquifer. This fact is shown by rise of water levels in summer when Elephant Butte water is available (Spiegel, 1958) and by the rapid recovery of ground water levels, after a long period of overdraft of the shallow ground water reservoirs, when excess surface irrigation water is available for application on agricultural lands of the river valley (Taylor, 1967). However, after cessation of pumping from wells, ground water levels would recover to drain level even without local surface recharge through releases of water from Elephant Butte Reservoir.

Under conditions of plentiful surface-water supply from Elephant Butte Reservoir, local recharge to the shallow aquifer of the Rio Grande Valley is discharged to the network of drains and, eventually, back to the Rio Grande. However, during periods of drought when surface-water releases are restricted, heavy ground-water pumpage from wells takes place, and ground water is removed from storage. During drought conditions the drain flow diminishes as withdrawals from the aquifer increase, indicating that the water normally discharged to the drains has been diverted by the wells. It is believed that under present conditions the bed of the Rio Grande itself provides only limited recharge to the aquifer because of a minimum of channel disturbance due to low turbulence of transmitted water and plugging of the river bed by clay and silt. Consequently, the farmland areas on the flood plain appear to be the major areas of downward seepage of water.

In areas other than the Rio Grande Valley, recharge is by precipitation directly on the basins and on adjacent mountain ranges. The precipitation rate is low and evaporation rate is high throughout the area. Thus, recharge is not great and is further inhibited by caliche and clay horizons in the subsurface of the basins and uplands. Discharge from wells is minimal, and the ground-water levels have not lowered in many places significantly from the levels measured by Conover (1954). In a few limited areas of heavy pumpage, like Butterfield Park (well 22.3E.9.3222) in the Southern Jornada del Muerto, it seems probable that a significant cone of depression has been created (pl. 1).

Chemical Quality of Ground Water

In general, the ground water discharging from the Santa Fe group and older rocks to the inner-valley alluvium is of good chemical quality in Dona Ana County, except locally near the state line. Ground water in the alluvium generally reflect the quality of ground water entering it from the Santa Fe group, but two factors cause the ground water in the alluvium to have generally higher dissolved solids than the Santa Fe group: (1) dissolution of soluble materials from buried flood plain deposits, and (2) concentration of minerals in surface irrigation water return (local recharge to the alluvium) by evapotranspiration.

The chemical quality of ground water and discharge to drains had probably approached an equilibrium level after several decades of surface irrigation under the works of the Elephant Butte Irrigation District. The large-scale use of ground water during droughts since 1951 probably has brought about a gradual increase in dissolved solids in the alluvium by recycling of salts. An investigation by the U. S. Geological Survey, in cooperation with the New Mexico State Engineer, has been made (Basler and Alary, 1968) on chemical quality in observation wells of the U. S. Bureau of Reclamation.

Ground-Water Conditions in the Southwestern Palomas Basin

Only the Southwestern Palomas Basin has been considered in this report. Davie and Spiegel (1967) have discussed the northern part of the basin and personnel of the State Engineer's Office have made an unpublished study of the Nutt-Hocket Basin.

Ground water moves into the Rio Grande Valley from the uplands to the valley border and then moves down the valley (pl. 1).

According to available well data, there are no wells producing large quantities of water from aquifer beds deeper than approximately 80 feet in the Rio Grande Valley portion of the Basin. Several wells have been drilled into the reservoir beds deeper than 80 feet, notably the Hatch Cooperative Gin Company well, with disappointing results (table 3, well 19.3W.9.411).

Only the most general kind of work was done in connection with this investigation with regard to the ground-water conditions to the west and southwest of the Village of Hatch. On the basis of available information it is clear that there is subsurface flow at a gentle gradient from the Nutt-Hockett area into the Rio Grande Valley. It is possible that the valley of Placitas Arroyo, which also receives inflow from the Northwest Sierra de las Uvas region, is underlain by relatively permeable gravels of an ancient tributary to the Rio Grande.

Ground-Water Conditions in the Rincon Valley-Selden Canyon Area

In this portion of the investigation area there is ground-water inflow to the valley from the east and the west, as well as a component of flow down the Rio Grande Valley.

As in the Southwestern Palomas Basin, productive aquifer beds extend only to depths of approximately 80 feet below the valley floor.

In the Sierra de las Uvas there is a ground-water divide located in the northwest corner of T22S,R2W, and the southeast corner of T21S, R1 and 2W, near the south end of Faulkner Canyon. The ground-water movement down Faulkner Canyon indicates that there is significant recharge to the valley from the uplands to the southwest, and other canyons and arroyos of the region undoubtedly would illustrate the same situation if subsurface data were available.

There is also ground-water inflow to the Rincon Valley from the Jornada del Muerto, as discussed in the next section.

Ground-Water Conditions in the Southern Jornada del Muerto

The boundary area between the Southern Jornada del Muerto and the Rincon Valley is characterized by lack of good ground water communication, except for the inflow from the Jornada in T19S,R2W. The San Diego Mountain-Selden Hills uplift appears to be a belt of Tertiary volcanics and associated sedimentary rocks where there are no Santa Fe group beds which occur in the zone of saturation, except for the beds of the older alluvial fan and clay facies. The region in T19S,R2W is, as described in the section on hydrogeology, one of the few places in the Southwestern Palomas Basin-Rincon Valley area where the fluvial facies of the Santa Fe group lie in the zone of saturation.

To the southeast of the San Diego-Selden Hills uplift, lie the Dona Ana Mountains and Tortugas Mountain. The trend of mountains and hills from San Diego Mountain to Tortugas Mountain is an almost continuous bedrock uplift which serves as a barrier to ground water movement from the Southern Jornada del Muerto to the Rincon Valley and the Mesilla Valley.

Previous ground-water contour maps (Conover, 1954, Dinwiddie, 1967) have indicated ground-water movement through the gaps between San Diego Mountain and the Selden Hills, between the Selden Hills and the Dona Ana Mountains and between the Dona Ana Mountains and Tortugas Mountain or, in general, southward and into the Rio Grande Valley.

Considering the postulated movement between San Diego Mountain and the Selden Hills and between the Selden Hills and the Dona Ana Mountains, recent field work and better subsurface control indicate that the ground water does not go through the areas of these surface topographic breaks, but, rather, flows northwestward parallel to the uplift barrier and into the area between San Diego Mountain and the Rincon Hills. In that area there is movement of ground water into the Rincon Valley.

In the T22 and 23S area of the Southern Jornada del Muerto, the ground-water movement is characterized by components of flow into the Mesilla Valley and also, by northwestward movement. Near the center of T22S, R2E, there is a possible steep gradient in the water table. Ground-water movement is westward to southwestward into the Mesilla Valley near Las Cruces. In the east half of T22S,R2E, and in most of

T22S,R3E, the postulated direction of movement is to the northwest. Thus, there is a ground water divide along a line roughly from Goat Mountain southeastward to Fillmore Canyon. It is believed that a gap in the buried bedrock barrier is present in this area, and that Fillmore Canyon alluvial fan materials form the aquifer. The dashed ground-water contour lines are drawn largely on the basis of the surface topography of the alluvial fan, because there are no wells for control south of the U. S. Highway 70 region in the south half of T22S,R3E, in the north half of T23S,R3E, in the northeast part of T23S,R2E, and in the southeast part of T22S,R2E. The postulated steep gradient is a reflection of the relatively low permeability of the alluvial fan sediments.

In the southern Jornada del Muerto east of the barrier region there is ground-water inflow westward from the Organ and San Andres Mountains. In addition there is flow from the San Diego Mountain-Selden Hills-Dona Ana Mountain uplift area eastward into the Jornada. The flow in the Jornada then goes northwestward to the outlet area into the Rio Grande Valley between San Diego Mountain and the Rincon Hills.

It should be noted that the chemical quality of Jornada del Muerto ground water supports the contention that the movement is northwestward. Sulphate content of the ground water, largely derived from the San Andres Mountain gypsum deposits, builds up from a very low parts per million figure in wells near U. S. Highway 70 to a much higher figure in wells farther north into the Jornada. The contrast, between 33 ppm sulphate in the J. W. Daugherty well (22.2E.13.411) and the 1568 ppm sulphate in the USDA Jornada Range Middle well (19.2E.33.123) is an example of the difference in sulphate content.

The northwestward slope of the water table in the Southern Jornada del Muerto is at a low gradient of 65 feet in approximately 27 miles. The low gradient is probably due to a combination of a high base level control of the flow system and good permeability of basin fill.

The steep ground-water gradient in the north half of T22S,R3E and T21S,R3E, near Organ, is due to the fact that bedrock is at a very shallow depth in a belt 3 miles wide adjacent to the mountain front.

Ground-water Conditions in the Mesilla Bolson East of the Mesilla Valley

There is a narrow zone of piedmont slopes east of the Mesilla Valley which includes the slopes of the Organ and Franklin Mountains and Bishop's Cap. While there is little subsurface control in the region, it is clear that the ground-water movement is into the Mesilla Valley.

The Fillmore Pass area, T25S,R3E and R4E, presents an interesting problem. Logs of wells K13 and K14 (Knowles and Kennedy, 1956) indicate at least 550 feet of saturated basin-fill material below the water table. Although it is possible that ground water flows from the Mesilla Bolson into the Tularosa Basin in this area, the water table through the Pass is nearly flat. There may be a ground-water divide. Since ground elevations on the west side of the pass are estimated from topographic maps, enough error is present to prevent the precise definition of the possible ground-water divide. Water quality studies and surveyed well elevations will be necessary to answer this question. At the present time, one gravel-packed irrigation well (25.3E.12.410) is being used to irrigate a portion of the south half of Section 12, but no reliable drawdown or production information is available.

Ground-Water Conditions in the Mesilla Valley of the Mesilla Bolson

In the Mesilla Valley south of the Dona Ana Mountains the water table under the floodplain is generally higher than the water table under the adjacent valley slopes. This fact is made particularly noticeable by observation of ground-water troughs in the area east of Las Cruces in T23S,R2E, in the area east of Anthony in T26 and 27S,R3 and 4E, and in the area northwest of Anapra in T27 and 28S,R2 and 3E. It is felt that the trough areas cited are not due to excessive pumpage but probably represent very permeable zones in the valley and basin-fill aquifers. The ground-water table configuration is probably due to a combined effect of irrigation water return seepage and hydrogeologic properties that have not been evaluated in detail.

In light of the statements above, it should also be mentioned that the water-level figures for the Mesilla Valley are from January and February measurements (table 1), which are maximum values in dry years and minimum values in wet years (Spiegel, 1958). All of the water-table figures for the Mesilla Valley represent water-table conditions in the shallow aquifer, while the figures for the adjacent mesa areas represent water in Santa Fe group aquifers. In the New Mexico part of the Mesilla Valley, wells have not penetrated the deep Santa Fe group aquifer, which is artesian in the Texas portion of the Valley, and few of the wells have penetrated deeply into the medium aquifer. Consequently, the water-level measurements represent unconfined-aquifer conditions.

Ground-Water Conditions in La Mesa Portion of the Mesilla Bolson

On La Mesa there are two features shown on the water-table-contour map which should be mentioned. These features are the southeastward projecting nose in the 3820 through 3760 contours in T25,26 and 27S,R2 and 3E, and the ground-water mound centered in T27 and 28S,R1W and R1E.

The trend of the nose is possibly indicative of a combination of more abundant recharge and lower permeability at the edge of La Mesa adjacent to the Mesilla Valley.

It is possible that the mound could be extended farther to the northwest on plate 1, but subsurface control in that area is too sparse to allow projection of contour lines. The explanation for the ground-water mounding must be related to Kilbourne, Hunt's and Phillip's Holes, which are volcanic explosion craters. However, the three depressions have but small drainage basins and catch but little precipitation. In addition, Kilbourne and Hunt's Holes have high rims which prohibit nearby precipitation from entering the holes by surface flow. On the other hand, the mound area on the water-table-contour map does closely approximate the total area of the drainage basin of the three holes.

Since the volcanic eruptions took place in mid-to-late Pleistocene, there could be communication with deeply buried rocks which serve as aquifers. For example, rock units from the nearby Potrillo Mountains may dip under the holes and be conveying water to them, perhaps under artesian conditions. Reiche (1941) reported thermal ground water in a well drilled in the Kilbourne Hole depression. It is believed that a study of the chemistry of the ground water of the mound region and adjacent areas would shed light on the character of the aquifer-soil-atmosphere system that causes the mounding.

Mountains and Basins West of the Mesilla Bolson

The ground-water divide in this area is along Mason Draw and, southward,is inferred to be along the West Potrillo Mountains.

At the south end of Mason Draw there is a ground-water mound which is caused by recharge from the drainage basin of the draw. There is a component of movement from the south end of Mason Draw which is directed to the southeast through the gap between the Aden Hills and the West Potrillo Mountains. The remainder of the ground water moves southwestward into the Mimbres Basin.

West of the East Potrillo Mountains in T27,28 and 29S,R2,R3 and 4W there is ground-water movement into Chihuahua.

CONCLUSIONS

The ground water systems of the area of investigation should be considered under two separate headings (a) the Rio Grande Valley and (b) the adjacent upland areas.

The aquifers of the Rio Grande Valley are capable of high yields and represent a precious resource for New Mexico. While the Southern Palomas Basin and Rincon-Fort Selden portions of the Valley have only a shallow alluvial aquifer, it is possible that the New Mexico portion of Mesilla Valley has a great aquifer thickness similar to that which is found in the Texas portion of the Valley.

The upland areas have highly variable ground-water conditions as discussed in the foregoing text. In general, the wells do not produce as much water as the valley wells because of less permeable aquifer beds. However, there are many areas on the uplands that have been only sparsely drilled, and more-transmissive aquifers may be present locally.

RECOMMENDATIONS FOR FURTHER STUDIES

The following recommendations are made for future study:

1. That the ground water of the Southwestern Palomas Basin, Rincon-Fort Selden Valley and Mesilla Valley aquifers be continuously monitored for water-level and quality data. As previously stated, a start has been made on this project by the United States Geological Survey and the State Engineer's Office. This project should be continued and expanded.

2. Deep test wells should be drilled in the Mesilla Valley to determine whether the medium and deep aquifers, that are yielding abundant quantities of water in the Texas portion of the Valley, are present and what the ground-water quantity and quality is.

3. In many parts of the investigation area, like the City of Las Cruces well fields, quantitative studies involving aquifer tests would be very useful and should be conducted.

4. A study of the Fillmore Pass area is recommended in order to determine whether there is ground-water communication between the Mesilla Valley and the Hueco Bolson.

5. An interesting, but not particularly pressing, problem is the nature of the recharge to the ground-water mound on La Mesa in T27 and 28S,R1W and R1E. A geochemical and water-temperature study in this region would be interesting.

RECOMMENDATIONS TO WELL DRILLERS AND CONSUMERS

The following recommendations are made to well drillers and persons planning to have wells drilled:

1. A small diameter test hole is recommended in every part of the study area in order to evaluate the aquifer system before a production well is drilled. Even in the Mesilla Valley, there is the chance of getting poor production or very poor quality of water.

2. Geological sample and mechanical geophysical logs, like electric logs, should be run in all of the test holes for proper evaluation of the aquifers.

3. The wells must be properly tested and completed for maximum production and, in many cases, to prevent the pumpage of abrasive sand. A good example of fine completion techniques is afforded by the gravel-pack technique used by the City of El Paso for wells completed in the fine sand of the Santa Fe group aquifers.

4. Great care must be exercised when an attempt is made to obtain an irrigation well on the upland areas. The results of such ventures have been, with a few exceptions, very disappointing. Should such an attempt be contemplated, a thorough study of the area is recommended prior to drilling the test hole. After a test hole is drilled, it should be very carefully logged, tested and evaluated before a large diameter well is drilled.

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TABLE 1

RECORDS OF WELLS IN THE RIO GRANDE VALLEY AND ADJACENT INTERMONTANE AREAS OF SOUTHERN NEW MEXICO

EXPLANATION

Location Number: See text for explanation of well-numbering system.

Altitude: Altitude of land surface at well, above mean sea level. Most altitudes interpolated from topographic maps. Altitudes of Bureau of Reclamation wells from Ground-Water Levels in New Mexico, Busch and Hudson (1965), for Mesilla Valley. Altitudes interpolated from topographic maps for USBR wells in Rincon Valley and wells in Noria-Strauss Area.

Depth of Water Level Below Land Surface: All depths measured to the nearest foot by authors, unless otherwise noted in remarks column. USBR and Noria-Strauss wells measured by government personnel, Busch and Hudson (1965 and 1966).

Altitude of Water Level: Measured and reported altitudes are given to the nearest foot. Probable accuracy: a. ± 0.51; b. ± 2.5'; c. ± 5'; d. ± 10'.

Source Material: A - Late quaternary valley-fill alluvium; B - Santa Fe group and Gila group basial fill; V - tertiary volcanics and associated sedimentary rocks; S - sedimentary rocks; I - igneous intrusives and associated metamorphic rocks.

Depth: From drillers' logs, owners' records, USGS and other publications.

Principal Use of Water: C, commercial; D, domestic; I, irrigation; N, none; O, Observation; PS, public supply; S, stock.

Remarks: All wells are drilled unless otherwise indicated in remarks column. Ca indicates that there is a chemical analysis for that well in Table 2. SWL indicates static water level.

Well Location	Owner	Approximate Altitude Above Sea Level (feet)	Depth of Water Level Below Land Surface (feet)	Altitude of Water Level (feet)	Date of Measurement	Source Material	Depth	Use of Water	Remarks
17.2E.33.200	Mr. Hille	4800	564	4236d	5-18-68	B?		S	Sand well.
18.2W.11.440	Neil Graham	4325	282	4043b	5-18-68	B?		S	Point of Rocks well.
18.2W.35.112	W. A. Winder	4179	152	4027b	1950	B		S	SWL from owner.
18.2W.36.322	W. A. Winder	4380	364	4016b	1-30-68	B		D,S	Ranch house well.
18.1E.7.223	Neil Graham	4360	267	4093b	5-18-68	B		D,S	Flat Lake Ranch, Hdqtrs. well.
18.1E.27.432	USDA - Jornada Range	4320	234	4086b	12-28-67	B	350	S	Red Lake well.
19.4W.29.130	Homer Jones	4489	160	4329a	1-30-68	B	180	S	
19.3W.32.200	Unknown	4515	28	4487c	6-20-68	A?			Well in canyon with bedrock near.
19.1W.22.122	W. A. Winder	4350	322	4028b	1-30-68	B		S	South Well.
19.1E.1.222	USDA - Jornada Range	4310	210	4100c	12-27-67	B	350	S	Middle well; Ca.
19.1E.16.240	USDA - Jornada Range	4380	306	4074c	12-28-67	B		S	Wagoner well.
19.2E.2.210	USDA - Jornada Range	4500	337	4163c	12-29-67	B		S	Turney well.
19.2E.33.123	USDA - Jornada Range	4330	267	4063c	12-26-67	B		D,S	Hdqtrs. Well West; Ca.
19.3E.19.120	USDA - Jornada Range	4500	229	4271c	12-29-67	B		S	Wooten well; Ca.
20.4W.6.210	Homer Jones	4513	119	4394a	1-30-68	B	160	S	
20.4W.7.320	Unknown	4550	177	4373b	6-20-68	B		S	
20.4W.20.132	O. L. Hilburn	4650	192	4458a	1-30-68	B		S	
20.4W.22.440	Unknown	4980	146	4834b	6-20-68	B?		S	
20.3W.4.320	Unknown	4710	18	4692c	6-20-68	A?		S	In canyon with bedrock near; tuff with basalt dike.

TABLE 1 (continued)

Well Location	Owner	Approximate Altitude above Sea Level (feet)	Depth of Water Level Below Land Surface (feet)	Altitude of Water Level (feet)	Date of Measurement	Source of Material	Depth	Use of Water	Remarks
22.2E.23.114	Charles Spaulding	4390	310	4080c	4-22-67	B	590	C,D	Spaulding Auto Parts Yard well; Ca. SWL from Schieffer Drilling Co.
22.2E.23.122	Chevron Pipeline Co.	4410	330	4080b	7-22-68	B	615?	C	SWL fr. Schieffer Dr.Co.
22.2E.28.3334	Mrs. Ernest Bruce	4230	370	3860c	3-14-62	BV?	502	D	SWL fr. owner,pump test.
22.2E.29.424	Vernon Krebs	4290	420	3870c	4-23-65	BV	485	D	SWL fr.Schieffer Dr.Co.
22.2E.30.331	E. J. Wescott	4025	147	3878c		B	264	D	SWL fr. " " "
22.2E.31.444	City of Las Cruces	4075	217	3858	8-5-65	B	650	P,S	Well No. 23; Ca.
22.3E.1.131	Lynn Wooley	5130	158	4972c	12-22-67	I		D	Lynn's Pawn Shop well
22.3E.1.132	Shell Oil Station	5160	130	5030c	12-21-67	I		C	
22.3E.7.444	Sam Osburn	4530	424	4106b	12-22-67	B		N	Hanger Lake well, West
22.3E.9.3222	M.C. Higgins	4640	564	4076b	7-27-68	B	634	P,S	Butterfield Park well.
22.3E.11.321	George A. Martin	4890	73	4817c	12-21-67	S?	204	S	
22.3E.23.321	George A. Martin	4930	133	4797c	12-22-67	B?	204	S,D	E.J. Isaac's Ranch well
23.4W.18.111	George W. Burris	4410	14	4396d	1-29-68	A	18	S,D	Ranch Hdqtrs. well.
23.4W.19.120	George W. Burris	4410	28	4382d	1-29-68	B?		S	
23.4W.26.441	Corralitos Ranch	4360	80	4280b	3-16-68	BV?	200	S	Mimms' well.
23.3W.20.432	Corralitos Ranch	4404	56	4348b	3-16-68	BV?		S	Temple well, East.
23.2W.13.330	Corralitos Ranch	4432	134	4298b	2-17-68	B		I	Ranch hdqtrs Irr. well.
23.2W.23.341	Corralitos Ranch	4458	158	4300c	3-16-68	B?	177	S	Horse Trap well.
23.2W.27.334	Corralitos Ranch	4465	151	4314c	3-16-68	BV?	172	S	Little Gap well.
23.1W.31.444	Dona Ana County	4440	420	4020d			1200+	N	Could not measure well; SWL is from electric log.
23.1E.1.413	Willard Smith	3901	36	3865c	6-24-65	A	158	D	SWL fr.Schieffer Dr.Co.
23.1E.20.213	Joella Lackey	4055	171	3884c	7-3-67	B	299	D	
23.1E.30.212	Unknown	4180	305	3875b	6-6-68	B	330	N	Jack Rabbit ranch
23.2E.5.113	City of Las Cruces	4070	212	3858c	1965	B	682	P,S	Well No. 22; Ca.
23.2E.6.311	Joe Yost	3945	75	3870c	8-11-65	B	201	D	SWL fr. Schieffer Dr.Co.
23.2E.6.331	P.T. Gonzales	3935	66	3869c	12-2-65	B	207	D	SWL " " " "
23.2E.7.211	City of Las Cruces	3945	78	3867b	1965	B	360	P,S	Well No. 11; Ca.
23.2E.7.412	City of Las Cruces	3935	63	3872b	1965	B	381	P,S	Well No. 10; Ca.
23.2E.8.433	City of Las Cruces	4040	192	3848b	1965	B	632	P,S	Well No. 18; Ca.
23.2E.9.221	City of Las Cruces	4110	245	3865b	1965	B	630	P,S	Well No. 17; Ca.
23.2E.9.311	City of Las Cruces	4080	232	3848b	1965	B	682	P,S	Well No. 21; Ca.
23.2E.9.331	City of Las Cruces	4060	208	3852b	1965	B	675	P,S	Well No. 19; Ca.
23.2E.16.121	City of Las Cruces	4080	228	3852b	1965	B	680	P,S	Well No. 20; Ca.
23.2E.16.133	City of Las Cruces	4030	204	3826b	12-65	B	500	P,S	Well No. 24.
23.2E.20.233	City of Las Cruces	3980	124	3856b	1965	B	283	P,S	Well No. 8; Ca.
23.2E.21.223	City of Las Cruces	4080	212	3868b	1965	B	420	P,S	Well No. 12; Ca.
23.2E.21.241	City of Las Cruces	4080	218	3862b	1965	B	393	P,S	Well No. 9; Ca.
23.2E.22.331	NMSU	4065	230	3835c	1965		607	I	Golf Course well.
23.3E.3.232	A. B. Cox	5080	41	5039b	9-14-68	B		S	
23.3E.20.222	Andrew M. Babey #1	4580	181	4399c	1-7-67	B	285	N	
23.3E.21.312	A. B. Cox	4592	175	4417a	9-27-66	B		S	Jesse Windmill well
23.3E.27.400	A. B. Cox	4760	144	4616b	9-14-68	B		S	South well.
24.5W.1.440	Joe Garcia	4270	111	4159d	1-29-68	BV?		D,S	Home well.
24.5W.13.222	Joe Garcia	4230	129	4101d	1-29-68	BV?		S	
24.4W.12.412	Joe Garcia	4315	90	4225b	3-3-68	BV?		S	Biggs well.
24.4W.24.420	Joe Garcia	4270	69	4219b	6-6-68	BV?		S	
24.3W.4.420	Corralitos Ranch	4355	356	3999b	3-16-68	BV?	366	S	Brass Ranch well
24.3W.6.444	Corralitos Ranch	4335	76	4259b	3-16-68	V	262	S	Mason Draw well
24.3W.17.440	Roderick Land & Cattle Co.	4315	227	4088b	6-6-68	BV?		S	

TABLE 1 (continued)

Well Location	Owner	Approximate Altitude above Sea Level (feet)	Depth of Water Level Below Land Surface (feet)	Altitude of Water Level (feet)	Date of Measurement	Source Material	Depth	Use of Water	Remarks
20.1W.10.424	New Mexico State University Ranch	4340	305	4035b	5-18-68	B	320	S	
20.1W.23.300	New Mexico Hwy. Dept.	4310	295	4015c	12-30-67	B	400	P,S	Ft Selden Rest Stop well.
20.1E.4.121	USDA - Jornada Range	4317	274	4043b	12-28-67	B	390	S	West well.
20.1E.14.144	USDA - Jornada Range	4363	318	4045b	12-28-67	B	356	S	Co-Op well.
20.1E.35.221	NMSU Ranch	4350	275	4075	12-29-67	B	373	D,S	Ranch Hdqtrs. well; Ca; SWL from manager.
20.2E.28.334	USDA - Jornada Range	4310	248	4062b	12-28-67	B	365	S	South well; Ca.
20.2E.35.113	J. A. Brown	4315	258	4057c	1965	B	700	I	Well # 1.
20.2E.35.244	J. A. Brown	4335	270	4065c	1965	B	790	I	Well # 2.
20.3E.12.332	NASA-Apollo Test Facility	4925	143	4782a	5 - 1963	S	1321	N	Test hole D; Ca.
20.3E.15.422	NASA-Apollo Test Facility	4735	212	4523a	5-19-63	SV?	578	N	Test hole G; Ca.
20.3E.16.233	NASA-Apollo Test Facility	4587	272	4315a	5 - 1963	VB?	1445	N	Test hole H; Ca.
20.3E.30.333	NASA-Apollo Test Facility	4400	315	4085a	5 - 1963	B	826	C,D	Well I; Ca.
20.3E.31.322	NASA-Apollo Test Facility	4410	334	4076a	5 - 1963	B	850	C,D	Well J; Ca.
21.2W.6.214	Unknown	4520	13	4507c	5-4-68	A		S	Hersey Place Well.
21.2W.31.432	Corralitos Ranch	4720	129	4591c	2-17-68	V	180	S	Adobe Ranch well; Andesite-Breccia outcrop near well.
21.1W.13.230	NMSU Ranch	4025	67	3958b	5-18-68	B?		S	E - side I-25.
21.1W.20.231	Shaw and McCall Ranch	4160	9	4151c	5-4-68	A?		S	Tuff & andesite in canyon near well.
21.1W.30.440	Unknown	4325	19	4306c	5-4-68	A?		S	Faulkner canyon.
21.2E.11.324	J. L. Smith	4305	247	4058c	1962	B		I	Measurement from Parson Co., Apollo Site Report; Ca.
21.2E.12.222	Unknown	4375	304	4071b	12-22-67	B	631	N	Parker well.
21.2E.25.433	W. F. Isaacs	4362	290	4072b	1962	B	342	D,S	Water level from Parsons Apollo Site Report; Ca.
21.3E.4.211	NASA-Apollo Test Facility	4590	360	4230a	5 - 1963	VB	1011	N	Test hole C; Ca.
21.3E.19.333	J. H. Creegan	4385	320	4065c	12-22-67	B		D	
21.3E.33.1222	Edsel MacArthur	4645	560	4085b	7-27-68	B	700	D	
22.4W.10.231	G. W. Burris	4815	260	4555b	1-29-68	BV?	383	S	Monterey well.
22.4W.30.120	G. W. Burris	4600	79	4521d	1-29-68	BV?	224	S	
22.3W.16.343	Corralitos Ranch	4605	12	4593b	3-16-68	V?	75	S	Little Mills well, South
22.3W.35.130	Corralitos Ranch	4545	12	4533b	2-17-68	BV?		S	Chandler tank well, close to small lake; 2 volcanic hills less than .5 mile to south.
22.2W.21.334	Corralitos Ranch	4615	239	4376b	2-17-68	BV?	280	S	Big Gap well.
22.1W.19.300	Corralitos Ranch	4460	144	4316c	2-17-68	B	180	S	Hawkins Ranch well.
22.1E.24.222	Fred Lemon, Jr.	4170	185	3985c	4-28-67	B	390	D	
22.1E.25.233	Edward Estrada	4000	79	3921c	9-15-65	B	223	D	SWL from Schieffer Drilling Co.
22.1E.25.413	C. A. Kennedy	3965	58	3907c	12-15-64	B	215	D	SWL,Schieffer Drl.Co.
22.1E.25.443	M. B. Brooks	4000	90	3910c	3-26-65	B	347	D	SWL,Schieffer Drl.Co.
22.2E.11.440	J. F. Apodaca	4410	315	4095c	12 - 1967			N	
22.2E.13.411	J. W. Daugherty	4453	375	4078c	3-26-48	B	430	D	C.S.Conover water level measurement; Ca.
22.2E.14.424	20th Century Fox	4430	348	4082b	10-11-63		770	N	
22.2E.15.143	George Garcia	4355	278	4077c	2-3-68	BV	850		Log in Table 3.
22.2E.21.123	C. E. Smith	4340	475	3865b	8 - 1966	BV	900?	D	SWL from owner.
22.2E.21.1244	Mr. Bethany	4340	478	3862b	7-27-68	BV		D,S	

TABLE 1 (continued)

Well Location	Owner	Approximate Altitude Above Sea Level (feet)	Depth of Water Level Below Land Surface (feet)	Altitude of Water Level (feet)	Date of Measurement	Source Material	Depth	Use of Water	Remarks
24.3W.25.234	Roderick Land & Cattle Co.	4565	195	4370c	2-3-68	V		S	Aden Wells, E. well.
24.1W.5.110	Roderick Land & Cattle Co.	4400	381	4019d	6-6-68	B		S	Windmill SE of U.S. Army Radar Station Well 23.1W.31.440
24.1W.22.123	Jack Arrington	4220	320	3900c	2-3-68	B		S	Norwood Ranch well.
24.1W.25.440	A.W. Moore	4220	371	3849b	4-12-68	B		S	
24.1E.7.440	V. W. Bilbo	4210	324	3886b	4-12-68	BV?		N	Federal Boles Oil Test well
24.2E.9.132	Hanes Knitting Mill	3860	20	3840b	4-10-65	B	510	C	
24.2E.33.141	Stahmann Farms	3845	19	3826b	5-28-67	B	147	C	Plaza Pecan Plant well.
25.4W.3.343	Johnson Bros. Ranch	4220	183	4037c	6-11-68	B	200	S	O. D. North well.
25.4W.15.330	Johnson Bros. Ranch	4165	138	4027c	6-11-68	B	222	S	O. D. South well.
25.4W.34.300	Johnson Bros. Ranch	4220	205	4015c	6-11-68	B		S	
25.3W.2.214	Edward Arrington	4480	391	4089b	2-3-68	VB?	527?	S	Aden Station well.
25.3W.8.210	Johnson Bros. Ranch	4360	202	4158c	6-12-68	VB?	296	S	Cinder Mine well.
25.2W.5.310	Edward Arrington	4425	124	4301c	5-11-68	VB?		S	
25.2W.9.440	Edward Arrington	4315	480	3835b	5-11-68	B		N	
25.2W.30.323	Johnson Bros. Ranch	4285	217	4068		B	217?	D	Ranch Hdqtrs. well; SWL from owner.
25.1W.16.330	Jack Arrington	4226	395	3831b	5-11-68	B		S	
25.1E.21.331	El Paso Nat'l Gas Co.	4230	410	3820c		B	586	C	Afton Turbine Station well; SWL fr.Co.records.
25.2E.28.221	Leo Nunn Ranch	3935	107	3828b	4-15-68	B	120	S	Babcock well.
25.2E.31.133	Leo Nunn Ranch	4173	380?			B	360	S	Stevens well; SWL fr.owner.
25.3E.12.410	Alfred Masters	4209	395	3814b	12-28-68	B		N	6" well near irrigation well measured.
25.3E.22.121	Paul Price	3985	170		12-30-68	B	185	N	Hutchins well.
25.4E.11.140	U. S. Army	4077.4	330	3747a	1-68	B	798	D	Well K-15; SWL fr. USGS.
25.4E.17.444	U.S.Geological Survey	4167.7	351	3816a	1-68	B	902	N,O	Test Well K-14; SWL from U.S.G.S.
25.4E.18.244	U.S.Geological Survey	4200.1	384	3816a	1-68	B	977	N,O	Test Well K-13; SWL from U.S.G.S.
25.4E.35.120	U.S.Geological Survey	4102.3	357	3745a	1-68	B	1085	N,O	Test Well K-16; SWL from U.S.G.S.
26.4W.6.400	Johnson Bros. Ranch	4190	141	4049d	6-11-68	B?		D,S	
26.4W.14.100	Johnson Bros. Ranch	4540	497	4043d	6-11-68	BV?	685	S	Tub well
26.4W.28.300	Johnson Bros. Ranch	4390	295	4095d	6-11-68	BV?	390	S	Sweet water well.
26.2W.15.440	Johnson Bros. Ranch	4250	420	3830c	6-7-68	B	437	S	Johnson stockade well.
26.2W.17.210	Johnson Bros. Ranch	4270	445	3825b	6-7-68	B		S	Tub well, South
26.1W.16.330	Johnson Bros. Ranch	4210	385	3825c	6-7-68	B	435	S	Norwood well, in malpais of Aden basalt flow
26.1E18.222	Leo Nunn	4212	395	3817b	6-25-68	B	440	D,S	
26.1E.35.330	R. A. Gardner	4160	358	3802c	6-25-68	B		S	Water well for Texaco, S.H. Weaver Oil Test.
26.2E.17.240	R. A. Gardner	4125	322	3803c	6-25-68	B	340	S	
26.2E.24.140	Gates Cyclo International	3960	174	3786c	8-67	B	460	C	
26.2E.32.330	R. A. Gardner	4130	330	3800b	6-27-68	B		S	
26.2E.2.341	N.Mex.Highway Department	3890	91	3799c	3-68	B	718	D	Berino Port of Entry
26.3E.25.431	Wholesome Dairy B & K feedlot	3875	118	3757b		B	366	D	Domestic well, South; SWL from Co. records.
26.4E.19.130	W. F. Blythe	3990	179	3811b	6-24-68	B?		S	
26.4E.24.244	W. F. Blythe	4185	384	3801a	6-26-68	S	520	S	Jessie Well
27.4W.27.200	P. O. L. Ranch	4575	546+	4030d	6012-68	VB?		S	Water deeper than 546'; could not reach static water with tape.

TABLE 1 (Continued)

Well Location	Owner	Approximate Altitude Above Sea Level (feet)	Depth of Water Level Below Land Surface (feet)	Altitude of Water Level (feet)	Date of Measurement	Source Material	Depth	Use of Water	Remarks
27.2W.14.440	S. J. Macias	4175	369	3806c	4-15-68	B		I	
27.1W.26.400	S. C. Carver & A. Gardner	4095	215	3880b	6-8-68	B	314	S	Phillips Hole well.
27.1E.33.200	S. C. Carver & A. Gardner	4155	309	3846b	6-8-68	B	453	N	
28.5W.12.114	P. O. L. Ranch	4190	301	3889b	6-12-68	B		S	Good Luck well.
28.4W.32.412	Homer Bennette	4247	376	3871a	6-27-68	VB?		S	Red Windmill
28.3W.15.111	Homer Bennette	4355	489	3866c	6-27-68	VB	500+	S	Mt. Riley Ranch, North well.
28.3W.33.400	Homer Bennette	4170	269	3901d	5-13-68	VB?		S	
28.1W.7.110	Unknown	4120	309	3811b	6-8-68	B		I	
28.2E.31.340	Frank Stewart	4100	307	3793c	4-11-68	B	400	D,S	Herrington's Lower Ranch well.
28.3E.34.331	Southern Pacific R.R. Co.	4000	236	3764c	6-21-66	B	1004	C	Lizard well, North.
29.4W.18.220	M. Beck	4004	128	3876b	5-13-68	B?		S	Birchfield Ranch well.
29.3W.13.300	Homer Bennette	4060	191	3869c	5-13-68	B		S	Mt. Riley Ranch well.
29.2W.6.230	Southern Pacific R.R. Co.	4109	265	3844b	6-27-68	B	715	N	Mt. Riley Station.
29.2W.15.200	Homer Bennette	4040	195	3845c	4-11-68	B		S	Pancho well.
29.1E.6.111	Frank Stewart	4130	327	3803b	5-13-68	B	400	N	Herrington's Home Ranch well.
29.1E.8.200	Frank Stewart	4125	334	3791b	4-11-68	B	565	S	Noria Station well.

RECORDS OF UNITED STATES BUREAU OF RECLAMATION TEST WELLS, RINCON VALLEY, JANUARY, 1966, IN FEET BELOW TOP OF CASING

17.5W.24.124	USBR Well No. 10	4130	14.3	4116	1-66	A		O	
18.4W.05.313	USBR Well # 1	4110	15.7	4094	1-66	A		O	
18.4W.17.422	USBR Well # 9	4095	14.4	4081	1-66	A		O	
18.4W.35.111	USBR Well # 2	4080	13.7	4066	1-66	A		O	
19.2W.08.333	USBR Well # 4	4034	8.8	4025	1-66	A		O	
19.2W.22.143	USBR Well # 5	4017	9.4	4008	1-66	A		O	
19.3W.07.131	USBR Well # 8	4065	12.0	4053	1-66	A		O	
19.3W.09.413	USBR Well # 3	4057	8.2	4049	1-66	A		O	
19.3W.13.132	USBR Well # 7	4040	10.8	4029	1-66	A		O	
20.2W.01.124	USBR Well # 6	4007	10.8	3996	1-66	A		O	

RECORDS OF UNITED STATES BUREAU OF RECLAMATION TEST WELLS, MESILLA VALLEY, JANUARY 1965, IN FEET BELOW LAND SURFACE DATUM

22.1E.9.232	USBR Well # 26	3934	13.5	3921	1-65	A		O	Railroad
22.1E.9.333	USBR Well # 20	3928	11.0	3917	1-65	A		O	Nakayama
22.1E.16.433	USBR Well # 19	3925	12.6	3912	1-65	A		O	Shalem
22.1E.33.324	USBR Well # 15	3900	11.2	3889	1-65	A		O	North Picacho
22.1E.35.334	USBR Well # 18	3910	18.1	3892	1-65	A		O	Baker
22.1E.35.443	USBR Well # 17	3912	18.9	3893	1-65	A		O	Las Cruces
23.1E.9.344	USBR Well # 16	3900	12.0	3888	1-65	A		O	Swader
23.1E.16.444	USBR Well # 12	3890	14.6	3875	1-65	A		O	School
23.1E.28.442	USBR Well # 11	3884	8.0	3876	1-65	A		O	Dicks
23.2E.8.443	USBR Well # 13	3866	16.7	3849	1-65	A		O	Salome
24.2E.9.433	USBR Well # 14	3865	15.6	3849	1-65	A		O	Seale
24.2E.23.134	USBR Well # 10	3850	13.0	3837	1-65	A		O	Carpenter
24.2E.23.342	USBR Well # 9	3852	13.9	3838	1-65	A		O	Brazito
24.2E.33.112	USBR Well # 8	3851	13.3	3838	1-65	A		O	Santo Tomas
24.2E.1.441	USBR Well # 25	3833	12.6	3820	1-65	A		O	Sweet

TABLE 2

CHEMICAL ANALYSES OF WATER FROM WELLS IN THE RIO GRANDE VALLEY AND ADJACENT INTERMONTANE AREAS OF SOUTHERN NEW MEXICO

(Analyses by New Mexico Department of Public Health (NMDPH); Terminal Testing Laboratories, Inc. (TTL), as noted in each case in remarks column. Chemical constituents in parts per million, unless otherwise stated.)

EXPLANATION

Location: See text for description of well-numbering system.

Footnotes: Footnotes appear at end of Table.

Owner or Name: The owner or name of the well at the time of the sampling visit.

Abbreviations Used: RSC, residual sodium carbonate; ALK, Alkalinity; B, boron; Mn, manganese; Al, aluminum

Location	Owner or Name	Date Collected	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na) and Potassium (K)	Sodium (Na)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulphate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids - Parts per million	Hardness as $CaCO_3$ Calcium-Magnesium	Hardness as $CaCO_3$ Non-Carbonate	Percent sodium	Sodium absorption ratio	Specific conductance (micromhos at 25°C)	pH	Remarks
19.1E.1.222	USDA - Jornada Range, Middle Well	9-7-62	29	-	232	224	149	131	93	0	1568	53	.4	0	2073	1500	-	-	-	2610	7.2	TTL; B 1.14
19.3E.19.120	USDA - Jornada Range, Wooten Well	9-7-62	5	-	400	7	139	135	138	0	1061	102	.8	0	1680	1030	-			2158	7.1	TTL; B .38
19.2E.33.123	USDA - Jornada Range, Hdqtrs. Well	9-7-62	6	-	60	35	61	56	119	0	277	22	.3	4	585	295	-	-	-	845	7.4	TTL; B . .
20.1E.35.221	New Mexico State Univ. Ranch, Hdqtrs. Well	9-7-62	20	-	32	18	100	95	159	0	194	20	.3	2	510	154	-	-	-	712	7.55	TTL; B .01
20.2E.28.334	USDA - Jornada Range, South Well	11-10-64	-	.26	112	51	160	152	89	0	690	22	1.0	2.7	1235	490	-	-	-	1430	8.2	NMDPH; Mn 0 Alk 89
20.2E.28.334	USDA - Jornada Range South Well	9-7-62	13	-	105	54	177	168	113	0	689	28	1.0	15	1130	483	-	-	-	1534	7.55	TTL; B .8
20.2E.35.113	Brown Ranch	11-10-64	-	.10	55	36	97	93	142	6	274	45	.55	6.6	665	285	-	-	-	935	8.4	NMDPH; Alk 148; Mn 0
20.2E.35.140	J. A. Brown	9-7-62	13	-	50	36	103	100	191	0	256	46	.6	6	675	276	-	-	-	950	7.6	TTL; B .02
20.3E.12.332	NASA Apollo Test Facility, Well D	1 - 63	10	.15	122	18	-	500	190	0	658	168	1.1	-	1750	267	-	-	-	-	7.5	TTL; Al 4
20.3E.15.422	NASA Apollo Test Facility, Well G	2 - 63	10	.05	140	116	-	300	216	0	562	122	1.4	-	1487	630	-	-	-	-	8.5	TTL; Al 9
20.3E.16.233	NASA Apollo Test Facility, Well H	3 - 63	-	.05	-	-	-	-	99	0	713	110	2.1	-	-	340	-	-	-	-	-	TTL
20.3E.18.210	USDA - Jornada Range, Taylor Well	9-7-62	10	-	116	67	185	182	183	0	584	143	1.0	20	1275	565	-	-	-	1780	7.35	TTL; B 1.21
20.3E.18.211	USDA - Jornada Range Taylor Well	11-10-64	-	1.2	119	67	171	167	136	5	595	124	1.15	19	1295	573	-	-	-	1700	8.4	NMDPH; Alk 141; Mn 0

TABLE 1 (continued)

Well Location	Owner	Approximate Altitude Above Sea Level (feet)	Depth of Water Level Below Land Surface (feet)	Altitude of Water Level (feet)	Date of Measurement	Source Material	Depth	Use of Water	
25.2E.4.132	USBR Well # 7	3840	15.3	3825	1-65	A		O	Duran
25.2E.23.221	USBR Well # 6	3827	13.6	3813	1-65	A		O	Dunn
25.2E.25.322	USBR Well # 5	3822	14.2	3808	1-65	A		O	Bartlett
25.3E.1.441	USBR Well # 24	3823	8.0	3815	1-65	A		O	Vado
25.3E.21.312	USBR Well # 4	3825	11.0	3814	1-65	A		O	Liberty
25.3E.33.122	USBR Well # 27	3815	12.6	3802	1-65	A		O	Anthony Lateral
26.3E.4.211	USBR Well # 21	3818	9.0	3809	1-65	A		O	Casita de Felix
26.3E.4.333	USBR Well # 23	3810	12.8	3797	1-65	A		O	Three Saints
26.3E.4.434	USBR Well # 22	3808	9.9	3798	1-65	A		O	Berino
26.3E.6.211	USBR Well # 3	3816	10.8	3805	1-65	A		O	Thalman
26.3E.15.112	USBR Well # 28	3802	8.9	3793	1-65	A		O	Price Road
26.3E.22.344	USBR Well # 32	3793	10.1	3783	1-65	A		O	McKamy
26.3E.22.443	USBR Well # 31	3795	7.9	3787	1-65	A		O	Campbell
26.3E.26.221	USBR Well # 30	3835	6.3	3829	1-65	A		O	Pool
26.3E.32.443	USBR Well # 39	3790	11.2	3779	1-65	A		O	High School
26.3E.35.333	USBR Well # 29	3785	8.6	3776	1-65	A		O	Anthony
27.3E.10.333	USBR Well # 38	3782	11.1	3771	1-65	A		O	Longwell
27.3E.28.332	USBR Well # 1	3772	13.9	3758	1-65	A		O	Casad Bridge
27.3E.32.122	USBR Well # 2	3779	14.1	3765	1-65	A		O	Old La Union
28.3E.11.130	USBR Well # 37	3757	8.9	3748	1-65	A		O	Borderland
28.3E.15.120	USBR Well # 36	3755	9.2	3746	1-65	A		O	Wade
28.3E.23.244	USBR Well # 35	3750	9.2	3741	1-65	A		O	Montoya
28.3E.24.342	USBR Well # 33	3748	10.0	3738	1-65	A		O	Mulberry
29.4E.6.244	USBR Well # 34	3738	6.9	3731	1-65	A		O	Boy Scout

RECORDS OF UNITED STATES GEOLOGICAL SURVEY MONITORED WELLS IN THE NORIA-STRAUSS AREA, JANUARY 1967

27.2E.25.111	Jesus Macias	4100	362	3738	1-66
28.1E.6.323	Ruben Alvarez	4154	294	3860	1-7-67
28.1E.6.333	Ruben Alvarez	4165	305	3860	1-7-67
28.1E.7.113	Gilbert Balch	4178	318	3860	1-7-67
28.2E.13.333	Unknown	4110	367	3743	1-7-67

TABLE 2 (continued)

Location	Owner or Name	Date Collected	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na) and Potassium (K)	Sodium (Na)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids - Parts per million	Hardness as $CaCO_3$: Calcium-magnesium	Hardness as $CaCO_3$: Non-carbonate	Percent sodium	Sodium absorption ratio	Specific conductance (micromhos at 25°C)	pH	Remarks
20.3E.30.333	NASA Apollo Test Facility, Well I	1-27-64	-	2.2	64	45	96	92	175	0	282	54	.65	13	715	345	-	-	-	975	7.8	NMDPH; Mn .12; Alk 175
20.3E.31.322	NASA Apollo Test Facility, Well J	1-27-64	-	7	61	46	62	58	180	0	208	47	.75	3	613	340	-	-	-	850	7.8	NMDPH;Mn .04; Alk 180
20.4E.17.400	Burke Spring	9-7-62	8	-	49	86	35	34	376	0	204	28	.3	7	740	480	-	-	-	987	7.35	TTL; B .48
21.2E.11.324	J. L. Smith	9-7-62	17	-	73	33	75	71	183	0	272	33	1.1	5	650	315	-	-	-	890	7.25	TTL; B 0
21.2E.25.433	W. F. Isaacks	9-7-62	14	-	26	25	66	62	198	0	90	29	1.0	2	425	167	-	-	-	586	7.85	TTL; B 0
21.3E.4.211	NASA Apollo Test Facility, Well C	4-63	25	.05	136	86	-	-	223	0	227	44	1.5	-	743	413	-	-	-	-	7.95	TTL; Al 15
21.3E.31.133	W. K. Miller	11-10-64	-	.56	40	28	31	28	119	6	118	18	.90	40	375	218	-	-	-	525	8.5	NMDPH; Alk 125, Mn 0
22.2E.13.411	J. W. Daugherty	9-7-62	11	-	23	4	33	31	104	0	33	15	.7	0	205	74	-	-	-	278	7.1	TTL; B .06
22.2E.31.442	City of L.C. Well 23	12-13-65	-	.10	24	28	109	103	180	0	82	102	.70	0	500	175	-	-	-	835	8.3	NMDPH; Alk 180; Mn 0
23.2E.1.330	2245 Carlisle Las Cruces	5-27-65	-	0	44	13	58	52	136	0	62	54	.6	-	418	165	-	-	-	555	7.9	NMDPH; Alk 136
23.2E.5.113	City of Las Cruces, Well 22	5-27-65	-	0	42	14	111	104	203	0	92	76	.60	-	518	163	-	-	-	775	7.9	NMDPH; Alk 203
23.2E.6.100	City of Las Cruces, Well 14	5-26-65	-	.94	138	39	127	116	181	0	347	174	.50	.00	1103	505	-	-	-	1485	7.8	NMDPH; Alk 181
23.2E.6.200	1530 Country Club Circle, Las Cruces	5-27-65	-	0	42	15	114	107	200	0	92	77	.60	.00	520	165	-	-	-	795	8.2	NMDPH; Alk 200
23.2E.7.211	City of Las Cruces Well 11	5-26-65	-	.06	43	13	57	51	135	0	62	55	.65	-	348	163	-	-	-	560	8.0	NMDPH; Alk 135
23.2E.7.412	City of Las Cruces Well 10	5-26-65	-	0	38	11	48	41	130	0	47	44	.60	-	303	140	-	-	-	480	8.0	NMDPH; Alk 130
23.2E.8.433	City of Las Cruces Well 18	5-26-65	-	.62	34	10	50	44	120	0	47	42	.65	-	285	128	-	-	-	465	8.2	NMDPH; Alk 120
23.2E.9.221	City of Las Cruces Well 17	5-26-65	-	0	75	19	77	70	158	0	116	94	.55	.53	613	265	-	-	-	830	8.2	NMDPH; Alk 158
23.2E.9.311	City of Las Cruces Well 21	5-27-65	-	0	60	18	78	71	145	0	115	85	.65	.35	500	223	-	-	-	775	8.0	NMDPH: Alk 145
23.2E.9.331	City of Las Cruces Well 19	5-26-65	-	.25	59	18	76	69	139	0	105	80	.70	.97	495	220	-	-	-	740	7.9	NMDPH; Alk 139
23.2E.16.121	City of Las Cruces Well 20	5-27-65	-	0	42	11	62	55	128	0	67	58	.65	.27	428	154	-	-	-	590	8.1	NMDPH; Alk 128
23.2E.18.310	Las Cruces, Memorial Hospital	5-27-65	-	0	54	17	72	65	136	0	96	75	.70	.35	568	205	-	-	-	700	8.1	NMDPH; Alk 136
23.2E.20.233	City of Las Cruces Well 8	5-26-65	-	.10	128	35	105	97	187	0	245	175	.35	1.7	1003	463	-	-	-	1315	7.8	NMDPH; Alk 187
23.2E.21.130	2250 E.Mo.,Las Cruces	5-27-65	-	.06	128	30	117	109	234	0	155	203	.40	.66	920	443	-	-	-	1350	7.4	NMDPH: Alk 234
23.2E.21.223	City of Las Cruces Well 12	5-26-65	-	0	142	31	154	145	282	0	150	252	.35	.62	1172	481	-	-	-	1585	7.3	NMDPH; Alk 282
23.2E.21.241	City of Las Cruces Well 9	5-26-65	-	.04	116	29	90	82	192	0	145	174	.35	.62	918	410	-	-	-	1175	7.3	NMDPH; Alk 192
23 2E.21.300	2205 Thomas Dr. Las Cruces	5-27-65	-	.06	126	30	124	116	235	0	146	207	.40	.35	1083	437	-	-	-	1350	7.5	NMDPH; Alk 235

TABLE 3

LOGS AND CONSTRUCTION DATA OF REPRESENTATIVE WELLS IN THE LOWER RIO GRANDE VALLEY AND ADJACENT INTERMONTANE AREAS OF SOUTHERN NEW MEXICO

The lithological descriptions in the logs in this table are sample logs and driller's logs. The sample logs were compiled, in every case, by professional geologists. In the case of the driller's logs, the terminology used is that of the driller, and it may not be the same as that used by geologists. For example, a driller may use the term "conglomerate" for a relatively uncemented gravel.

Stratigraphic unit designations within the logs have been made on the basis of comparison with the known sequence of rocks in the region.

Stratigraphic Unit and Material	Thickness (feet)	Depth (feet)
Well 16.5W.25.143 Earl Riggs Driller's log: John A. Tipton		
Late Quaternary Rio Grande Alluvium		
Gravel and sand	35	35
Small gravel and sand	8	43
Yellow clay conglomerate	12	55
Fine sand and gravel	8	63
Red clay	3	66
Sand and gravel	6	72
Santa Fe Group		
Red clay	5	77
Well 17.5W.2.224 Roy Langendorf Driller's log: John A. Tipton		
Late Quaternary Rio Grande Alluvium		
Gravel	3	3
Clay	9	12
Sand	13	25
Sand and gravel	5	30
Sandstone	2	32
Sand and fine gravel	54	86
Santa Fe Group (?)		
White clay and conglomerate	5	91
White clay	1	92

Table 3 (continued)

Stratigraphic Unit and Material	Thickness (feet)	Depth (feet)
Well 17.5W.13.311 Price-Black Dairy		
Driller's log: John A. Tipton		
Late Quaternary Rio Grande Alluvium		
Clay and sand fill	12	12
Sand	6	18
Clay	4	22
Sand	10	32
Water gravel	11	43
Water sand	6	49
Water gravel	11	60
Santa Fe Group (?)		
Clay	3	63
Well 17.4W.6.113 Henry Lara		
Driller's log: John A. Tipton		
Log starts at 23.5 feet. It was a dug open well to that depth.		
Late Quaternary Rio Grande Alluvium		
Gravel	6.5	30
Brown clay	5	35
Sand (water)	5	40
Fine sand and clay	37	77
Santa Fe Group		
Clay	4	81
Well 17.4W.30.141 T. J. Simpson		
Driller's log: John A. Tipton		
Late Quaternary Rio Grande Alluvium		
Rock and clay	30	30
Gravel	2	32
Clay	10	42
Sand and gravel	21	63
Clay	2	65
Sand and gravel	14	79
Blue clay	3	82
Sand and gravel	1	83
Santa Fe Group		
Sand and blue clay	5	88
Sand and silty clay streaked with red and white clay	17	105

Remarks: Casing set at 89'3".
Perforated 60' of 18" casing.

Table 3 (continued)

Stratigraphic Unit and Material	Thickness (feet)	Depth (feet)
Well 17.4W.30.441 Mrs. Ben Luchini		
Driller's log: John A. Tipton		
Late Quaternary Rio Grande Alluvium		
Clay and conglomerate fill	20	20
Sand and gravel	45	65
Gravel and sand	7	72
Gravel and clay	6	78
Silty sand	12	90
Gravel and sand	5	95
Gravel	4	99
Remarks: Not possible to pick up the top of the Santa Fe Group from this log.		
Well 17.4W.31.323 Adrian Ogaz		
Driller's log: John A. Tipton		
Late Quaternary Rio Grande Alluvium		
Clay	3	3
Sand	4	7
Sand and gravel	21	30
Clay	5	35
Sand and gravel	4	39
Red clay	1	40
Sand	5	45
Sand and gravel	7	52
Red clay	2	54
Sand and gravel	2	56
Red clay	6	62
Sand	4	66
White clay	2	68
Sand	2	70
White clay	3	73
Sand and gravel	2	75
Santa Fe Group		
White clay	12	87
Well 18.4W.8.431 Lee Mitchell		
Driller's log: John A. Tipton		
Late Quaternary Rio Grande Alluvium		
Soil and silt	12	12
Sand	10	22
Sand and gravel	42	64

Table 3 (continued)

Stratigraphic Unit and Material	Thickness (feet)	Depth (feet)
Well 18.4W.8.431 Lee Mitchell (continued)		
Driller's log: John A. Tipton		
Santa Fe group (?)		
Red clay	6	70
Remarks: 71'2" of 18" casing, 45' perforated with 2' blank on bottom.		
Well 18.4W.8.442 Ed Berridge		
Driller's log: John A. Tipton		
Late Quaternary Rio Grande Alluvium		
Sand and clay fill	8	8
Sand	12	20
Gravel	40	60
Rock	3	63
Santa Fe Group (?)		
Red clay	4	67
Well 18.4W.25.411 H. F. Greenfield		
Driller's log: John A. Tipton		
Late Quaternary Rio Grande Alluvium		
Sandy loam	15	15
Gravel	5	20
Sandy loam	7	27
Gravel	6	33
Sandy loam	9	42
Gravel	16	58
Sand and gravel	39	97
Santa Fe Group (?)		
Clay	3	100
Sand	3	103
Clay	1	104
Well 18.4W.26.443 Leonardo Castillo		
Driller's log: John A. Tipton		
Late Quaternary Rio Grande Alluvium		
Sand and conglomerate fill	28	28
Boulders	4	32
Sand	24	56

Table 3 (continued)

Stratigraphic Unit and Material	Thickness (feet)	Depth (feet)
Well 18.4W.26.443 Leonardo Castillo (continued)		
Gravel and clay	1.5	57.5
Clay	0.5	58
Sand	6	64
Gravel	6	70
Remarks: 6" well, domestic.		
Well 18.4W.27.443 Red Russell		
Driller's log: John A. Tipton		
Late Quaternary Rio Grande Alluvium		
Sand fill and gravel	5	5
Sand	7	12
Water sand and gravel	30	42
Water gravel	12	56
Coarse water gravel	15	71
Santa Fe Group		
Red clay	3	74
Well 19.3W.9.320 Ramon Avilucea		
Driller's log: John A. Tipton		
Late Quaternary Rio Grande Alluvium		
Clay	9	9
Sand and gravel	13	22
Clay	2	24
Sand and gravel	6	30
Clay	5	35
Sand and gravel	3	38
Clay	2	40
Gravel	6	46
Clay	5	51
Sand and gravel	3	54
Red clay	4	58
Sand and gravel	6	64
Santa Fe Group		
Red clay	5	69
Remarks: 16" casing set at 69'; 45' perforated.		

Table 3 (continued)

Stratigraphic Unit and Material	Thickness (feet)	Depth (feet)
Well 19.3W.9.400 Village of Hatch		
Driller's log: John A. Tipton		
Late Quaternary Rio Grande Alluvium		
Clay and boulders	17	17
Red clay and rock	21	38
Gravel	2	40
Clay	11	51
Gravel	2	53
Santa Fe Group		
Red clay	133	186
Remarks: Well casing parted and 87'8" of well casing was lost in the hole.		

Stratigraphic Unit and Material	Interval (feet)
Well 19.3W.9.411 Hatch Coop Gin Company	
Sample log: King	
Santa Fe Group	
Gravel 98%, consisting of 93% mixed volcanics of buff-colored rhyolite, gray andesite and andesite porphyry, green tuff, pink andesite, clear colorless quartz and 5% cream-colored limestone; 2% sand and clay. This sample was probably washed by the driller and the sand and clay fraction was lost	108-145
Very coarse, 1 to 2 mm., sand, 85%, consisting of mixed volcanics composed of green tuff, gray to maroon andesite and andesite porphyry, tan rhyolite, colorless quartz and tan rhyolitic tuff; occasional fragments of pink granite; 15% tan quartz sandstone and clay (10 YR 7/4m)	179-270
Gravel 95%, 1/8 to 1/4 inch, composed of gray rhyolitic tuff, andesite porphyry and cream-colored rhyolite with a trace of tan limestone; occasional fragment of pink granite; 5% quartz sandstone; appears to be a washed sample and perhaps sand and clay fraction, if present, is gone	285-335
Silty clay 95%, (5 YR 5/6m), calcareous; silt fraction mainly clear quartz; 5% mixed volcanics gravel of andesite porphyry, rhyolite and green tuff	335-395

Table 3 (continued)

Stratigraphic Unit and Material	Interval (feet)
Well 19.3W.9.411 Hatch Coop Gin Company (continued)	
Santa Fe Group (continued)	
Fine sand, .125 to .25 mm., 50%, composed of quartz and mixed igneous rocks; clay (5 YR 5/6m) 50%, calcareous	395-410
Silty clay 90%, (5 YR 5/6m) calcareous; gravel,10%, composed of mixed igneous rocks, mainly gray andesite, gray to tan rhyolite tuff and rhyolite .	410-472
Sand, medium, .25 to .50 mm., 60% of quartz and mixed igneous rocks; clay 40%, (5 YR 5/6m), slightly calcareous	472-485
Silty clay,90%, (5 YR 5/6m); gravel 1/8 to 1/4 inch, 10% of green tuff, gray andesite and tan rhyolite	485-515
Coarse sand, .50 to 1.0 mm.,70%, composed of mixed igneous rocks of gray andesite, gray andesite tuff, green tuff, tan rhyolite, colorless quartz, and a few pink granite fragments; silty clay (5 YR 6/4m) 30%,calcareous	515-535
Silty clay (5 YR 5/6m),85 %; fine sand of quartz and mixed igneous rocks,15%, colorless	535-585

Remarks: These are the only samples of the 2000± foot well that remain for study. Drilled by E. L. Brawley, deceased. Samples obtained from Mr. Neil Hartman, gin manager. The materials appear to be from both alluvial-fan and clay (lacustrine?) facies of the Santa Fe Group.

Stratigraphic Unit and Material	Thickness (feet)	Depth (feet)
Well 20.1W.23.300 New Mexico Highway Department, Selden Rest Stop Well on I-25		
Drillers' log: Taylor and R.L. Guffey and Sons		
Santa Fe Group		
Two feet of sandy red clay, then 18 feet of caliche and cemented sand	20	20
Caliche and a little clay	4	24
Clay with sand	6	30
Thick layers of clay with thin lenses of sand and gravel, mixed rounds present	20	50
Lenses of sand, gravel, and clay in about equal portions. Gravels are mixed rounds	10	60
No sample	4	64

Table 3 (continued)

Stratigraphic Unit and Material	Thickness (feet)	Depth (feet)
Well 20.1W.23.300 New Mexico Highway Department, Selden Rest Stop (continued)		
Santa Fe Group (continued)		
Clay	3	67
Clay	3	70
Clay with gravel	10	80
Sand	10	90
White to tan clay with fine gravel	10	100
Clay and sand	12	112
Soft sand	8	120
Sand with fine gravel	10	130
Sand with fine gravel and thin lenses of clay . .	4'9"	134'9"
Sand with fine gravel, thin lenses of clay	5'3"	140
Gravel with clay, a little sand	7	147
Lenses of sand, gravel, clay	13	160
Clay with a little gravel	10	170
Clay with more gravel	10	180
Gravel with sand and clay	20	200
Gravel with sand and a little clay	10	210
Gravel with sand and a little clay, last 2' clay	4	214
Mixed gravel and clay lenses	26	240
No sample	10	250
Clay with thin lenses of gravel	9	259
Clay with trace of gravel	11	270
Clay with lenses of sand, gravel	11	281
Clay, soft, with lenses of sand (30%)	9	290
Sand with lenses of clay (30%), trace of gravel .	14	304
Clay, very soft, with lenses of sand; last 2' very sandy	6	310
Lenses of sand, gravel, and clay (33% of each) . .	10	320
Clay (50%) with lenses of sand and gravel	8	328
Clay (60%) with lenses of sand and gravel	7	335
Gravel, sand, with 20% clay	5	340
Same, with more sand, less gravel	5	345
Same, with more clay	3'5"	348'5"
Gravel, sand, with 35% clay	12'7"	370
70% clay with thin lenses of sand and gravel . . .	5	375
80% clay with thin lenses of sand and gravel . . .	6	381
65% clay with thin lenses of sand, gravel	4	385
Sand with 10% clay	5	390
35% clay with lenses of sand	5	395
45% clay with lenses of sand	5	400

Remarks: The well probably penetrated inter-tonguing fluvial, alluvial-fan and playa-lacustrine facies of the upper part of the Santa Fe Group.

Table 3 (continued)

Stratigraphic Unit and Material	Thickness (feet)	Depth (feet)
Well 20.2W.12.110 Jimmy Harris		
Driller's log: Schieffer Drilling Company		
Late Quaternary Rio Grande Alluvium		
Soil	4	4
Sand	42	46
Gravel	22	68
Gray clay	2	70
Remarks: Mill slotted casing from 70' to 50'. Blank 16" O.D. x ¼" w/t casing from 50' to top of well. Possibly top of Santa Fe Group clay facies at 68'.		
Well 21.1W.9.240 William Henderson		
Driller's log: John A. Tipton		
Late Quaternary Rio Grande Alluvium		
Clay fill	8	8
Clay and gravel	6	14
Clay	8	22
Clay and gravel	7	29
Sand	1	30
Gravel and clay	6	36
Clay	1	37
Sand	1	38
Gravel and clay	10	48
Gravel	1	49
Rock	13	62
Clay	4	66
Fine sand	2	68
Rock	11	79
Sandstone (possibly some water)	6	85
Sand, gravel and clay	7	92
Sandstone (possibly water)	9	101
Clay (some water)	5	106
Rock	19	125
Remarks: Located in an arroyo bottom.		
Well 21.1W.10.143 O.W. Preece		
Driller's log: John A. Tipton		
Late Quaternary Rio Grande Alluvium		
Sand and clay fill	15	15
Gravel	30	45
Clay	11	56
Gravel and sand (water)	6	62

Table 3 (continued)

Stratigraphic Unit and Material	Thickness (feet)	Depth (feet)
Well 21.1W.10.143 O.W. Preece (continued)		
Clay	4	66
Sand (water)	5	71
Clay	3	74
Sand (water)	3	77
Santa Fe Group (?)		
Clay	4	81
Well 21.1E.31.444 V. A. Garcia		
Driller's log: Schieffer Drilling Company		
Late Quaternary Rio Grande Alluvium		
Sandy soil	12	12
Sandy clay	19	31
Sand	14	45
Gravel	30	75
Santa Fe Group		
Sand and gravel	45	120
Remarks: 65' of new ¼" wall 16" O.D. Casing with 24 rows of ¼"x3" mill slots. Blank pipe with closed swage from 115' to 120'. Blank 16"¼ wall new casing from 50' to top of well.		
Well 22.1E.24.222 Fred Lemon		
Driller's log: Schieffer Drilling Company		
Upper Santa Fe Group with Thin Late Quaternary Overlay		
Surface sand, clay streaks	12	12
Sand, clay, caliche streaks	37	49
Clay	6	55
Clay and caliche, streaks of sandy clay	14	69
Clay and sandy clay, streaks of hard gravel	38	107
Hard clay, streaks of gravel	8	115
Sandy clay, streaks of sand	33	148
Hard clay, streaks of gravel and sandy clay	21	169
Sand, streaks of sandy clay	12	181
Sand and small gravel, thin streaks of sandy clay	64	245
Gravel with broken clay lenses	61	306
Clay and gravel streaks	29	335
Gravel	55	390
Remarks: Pump: 1 SE30A-21 Meyers 3 HP jet pump set at 231' of 1½" drop pipe. #10 3-wire jacketed cable.		

Table 3 (continued)

Stratigraphic Unit and Material	Thickness (feet)	Depth (feet)
Well 22.2E.14.424 20th Century Fox On site examination of samples by Hawley supplemented with driller's log.		
Santa Fe Group, with Less Than 10-foot Thick Overlay of Late Quaternary Alluvium		
Surface - in part caliche - cemented (no noticeable cemented zones in upper 150' other than this surficial zone)	10	10
Light reddish brown clayey sand to sandy clay, with some scattered pebble gravel, locally derived; monzonite grains, mixed sedimentary rock fragments and minor volcanics	30	40
Light reddish brown clayey sand to sandy clay, and sand and gravel. Composition as above; "boulder" (probably cobbly)zone, 60-65' . .	30	70
"Light chocolate" colored sandy clay, with coarse sand zone, 80-82'	30	100
Light brown to red sandy clay, with scattered fine locally derived gravel as above	30	130
Note: No "Mixed-Rounded Gravel" suite in upper 130 feet (or below); all locally derived alluvial sediments.		
Brown to red sandy clay	20	150
Brown sandy clay	10	160
Brown to red sandy clay	38	198
Brown to red sandy clay to clayey sand and fine gravel, locally derived, angular to subrounded Soledad rhyolite, intermediate volcanics (greenish andesite, etc.), minor sedimentary rocks of mixed composition, little or no monzonite derived material; this suite continues to bottom of hole (Note that monzonite derived materials seem to drop out between 130 and 198') . . .	4	202
Sand and gravel; cobbly zone 202-205'	8	210
Gray to brown clayey sand and fine gravel . .	10	220
Gray to brown sandy clay, and sand and gravel; cobbly zone at 221'.	10	230
Gray, brown and red sandy clay, and sand and gravel; cobbly zones 235-239'	10	240
Sand and pebble gravel, and gray brown to red sandy clay	10	250

Stratigraphic Unit and Material	Thickness (feet)	Depth (feet)
Well 22.2E.14.424 20th Century Fox (continued)		
Santa Fe Group, etc. (continued)		
Light brown to red sandy clay and gravel; cobbly zones at 265, 271, 279, 284-286'	45	295
Gravel and sandy clay; mostly pebble to cobble gravel, with possibly a few fine boulders from 301-310'	15	310
Gravel with minor light gray, brown and red sandy clay; interbedded cobbly and non-cobbly zones (material from this zone subsequently caved into hole)	30	340
Gravel and some light gray, brown and red sandy clay; interbedded cobbly and non-cobbly zones; amount of sandy clay increasing with depth	20	360
Gravel and light gray, brown and red sandy clay; interbedded cobbly and non-cobbly zones	37	397
Brown sandy clay and pebble gravel, with interbedded cobbly zones	13	410
Brown sandy clay and gravel (slightly less clay than above); cobbly zones at 410, 412 and 417'	10	420
Brown to red sandy clay and gravel (slight pick-up in clay); cobbly zones at 422, 424, 426, 427-428'	10	430
As above, grading to pebble gravel and sandy clay	10	440
Brown to red sandy clay and gravel; several cobbly zones (very hard drilling - either due to 440-450' zone being cemented or to dulling of bit in a "hard pan" zone above 440'); sample recovery poor; fines probably passing through sample screen	10	450
Very light brown, brown and reddish brown sandy clay and gravel, with interbedded cobbly zones (very hard zone at 454')	10	460
Light brown to reddish brown sandy clay and pebble gravel with interbedded cobbly zones . .	20	480
Sand, fine gravel and minor brown sandy clay . .	70	550
Gravel, sand and minor brown sandy clay; interbedded cobbly zones	30	580
Clay	4	584
Gravel, sand and minor brown sandy clay; interbedded cobbly zones	26	610

Note: Hole caved back to about 500', with loose material coming from 550-610' interval; added "Aquagel". No commercial drilling mud used in upper 600'.

Table 3 (continued)

Stratigraphic Unit and Material	Thickness (feet)	Depth (feet)
Well 22.2E.14.424 20th Century Fox (continued)		
Santa Fe Group, etc. (continued)		
Brown to reddish brown sandy clay and gravel with interbedded coarse gravelly or fine cobbly zones	80	690
Brown sandy clay to clayey sand with minor fine gravel	20	710
Brown sandy clay	25	735
Cemented sand with few scattered gravelly zones	35	770
Remarks: All in alluvial fan facies .		
Well 22.2E.15.143 George Garcia		
Sample log: King and Hawley		
Santa Fe Group		
Reddish brown (5 YR 5/4m) (15% to 25% clay silt) very coarse sandy loam, arkosic, calcareous with common pink (5 YR 8/3) caliche fragments, surface soil (red brown in upper 2 to 3' over thick caliche)	0	10
Reddish brown (5 YR 5/3m) (15% to 25% clay silt) coarse sandy loam, arkosic, calcareous with common pink (5 YR 8/3m) caliche fragments plus scattered hard aggregates of fine to medium sand (silica cement) . . .	10	20
Brown (7.5 YR 5/4m) fine to very coarse (5 to 10% clay silt) loam, sand, arkosic, calcareous with abundant light brown (7.5 YR 6/4m) to pink (7.5 YR 7/4m) caliche fragments, and common selenite crystals . .	10	30
Brown (7 YR 5/4m) (40% to 50% silt clay) sandy clay loam, calcareous, arkosic with common to abundant caliche fragments (as above) selenite crystals common	10	40
Brown (7.5 YR 5/4m) (50% to 60% silt clay) sandy clay loam to sandy clay, calcareous, arkosic with abundant caliche fragments and selenite crystals	10	50
Gray brown to brown, coarse sand, clean arkosic, non to weakly calcareous. Note: first indication of mixed rounded lithology, some pinkish potassium feldspar and granite fragments present. Feldspars in upper 50' appear to be monzonite-derived	10	60

Table 3 (continued)

Stratigraphic Unit and Material	Thickness (feet)	Depth (feet)
Well 22.2E.15.143 George Garcia (continued)		
Santa Fe Group (continued)		
Gray brown to brown, medium to very coarse sand slightly dirty (may be drilling mud contamination) arkosic, pinkish potassium feldspar and granite grains noted, with scattered very fine pebbles of mixed rounded rock-types and caliche fragments, mostly noncalcareous	20	80
Fine to very fine pebble-size gravel, gravel fragments and caliche fragments. Rock types include mixed acid and intermediate volcanics, granite, quartz, minor sandstone, silt-stone and chert; caliche fragments comprise 1/2 to 1/3 of the sample; rock pebbles range from angular to well rounded, looks like typical mixed rounded lithology; minor calcareous-non calcareous silty clay blebs may be from drilling mud	10	90
Gravel as above with 10% to 15% sand, also about 25% caliche fragments, also a few monzonite pebbles, and one fragment of yellowish brown (10 YR 5/4m) clay (hard, non-calcareous, Santa Fe type)	10	100
Fine to very fine pebble gravel (70%), sand (25%), silt clay (5%); about 20% to 30% of the gravel fraction is caliche fragments; the rest is mixed rounded rock types as above;several percent hard fragments, non-calcareous, of yellowish brown (10 YR 5/4m), dark yellowish brown (10 YR 4/4m) and reddish brown (5 YR 4/3m) clay along with minor amounts of soft non-calcareous to calcareous brown (10 YR 5/3m) sandy clay; soft clay may be drilling mud contamination	20	120
Same as above, except with more soft sandy clay (5% to 10%) which still could be drilling mud contamination; total silt clay in sample about 15%. Note: One tooth-shaped piece of "bone-like" material	10	130

Table 3 (continued)

Stratigraphic Unit and Material	Thickness (feet)	Depth (feet)
Well 22.2E.15.143 George Garcia (continued)		
Santa Fe Group (continued)		
Fine to very fine sized pebbles to pebble fragments (65%), sand (20%), silt clay (15%), about 10% to 15% of gravel fraction is caliche fragments, the rest is mixed rounded rock types including acid and intermediate volcanics and minor amounts of quartz, granite, chert and sandstone; less than 1% hard fragments of non-calcareous, reddish brown (5 YR 5/3m) and yellowish brown (10 YR 5/4m) clay	10	140
Fine to very fine sized pebbles and pebble fragments (80%), sand (15%), silt clay (5%), about 15% of pebble fraction is caliche fragments; the rest is mixed rounded rock types, as above; less than 1% hard fragments noncalcareous redish brown (5 YR 5/3m) clay; greater than 5% reddish brown (5 YR 5/3m) soft clay to sandy clay, calcareous	10	150
Fine to very fine size pebbles and pebble fragments (60%), fine to very coarse sand (35%), silt clay (5%); about 5% to 10% of fraction is caliche fragments, the rest is mixed rounded rock types as above (plus one cluster of selenite); less than 1% hard fragments noncalcareous brown to dark brown (7.5 YR 5/4m) and dark yellowish brown (10 YR 4/4m) clay; and less than 5% brown (7.5 YR 5/4m) soft clay to sandy clay, calcareous	10	160
Fine to very fine size pebbles and pebble fragments (70%), Sand (25%), silt clay (5%); about 10% of gravel fraction is caliche fragments, the rest is mixed rounded rock types as above; less than 1% hard fragments, non-calcareous, reddish brown (5 YR 5/3m), brown (7.5 YR 5/4m) and dark yellowish brown (10 YR 4/4m) clay and less than 5% brown (7.5 YR 5/4m) to reddish brown (5 YR 5/3m) soft clay to sandy clay, calcareous	10	170
Reddish brown (5 YR 5/3.5m) low gravelly loam (35%, clay-silt (60%), sand (5%), very fine to fine pebble gravel, calcareous gravel fraction consists of mixed rounded types with a minor amount of caliche fragments; one obsidian pebble and minor hard fragments of reddish brown (5 YR 5/3m) hard clay, noncalcareous	10	180

Table 3 (continued)

Stratigraphic Unit and Material	Thickness (feet)	Depth (feet)
Well 22.2E.15.143 George Garcia (continued)		
Santa Fe Group (continued)		
Reddish brown (5 YR 5/3) gravelly sandy clay (40% silt-clay, 30% sand, 30% very fine to fine pebbly gravel), calcareous; gravel fraction consists of mixed rounded types as above	10	190
Medium to very coarse sand (90%), with minor very fine pebble gravel; silt-clay (5% to 10%), reddish brown (5 YR 5/3) calcareous rock types dominantly mixed local igneous with common monzonite and mixed rhyolite and andesite volcanics; minor amount of types . .	10	200
Same as above, slightly more silt-clay (10% to 15%); 190 feet is approximately the base of the mixed rounded type sediments, i.e., Pleistocene Santa Fe with exotic rock types .	10	210
As above except slightly more silt and clay of 10% to 15%	10	220
Silty clay (60%) (5 YR 6/3m); mixed volcanics (35%) of cream-colored rhyolite, gray monzonite, gray andesite porphyry, and green tuff; minor amounts of gray limestone and maroon andesite	10	230
Decrease to 15% silty clay; 80% mixed volcanics, as above, with increase in cream-colored rhyolite	20	250
Decrease to 5% silty clay; remainder of sample as above, with 95% mixed volcanics and limestone	30	280
Mixed volcanics (100%); sample was thoroughly washed by driller, so clay portion, if any, is gone; volcanics consist of cream-colored rhyolite, purple to gray andesite and andesite porphyry, gray monzonite like that outcropping in the Dona Ana Mountains, green tuff and gray andesite	20	300
Mixed volcanics 95%, including purple to gray andesite and andesite porphyry with phenocrysts of feldspar, 60%, cream-colored rhyolite 15%, green to gray tuff similar to that outcropping in Dona Ana Mts. 10%, mixed intermediate volcanics 10%; tan and gray limestone 5%, clay portion of sample impossible to determine because sample was washed thoroughly; seems to be a coarse gravel	10	310

Table 3 (continued)

Stratigraphic Unit and Material	Thickness (feet)	Depth (feet)
Well 22.2E.15.143 George Garcia (continued)		
Santa Fe Group (continued)		
Rhyolitic calcareous tuff with large abundant crystals of secondary gypsum and calcite, crystals of gypsum make up 50% of rock volume, magnetite and altered hornblende and mica crystals in rock, 85%; clay (5 YR 5/4m) (15%); trace of green tuff	30	340
As above, except clay equals 25% and green tuff is 5%; rhyolitic tuff equals 70%	10	350
As above, except clay equals 50% and rhyolitic tuff is 50%	40	390
Return to 85% rhyolitic calcareous tuff; 15% (5 YR 5/4m) clay; trace of green tuff and white rhyolite	30	420
Rhyolitic calcareous tuff (95%); 5% (5 YR 5/4m) clay; traces of green tuff and white rhyolite; trace of gray limestone; trace of purple-brown andesite porphyry; this rock is belived to be a gravel bed despite the high percentage of rhyolitic tuff; the drilling time remained very fast	70	490
Rhyolitic calcareous tuff (50%); clay (45%), (5 YR 3/4m); green tuff (5%); white rhyolite	10	500
Rhyolitic calcareous tuff (75%), as above; clay (15%), (5 YR 3/4m); mixed white rhyolite (10%), purple brown andesite and andesite porphyry, gray andesite, tan sandstone	60	560
Rhyolitic calcareous tuff (75%), as above; clay (5%), (5 YR 3/4m); mixed volcanics (20%), of which 5% is purplish-brown andesite porphyry, 5% white to tan rhyolite, and remaining 10% mixed gray andesite, green tuff, cinnamon andesite porphyry, basalt, tan-calcareous sandstone	50	610
As in interval above except increase in gray andesite to 10% of sample	30	640
Base of Santa Fe Group		
As in interval above except there is an influx of about 5% gray andesite porphyry with phenocrysts of white plagioclase feldspar and hornblende, biotite, chlorite and magnetite; ferromagnesian minerals are badly altered to iron oxides in many cases; Note: although the drilling time remained fast, this gray andesite porphyry is believed to be consolidated. Subsequent samples show an increasing percentage and the drilling time dropped off sharply at 670'	10	650

Table 3 (continued)

Stratigraphic Unit and Material	Thickness (feet)	Depth (feet)
Well 22.2E.15.143 George Garcia (continued)		
Gray andesite porphyry (85%); rhyolitic calcareous tuff (15%), which is interpreted as float from above coming down the hole	10	660
Gray andesite porphyry (95%), similar to outcrops of same rock in Dona Ana Mts. to the west; green tuff (5%) and rhyolitic calcareous tuff from up the hole	90	750
Mixed volcanics (90%); gray andesite porphyry (45%), as above; green tuff (45%); clay (10%) (5 YR 5/4m); trace of cream-colored rhyolite	30	780
Increase in green tuff to 70% of sample; gray andesite porphyry (25%); clay (5%).	20	800
Increase in clay (5 YR 5/4m) to 25%; green tuff (45%); gray andesite porphyry (15%); white rhyolitic tuff (10%)	20	820
Mixed volcanics 95% of sample; white rhyolitic tuff (35%); green tuff (40%), gray andesite porphyry (20%), clay (5 YR 5/4m) (5%)	10	830
Mixed volcanics 95% of sample; gray andesitic tuff (50%); white rhyolitic tuff (30%); green tuff (15%); clay (5%), (5 YR 5/4m)	20	850

Remarks: Fluvial facies of Upper Santa Fe Group (with thin alluvial fan overlay) to about 190'. Material between 190 and 640' interpreted as alluvial fan deposits. Tertiary volcanics and volcanic-derived sediments underlie the Santa Fe Group.

Well 22.2E.21.444 Jeff Hooker, Hydrotech Well
Driller's log: J. F. Glasscock with notes by Hawley

Santa Fe Group, Fluvial/Alluvial Fan Facies		
Caliche and sand	30	30
Gravel and fine sand	25	55
Clay	25	80
Sandy clay	100	180
Coarse gravel and sand	20	200
Sandy clay	25	225
Gravel, fine to coarse, with streaks of clay	80	305
Gravel, coarse, with streaks of clay	60	365

Table 3 (continued)

Stratigraphic Unit and Material	Thickness (feet)	Depth (feet)
Well 22.2E.21.444 Jeff Hooker, Hydrotech Well (continued)		
Base of Santa Fe Group about 365 feet		
Volcanic rock, black to brown to light gray; drilling time varies from 1 to 2' per hour	255	620
Remarks: Samples of last group of cuttings are of maroon to gray intermediate volcanic intrusive quartz latite to andesite. No water produced by this test hole.		
Well 22.2E.23.111 William Hanson		
Driller's log: F. O. Johnson, supplemented with notes by Hawley		
Santa Fe Group		
Surface sand and gravel	60	60
Clean sand and gravel	42	102
Silt and sand	6	108
Conglomerate, rock and clay, solid, with slower drilling	25	133
Sand and clay, little gravel	33	166
Broken clay shale	28	194
Gravel and clay	30	224
"Volcanic" gravels	26	250
Clay, reddish-brown	30	280
Clay, reddish-brown, harder	9	289
"Volcanic" gravels, slow drilling	22	311
Clay, gray sand and "volcanic" gravels . . .	89	400
Hard clay and "volcanic" gravels or fractured volcanic rock, hard drilling	75	475
Clean, gray sand; fast drilling	2	477
Volcanic rock (?); very hard; 4 hours drilling time	23	500
Black volcanic rock (?)	130	630
Yellow volcanic rock (weathered?)	22	652
Gray igneous rock, andesitic; gypsum veins in the rock	7	657
Gray igneous rock, andesitic	3	660
Remarks: Rotary tools to 550', cable tools below that depth.		
Log (above) from memory of driller and modified by Hawley.		
Samples of igneous rock from 652 to 660' examined by Hawley in the field. This igneous rock may correlate with the igneous bed in wells 22.2E.21.444, Jeff Hooker, and 22.2E.29.424, Vernon Krebs.		
Alluvial-fan facies of Santa Fe Group, except possibly for 60-102' zone which could be the fluvial facies.		

Table 3 (continued)

Stratigraphic Unit and Material	Thickness (feet)	Depth (feet)
Well 22.2E.23.114 Charles Spalding Wrecking Yard		
Driller's log: Schieffer Drilling Company		
Santa Fe Group, Alluvial-Fan Facies		
Clay, streaks of caliche	27	27
Firm red and brown clay, streaks of white caliche	42	69
Red clay	5	74
Brown clay, streaks of white caliche and red clay	73	147
Streaks of caliche	43	190
Clay and gravel	4	194
Small gravel, streaks of clay	7	201
Clay, thin hard streaks	50	251
Conglomerated gravel, thin clay lenses	105	356
Clay, streaks of small gravel (cemented)	34	390
Hard, broken rock or cemented gravel	4	394
Conglomerated gravel and clay streaks	95	489
Thick clay breaks and conglomerated gravel	72	561
Fairly clean gravel, thin clay streaks	29	590
Remarks: Pump: 1 SE20C21 2 HP Myers submersible pump set at 483' on 1¼" drop pipe with #8 jacketed cable.		
Well 22.2E.28.3334 Ernest Bruce		
Driller's log: Boyd & Son Drilling Co. and John Morrison		
Santa Fe Group, with Very Thin Late Quaternary Overlay		
Top soil	5	5
Caliche	10	15
Sand	15	30
Clay	4	34
Sand and gravel	26	60
Boulders	11	71
Clay	5	76
Sand	15	91
Clay	15	105
Sand	3	108
Clay and gravel	3	111
Sand and gravel	30	141
Rocks and gravel	16	157
Sand and gravel	9	166
Hard clay	5	171

Table 3 (continued)

Stratigraphic Unit and Material	Thickness (feet)	Depth (feet)
Well 22.2E.28.3334 Ernest Bruce (continued)		
Santa Fe Group, etc. (continued)		
Sand and clay	10	181
Sand and gravel	4	185
Clay	5	190
Clay and gravel	20	210
Clay	60	270
Gravel	2	272
Clay	34	306
Rock	37	343
Clay streaks and rock	7	350
Rock	6	356
Hard clay	16	372
Sand streaks	36	408
Rock	7	415
Sand streaks	2	417
Rock	3	420
Hard sand	30	450
Clay	30	480
Sand	22	502
Base of Santa Fe Group - 502'		
Blue rock		502

Remarks: 6" screen from 438 to 475'.
The blue rock mentioned at 502' is possibly the same andesite bed found at 365' in well 22.2E.21.444, the Jeff Hooker well, and in well 22.2E.29.424, Vernon Krebs. No samples are available.
Upper part of hole in fluvial facies of the Santa Fe Group. Lower part in alluvial fan facies. Exact position of facies change is unknown.

Well 22.2E.29.424 Vernon Krebs
Driller's log: Schieffer Drilling Company with notes by Hawley

Stratigraphic Unit and Material	Thickness (feet)	Depth (feet)
Santa Fe Group, Fluvial/Alluvial Fan Facies		
Sand and gravel (mixed roundeds)	60	60
Sand and red clay	33	93
Clay, red, and gravel	94	187
Clay, red	108	295
Clay, red, and gravel	40	335
Gravel and red clay streaks	27	362
Gravel (fine to coarse pebbles, locally derived)	23	385
Clay, red, and gravel	82	467
Rock and gravel	13	480

Table 3 (continued)

Stratigraphic Unit and Material	Thickness (feet)	Depth (feet)
Well 22.2E.29.424 Vernon Krebs (continued)		
Base of Santa Fe Group		
Rock	5	485
Remarks: Rock sampled from 480' to 485' is intermediate volcanic, andesite, like that in well 22.2E.21.444, Jeff Hooker. Drilling time from 467' to total depth averaged 3'/hr.		
Well 22.2E.31.444 City of Las Cruces, Well No. 23		
Sample log: Taylor		
Santa Fe Group with Thin Overlay of Picacho Alluvium		
Gravelly sand (20% gravel, 28% sand, 20% clay; gravel - angular to rounded (2 to 70 mm.), lithology; purple rhyolite, mixed rounds, intermediate volcanics, limestone, quartz, chert, quartzite, siltstone, potassium feldspar; sand - (1.8 to 2 mm.), angular to rounded, lithology; mainly quartz.	10	10
Gravel (98% gravel, 2% sand); gravel (2 to 23 mm.), angular to rounded, majority (7 to 23 mm.), lithology: major - rhyolite, black limestone, chert, quartz, siltstone, quartzite; minor - granite, sandstone intermediate volcanics (andesite)	10	20
Sandy gravel (95% gravel, 5% sand); gravel (2 to 21 mm.), majority (2 to 9 mm.), angular to rounded, lithology: major - rhyolite, quartz, quartzite, black limestone, siltstone, minor - granite, intermediate volcanics; sand (1 to 2 mm.), mainly quartz with lesser amounts of the other gravel lithology constituents	10	30
Same as above (20 to 30') except major gravel range is 2 to 13 mm., a little larger	10	40
Same as above (20 to 40') except gravel range is 2 to 32 mm., majority is 14 to 32 mm. . . .	10	50
Gravelly sand (30% gravel, 70% sand); mixed rounds high; gravel (2 to 32 mm.), angular to rounded, lithology; major - quartz, minor - gravel type lithology	10	60

Table 3 (continued)

Stratigraphic Unit and Material	Thickness (feet)	Depth (feet)
Well 22.2E.31.444 City of Las Cruces, Well No. 23 (continued)		
Santa Fe Group with Thin Overlay, etc. (continued)		
Same as above (40 to 50') decreasing mixed rounds, more alluvial particles	10	70
Same as above (50 to 60') plus calcrete fragments	10	80
Sandy gravel (60% gravel, 35% sand, 5% clay); gravel, angular to rounded; lithology: same as above (20 to 80'); sand, same as above (50 to 60', 70 to 80'); clay blebs, (10 YR 5/4), plus calcrete	10	90
Gravelly clay (20% gravel, 30% sand, 50% clay); gravel (2 to 17 mm.), angular to rounded, lithology: same as above (20 to 90'); sand, same as above (50 to 60', 70 to 90'), some clear plagioclase grains, quartz still rounded; clay blebs (10 YR 5/4)	10	100
Clayey sand (2% gravel, 60% sand, 38% clay); gravel, angular to rounded (2 to 15 mm.), lithology: rhyolite, andesite, quartz, potassium feldspar, quartzite, black limestone; sand (1/8 to 2 mm.), angular to rounded, lithology: major - quartz, rounded, minor - plagioclase, magnetite, potassium feldspar; clay blebs (10 YR 6/3)	10	110
Sandy gravel (50% gravel, 45% sand, 5% clay); gravel, angular to rounded (2 to 22 mm.), lithology: major - rhyolite, minor - black limestone, intermediate volcanics, quartzite, siltstone, potassium feldspar, chert; sand (1/8 to 2 mm.), angular to rounded, lithology: major - rounded quartz, minor - gravel-type lithology; clay blebs (10 YR 6/4, 5 YR 4/4)	10	120
Gravelly clay (30% gravel, 40% sand, 30% clay); base of mixed rounds; percentage practically zero; gravel, angular, some few rounded (2 to 19 mm.), lithology: major - purple rhyolite, minor - black limestone, intermediate volcanics, quartz, siltstone, quartzite, red potassium feldspar, chert; sand, angular to well-rounded quartz; some euhedral quartz grains (1/8 to 1/2 mm.), lithology: mainly quartz; clay blebs (7.5 YR 5/4, 10 YR 5/4) .	10	130

Table 3 (continued)

Stratigraphic Unit and Material	Thickness (feet)	Depth (feet)
Well 22 2E.31.444 City of Las Cruces, Well No. 23 (continued)		
Santa Fe Group with Thin Overlay, etc. (continued)		
Sandy gravel (70% gravel, 20% sand, 10% clay); base of mixed rounds; percentage practically zero; gravel, angular to rounded, mostly angular (2 to 18 mm.), lithology: major - purple rhyolite, minor - black limestone, intermediate volcanics, quartz, siltstone, quartzite, red potassium feldspar, chert; sand, angular to well-rounded quartz and some euhedral (1/8 to 2 mm.), lithology: mainly quartz; clay blebs (7.5 YR 6/4, 10 YR 5/3)	10	140
Gravelly sand (10% gravel, 80% sand, 10% clay); gravel, angular to sub-rounded (2 to 15 mm.), lithology: major purple rhyolite, minor - black limestone, intermediate volcanics, quartz, quartzite, siltstone, potassium feldspar, chert; sand, angular to well-rounded (1/8 to 2 mm.), lithology: mainly quartz; clay blebs (10 YR 6/4); hard shale	10	150
Gravelly sand (10% gravel, 88% sand, 2% clay); gravel, angular to sub-rounded (2 to 12 mm.), lithology: major - purple rhyolite, minor - black limestone, intermediate volcanics, quartz, quartzite, siltstone, potassium feldspar, chert; sand, mostly angular, some rounded (1/8 to 2 mm.), lithology: mainly quartz; clay blebs (10 YR 6/4, 10 YR 6/3); hard shale; plus calcrete, pieces and cemented quartz sand; solid layer	20	170
Same as above (150 to 170'), except increase in gravel to 20% and increase in calcrete sandstone	20	190
Sandy gravel (70% gravel, 25% sand, 5% clay); gravel, mainly angular (2 to 14 mm.), lithology: major - purple rhyolite, minor - intermediate volcanics, quartz, quartzite, siltstone, potassium feldspar, chert; sand (1/8 to 2 mm.), mainly angular, some rounded; lithology: mainly quartz	7	197

Table 3 (continued)

Stratigraphic Unit and Material	Thickness (feet)	Depth (feet)
Well 22.2E 31.444 City of Las Cruces, Well No. 23 (continued)		
Santa Fe Group with Thin Overlay, etc. (continued)		
Clayey sand (20% gravel, 50% sand, 30% clay); gravel (2 to 15 mm.), angular to sub-rounded, lithology: major - purple rhyolite, minor - green intermediate volcanics, other intermediate volcanics, potassium feldspar, chert, quartz, quartzite, siltstone; sand (1/8 to 2 mm.) angular, some rounded, lithology: mainly quartz	3	200
Sand (2% gravel, 96% sand, 2% clay); sand (1/8 to 1/2 mm.), angular, some rounded, mainly quartz; clay blebs (7.5 YR 5/4)	10	210
Sand (100% sand), 1/16 to 1/4 mm.), angular to sub-rounded, lithology: mainly quartz . .	10	220
Gravelly sand (20% gravel, 80% sand, 1% clay); gravel (2 to 4 mm.), angular, lithology: same as above (197 to 200'); sand, angular to sub-rounded, (1/16 to 1/4 mm.), lithology: quartz	10	230
Sandy gravel (60% gravel, 39% sand, 1% clay); gravel, angular to sub-rounded, (2 to 10 mm.), lithology: same as above (197 to 200', 220 to 230'); sand, (1/16 to 1/4 mm.), angular to sub-rounded, lithology: quartz	10	240
Gravelly sand (30% gravel, 70% sand); gravel (2 to 8 mm.), angular to sub-rounded, lithology: same as above (197 to 200', 220 to 240'); sand (1/16 to 1/4 mm.), angular to sub-rounded, lithology: quartz	10	250
Sandy gravel (40% gravel, 60% sand); gravel (6 to 32 mm.), angular to rounded, lithology: same as above (197 to 200', 220 to 250'); sand (1/16 to 1/4 mm.), angular to sub-rounded, lithology: quartz	10	260
Gravelly sand (20% gravel, 80% sand); gravel, angular to sub-rounded (2 to 13 mm.), lithology: same as above (197 to 200', 220 to 260'); sand (1/16 to 1/2 mm.), angular to sub-rounded, lithology: quartz	10	270
Sandy gravel (60% gravel, 40% sand); gravel, angular to sub-rounded (2 to 16 mm.), lithology: same as above (197 to 200' 220 to 270'); sand (1/16 to 1/4 mm.), angular to sub-rounded, lithology: quartz	10	280

Table 3 (continued)

Stratigraphic Unit and Material	Thickness (feet)	Depth (feet)
Well 22.2E.31.444 City of Las Cruces, Well No. 23 (continued)		
Santa Fe Group with Thin Overlay, etc. (continued)		
Gravelly sand (10% gravel, 90% sand); gravel (2 to 13 mm.), angular to sub-rounded, lithology: same as above (197 to 200', 220 to 280'); sand 1/16 to 1/2 mm.), angular to sub-rounded, lithology: quartz . . .	40	320
Sandy gravel (60% gravel, 40% sand); gravel (2 to 14 mm.), angular to sub-rounded lithology: same as above (197 to 200', 220 to 280'); sand, same as above (197 to 200', 220 to 280')	50	370
Gravelly sand (10% gravel, 90% sand); gravel (2 to 8 mm.), angular, lithology: same as above; sand, same as above.	10	380
Gravelly sand (20% gravel, 80% sand); gravel (2 to 5 mm.), otherwise same as above	15	395
Sandy gravel (60% gravel, 40% sand); gravel (2 to 8 mm.), otherwise same as above	5	400
Sandy gravel; gravel (2 to 34 mm.), angular to sub-rounded, lithology: major - purple rhyolite, minor - quartz, chert, siltstone, limestone, intermediate volcanics, green andesite, black andesite; sand, mainly quartz (1/8 to 2 mm.)	5	405
Gravelly sand; gravel (2 to 5 mm.), angular to sub-rounded, lithology: major - purple rhyolite, minor - quartz, chert, siltstone, limestone, intermediate volcanics, green andesite, black andesite; sand, mainly quartz (1/8 to 2 mm.)	30	435
Gravelly sand (2 to 14 mm.), mainly angular, some sub-rounded; gravel, lithology: major - purple rhyolite, minor (very minor) - intermediate volcanics, chert, andesite, green andesite, quartzite, siltstone; sand (1/8 to 2 mm.), angular to sub-rounded (1/8 to 1/2 mm.), quartz (1/2 to 2 mm.), gravel lithology; clay blebs	25	460
Gravel, angular to sub-rounded (2 to 37 mm.), lithology: same as above (435 to 460'); sand, same as above (435 to 460')	5	465
Gravelly sand; gravel, angular to sub-rounded (2 to 15 mm.), lithology: major - purple rhyolite and purple porphyritic andesite, minor - chert, quartz, andesite, siltstone, quartzite, intermediate volcanics		

Table 3 (continued)

Stratigraphic Unit and Material	Thickness (feet)	Depth (feet)
Well 22.2E.31.444 City of Las Cruces, Well No. 23 (continued)		
Santa Fe Group with Thin Overlay, etc. (continued)		
(green andesite); sand, angular to subrounded (1/8 to 2 mm.), lithology: same as gravel plus magnetite	35	500
Same as above (465 to 500'), with increase in gravel size to 30 mm.	5	505
Same as above (500 to 505')	5	510
Same as above (465 to 500')	25	535
Same as above (465 to 500', 510 to 535'), except gravel size (2 to 50 mm.)	5	540
Same as above (465 to 500', 510 to 535') . . .	25	565
Gravelly sand (2 to 12 mm.), angular to subrounded, lithology: major - purple porphyritic andesite, minor - purple rhyolite, intermediate volcanics, quartz, green andesite; sand, angular to subrounded (1/8 to 2 mm.), lithology: same as gravel	25	590
Same as above (565 to 590'), except clay blebs (2.5 YR 5/2), heavy increase in clay content .	25	615
Same as above (590 to 615'), except clay (7.5 YR 5/2)	35	650
Remarks: Fluvial facies of Santa Fe Group above 90'. Possible transition from fluvial facies to alluvial - fan facies from 90' to 140'. Mainly alluvial-fan facies from 140 to 435', with possible intertonguing of fluvial gravel and sand. Alluvial-fan facies below 435'.		
Well 23.1W.22.000 West Las Cruces Airport Driller's log: John A. Tipton		
Log begins at 550'. Deepening of an existing well of low yield.		
Red clay and conglomerate	25	575
Base (?) of Santa Fe Group		
Blue clay and conglomerate	40	615
Light clay and conglomerate	5	620
Blue clay and conglomerate	43	663
Blue clay and sandstone	84	747

Table 3 (continued)

Stratigraphic Unit and Material	Thickness (feet)	Depth (feet)
Well 23.1W.22.000 West Las Cruces Airport (continued)		
Blue mud	3	750
Blue shale and sandstone	20	770
Shale and sandstone	8	778
Blue clay	12	790
Blue clay and sandstone	10	800
Shale	30	830
Sandstone and blue clay	125	955
Shale and blue clay	5	960
Red shale	6	966
Blue shale	20	986
Blue clay and sandstone	21	1007
Shale and blue clay	4	1011
Blue clay and sandstone	49	1060
Shale	4	1064
Red rock	2	1066
Blue clay and shale	17	1083
Blue clay and sandstone	7	1090
Blue clay	6	1096
Blue shale and clay	29	1125
Red shale	23	1148
Shale and gray clay	6	1154
Red and gray shale with conglomerate	26	1180
Rock	4	1184
Red shale and clay	3	1187

Remarks:
Driller reported no extractable water at all in deep well zones.

Well 23.1W.31.440 U. S. Army Radar Station
Driller's log: Cass Drilling Company

Stratigraphic Unit and Material	Thickness (feet)	Depth (feet)
Santa Fe Group with Probable Thin Quaternary Overlay		
Top soil	6	6
Caliche	18	24
Sand and gravel	36	60
Sand	70	130
Clay	35	165
Clay and gravel	25	190
Streaks of clay, sand, and gravel	25	215

Table 3 (continued)

Stratigraphic Unit and Material	Thickness (feet)	Depth (feet)
Well 23.1W.31.440 U.S. Army Radar Station (continued)		
Santa Fe Group with Probable Thin Quaternary Overlay (continued)		
Streaks of clay and pink rock	20	235
Brown rock	20	255
Sandstone and boulders	10	265
Streaks of clay and rock	20	285
Streaks of sand and clay	20	305
Gray clay	20	325
Clay and sand streaks	10	335
Streaks of sand, gravel, and clay	35	370
Sand	5	375
Sand and pink rock	20	395
Clay	10	405
Sandstone	5	410
Sand and clay streaks	15	425
Clay	11	436
Sand	4	440
Base (?) of Santa Fe		
Blue clay	65	505
Streaks of blue and pink clay	85	590
Sand	10	600
Clay	65	665
Clay and sand streaks	20	685

Remarks: Pipe and screen set at 685' although there was not sufficient water according to driller.

Well was later deepened to 1200' according to memory of driller; log on well was lost. Rotary tools to 900'; then cable tools to total depth.

Lithology from 685' to total depth was mainly blue and red clay; very few sands according to driller.

Drillers said that 5 gallons per minute could have been produced from 700' to 750', 900' and 1180' to 1200'.

Schlumberger Electric Log and Microlog available from 166' to 503'.

Army required 25 gallons per minute but well would not provide it. Site is now on City of Las Cruces water system.

Well drilled just west of small basalt hill. Water reported to be warm.

Table 3 (continued)

Stratigraphic Unit and Material	Thickness (feet)	Depth (feet)
Well 23.1E.20.213 Mrs. Joella Lackey Sample log: Wilson and King		
Upper Santa Fe Group, Fluvial Facies		
Gravelly silty sand; gravel 25%, sand 70%, silt 5%; gravel 2.0-35.0 mm., angular to rounded, mainly subangular; lithology: mixed igneous rock, mainly rhyolite; sand very fine to very coarse, poor sorting, angular to rounded, mainly subangular, 85% quartz and mixed igneous rocks with chert, 15% feldspar	10	10
Gravelly sand; gravel 40%, sand 58%, silt 2%; gravel 2.0-35.0 mm., angular to subrounded, mainly subangular to subrounded; mixed igneous rocks; sand medium to very coarse, mainly coarse, poor to moderate sorting, angular to rounded, mainly subangular, quartz 85%, mixed igneous rocks with chert 15%	10	20
Gravelly, clayey sand, gravel 10%, sand 80%, clay 10%, gravel 2.0-30.0 mm, mainly subangular, mixed igneous rocks; sand, fine to very coarse, mainly coarse, poor sorting, angular to rounded, mainly angular-subangular, quartz 85%, mixed igneous rocks with chert 15%; clay (10 R 6/2), hard lumps in gravel fraction, 5.0-10.0 mm., probably thin clay bed	10	30
Clayey, gravelly sand, gravel 10%, sand 65%, silt 5%, clay 20%; gravel 2.0-25.0 mm., mainly subangular,mixed igneous rock; sand very fine to very coarse, poor sorting, angular to subrounded, mainly subangular, quartz 85%, mixed igneous, chert 15%; clay, lumps in gravel fraction, 5.0-15.0 mm., (10 R 6/2), probably thin beds broken by the bit	10	40
Silty, gravelly, muddy sand; gravel 5%, sand 60%, silt-clay 35%; gravel 5.0-15.0 mm., mainly subrounded, mixed igneous rock; sand mainly fine to very fine, quartz 60%+, calcareous 40%-; similar to a sandy, muddy caliche	10	50

Table 3 (continued)

Stratigraphic Unit and Material	Thickness (feet)	Depth (feet)
Well 23.1E.20.213 Mrs. Joella Lackey (continued)		
Upper Santa Fe Group, Fluvial Facies (continued)		
Gravelly silty sand; gravel 10%, sand 65%, silt-clay 25%; gravel angular to subrounded, 2.0-35.0 mm., mixed igneous rock, one pebble of sandstone with calcite cement; sand very fine to very coarse, poor sorting, angular to subrounded, mainly subangular, quartz 85%, mixed igneous rocks with chert 15%; clay, lumps in gravel and disseminated, clay and silt contain 10-20% calcareous material	10	60
Gravelly, muddy sand; gravel 5%, sand 80%, silt-clay 15%; gravel angular to subrounded, 2.0-15.0 mm., mixed igneous rocks, caliche; sand very fine to very coarse, poor sorting, angular to subrounded, mainly subangular, quartz 85%, mixed igneous rock with chert 15%; silt-clay,10% calcareous material	10	70
Gravelly, silty sand; gravel 20%, sand 60%, silt-clay 20%; gravel angular to subrounded, 2.0-35.0 mm., mixed igneous rock, 10% sandstone with calcrete cement; sand very fine to very coarse, poor sorting, angular to rounded, mainly subangular, quartz 85% mixed igneous rocks with chert 15%, few clay lumps in gravel (thin clay bed?)	10	80
Gravelly sand; gravel 10%, sand 87%, silt 2-3%; gravel, very angular to subrounded, 2.0-15.0 mm., mixed igneous rock, feldspar; sand medium to very coarse, poor sorting, angular to rounded, mainly subangular, quartz 80%, mixed igneous rock with chert 20%	10	100
Sandy, slightly silty gravel; gravel 60%, sand 35%, silt-clay 5%; gravel very angular to rounded, mainly subangular to subrounded, mixed igneous rocks, little quartz and chert; sand fine to very coarse, poor sorting, very angular to rounded, mainly subangular, quartz 85%, mixed igneous rock with chert 15%; clay, lumps in gravel, 5.0-10.0 mm., probably few thin clay beds	10	110
Gravelly silty sand; gravel 25%, sand 55%, silt-clay 20%; gravel angular to subrounded, 5.0-25.0 mm., mixed igneous rock with a little quartz and feldspar 70%, caliche 30%; sand very fine to very coarse, mainly fine; poor		

Table 3 (continued)

Stratigraphic Unit and Material	Thickness (feet)	Depth (feet)
Well 23.1E.20.213 Mrs. Joella Lackey (continued)		
Upper Santa Fe Group, Fluvial Facies (continued)		
sorting, very angular to rounded, mainly subangular; quartz 80%, mixed igneous rock with chert and calcite, 20%; silt-clay - clay lumps in gravel, 5.0-15.0 mm., probably about 30% calcareous	10	120
Gravelly silty sand; gravel 20%, sand 65%, silt-clay 15%; gravel, mainly subangular, 2.0-20.0 mm., mixed igneous rock with little quartz and feldspar; sand, very fine to very coarse, poor sorting, angular to rounded, mainly subangular, quartz 85%, mixed igneous rock with chert and calcite 15%; silty clay lumps in gravel, 5.0-15.0 mm., 30% calcareous material in silt-clay . .	10	130
Gravelly silty sand; gravel 40%, sand 50%, silt 10%; gravel, mainly subangular, 2.0-20.0 mm., mixed igneous rock, little chert, quartz, feldspar; sand, very fine to very coarse, poor sorting, very angular to rounded, mainly angular to subangular, quartz 80%, mixed igneous rocks with chert and calcite 20%; silt-clay - few clay lumps in gravel, 5% calcareous	10	140
Silty gravelly sand; gravel 15%, sand 65%, silt-clay 20%; gravel 2.0-30.0 mm., mixed igneous rock with little feldspar; sand, fine to very coarse, mainly medium coarse, poor to moderate sorting, very angular to subrounded, mainly angular to subangular, quartz 90%, mixed igneous rock with chert 10%; silt-clay - clay lumps in gravel, 5% calcareous	10	150
Gravelly slightly silty sand; gravel 20%, sand 75%, silt-clay 5%; gravel subangular to rounded, 2.0-25.0 mm., mixed igneous rock with little quartz and feldspar; sand fine to very coarse, mainly medium coarse, angular to subrounded, mainly subangular, poor sorting, quartz 85%, mixed igneous rocks with chert and calcite 15%	10	160
Silty gravelly sand; gravel 15%, sand 65%, silt-clay 20%; gravel, angular to subrounded, 2.0-20.0 mm., mixed igneous rock with little quartz; sand, very fine to very coarse, poor sorting, very angular to		

Table 3 (continued)

Stratigraphic Unit and Material	Thickness (feet)	Depth (feet)
Well 23.1E.20.213 Mrs. Joella Lackey (continued)		
Upper Santa Fe Group, Fluvial Facies (continued)		
rounded, mainly subangular, quartz, 80%, mixed igneous rock 20%; silt-clay lumps in gravel, 30% calcareous	20	180
Silty gravelly sand; gravel 5%, sand 80%, silt-clay 15%; gravel, angular to rounded, 2.0-30.0 mm., mixed igneous rocks; sand very fine to coarse, mainly fine to medium, poor sorting, angular to subrounded, mainly subangular, quartz 85%, mixed igneous rock with chert 15% .		circ.@ 178
Gravelly silty sand; gravel 5%, sand 85%, silt-clay 10%; gravel, angular to rounded, 2.0-10.0 mm., mixed igneous rock; sand very fine to very coarse, mainly fine to coarse, poor sorting, very angular to rounded, mainly subangular to angular, quartz 85%, mixed igneous rocks with chert 15%; silt-clay, clay lumps in gravel	10	190
Silty gravelly sand; gravel 5%, sand 80%, silt-clay 15%; gravel, angular to subrounded, 2.0-15.0 mm., mixed igneous rocks with little feldspar; sand very fine to very coarse, poor sorting; very angular to rounded, mainly angular to subangular, quartz 85%, mixed igneous rocks with chert 15%; silt-clay 25% calcareous	10	200
Gravelly silty sand; gravel 10%, sand 75%, silt 15%; gravel 2.0-25.0 mm., mixed igneous rock, little quartz, feldspar; sand very fine to coarse, mainly fine, poor sorting, angular to rounded, mainly subangular; quartz 90%, mixed igneous rock with chert 10%; silt-clay, calcareous 25%	10	210
Gravelly silty sand; gravel 10%, sand 80%, silt 10%; gravel 2.0-15.0 mm., mixed igneous rock; sand very fine to coarse, poor sorting, angular to rounded, mainly subangular, quartz 85%, mixed igneous rock with chert 15%; silt-clay, mainly calcareous, some clay fragments	10	220
Silty sand with 5% gravel; sand 75%, silt 20%; sand is 90% quartz and mixed volcanics; gravel is andesite, rhyolite and quartz pebbles with a few pink granite pebbles; trace of calcareous shale (5 YR 6/4m)	20	240

Table 3 (continued)

Stratigraphic Unit and Material	Thickness (feet)	Depth (feet)
Well 23.1E.20.213 Mrs. Joella Lackey (continued)		
Upper Santa Fe Group, Fluvial Facies (continued)		
As above except gravel increase to 10%, sand 80% and silt and clay 10%; andesite very prominent in mixed volcanics of gravel; occasional pebble of pink granite . . .	10	250
As above except increase in clay (5 YR 6/4m) to 20%; gravel 5%; sand 70%; silt 5% . .	10	260
Gravel with abundant pink granite and other mixed volcanics 35%; sand predominantly quartz, 85%, and mixed volcanics 50%; silt 10% and clay (5 YR 6/4m) 5%; mixed rounded gravels still present in last sample	40	300
Well 23.2E.12.411 Ikards Furniture Store		
Driller's log: Schieffer Drilling Company		
Late Quaternary Rio Grande Alluvium		
Surface	3	3
Sand and clay	9	12
Clay	6	18
Sand	10	28
Gravel	41	69
Upper Santa Fe Group, Fluvial Facies (?)		
Sand and sandy clay	27	96
Sand	30	126
Sandy clay	19	145
Sand and clay streaks	25	170
Hard clay	2	172
Clay	14	186
Sand	29	215

Remarks: Casing and screen set in 9-7/8" rotary drilled hole.

Casing and screen set in continuous welded string. 0' to 100' new 8-5/8" standard schedule 30 P.E. 100' to 200' new 6-5/8" in standard schedule 30 P.E. 200' to 215' 6" pipe size 304 stainless steel #20 slot screen. Bottom of screen equipped with 6" figure T washdown fitting.

Well washed developed and jetted with water jet and compressed air. Water tested 15 grains hardness per gallon (field color change test.)

Table 3 (continued)

Stratigraphic Unit and Material	Thickness (feet)	Depth (feet)
Well 23.2E.16.133 City of Las Cruces, Well No. 24 Sample log: Taylor		
Santa Fe Group with Thin Overlay of Fillmore Alluvium		
Clayey sand (70% sand, 30% clay) mixed rounds present; sand (0.0625 to 1 mm.), angular to rounded, lithology: quartz; clay disseminated	10	10
Same as above with some pebbles (2 to 15 mm.); mainly rhyolite; mixed rounds	10	20
Gravelly sand (30% gravel, 60% sand, 10% clay); mixed rounds present; gravel (2 to 6 mm.), few coarse pebbles up to 26 mm., angular to subrounded, lithology: major - quartz, granite, potassium feldspar, rhyolite, intermediate volcanics; minor - siltstone, chert, black andesite, quartzite, obsidian; sand (0.125 to 2 mm.), angular to subrounded, lithology: mainly quartz; clay, disseminated	70	90
Clayey gravel (60% gravel, 40% clay); mixed rounds; gravel (6 to 14 mm.), angular to rounded, lithology: major - rhyolite, intermediate volcanics, quartz, chert; minor - granite, potassium feldspar, siltstone; clay (7.5 YR 6/4)	20	110
Gravelly sand (40% gravel, 50% sand, 10% clay); mixed rounds present; gravel (2 to 26 mm.), angular to subrounded, lithology: major - rhyolite, intermediate volcanics, chert, quartzite; minor - potassium feldspar; sand (0.25 to 2 mm.), angular to subrounded, lithology: mainly quartz; clay, disseminated; also calcrete fragments	60	170
Sandy gravel (60% gravel, 35% sand, 5% clay); alluvial gravels, Fillmore Canyon lithology; gravel (2 to 21 mm.), angular to subrounded, lithology: major - rhyolite, Soledad; minor - intermediate volcanics, siltstone, quartzite, epidotized Orejon andesite, chert, trace of potassium feldspar, black andesite; sand (0.125 to 2 mm.), angular to subrounded, lithology: mainly quartz; clay, disseminated	110	280
No sample	8	288

Table 3 (continued

Stratigraphic Unit and Material	Thickness (feet)	Depth (feet)
Well 23.2E.16.133 City of Las Cruces Well No. 24 (continued)		
Santa Fe Group with Thin Overlay, etc. (continued)		
Gravelly sand (35% gravel, 40% sand, 5% clay); mixed rounds present; gravel (2 to 19 mm.), angular to rounded, lithology: major - rhyolite, minor - quartzite, potassium, feldspar, chert, quartz, intermediate volcanics; sand (0.125 to 1 mm.), angular to rounded, lithology: mainly rounded; clay disseminated . . .	15	300
Gravelly sand (55% gravel, 25% sand, 20% clay); gravels alluvial; Fillmore Canyon lithology; gravel (2 to 32 mm.), angular to subrounded, lithology: major - Soledad rhyolite, minor - Orejon andesite, quartz, monzonite, tuff, black andesite, trace of white marble; sand (0.125 to 2 mm.), angular to subrounded; lithology same as gravel plus quartz; clay (5 YR 5/2)	30	330
Same as above (300 - 330'), except gravel size is (2 to 8 mm.)	15	345
No sample	5	350
Same as above (300 to 330')	45	395
Same as above (350 to 395'), (300 to 330'), except gravel size is smaller (2 to 8 mm.); trace of Precambrian granite	40	435
Same as above (350 to 395'), (300 to 330'), except gravel is coarser (2 to 40 mm.)	65	500
Remarks: Santa Fe Group, fluvial facies above 170 and from 280 to 300'; alluvial facies from 170 to 280, and from 300 to 500'.		
Well 23.2E.22.331 New Mexico State University Well No. 4, University Golf Course Driller's log: Schieffer Drilling Company		
Picacho Alluvium		
Gravel, sand and boulders	43	43
Santa Fe Group, Fluvial Alluvial-fan Facies		
Sand and gravel with few boulders	38	81
Sand, small gravel, with streaks of clay and caliche	32	113
Caliche, streaks of sand and sandy clay	26	139
Sand and sandy clay	5	144
Sandy clay, caliche, thin hard streaks	9	153

Table 3 (continued)

Stratigraphic Unit and Material	Thickness (feet)	Depth (feet)
Well 23.2E.22.331 New Mexico State University Well No. 4 (continued)		
Santa Fe Group, Fluvial Alluvial-fan Facies (continued)		
Hard clay and caliche	6	159
Sandy clay and streaks of sand	9	168
Sand (hard streaks)	7	175
Clay	19	194
Sandy clay, streaks of sandy lime	25	219
Sand and streaks of sandy clay	58	277
Hard sandy clay, streaks of sand	16	293
Sand, streaks of hard sandy clay	37	330
Hard clay with streaks of gravel	11	341
Sandy clay, streaks of hard gravel	15	356
Hard conglomerate gravel, streaks of sand and sandy clay	127	483
Hard clay with streaks of gravel and hard sand	124	607
Remarks: Schlumberger Induction--Electric log is available.		
Well 23.2E.28.331 New Mexico State University Well No. 8		
Driller's log: Taylor and Boyd & Son Drilling Company		
Santa Fe Group, with Thin Late Quaternary Overlay		
Fine sand and clay; much time spent conditioning hole at outset during this 10' interval. Mud was very thin and probably not returning pebbles	10	10
Mainly sand with a few pebbles of about ¼" in size. Clay stringer at about 18'	10	20
Brown sand with a few pebbles up to ¼"; (22-30'), coarser rock chips plus clay blebs, seems to be hard shale zone with cobbles . . .	10	30
Gravel	10	40
Gravel plus boulders	10	50
Gravel and shale, increased amount of shale . .	10	60
Brown sand and a little gravel	10	70
Brown sand; small percentage of clay; virtually no gravel; last 4 or 5' fine sand	10	80
First 5' coarser sand than above. A little gravel in the last 5', along with the sand; small amount of brown sandy clay in middle portion, then back to coarse gravel in last 2'	10	90

Table 3 (continued)

Stratigraphic Unit and Material	Thickness (feet)	Depth (feet
Well 23.2E.28.331 NMSU Well No. 8 (continued)		
Santa Fe Group, etc. (continued)		
Fine sand and clay	10	100
Sand	10	110
Sand	10	120
Sand	4	124
Gravel	4	128
Sand	2	130
Sand with clay streaks	10	140
Sand with a little clay	10	150
Sand and gravel	10	160
Coarse gravel	10	170
Gravel	3	173
Sand	7	180
Sand with small amount of clay - clay builds in quantity in last 4'	10	190
Sand with clay, abundant in 197-200' interval . .	10	200
Sand and clay, clay abundant from 205-210'	10	210
Fine sand and clay	20	230
Fine sand and clay; more sand in last 2' and coarser	10	240
Sand with clay, sand fairly coarse as in 230-240', some pebbles	10	250
Fine sand	20	270
Gravel, sand and clay	10	280
Soft clay and gravel	10	290
Mostly sand, also clay and pebbles	10	300
Mostly sand with a few pebbles going to a finer sand at 306 to 310'	10	310
Gray sand, medium sized	10	320
Sand with a little more clay but clay amount is small, a little fine gravel; clay buildup a little in lower 5', to significant amount (30-40%)	10	330
Sand and clay	10	340
Coarse gray sand with small pebbles, minor amount of clay	10	350
Sand, finer than above, small amount of clay . . .	10	360
Medium sized gray sand with 10-20% clay	10	370
As above with less clay	20	390
Tan clay (75%); small amount sand; clay compact and in large chunks, a few pebbles; gray sand as in interval above builds up in lower 4' of this 10'	10	400
Sand with 25% clay	10	410
Gray sand with buff clay as above; sand is comprised of mainly volcanic fragments	10	420

Table 3 (continued)

Stratigraphic Unit and Material	Thickness (feet)	Depth (feet)
Well 23.2E.28.331 NMSU Well No. 8 (continued)		
Santa Fe Group, etc. (continued)		
Sand with fragments of igneous rock of about 1/8 to 1/4 inch in size, gray sand as above; lower 5' interval has fewer fragments of igneous rock of size above and more clay	10	430
Tan to gray sand and clay, clay percentage higher than above 10'	10	440
Gray fine to medium sand with small percentage of clay (15%)	20	460
Gray fine to medium sand as above	10	470
Good coarse gray to tan sand; very little clay content but a few fragments of hard tan clay . .	10	480
Fine sand	10	490
Fine to medium sand; small percentage silt and clay	10	500
Coarse sand	10	510
Fine to medium tan sand, little clay	20	530
Sand coarser than above; might be breaking up a fine gravel	10	540
Medium sized sand but last 1' showed coarser material; not as coarse at 530-540'	10	550
Coarse sand	10	560
Medium to fairly coarse tan sand with large (1/8") particles of igneous rock in small (less than 5%) amount	10	570
Medium to fine sand; very little (less than 10%) clay content	20	590
As above (580-590) but coarser	10	600
Fine sand	30	630
Remarks: Schlumberger Dual Induction - Laterolog is available.		
Possibly fluvial facies of the Upper Santa Fe Group above 500' and alluvial-fan facies below.		
Well 23.2E.34.41 Dr. Latimer Evans		
Driller's log: Schieffer Drilling Company		
Santa Fe Group with Thin Overlay of Fillmore and Picacho Alluvium		
Sand and small gravel	45	45
Sandy clay	16	61
Sand, small gravel, streaks of clay	22	83
Clay	8	91
Sand and small gravel	16	107

Table 3 (continued)

Stratigraphic Unit and Material	Thickness (feet)	Depth (feet)
Well 23.2E.34.41 Dr. Latimer Evans (continued)		
Santa Fe Group, etc. (continued)		
Clay and gravel	22	129
Cemented gravel and hard clay	23	152
Sand, streaks of hard gravel	19	171
Hard gravel, streaks of clay	23	194
Sand, streaks of clay and gravel	32	226
Clay	5	231
Sand and sandy clay	24	255
Sand	9	264
Sand, streaks of sandy clay	12	276
Clay and sandy clay	5	281
Clay, streaks of hard gravel	12	293
Sand and sandy clay	22	315
Sand	17	332

Remarks: Total depth of 332'; 6' of 20 slot stainless steel screen from 326 to 332'; water tested 12 grains hardness (soap test). Fluvial facies, Upper Santa Fe Group, possibly to 107 feet. Alluvial-fan-facies below 107 feet.

Well 24.3W.6.444 Corralitos Ranch, Mason Draw Well
Driller's log: Schieffer Drilling Company

Stratigraphic Unit and Material	Thickness (feet)	Depth (feet)
Gila Group, Thin Overlay of Late Quaternary Alluvium		
Surface soil and clay	12	12
Sand and gravel	9	21
Clay	39	60
Sand	13	73
Clay	7	80
Gravel	5	85
Probable Base of Gila, Top Tertiary Volcanics		
Sand rock, and rock	17	102
Clay, sand and rock	58	160
Blue lava rock, streaks hard sand	92	252
Red clay and gravel	10	262

Well 24.1E.2.220 Stahmann Farms, Inc.
W. J. Stahmann Home
Driller's log: Schieffer Drilling Company

Stratigraphic Unit and Material	Thickness (feet)	Depth (feet)
Late Quaternary Rio Grande Alluvium		
Clay and sand	21	21
Clay and small gravel	21	42
Sand and gravel	32	74

Table 3 (continued)

Well 24.1E.2.220 Stahmann Farms, Inc. (continued)

Stratigraphic Unit and Material	Thickness (feet)	D[illegible] ([illegible])
Upper Santa Fe Group, Fluvial Facies		
Clay	2	76
Sand and soft clay	8	84
Sand and soft clay	21	105
Sand and soft clay	11	116
Sand and small gravel	10	126
Sand	11	137
Clay	3	140
Sand	18	158
Clay	1	159
Sand	9	168
Sand and soft clay	11	179
Sand	20	199
Clay	2	201
Sand and soft clay	7	208
Sand and small gravel	11	219

Remarks: 10' of 2-1/2" stainless steel screen.
5-1/2' x 2-1/2" blank pipe
2-1/2' x 4" lead seal.

Well 24.2E.33.141 Stahmann Farms, Inc.
Plaza Pecan Plant
Driller's log: Schieffer Drilling Company

Stratigraphic Unit and Material	Thickness (feet)	D[illegible] ([illegible])
Late Quaternary Rio Grande Alluvium		
Sand and soft clay	21	21
Sand and small gravel	18	39
Clay	2	41
Sand and gravel	27	68
Upper Santa Fe Group, Fluvial Facies		
Clay	3	71
Sand	9	80
Clay	3	83
Sand	12	95
Clay	10	105
Sand and soft clay	21	126
Sand	11	137
Clay	1	138
Sand and small gravel	9	147

Remarks: 5' of 2-1/2" stainless steel screen.
10-1/4' of 2-1/2" blank pipe.

Table 3 (continued)

Stratigraphic Unit and Material	Thickness (feet)	Depth (feet)
Well 24.2E.9.132 Hanes Knitting Company Sample log: Hawley		
Sampling started at 80'		
Upper Santa Fe Group, Fluvial Facies		
Dark gray brown (10 YR 4/2m) to gray brown (10 YR 5/2m) sand, fine to coarse (minor amount very fine and very coarse grains), mainly quartz (angular to well rounded) but with common lithic and feldspathic grains; low gravelly (less than 10% very fine-fine pebbles (2-8 mm.)); and moderately clean (less than 3% clay-silt matrix). Scattered ($<$5%): soft clay to sandy clay blebs, calcareous, dark reddish brown (5 YR 4/2-4/3m) and dark gray (10 YR 4/1m): hard fine sandy clay fragments, weakly calcareous, dark gray to dark gray brown (10 YR 4/1-4/2); and calcrete fragments, light yellowish brown (10 YR 6/4m). Pebbles mainly rhyolitic and intermediate volcanics, with several rounded quartz pebbles and one angular granite pebble. Some pebbles have secondary carbonate coatings.	30	110
Gravelly sand to sandy gravel, clean, 50-60% very fine to medium pebbles (2mm -3/4 inch) of mixed lithology: rhyolitic and intermediate volcanics abundant, with lesser amounts of quartz, quartzite chert, minor granite and potash feldspar and sedimentary rocks (no limestone), whole and broken rounded-well rounded pebbles of quartz and mixed volcanic types are common. Sand fraction, fine to coarse, dark gray brown to gray brown (10 YR 4/2-5/2m), mainly quartz (angular to well-rounded), but with common lithic and feldspathic grains, and trace mica; scattered calcrete fragments present in gravel fraction; carbonate coatings on a few pebbles	30	140
Gravelly sand to sandy gravel, as above, with about 50% very fine to medium pebble gravel . .	30	170
Sandy gravel, as above, but with 71% gravel (sieved: 45% 4.7 to 16 mm., 26% 2-4.7 mm., 29% 0.06-2mm, mostly in fine to coarse sand range, 0.125 to 1 mm.); rounded pebbles of mixed lithologic composition as described above are common	30	200

Table 3 (continued)

Stratigraphic Unit and Material	Thickness (feet)	Depth (feet)
Well 24.2E.9.132 Hanes Knitting Company (continued)		
Upper Santa Fe Group, Fluvial Facies (continued)		
Sandy gravel, as above, about 75-80% very fine to medium pebble gravel	20	220
As above (200-220')	20	240
As above (200-240')	20	260
As above, about 70-75% very fine to medium pebble gravel	20	280
As above (260-280')	20	300
Sand, fine to medium, with minor amount coarse and very coarse sand grains; low gravelly (less than 20% gravel with composition similar to that above). Transition zone from gravelly to none or very slightly gravelly sediments	20	320
Dark gray-brown to gray-brown (2.5 Y 4/2 to 5/2) sand, fine to medium (0.125-0.5 mm.) with minor amount of coarse and very coarse grains (0.5-2 mm.), mainly quartz (angular to well-rounded) with common lithic and feldspathic grains, and trace of mica; very fine pebble of intermediate volcanic rock	8	328
Note: Water sample at 328 feet.		
Dark gray-brown to gray-brown sand, as above; about 1% very fine to fine pebbles and pebble fragments (mostly broken rounds of mixed composition: rhyolitic and intermediate volcanics, quartz, chert and quartzite). Trace of dark reddish brown (5 YR 3/4 m), gray (5 Y 5/1) and white (5 Y 7/1 m) calcareous clay blebs and gray-brown (2.5 Y 5/2 m) calcrete fragments	12	340
As above (328-340')	10	350
Gray-brown to dark gray-brown (2.5 Y 5/2-4/2 m) sand, fine to medium with minor amount of coarse and very coarse grains, mainly quartz (angular to well-rounded) with common lithic and feldspathic grains, and trace of mica. Scattered very fine-fine pebbles and pebble fragments ($<$ 2%) of mixed volcanic rock types; minor ($<$ 2%) soft clay to sandy clay, calcareous, brown to dark brown (7.5 YR 4/2 m); trace of clay blebs as as above; trace: dark olive gray (5 Y 3/2m) clay shale, noncalcareous; light gray (5 Y 5/1m) calcareous clay shale; and calcrete fragment (carbonate cemented sand and silt).	10	360

Table 3 (continued)

Stratigraphic Unit and Material	Thickness (feet)	Depth (feet)
Well 24.2E.9.132 Hanes Knitting Company (continued)		
Upper Santa Fe Group, Fluvial Facies (continued)		
Note: Clay blebs, shale and calcrete fragments may be from thin beds or lenses with the general sequence of sand beds.		
Dark gray brown (10 YR 4/2m) sand, very fine to medium, low gravelly (< 2% very fine-medium pebbles) and not as clean as above; with minor amount (< 5%) of soft calcareous clay to sandy clay, brown to dark brown (7.5 YR 3/2-4/2m) and reddish brown to dark reddish brown (5 YR 3/3-4/3). The scattered pebbles and pebble fragments are mostly broken rounds of mixed rhyolitic intermediate volcanic types, quartz, granite and chert. Trace of calcrete fragments and very dark gray to dark olive gray (5 Y 3/1-3/2m) clay shale fragments (non to weakly calcareous)	10	370
As above (360-370')	10	380
Sand, as above, but with slight increase in pebble gravel content (still less than 3%) and decrease in amount of soft clay (to less than 3%). Trace: soft calcareous sandy clay to clay blebs, gray (5 YR 5/1m), dark gray (5 Y 4/1m), and dark greenish gray (5 GY 4/1m); calcareous siltstone fragments, dark gray (5 Y 4/1m). Pebble fraction mainly acid-intermediate volcanics with trace of potash feldspar	10	390
Sand, as above, slight increase in soft clay to sandy clay (still less than 5%)	10	400
Sand, as above, with 5-10% clay, sandy clay and silt mainly as individual "clay blebs"; very fine-medium pebble gravel (< 3%), of mixed volcanic rock types plus minor chert, subangular to rounded. No quartz or granite observed	10	410
Dark gray brown to gray brown (10 YR-2-5 Y 4.52m) sand, fine to medium, with very minor amount of coarse and very coarse grains, mainly quartz (angular to well rounded) with common lithic and feldspathic grains; low gravelly (< 5%), very fine to medium pebbles		

Table 3 (continued)

Stratigraphic Unit and Material	Thickness (feet)	Depth (feet)
Well 24.2E.9.132 Hanes Knitting Company (continued)		
Upper Santa Fe Group, Fluvial Facies (continued)		
(mixed acid-intermediate volcanics); cleaner than above, with minor amount (< 3%) of soft clay to sandy clay blebs, dark brown to brown (7.5 YR 4/2m) and gray (5 Y 5/1 moist); trace of calcrete fragments	10	420
As above (410-420')	10	430
As above (410-430'), plus trace of dark gray to dark greenish gray (5 YR 5 GY 4/1m) soft calcareous clay blebs; and dark reddish brown (5 YR 3/4m) clay shale fragments of non to weakly calcareous	10	440
Dark brown to gray brown (10 YR-2.5Y 4.5/2m); very fine to medium sand, with minor amount of coarse and very coarse grains; slightly clayey, 5-10% clay-silt as discrete soft blebs as above, and as matrix (?); scattered (less than 2-3%) very fine to medium pebble gravel of mixed volcanic composition, as above, with one broken round milky quartz and one rounded chert pebble; trace of noncalcareous friable sandstone . . .	10	450
As above, gravel fraction mainly acid-intermediate volcanics (local types)	10	460
Dark gray (10 YR-2.5Y 4/1m), clayey very fine to medium sand, with about 20% calcareous clay to silty clay apparently mainly as matrix; scattered discrete soft blebs of calcareous clay, gray (5 Y 5/1m), dark gray (5 Y 4/1m), dark greenish gray (5GY 4/1m), brown to dark brown (7.5YR 4/2m), and reddish brown (5 YR 4/3 m); less than 3% very fine to medium pebble gravel, mainly of mixed volcanic composition with one broken rounded quartz pebble; quartz sand grains (angular to well rounded) are still predominant, with common lithic and feldspathic grains and trace of mica	10	470
As above, except slightly less clay-silt (about 15%)	10	480
Dark gray brown (10 YR-2-5Y 4/2m) very fine-medium sand with minor coarse and very coarse sand; and scattered (< 3%) very fine-medium pebble gravel (acid-intermediate volcanics); with discrete soft blebs (8-10%) of clay to sandy clay as above	10	490

Table 3 (continued)

Stratigraphic Unit and Material	Thickness (feet)	Depth (feet)
Well 24.2E.9.132 Hanes Knitting Company (continued)		
Upper Santa Fe Group, Fluvial Facies (continued)		
As above (480-490') except fewer clay blebs (5-8%)	10	500
Gravelly dark gray brown (10 YR-2-5Y 4/2m) fine to medium sand, with minor amount of coarse and very coarse grains, mainly quartz (angular to well rounded) with common lithic and feldspathic grains and trace of mica; gravel contents about 30% very fine to medium pebble gravel of mixed rhyolitic and intermediate volcanic composition, with one well rounded fine quartz pebble observed. Scattered (<10%) soft calcareous clay blebs, gray brown (10 YR-2.5Y 5/2m), dark brown (7.5 YR 4/2m) to dark gray brown (10 YR 3/2m) to dark brown (7.5 YR 3/2m) with very fine white carbonate nodules	10	510
Remarks: Sieve analyses run for 170-200, 320-328, and 500-510'. Water sample taken at 513'		
Schlumberger Dual Induction - Laterolog and Microlog available.		
Dry sieve mechanical analyses for intervals: 170-200, 320-328, 500-510.		
Pebble count from interval 170-200.		
Well 25.1E.21.331 El Paso Natural Gas Company Afton Turbine Station Water Well No. 2 Driller's log: K.C. Wheeler Drilling Company		
Santa Fe Group		
Top soil and caliche	15	15
Sand and caliche	25	40
Fine sand to pebble gravel	90	130
Fine sand to granular gravel	34	164
Red silty clay with small pebble gravel . . .	11	175
Red silt to coarse sand	10	185
Fine to coarse sand	109	294
Brown silty clay	16	310
Fine to medium sand	20	330
Brown silty clay and medium sand	92	422

Table 3 (continued)

Stratigraphic Unit and Material	Thickness (feet)	Depth (feet)
Well 25.1E.21.331 El Paso Natural Gas Co. (con.)		
Santa Fe Group (continued)		
Fine to coarse sand (water)	28	450
Reddish brown clay	26	476
Medium sand to granular gravel (water)	24	500
Sandy clay with some gravel	35	535
Sand and gravel	30	565
Sandy clay	21	586
Remarks: Probably mainly in fluvial facies of Upper Santa Fe Group, with clays, below 294 feet, possibly representing lacustrine beds.		
Well 25.3E.32.421 Bowman Brothers Log: Hawley, Taylor, & Schieffer Drilling Co.		
Late Quaternary Rio Grande Alluvium		
Sand with streaks of clay, minor fine gravel	20	20
Sand and minor pebble gravel (quartz, feldspar mixed volcanics, siltstone)	6	26
Sandy clay, brown streaks of sand and carbonaceous fragments	4	30
Sand and pebble gravel (rhyolite, chert feldspar, intermediate volcanics)	1	31
Clay (calcareous) sand, and gravel (rhyolite; rounded quartz, intermediate volcanics, chert, jasper, granite, siltstone)	10	41
Sand and minor pebble gravel (clean, rounded, mixed lithology as above)	10	51
Sand and pebble gravel (as above)	23	74
Sand with scattered pebbles (as above)	6	80
Santa Fe Group "Sand" and "Clay" Facies		
Clay and soft shale (variegated, reddish-greenish); interbedded sand stringers	1	81
Soft shale (variegated, as above), hard white to gray sandstone and claystone zones, noncalcareous	3	84
Sandy clay, reddish brown, weakly calcareous	5	89
Sandy clay and sand (arkosic) gray-brown to white, calcareous, with thin hard layer at base	5	94

Table 3 (continued

Stratigraphic Unit and Material	Thickness (feet)	Depth (feet)
Well 25.3E.32.421 Bowman Brothers (continued)		
Santa Fe Group "Sand and "Clay" Facies		
Sand (arkosic), trace very fine pebbles	7	101
Sand (arkosic) sandy clay; and interbedded hard, "chert-like" layers, light reddish, calcareous; minor very fine pebble gravel	4	105
Sand (arkosic, with thin hard, fine-grained interbeds; minor clay zone at 110 feet	11	116
Sand (arkosic) with greenish to reddish, soft shale partings; minor very fine volcanic pebbles	10	126
Sand, (arkosic) fine to coarse, clean	20	146
Clay, reddish brown to greenish shale, trace fine volcanic rock fragments and mica	1	147
Sand (arkosic), fine to medium; few thin, reddish brown shale partings	11	158
Sand (arkosic), fine to medium; minor coarse sand in lower part	13	171
Sand, soft claystone, fine volcanic pebbles	1	172
Hard gray to brown argillaceous layer grading down into brown calcareous clay	3	175
Interbedded brown, calcareous clay, sand and sandy clay (thin bedded); trace fine to medium volcanic pebbles, mainly rhyolite	14	189
Clay to sandy clay	2	191
Sand (arkosic), fine to medium; hard layers 213 and 227 feet	36	227
Clay to soft claystone	4	231
Sand (arkosic), fine to medium	42	274
Clay	3	277
Sand (arkosic), fine to medium, hard layer at 288 feet	16	293
Sandy clay, brown	5	298
Sand (arkosic), fine to medium	26	324
Sandy clay to clay, hard, reddish brown	2	326
Sand (arkosic), fine to medium	2	328
Sandy clay, moderately hard	6	334
Sand (arkosic), fine to medium	3	337
Sandy clay	13	350
Sand (arkosic), fine to medium	8	358
Sandy clay	6	364

Table 3 (continued)

Stratigraphic Unit and Material	Thickness (feet)	Depth (feet)
Well 25.3E.32.421 Bowman Brothers (continued)		
Santa Fe Group "Sand" and "Clay" Facies		
Sand (arkosic), fine to medium	14	378
Clay to sandy clay, reddish brown, white	3	381
Sand; hard streaks, 383 and 391'	10	391
Clay to sandy clay, same as 378-381'	7	398
Sand (arkosic), fine to medium	10	408
Clay	3	411
Sand (arkosic), fine to medium	27	438
Drillers' log below 438' shows sand layers ranging from 2 to 22' thick, alternating with clay layers from 2 to 10' thick; clays reddish brown, often sandy; scattered cemented streaks present	180	618
Well 26.1E.35.332 Texaco, S.H. Weaver-Federal Sample log: H.L. Beckmann, Geological Serv. Co.		
Santa Fe Group, Undifferentiated		
Sandy-silty limestone, cream to pale yellow to pale pink, dense	20	20
Sandstone, clear, medium to coarse to very coarse grained, subangular to subrounded . .	20	40
Gravel, multi-colored, coarse to very coarse grained, subrounded, few very large igneous pebbles	100	140
Shaly, sandy gravel (20% shale), very soft; shale, pink	10	150
Sandstone, medium coarse to very coarse, subangular to subrounded, quartz grains . . .	210	360
Shaly sandstone (30% shale, 70% sandstone); shale, pink, very soft	10	370
Shale, pink	10	380
Mainly sandstone with some shaly sandstone (shale 20 to 30%); sandstone clear, subrounded, medium to coarse, quartz grains; shale pink, very soft; some very coarse grained igneous pebbles from 1500 to 1600'	1270	1650
Silty, shaly sandstone (40 to 100% shale); sandstone, medium fine to medium coarse, subrounded, lenses of quartz grains; shale pink, very soft, some sandy	160	1810
Sandy, silty shale, pink, very soft, some sandy	50	1860
Shaly sandstone (20% shale, 80% sandstone); sandstone medium to coarse to very coarse, subrounded, clear, quartz grains, shale pink .	10	1870

Table 3 (continued)

Stratigraphic Unit and Material	Thickness (feet)	Depth (feet)
Well 26.1E.35.332 Texaco, S.H. Weaver-Federal (continued)		
Santa Fe Group, Fluvial Facies (continued)		
Sandy, silty shale (50% shale, 30% sandstone); shale, pink	20	1890
Sandy, silty shale (70% to 100% shale); shale, pink	30	1920
Conglomeratic shale (80% shale, 20% conglomerate); shale, pink, very soft, some sandy; conglomerate, multi-colored, very coarse grained, igneous pebbles	10	1930
Conglomerate, multi-colored, very coarse grained, igneous pebbles	90	2020
Tertiary Volcanics		
Intermediate igneous rock, coarse grained, conglomerate (30%)	10	2030
Intermediate igneous rock, dull brown red to red, fine grained, some hematite staining	60	2090

Remarks: Total depth is 6600 feet.
Only the portion of the well pertinent to water supply is shown.

Well 26.2E.24.140 Gates Cyclo International, Inc.
Driller's log: Schieffer Drilling Company

Stratigraphic Unit and Material	Thickness (feet)	Depth (feet)
Upper Santa Fe Group		
Soil, sand and gravel	25	25
Sand and clay	26	51
Clay	35	86
Sand and sandy clay	26	112
Sand	40	152
Clay	15	167
Sand and clay streaks	21	188
Clay	8	196
Sand	49	245
Sand, gravel and clay	63	308
Clay	13	321
Sand and sandy clay	54	375
Clay	18	393
Sand and thin sandy clay streaks	67	460

Remarks: 440' of 8-5/8 T&C galvanized 28 lb. per ft. casing set in 12¼" rotary-drilled hole, pressure cemented from 440' to ground elevation. 15' of all stainless steel 18 gauge slot size, 6" pipe size screen set from 460' to 445'. 42' of standard 6-5/8 galvanized blank pipe from 445' to 403'.
Probably mainly in fluvial facies of Upper Santa Fe Group, but may include some lacustrine clays.

Table 3 (continued)

Stratigraphic Unit and Material	Thickness (feet)	Depth (feet)
Well 26.3E.2.341 New Mexico Highway Department Sample log: King		
Santa Fe Group, with Probable Thin Late Quaternary Overlay		
Brown (10 YR 6/3m) sand, medium (0.25 to 0.50 mm.), angular to well rounded and frosted, 80% quartz and 20% mixed volcanics, mainly rhyolite; sample 95% sand and 5% pebbles of rhyolite, andesite and gray fossiliferous limestone; only a small trace of clay, less than 1% . . .	5	5
Very coarse sand and gravel; 80% gravel (¼" to 1½") of clear angular quartz and mixed volcanics; volcanics of tan to gray rhyolite and rhyolite porphyry with quartz phenocrysts, purple-gray andesite; trace gray-black quartzite and gray limestone; sample from 10-20' has larger pebbles	15	20
Clay, gravel, and fine sand; clay (10 YR 6/4m), 50% of sample; angular to rounded clear quartz sand 10% of sample; pebbles (¼" to 1½") of rhyolite, andesite, rhyolite and andesite porphyry, quartzite; tan tuff in minor amount	10	30
Mixed volcanics and quartzites, as in above interval, 95%; minor, 5%, amount of clay (10 YR 6/4m); clear quartz sand 5%	10	40
Loosely cemented calcareous sandstone (10 YR 8/4m) 65%; clay (10 YR 6/4m) 15%; trace mixed volcanic pebbles; sandstone mainly quartz and rhyolite grains with calcareous cement; pebbles (½ to 3/4") mainly of rhyolite and andesite; trace of basalt and quartzite pebbles	10	50
Clay (10 YR 5/3m) 70%; fine (.125 to .25 mm) quartz sand 25%; pebbles of mixed volcanics (½-¼") 5%; trace of cemented calcareous sand, as mentioned above	10	60
Clay (10 YR 5/3m) 70%; fine (.125 to .25 mm) quartz and rhyolite sand 20%; mixed volcanics 5%; pebbles of cream colored limestone (2.5Y 8/2 m) 5%; trace of calcareous tan sandstone	10	70

Table 3 (continued)

Stratigraphic Unit and Material	Thickness (feet)	Depth (feet)
Well 26.3E.2.341 New Mexico Highway Dept. (continued)		
Santa Fe Group with Probable Thin Late Quaternary Overlay (continued)		
Clay (10 YR 5/3m) 75%; fine (.125 to .25 mm) quartz and rhyolite sand 20%; mixed rhyolite and andesite pebbles (¼ to ½") 5%; trace cream-colored limestone pebbles	60	130
Clay (10 YR 5/3m) 65%; fine (.125 to .25 mm) quartz sand 20%. Consolidated but loosely cemented tan to gray sandstone with calcareous cement, 5%; cream-colored limestone pebbles 5%; mixed andesite and rhyolite volcanics with traces of basalt and quartzite, 5%	20	150
Lithology as mentioned above; clay 55%; fine sand 35%; sandstone 5%; limestone 5%; mixed volcanics 5%	40	190
Clay (10 YR 5/3m) 50%; consolidated tan sandstone cemented with calcite 45%; largely quartz grains but also rhyolite and volcanic fragments; cream colored limestone (2.5 Y 8/2m) 5%; trace of mixed volcanics, mainly andesite	20	210
Sand; gray to tan (10 YR 6/1m to 10 YR 6/3m), medium (.25 to .50 mm) angular to rounded, quartz grains, rest of grains mixed volcanics 80%. Clay (10 YR 6/4m) blebs, 15%; calcareous tan sandstone, mixed volcanics and limestone of coarse sand size (1-2mm) 5%	20	230
Clay (5 YR 3/4m) 80%; sand (.25 to .50mm) mainly of quartz, angular to rounded 15%; calcareous tan sandstone and cream-colored limestone 5%	20	250
Sandy clay (10 YR 7/1m) calcareous with quartz and mixed volcanics sand grains, 80%; clay (5 YR 3/4m) 10%; angular to rounded quartz sand 10%; trace of cream-colored limestone and gray siltstone	10	260
Clay (5 YR 3/4m) calcareous 50%; cemented tan sandstone (10 YR 8/1m) with calcareous cement 25%; gray (7.5 YR 6/1m) calcareous compact siltstone 20%; quartz sand and andesite fragments 5%	20	280

Table 3 (continued)

Stratigraphic Unit and Material	Thickness (feet)	Depth (feet)
Well 26.3E.2.341 New Mexico Highway Dept. (continued)		
Santa Fe Group, etc. (continued)		
Clay (5 YR 5/4m) calcareous 80%; tan to gray calcareous sandstone 10%; quartz sand 5%; cream colored limestone 5%; trace gray siltstone	10	290
As in above interval except clay 70%; tan calcareous sandstone 20%; quartz sand 5%; cream-colored limestone 5%	60	350
Clay (5 YR 5/4m) calcareous 60%; tan to gray compact sandstone with 80% of grains of quartz, calcareous cement 30%; cream-colored limestone 10%; 20% of grains of mixed volcanics	10	360
Clay (5 YR 5/4m) sandy and calcareous 80%; angular to rounded quartz sand 20%; trace of tan calcareous sandstone, as mentioned above, and cream-colored limestone	20	380
As in above interval except sandy clay 75%; sand 15%; cream-colored limestone 5%, and tan sandstone 5%.	20	400
Sandy clay (10 YR 5/4m) 100%; only traces of cream limestone and tan calcareous sandstone	40	440
Sandy calcareous clay (10 YR 5/4m) 55%; clay (10 YR 6/4m) 10%; gray (10 YR 7/1m) coarse to fine grained calcareous sandstone with 50% of grains quartz and 50% of grains mixed volcanics, 30%; quartz sand and cream-colored sandy limestone 5%	10	450
Decrease in clay, as mentioned above, to 45% and increase in quartz sand to 25%; gray calcareous sandstone 25%; mixed volcanics and cream-colored limestone 5%	10	460
Sandy calcareous clay (10 YR 5/4m) 85%; gray calcareous sandstone 5%; angular to rounded quartz sand 10%	20	480
Sandy calcareous clay (10 YR 5/4m) 10%; angular to rounded quartz sandstone 30%	10	490
Sandy calcareous clay (10 YR 5/4m) 100%, sand fraction of clay is 70% angular to rounded quartz and 30% mixed volcanics and limestone	170	660
Sandy calcareous clay (10 YR 5/4m) 95%; sandy calcareous clay (10 YR 5/6m) 5%	20	680

Table 3 (continued)

Stratigraphic Unit and Material	Thickness (feet)	Depth (feet)
Well 26.3E.2.341 New Mexico Highway Dept. (continued)		
Santa Fe Group, etc. (continued)		
Sandy calcareous clays, as mentioned above, and in same percentages. Trace of gray finely crystalline limestone.	10	690
Sandy calcareous clay (10 YR 5/4m) 95%; limestone; some of limestone has diagnostic Paleozoic (Penn.) fusulinid fossils,5%; trace of silicified gray to cream-colored limestone and tan calcareous sandstone	10	700
All of the samples up the borehole from this last sample were unwashed. The last sample was washed by the driller, and it can be assumed an unknown portion of clay washed from the sample. Limestone fragments, tan, gray black, some bearing Pennsylvanian fossils 95%; 2% gray silicified limestone; 3% tan calcareous sandstone; drilling time would indicate that the limestone is in gravel form, rather than being bedrock	18	718
Remarks: Fluvial facies, Upper Santa Fe Group, to about 40'. Clay facies of uncertain depositional environment below 40'.		
Well 26.3E.25.323 B & K Farms, Wholesome Dairy Irrigation Well		
Driller's log: Cass Drilling Company		
Santa Fe Group, with Probable Thin Late Quaternary Overlay		
Sand, gravel and scattered rocks	35	35
Gravel embedded in clay.	42	77
Gravel and streaks of clay	10	87
Clay	33	120
Clay and gravel	15	135
Gravel and clay streaks	25	160
Clay	10	170
Sand and gravel	20	190
Gravel and clay streaks	35	225

Table 3 (continued)

Stratigraphic Unit and Material	Thickness (feet)	Depth (feet)
Well 26.3E.25.323 B & K Farms, Wholesome Dairy (continued)		
Santa Fe Group, with Probable Thin Overlay, etc.) (continued)		
Clay	12	237
Gravel and clay	33	270
Sandstone, hard	10	280
Gravel with clay	20	300
Clay	15	315
Gravel and clay with streaks of hard sandstone	25	340
Gravel and sand	15	355
Gravel embedded in clay, streaks of hard sandstone	30	385
Sand and gravel	16	401
Clay	2	403
Well 26.3E.26.144 Luis Arellano Driller's log: Schieffer Drilling Company		
Late Quaternary (?) Alluvium		
Soil	8	8
Gravel	21	29
Clay	9	38
Gravel	6	44
Clay	9	53
Clay and big gravel streaks	20	73
Santa Fe Group		
Clay	17	90
Sand and sandy clay	51	141
Sand	17	158
Clay	5	163
Sand	6	169
Clay	3	172
Sand	8	180
Sandy clay	25	205
Sand	10	215
Remarks: 5' of 4" stainless steel screen from 210' to 215'.		

Table 3 (continued)

Stratigraphic Unit and Material	Thickness (feet)	Depth (feet)
Well 26.3E.26.213 B & K Farms, Wholesome Dairy Sample log: Taylor		
Santa Fe Group with Probable Thin Late Quaternary Overlay		
Sand (100%), (0.25 to 2 mm.), angular to rounded, lithology: major - quartz, minor - rhyolite, muscovite, potassium feldspar; some calcrete fragments	5	5
Clayey sand (10% gravel, 60% sand, 30% clay); gravel (2 to 18 mm.), angular to rounded, lithology: major - rhyolite, minor - chert, quartz, quartzite; clay disseminated; sand (0.625 to 2 mm.), angular to rounded, lithology: major - quartz, minor - rhyolite	5	10
Clayey sand (2% gravel, 60% sand, 38% clay); gravel (2 to 5 mm.), angular to rounded, lithology: major - rhyolite, minor - chert, quartz, quartzite; sand (0.0625 to 2 mm.), angular to rounded, lithology: major - quartz, minor - rhyolite; clay disseminated	5	15
Gravelly sand (20% gravel, 60% sand, 20% clay); gravel (2 to 8 mm.), angular to rounded, lithology: major - rhyolite, minor - potassium feldspar, quartz, siltstone, quartzite; sand (0.0625 to 2 mm.), angular to rounded, lithology: major - quartz, plagioclase; clay, disseminated; plus calcrete fragments	5	20
Sandy gravel (2% sand, 98% gravel); gravel (2 to 10 mm.), angular to rounded, majority is rounded, lithology: major - rhyolite, potassium feldspar, gneissic granite, quartz, plagioclase, quartzite, siltstone, intermediate volcanics, basalt; sand (0.25 to 1.0 mm.), angular to rounded, lithology: quartz	10	30
Clayey gravel (90% gravel, 10% clay); gravel (9 to 27 mm.), angular to well-rounded, lithology: major - rhyolite, minor - intermediate volcanics, potassium feldspar, quartz, chert, basalt, quartzite, siltstone; clay (7.5 YR 6/4)	5	35

Table 3 (continued)

Stratigraphic Unit and Material	Thickness (feet)	Depth (feet)
Well 26.3E.26.213 B & K Farms, Wholesome Dairy (continued)		
Gravelly clay (20% gravel, 80% clay); gravel (9 to 16 mm.), angular to well rounded, lithology: major - rhyolite, intermediate volcanics, minor - feldspar; clay (7.5 YR 5/4)	5	40
Clay (100%), (5 YR 4/3), trace of rhyolite and intermediate volcanics	5	45
Clayey sand (80% sand, 20% clay); sand (0.0625 to 2 mm.), angular to rounded; lithology: quartz and plagioclase; clay (5 YR 4/3)	5	50
Same as above (45 to 50'), except about 5% gravel; gravel (2 to 15 mm.), angular to rounded, lithology: major - rhyolite, minor - potassium feldspar, intermediate volcanics, basalt, siltstone, chert	10	60
Same as above (50 to 60'), except increase in gravel to about 15%	5	65
Clay (100%), (5 YR 4/6); trace of gravel, rhyolite, basalt, intermediate volcanics . .	5	70
Same as above (50 to 60')	15	85
Same as above (50 to 60', 70 to 80'), plus increase in gravel to 10%	20	105
Clayey sand (trace of gravel, 75% sand, 25% clay); sand (0.0625 to 1 mm.), angular to rounded, lithology: quartz and plagioclase; clay (5 YR 4/4); trace of gravel, rhyolite mainly, some intermediate volcanics; some calcrete fragments	30	135
Sandy clay (trace of gravel, 40% sand, 60% clay); sand (0.0625 to 1.0 mm.), angular to rounded, lithology: quartz and plagioclase; clay (5 YR 4/3); some calcrete fragments	50	185
Clayey sand (trace of gravel, 55% sand, 45% clay); sand (0.0625 to 0.25 mm.), angular to rounded, lithology: quartz and plagioclase; clay (5 YR 4/4), (5 YR 4/3); some calcrete fragments	343	528

Remarks: Welex Induction - Electric log available. This test hole was abandoned because of the poor potential of the stratigraphic section to produce water.
Fluvial facies, Upper Santa Fe Group, to about 35'. Clay facies of uncertain depositional environment below 35'.

Table 3 (continued)

Stratigraphic Unit and Material	Thickness (feet)	Depth (feet)
Well 28.3W.15.111 Homer Bennett		
Driller's log: Cass Drilling Company w/comments by Tom Cliet		
First samples studied were at 85'		
Quaternary Basalt		
Basalt, black, with rhyolite gravel and clear quartz, well rounded sand	5	90
Basalt with quartz inclusions	16	111
Sand (95%), red stained, rounded to well-rounded; basalt (5%)	4	115
Basalt with olivine crystals	50	165
Basalt (60%); ash (40%); ash is red with fine sand	9	174
Ash, red, with basalt sand	8	182
Basalt with some red to tan ash	8	190
Basalt	13	203
Basalt with some ash	6	209
Basalt	14	223
Basalt with some tan ash	10	233
Ash with basalt gravel	8	241
Basalt with some tan ash	15	256
Basalt	34	290
Ash, tan, with basalt	16	306
Ash, tan to gray, with basalt gravel	13	319
Basalt with tan ash	11	330
Basalt	40	370
Basalt with tan ash	5	375
Ash, tan to gray, with basalt sand	20	395
Sand, fine grained, well-rounded to angular; ash, tan to gray	5	400
As above with less ash	5	405
Remarks: Well is over 500' deep, but samples for last 95' + were not available. Static water level is 489'. Last 7' of well at 500'± was reported to be water producing sand.		
Well 28.3E.34.331 Southern Pacific Railroad Company Lizard Well		
Sample log: Taylor		
Santa Fe Group		
Sand (0.125 to 1.0 mm.), angular to well-rounded, lithology: mainly quartz, trace of andesite porphyry fragments	20	20

(Table 3 (continued)

Stratigraphic Unit and Material	Thickness (feet)	Depth (feet)
Well 28.3E.34.331 Southern Pacific (continued)		
Santa Fe Group (continued)		
Sand (0.125 to 1.0 mm.), angular to well rounded, lithology: mainly quartz, trace of red shale	10	30
Sand with layers of shale; (90% sand, 10% shale); sand (0.125 to 1.0 mm.), angular to well rounded, lithology: mainly quartz, small shale fragments . .	10	40
Sand (0.125 to 1.0 mm.), angular to well rounded, lithology: mainly quartz and plagioclase, trace shale fragments (probably contamination	20	60
Sand (0.125 to 0.5 mm.), angular to sub-rounded, lithology: mainly quartz, plagioclase	50	110
Gravelly sand and shale layer with caliche concretions (5% gravel, 70% sand, 25% shale); gravel (2 to 8 mm.), subrounded, lithology: Santa Fe mixed rounded types; quartz, potassium feldspar, chert, quartzite, rhyolite, welded tuff, intermediate volcanics, also andesite porphyry fragments, float, of local origin; lithology: mainly quartz; sand (0.125 to 2 mm.), angular to well rounded; shale (7.5 YR 5/4), (10 YR 6/2); plus calcrete fragments	3	113
Sand and thin shale layers (95% sand, 5% shale); gravel, trace, also andesite porphyry float; sand (0.125 to 0.5 mm.), angular to subrounded, lithology: mainly quartz; shale (7.5 YR 5/4), (7.5 YR 6/4)	17	130
Sand (0.125 to 0.5 mm.), angular to sub-rounded, lithology: mainly quartz	10	140
Sand and shale layers (95% sand, 5% shale); sand (0.125 to 0.5 mm.), angular to sub-rounded, lithology: mainly quartz; shale (7.5 YR 5/4)	20	160
Sand and soft shale layers (92% sand, 8% shale); sand (0.125 to 0.5 mm.), angular to rounded, lithology: mainly quartz; shale (5 YR 4/4),(10 YR 6/3), trace of diorite float fragments	10	170
Sand and shale layers (88% sand, 12% shale); sand (0.0625 to 0.5 mm.), angular to sub-rounded, lithology: mainly quartz; shale, mostly disseminated (5 YR 5/4), (10 YR 6/3)	10	180

Table 3 (continued)

Stratigraphic Unit and Material	Thickness (feet)	Depth (feet)
Well 28.3E.34.331 Southern Pacific (continued)		
Santa Fe Group (continued)		
Sand and shale layers (84% sand, 16% shale); sand (0.0625 to 0.5 mm.), angular to subrounded, lithology: mainly quartz; shale, mostly disseminated, (10 YR 5/3), trace of andesite porphyry float fragments	20	200
Sand and shale layers (75% sand, 25% shale); sand (0.0625 to 0.5 mm.), angular to subrounded, lithology: mainly quartz; shale (5 YR 5/4)	10	210
Sand and shale layers (85% sand, 15% shale); sand (0.0625 to 0.5 mm.), angular to subrounded, lithology: mainly quartz; shale, mostly disseminated (2.5 YR 4/4)	10	220
Sand and shale layers (85% sand, 15% shale); sand (0.0625 to 0.5 mm.), angular to subrounded, lithology: mainly quartz; shale, mostly disseminated (5 YR 5/1), (6 YR 4/3); trace of andesite porphyry float fragments	10	230
Sand and shale layers (90% sand, 10% shale); sand (0.0625 to 0.5 mm.), angular to subrounded, lithology: mainly quartz; shale, mostly disseminated (5 YR 4/4); plus calcrete	20	250
Sand and shale layers (88% sand, 12% shale); sand (0.0625 to 0.5 mm.), angular to subrounded, lithology: mainly quartz; shale, mostly fine fragments, (5 YR 4/3); also gray clay plus calcrete fragments	10	260
Sand and shale layers (91% sand, 9% shale); sand (0.0625 to 0.5 mm.), angular to subrounded, lithology: mainly quartz; shale, largely fine fragments of shale, (5 YR 4/3); plus calcrete fragments	10	270
Sand and shale layers (93% sand, 7% shale); sand (0.0625 to 0.5 mm.), angular to subrounded, lithology: mainly quartz; shale, largely fine fragments of shale, (5 YR 4/4); plus calcrete fragments	10	280
Sand and shale (95% sand, 5% shale); sand (0.0625 to 0.5 mm.), angular to subrounded, lithology: mainly quartz; shale, (5 YR 5/3); plus calcrete fragments	10	290

Table 3 (continued)

Stratigraphic Unit and Material	Thickness (feet)	Depth (feet)
Well 28.3E.34.331 Southern Pacific (continued)		
Santa Fe Group (continued)		
Sand and shale layers (97% sand, 3% shale); sand (0.0625 to 0.5 mm.), angular to subrounded, lithology: mainly quartz· shale (5 YR 4/4), (5 YR 6/3); plus calcrete fragments	10	300
Sand and shale layers (98% sand, 2% shale); sand (0.0625 to 0.5 mm.), angular to subrounded, lithology: mainly quartz; shale (5 YR 4/4, (5 YR 5/4); plus calcrete fragments, also trace of andesite porphyry fragments	10	310
Sand and shale layers (92% sand, 8% shale); sand (0.0625 to 0.5 mm.), angular to subrounded, lithology: mainly quartz; shale (7.5 YR 5/4); plus calcrete fragments	26	336
Sand and shale layers (80% sand, 20% shale); sand, lithology: mainly quartz; shale, mostly disseminated, (5 YR 5/4), (5 YR 6/2), (7.5 YR 5/4)	34	370
Sand and shale layers (75% sand, 25% shale); sand (0.0625 to 0.25 mm.), angular to subrounded, lithology: mainly quartz; shale, mostly disseminated, (5 YR 5/3), (2.5 YR 4/4); plus soft white clay	20	390
Sand and shale layers (85% sand, 15% shale); sand (0.0625 to 0.25 mm.), angular to subrounded, lithology: mainly quartz; shale (5 YR 4/3); also soft white clay, plus calcrete fragments . . .	10	400
Sand and shale layers (65% sand, 35% shale); sand (0.0625 to 0.25 mm.), angular to subrounded, lithology: mainly quartz; shale (2.5 YR 5/4), (5 YR 5/3); plus soft white clay, trace of andesite porphyry, float fragments	10	410
Sand and shale layers (55% sand, 45% shale); sand (0.0625 to 0.25 mm.), angular to subrounded, lithology: mainly quartz; shale (5 YR 5/3); plus soft white and gray clay	110	520

Table 3 (continued)

Stratigraphic Unit and Material	Thickness (feet)	Depth (feet)
Well 28.3E.34.331 Southern Pacific (continued)		
Santa Fe Group (continued)		
Sand and shale layers (92% sand, 8% shale); sand (0.0625 to 0.25 mm.), angular, lithology: mainly quartz; shale (5 YR 5/3)	10	530
Sand and shale layers (78% sand, 22% shale); sand (0.0625 to 0.25 mm.), angular, lithology: mainly quartz; shale (5 YR 5/3), (5 YR 5/1)	20	550
Sand and shale layers (70% sand, 30% shale); sand (0.0625 to 0.25 mm.), angular, lithology: mainly quartz; shale (5 YR 4/3); plus white clay with black stains	30	580
Sand and shale layers (92% sand, 8% shale); sand (0.0625 to 0.25 mm.), angular, lithology: mainly quartz; shale (5 YR 5/3), (5 YR 6/3); plus soft white clay	10	590
Same as above (580 to 590'), except (88% sand, 12% shale)	10	600
Same as above (580 to 590')	10	610
Sand and shale layers (90% sand, 10% shale); sand (0.0625 to 0.25 mm.), angular, lithology: mainly quartz; shale (5 YR 5/3), (10 YR 7/1)	10	620
Sand, shale, soft clay layers (80% sand, 20% clay); sand (0.0625 to 0.25 mm.), angular, lithology: mainly quartz; clay, disseminated, light tan and gray; shale (5 YR 5/3)	60	680
Sand and shale layers (90% sand, 10% shale); sand (0.0625 to 0.25 mm.), angular, lithology: mainly quartz; shale (5 YR 6/3), (5 YR 5/3), (10 YR 5/2), (2.5 YR 4/2), (2.5 YR 5/2)	20	700
Sand and shale layers (75% sand, 25% shale); sand (0.0625 to 0.25 mm.), angular, lithology: mainly quartz; shale (7.5 YR 5/2)	10	710
Sand and shale layers (93% sand, 7% shale); sand (0.0625 to 0.25 mm.), angular, lithology: mainly quartz; shale (7.5 YR 5/2), (10 YR 5/2), (10 YR 5/3), (5 YR 5/3)	10	720

Table 3 (continued)

Stratigraphic Unit and Material	Thickness (feet)	Depth (feet)
Well 28.3E.34.331 Southern Pacific (continued)		
Santa Fe Group (continued)		
Sand and shale layers (85% sand, 15% shale); sand (0.0625 to 0.5 mm.), angular, lithology: mainly quartz; shale (2.5 YR 4/4), (5 YR 5/3)	20	740
Sand and shale layers (92% sand, 8% shale); sand (0.0625 to 0.25 mm.), angular, lithology: mainly quartz; shale (5 YR 5/2), (5 YR 5/3)	10	750
Sand and shale layers (88% sand, 12% shale); sand (0.0625 to 0.25 mm.), angular, lithology: mainly quartz; shale (5 YR 5/3)	10	760
Sand and shale layers (94% sand, 6% shale; sand (0.0625 to 0.25 mm.), angular, lithology: mainly quartz; shale (7.5 YR 4/2), (5 YR 5/2)	10	770
Sand and shale layers (89% sand, 11% shale); sand (0.0625 to 0.25 mm.), angular, lithology: mainly quartz; shale (5 YR 6/1), (7.5 YR 5/2)	10	780
Sand and shale layers (91% sand, 9% shale); sand (0.0625 to 0.25 mm.), angular, lithology: mainly quartz; shale (7.5 YR 5/2), (5 YR 4/3)	10	790
Sand and shale layers (92% sand, 8% shale); sand (0.0625 to 0.25 mm.), angular, lithology: mainly quartz; shale (7.5 YR 5/2), (5 YR 5/3)	20	810
Sand and shale layers (86% sand, 14% shale); sand (0.0625 to 0.25 mm.), angular, lithology: mainly quartz; shale (5 YR 5/2)	10	820
Sand and shale layers (94% sand, 6% shale); sand (0.0625 to 0.25 mm.), angular, lithology: mainly quartz; shale (5 YR 5/3)	5	825
Gravelly sand with shale layers (4% gravel, 86% sand, 10% shale); gravel (2 to 10 mm.), angular to rounded, lithology: major - intermediate volcanics, minor - quartzite, siltstone, chert, not mixed round lithology, local origin	10	835

Table 3 (continued)

Stratigraphic Unit and Material	Thickness (feet)	Depth (feet)
Well 28.3E.34.331 Southern Pacific (continued)		
Santa Fe Group (continued)		
Gravelly sand and shale layers (30% gravel, 60% sand, 10% shale); gravel (2 to 9 mm.), angular to rounded, lithology: major - intermediate volcanics, minor - quartzite, siltstone, chert, limestone; sand (0.0625 to 0.25 mm.), angular, lithology: mainly quartz; shale (5 YR 5/2)	20	855
Gravelly sand and shale layers (2% gravel, 95% sand, 6% shale); gravel same as above (835 to 855'); sand (0.0625 to 0.25 mm.), angular, lithology: mainly quartz; shale (5 YR 5/2),(7.5 YR 5/2)	10	865
Gravelly sand and shale layers (4% gravel, 78% sand, 18% shale); same as above (835 to 865'); sand (0.0625 to 0.25 mm.), angular, lithology: mainly quartz; shale (5 YR 6/3), (7.5 YR 6/4)	15	880
Sand and shale layers (94% sand, 6% shale); sand (0.0625 to 0.5 mm.), angular, lithology: mainly quartz; shale (2.5 YR 4/4), (5 YR 5/3); trace of gravel	10	890
Gravelly sand and shale layers (15% gravel, 70% sand, 15% shale); gravel, same as above, (835 to 880'); sand (0.0625 to 0.5 mm.), angular, lithology: mainly quartz; shale (5 YR 5/3), (7.5 YR 5/4)	10	900
Gravelly sand and shale layers (8% gravel, 82% sand, 10% shale); gravel, same as above (835 to 880, 890 to 900'); sand (0.0625 to 0.5 mm.), lithology: quartz (0.5 to 2.0 mm.), lithology: same as gravel; shale (10 YR 5/3),(5 YR 5/3)	10	910
Gravelly sand and shale layers (4% gravel, 86% sand, 10% shale); gravel, same as above, (835 to 880, 890 to 910'); sand, same as above (900 to 910'); shale (5 YR 5/3), (10 YR 5/3)	10	920
Same as above (910 to 920'), except:(4% gravel, 81% sand, 15% shale)	10	930
Same as above (910 to 920')	10	940
Sand and shale layers (94% sand, 6% shale); sand (0.0625 to 0.5 mm.), angular, lithology: mainly quartz; sand (0.5 to 2.0 mm.), angular, lithology: same as gravel above,		

Table 3 (continued)

Stratigraphic Unit and Material	Thickness (feet)	Depth (feet)
Well 28.3E.34.331 Southern Pacific (continued)		
Santa Fe Group (continued)		
(835 to 880, 890 to 940'); shale (5 YR 5/3)	10	950
Sand and shale layers (88% sand, 12% shale); sand (0.0625 to 0.25 mm.), angular, lithology: mainly quartz, (0.25 to 2 mm.), angular, lithology: same as gravel above (835 to 880, 890 to 950'); shale (5 YR 4/3), (7.5 YR 6/2) . . .	10	960
Sand (0.0625 to 0.5 mm.), angular to subrounded, lithology: mainly quartz . . .	43.7	1003.7
Remarks: Schlumberger Dual Induction - Laterolog available. Fluvial facies, with interbedded clayey strata of possible playa or lake origin, to a depth of about 825'. Alluvial-fan facies below 825'.		
Well 29.3E.3.243 Southern Pacific Railroad Company South Lizard Well		
Sample log: Taylor		
Santa Fe Group		
Sand (0.125 to 0.25 mm.), angular to well rounded, lithology: major - quartz and plagioclase, minor - epidote, magnetite, biotite, muscovite, hornblende	10	10
Same as above (0 to 10'), plus some shale fragments; shale (5 YR 4/4)	10	20
Sand (0.125 to 0.25 mm.), angular to well-rounded lithology: same as above (0 to 20'); no clay, plus calcrete fragments	20	40
Sand, thin, with shale layers (0.25 to 2 mm.), (95% sand, 5% shale); sand, lithology: mainly quartz and plagioclase; shale (5 YR 4/4); plus calcrete fragments . .	20	60
Same as above (40 to 60'), except sand is much finer (0.0625 to 0.5 mm.)	10	70
Sand and shale (60% sand, 40% shale); sand (0.0625 to 0.5 mm.), angular to well-rounded, lithology: mainly quartz and plagioclase; shale (5 YR 5/4)	10	80

Table 3 (continued)

Stratigraphic Unit and Material	Thickness (feet)	Depth (feet)
Well 29.3E.3.243 Southern Pacific (continued		
Santa Fe Group (continued)		
Same as above (70 to 80'), except 70% sand, 30% shale)	10	90
Same as above (80 to 90'), except shale is harder and fragments are larger	10	100
Shaley sand (90% sand, 10% shale); sand (0.0625 to 0.5 mm.), angular to well-rounded, lithology: mainly quartz and plagioclase; shale (5 YR 5/4)	40	140
Same as above except increase in clay (80% sand, 20% shale)	10	150
Shaley sand (50% sand, 50% shale); sand (0.0625 to 0.5 mm.), angular to well-rounded, lithology: mainly quartz and plagioclase; shale (5 YR 5/4)	7	157
Same as above (150 to 157'), except increase in sand (70% sand, 30% hard shale)	13	170
Same as above (157 to 170'), plus calcrete fragments	20	190
Shaley sand (90% sand, 10% shale); sand (0.0625 to 0.5 mm.), angular to rounded, lithology: mainly quartz and plagioclase; shale, (5 YR 5/3), (5 YR 6/3), 10 YR 7/2)	20	210
Same as above (190 to 210'), except more sand, less shale (95% sand, 5% shale)	20	230
Same as above (210-230') except increase in shale and clay (85% sand, 15% shale).	20	250
Same as above (230 to 250'), except increase in shale and clay (60% sand, 40% shale)	38	288
Base of Santa Fe Group		
Andesite porphyry fragments from bedrock (see petrographic description under Basic Data, Table 4)	10	298
Remarks: Probably mainly fluvial facies with possible lake or playa clays in lower 60'.		

TABLE 4

THIN SECTION DESCRIPTIONS

Name	Locality	Township and Range	Number	Description
Andesite Porphyry	Outcrop in Arroyo	23.3E.10.344	1	Color reddish-purple vesicular structure, porphyry, contains plagioclase and altered hornblende (?) with minor magnetite and unidentified red mineral in aphanitic groundmass.
Andesite Porphyry	Outcrop in Arroyo	23.3E.10.343	1	Color gray, porphyry texture, contains plagioclase and hornblende phenocrysts with minor magnetite in aphanitic groundmass.
Andesite Porphyry	Cerro de Muleros	29.4E.16	1	Contains plagioclase, hornblende and biotite with minor magnetite and quartz in aphanitic groundmass of plagioclase.
Rhyolite Tuff	Fillmore Canyon	23.4E.5 & 23.4E.6	1	Color white, contains small quartz grains in aphanitic groundmass of feldspar and quartz.
Epidotized Andesite	Fillmore Canyon	23.4E.5 & 23.4E.6	2	Contains secondary epidote and calcite in fractures and vugs in felty groundmass of aphanitic plagioclase laths with some magnetite grains.
Epidotized Orejon Andesite Porphyry	Fillmore Canyon	23.4E.5 & 23.4E.6	3	Color pale green with orthoclase and plagioclase phenocrysts and minor quartz; hematite and epidote in aphanitic groundmass. Alteration of biotite to epidote and hornblende to epidote and hematite, with last stage of alteration consisting of quartz vug fillings.
Epidotized Andesite	Fillmore Canyon	23.4E.5 & 23.4E.6	4	Color black, contains orthoclase and plagioclase with minor quartz, epidote, biotite, magnetite and pyrite in aphanitic groundmass. Alteration extreme; feld-spars, biotite and hornblende badly altered.

TABLE 4 (continued)

Name	Locality	Township and Range	Number	Description
Andesite	Fillmore Canyon	23.4E.5 & 23.4E.6	5	Color black, contains orthoclase and plagioclase with minor quartz, magnetite, epidote, hematite and hornblende (?) in aphanitic groundmass. Feldspars are partially altered to epidote, hornblende is altered to epidote and hematite.
Orejon Andesite Porphyry	Fillmore Canyon	23.4E.5 & 23.4E.6	6	Contains orthoclase, plagioclase and hornblende altered to hematite (?) with minor quartz and epidote in aphanitic groundmass.
Orejon Andesite Porphyry	Near La Cueva	23.3E.1.231	1	Contains altered plagioclase with minor magnetite, quartz, biotite and hornblende altered to chlorite. Secondary calcite in vugs. Groundmass aphanitic.
Andesite Tuff	Picacho	23.1E.6.141	1	Contains plagioclase phenocrysts and fragments of tuff with very minor quartz and magnetite in aphanitic groundmass.
Andesite Porphyry	Southern Pacific R.R. South Lizard Well	29.3E.3.243	1	Color gray, contains zoned plagioclase with albite and Carlsbad twinning and minor brownish-green hornblende, brown biotite, magnetite, orthoclase and euhedral apatite crystals in aphanitic groundmass.
Andesite Porphyry	"	"	2	Contains hornblende exhibiting typical hornblende cleavage.
Andesite Porphyry	"	"	3	Contains plagioclase exhibiting well-defined zoning and euhedral isotropic section of quartz crystal.