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Summary of hydrologic investigations by the United States Geological Survey at White Sands Missile Range, New Mexico

by

Leon V. Davis and Fred E. Busch

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CONTENTS

CONTENTS - Concluded

Illustrations

Reference Page

Illustrations - Concluded

Tables

Tables - Concluded

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Introduction

The White Sands Missile Range (including the Range Extension) lies principally in the vast semiarid Tularosa Basin of south-central New Mexico but includes also the San Andres Mountains, along the western side of the missile range; the San Augustin Mountains, at the southwestern corner; the Sierra Oscura, in the north-central part; and the Los Pinos Mountains, in the northwestern part of the North Extension of the range.

The U.S. Geological Survey for many years has, at the request of the U.S. Army, made investigations to determine the availability and quality of water that might be utilized by military installations in and near the Missile Range. The studies involved geologic mapping, well inventory, drilling, testing by pumping of exploratory test wells, obtaining quality of water data, rendering technical assistance during the drilling and completion of supply wells, and monitoring water levels, chiefly in the Headquarters area. The results of the various studies are summarized in this report.

Explanatory text is at a minimum; maps, charts, and tables present the data in graphical form. The reader is referred to the list of references for the individual reports from which most of these data were taken. The summary was prepared at the request of the U.S. Army Post Engineer, White Sands Missile Range. The location of the Missile Range is shown in figure 1.

Figure 1 (caption on next page) belongs near here.

Figure 1.--Index map showing White Sands Missile Range. Large circled numbers indicate areas of separate sheets of figures 4 and 5; hachured areas are overlap between sheets. Small circled numbers refer to areas mentioned in text and listed at upper right of this map.

This summary report contains maps showing the areas of investigation; the outcrops of consolidated sedimentary and igneous rocks, and alluvium (bolson fill); contours on the water table in alluvium; water-level changes; quality of water data; areas where potable water[1/] is known to be or probably is present; areas where inferior water is known to be or probably is present, and areas where non-potable water **probably is** present. The general occurrence of water at the White Sands Missile Range and the hydrologic and geologic conditions at the Headquarters area, within the range, are shown on maps and cross sections. Records of wells and detailed chemical analyses of water are given in tables. Most electrical and other types of geophysical logs of many wells in the White Sands Missile Range and adjoining areas are on file at the U.S. Geological Survey, Geology Building, University of New Mexico, Albuquerque, N. Mex., and at Headquarters, White Sands Missile Range.

1/ In this region, sulfate and chloride are the principal mineral constituents that render much of the water unfit for human consumption. Generally, if neither of these constituents is present in objectionable quantities, the water does not contain other dissolved minerals in objectionable quantities. In this report, the term "potable" describes water in which neither the sulfate nor the chloride is present in excess of 250 ppm (parts per million), as recommended in the U.S. Public Health Service standards. Water containing between 250 and 500 ppm of either sulfate or chloride and less than 750 ppm of the two together is called "inferior" or "near potable". Water containing more than 500 ppm of sulfate or chloride or more than 750 ppm of both is called "nonpotable". Water containing more than 1,000 ppm of dissolved water commonly is called "saline water."

Well-numbering system

The system of numbering wells and springs used in this report is that used by the Geological Survey in New Mexico and is based on the common subdivisions in sectionized land. The number, in addition to designating the well or spring, locates its position to the nearest 10-acre tract in the land net. The number is divided by periods into four segments. The first segment denotes the township south or north of the New Mexico base line; the second denotes the range east or west of the New Mexico principal meridian; and the third denotes the section. Most of the area discussed in this report is south of the base line, and most of it is east of the principal meridian. The letter N has been placed after the first segment of the number if the well or spring is north of the base line.

The fourth segment of the number, which consists of three digits, denotes the particular 10-acre tract in which the well or spring is situated. For this purpose, the section is divided into four quarters, numbered 1, 2, 3, and 4, in the normal reading order, for the northwest, northeast, southwest, and southeast quarters, respectively. The first digit of the fourth segment gives the quarter section, which is a tract of 160 acres. The quarter section is divided into four 40-acre tracts numbered in the same manner, and the second digit denotes the 40-acre tract. Finally, the 40-acre tract is divided into four 10-acre tracts, and the third digit denotes the 10-acre tract. Thus, well 17.9.12.422 is in the NE$\frac{1}{4}$NE$\frac{1}{4}$SE$\frac{1}{4}$ sec. 12, T. 17 S., R. 9 E., as shown in figure 2.

Figure 2 (caption on next page) belongs near here.

If a well or spring cannot be located accurately within a 160-acre tract, zeros are used for the appropriate digits of the final segment. If the well or spring cannot be located more closely than the section, the fourth segment of the well number is omitted. Letters a, b, c...are added to the last segment to designate the second, third, fourth, and succeeding wells or springs listed in the same 10-acre tract. An S in front of the number indicates a spring.

Some wells and test wells are listed by the White Sands Missile Range Post Engineer numbers as well as the numbers in the general well-numbering system.

Figure 2.--System of numbering wells and springs in New Mexico (S in front of number indicates a spring).

Definitions of terms used in the summary

Aquifer - A geologic formation, a part of a formation, or a group of formations that is water bearing.

Field coefficient of permeability - the number of gallons of water that can pass in 1 day through a 1-square-foot cross section of the aquifer at right angles to the direction of flow under hydraulic gradient of unity at the prevailing temperature.

Coefficient of transmissibility - the coefficient of transmissibility, in gallons per day, is equal to the field coefficient of permeability multiplied by the thickness of the saturated aquifer, in feet.

Coefficient of storage - the volume of water an aquifer releases or takes into storage per unit surface area of the aquifer per unit change in the component of head normal to that surface.

Specific yield - the ratio of the volume of water a saturated rock will yield by gravity to its own volume.

Specific capacity - yield in gallons per minute per foot of drawdown.

Abbreviations used in the summary

acre-ft = water discharge, or volume, in acre-ft

(the volume of water required to cover 1 acre to a depth of 1 foot).

Equal to 43,560 cubic feet, or 325,850 gallons.

gpm = gallons per minute

gpd = gallons per day

ppm = parts per million

T = coefficient of transmissibility

S = coefficient of storage

P = coefficient of permeability

t = time, in any specified unit

s = drawdown, in feet

Q = discharge, in gallons per minute

MP = measuring point

General occurrence and quality of water

Supplies of potable ground water are relatively sparse at the White Sands Missile Range in south-central New Mexico. Potable water generally is confined to permeable zones in the fanslope debris along the flanks of the mountains that bound the Tularosa basin. The few streams containing potable water in White Sands Missile Range and adjoining areas are fully appropriated and other than the Rio Grande are restricted to the mountains along the east side of the basin.

Although supplies of potable water are sparse, abundant supplies of water of inferior or nonpotable quality are available in the lower fanslopes and in the basin proper (fig. 3).

Figure 3 (caption on next page) belongs near here.

Figure 3.--Diagrammatic section showing general occurrence of ground water along the flanks of the uplifts in Tularosa Basin.

Because of the wide range in climate from lowest to highest elevations and because rocks in the region differ greatly in hydraulic characteristics, the occurrence of both surface water and ground water vary greatly at different places.

The only economically important bodies of surface water near the Missile Range, aside from infrequent flood flows, are the Rio Grande and the perennial streams in the Sacramento Mountains and Sierra Blanca, which are Rio Tularosa northeast of the town of Tularosa, Rio Bonito, Eagle Creek, and the upper parts of the Three Rivers drainage system, in Three Rivers Canyon and Indian Creek. Malpais Spring, in the floor of Tularosa Basin, discharges about 1,500 gpm (gallons per minute) of saline water to Salt Creek. Lake Lucero, in the west central part of Tularosa Basin, is a large wet-weather lake. The water is highly saline.

The quantity and quality of ground water varies widely. The potential yield, or amount in storage, of water of different quality is given in table 1; the general water-bearing characteristics of the various water-bearing beds are given in table 2; well data are given in table 3; and quality-of-water data for wells are given in table 4; spring data are given in table 5; and quality-of-water data for springs are given in table 6.

Table 1.--Potential perennial yield or amount in storage of water of different quality in Tularosa Basin and adjoining areas.

Area	Potable water (potential perennial yield, in acre-feet per year, except where noted otherwise)	Inferior water (potential perennial yield, in acre-feet per year, except where noted otherwise)	Nonpotable water (acre-feet in storage)	Typical yield of wells Range (gpm)
Northern Jornada del Muerto	30	200	11,000,000	25-1,000
Rio Grande valley at Bosque del Apache	30,000	-	-	20-1,800
Northern Tularosa Basin	30	200	6,000,000	15- 225
Carrizozo area	-	20,000	1,500,000	
Three Rivers area	1,000	1,000	200,000	10- 225
Tularosa-Alamogordo	a/ 1,000	500	8,000,000	100-1,076
Area southeast of Valmont	1,000	1,000	1,000,000	---
Upper Sacramento River canyon	800	-	-	50- 100
Hueco Plateau	b/ 250,000	b/ 1,000,000	7,000,000	---
Southern Tularosa Basin-Hueco Bolson	15,000	5,000	65,000,000	25- 450
White Sands Missile Range Headquarters area	2,000	-	3,000,000	35- 800
West-central Tularosa Basin	30	60	50,000,000	25- 280
Southern Jornada del Muerto	b/ 1,500,000	b/ 6,000,000	3,000,000	25-1,000

a/ Temporary yield, for at least several years; quality likely to worsen if rate of withdrawal continues or is appreciably increased.

b/ Acre-feet in storage.

Page 69 Follows

The largest supplies of potable ground water are in the Rio Grande valley in the vicinities of Bosque del Apache Wildlife Refuge and Las Cruces, and in the southwestern part of Tularosa Basin and the northwestern part of Hueco Bolson between White Sands Missile Range and El Paso, Texas. Potable ground water also underlies parts of southern Jornada del Muerto, relatively small areas at the sides of Tularosa Basin, and extremely small areas in the rest of the region.

Twelve large-capacity wells have been constructed west of the Rio Grande in the Bosque del Apache wildlife Refuge by the U.S. Fish and Wildlife Service; one reportedly was tested at 1,500 gpm and the other at more than 2,000 gpm. A test well to determine the availability of ground water on the east side of the river in the Bosque del Apache Wildlife Refuge as a source of supply for Stallion Range Camp yielded 150 gpm and had 37 feet of drawdown. This area is within the Rio Grande Underground Water Basin, closed by the State Engineer to additional appropriation of water except for domestic use. Under the regulations, additional large wells can be developed only if appropriations of surface water or ground water equalling in quantity the amount to be pumped from the new wells are retired from use.

A zone of potable ground water extends from the Headquarters area of White Sands Missile Range along the east side of the Organ and Franklin Mountains to the El Paso area. The Hueco Bolson probably has as much as 6.2 million acre-feet of potable ground water in storage in New Mexico and 7.4 million acre-feet in Texas. Proper well-field planning would permit recovery of at least half this amount before that remaining became critically contaminated by underlying highly-mineralized water. However, this area has not been adequately evaluated by drilling and testing. Pumpage in the El Paso area was about 69,000 acre-feet in 1962 (Marvin E. Davis, written communication, 1964).

Other occurrences of potable ground water, important because of location, are as follows: In the northern part of Jornada del Muerto, the Fite PW well in the SW$\frac{1}{4}$ sec. 4, T. 6 S., R. 2 E., the Hardin Ranch well in the NE$\frac{1}{4}$ sec. 27, T. 12 S., R. 2 E., and the Trail Canyon well in the SW$\frac{1}{4}$ sec. 36, T. 6 S., R. 5 E. yield small quantities. In the northern part of Tularosa Basin, the Baca well in the NE$\frac{1}{4}$ sec. 34, T. 6 S., R. 6 E. and the Mockingbird Gap well in the NW$\frac{1}{4}$ sec. 15, T. 9 S., R. 5 E. yield small quantities. In the west-central part of Tularosa Basin, the MAR wells in the SW$\frac{1}{4}$ sec. 17, T. 19 S., R. 5 E. yield potable water, and the Bairds Ranch well in the SE$\frac{1}{4}$ sec. 23, T. 17 S., R. 4 E. yields near-potable water.

The Murray well in the SE$\frac{1}{4}$ sec. 32, T. 8 S., R. 5 E., during a test, yielded 100 gpm of water that contained about 300 ppm sulfate and less than 700 ppm dissolved solids. The well is one of the few sources of usable water in that area.

Most recharge to the aquifers in and near the White Sands Missile Range is in the areas adjacent to the mountain masses and in the Rio Grande Valley. Precipitation that falls in the recharge areas is partly absorbed by porous fan materials and percolates downward to the water table. Part of the runoff in arroyos heading in the mountains also infiltrates and recharges the aquifers. In the Rio Grande Valley water infiltrates directly from the river and from irrigated fields.

Recharge in the region is small and most ground-water bodies have attained their present storage only through many hundreds, perhaps thousands, of years of accretion from recharge. Although recharge is expressed as a certain figure annually, there may be no recharge during some years.

The potable ground-water supplies can be recharged to some extent by artificial recharge through wells or ponds.

Additional ground-water supplies may be developed in untested areas in which hydrologic investigations indicate possible sources of potable water. Most of these areas will be along the flanks of the mountains bounding Tularosa Basin. It is possible that potable water will be found in the alluvial fans on the sides of the San Andres Mountains throughout its extent in the missile range. Figure 4 (in

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pocket) shows well locations, probable quality of ground water, and possible occurrence of water in the White Sands Missile Range. Figure 5

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(in pocket) shows locations of wells, outcrop of consolidated sedimentary rocks, igneous rocks, and contours on the water table in the Bolson fill. Test wells should be located in geologically favorable areas because of the inhomogeneity of the fan material. Alluvial fan sediments may be too poorly sorted to yield much water, even in areas geologically favorable for potable water.

Figure 4.--Map showing locations of wells; chemical quality of water, and areas of possible occurrence of potable, inferior, and non-potable water in the White Sands Missile Range and adjacent areas.

5.--Map showing location of wells, well data, extent of bolson fill, and contours on the water table in the bolson fill in the White Sands Missile Range and adjacent areas.

Headquarters area

(References: Herrick, 1960, 1961; Hood, 1963)

The headquarters of White Sands Missile Range is principally in sec. 24, T. 22 S., R. 4 E., in eastern Dona Ana County, about 25 miles east of Las Cruces, N. Mex., and about 40 miles north of El Paso, Tex. The headquarters area lies within a reentrant in the mountains bordering Tularosa Basin on the west (figs. 4 and 5). The wells supplying water to the Missile Range headquarters are in sec. 13 and the northern part of sec. 24, T. 22 S., R. 4 E., at the mouth of the reentrant.

The configuration of the bedrock in the reentrant is presented on two maps (figs. 6 and 7), one showing the thickness of the bolson

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deposits, the other showing altitude of the bedrock surface above sea level.

Figure 6.--Approximate thickness, in feet, of the bolson deposits in the Headquarters area, White Sands Missile Range, based on earth resistivity data.

7.--Approximate altitude, in feet, of the bedrock surface in the Headquarters area, White Sands Missile Range, based on earth resistivity data.

The direction of slope and the gradient of the water table within the reentrant in 1954 and 1964 are shown by means of contour lines on figures 8 and 9. The contour lines indicate that within that part of

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the reentrant between Antelope Hill and the central part of the Organ Mountains the ground water moves eastward through the bolson deposits. The depression contour in the east half of section 13 on the 1964 map shows that pumpage has reversed the water-table gradient in that area.

The depth to water within the reentrant in 1954, as shown in figure 10, ranged from a few feet near the mountains to about 400 feet

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in the vicinity of test well T-1 (22.4.1.444). By 1964 the water level had declined below the bottom of T-1 at 412 feet below land surface and was about 410 feet below land surface at well 15 (22.4.13.424) in the Headquarters well field (fig. 11). The decline of the water

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level from 1954 to 1964 is shown in figure 12. The decline of the

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level in the Main Gate well for the period 1961-63 is shown in figure 13.

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The total volume of saturated materials underlying that part of the reentrant west of the access highway is about 4 million acre-feet. If an average porosity of 25 percent is assumed, the total quantity of ground water within the reentrant area is approximately 1 million acre-feet. A large part of this water is not available to wells, of course. The ground water in the bolson deposits east of the access highway is highly saline, and overpumping of wells could induce migration of the saline water toward the wells.

The section in figure 14 shows the general relation between land

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surface, water table, and bedrock within the reentrant at the Headquarters area in 1963.

Logs of wells and construction data for wells in the Headquarters area are given in tables 7, 8, and 9.

Figure 14.--Section along line A-A', 1963. (See fig. 9 for line of section.)

Table 7.--Logs of wells in the Headquarters area

Test well T-1 (22.4.1.444)

1 of 48

Depth of sample (feet)	Percentages of sample by volume			
	Gravel	Very coarse and coarse sand	Medium and fine sand	Very fine sand, silt, and clay
	>2.0 mm.	2.0 - 0.5 mm.	0.5 - 0.125 mm.	<0.125 mm.
0- 10	-	-	-	-
10- 20	71	20	7	2
20- 30	40	37	18	5
30- 40	31	40	23	6
40- 50	44	28	23	5
50- 60	90	5	3	2
60- 70	85	5	5	5
70- 80	79	14	5	2
80- 90	27	45	21	7
90-100	29	45	23	3
100-110	30	42	24	4
110-120	73	14	10	3
120-130	86	9	3	2
130-170	65	17	14	4
170-180	65	15	13	7
180-190	65	19	10	6
190-200	48	38	11	3
200-210	73	19	7	1
210-220	67	26	6	1
220-230	62	30	7	1

Table 7.--Logs of wells in the Headquarters area - continued

Test well T-1 (22.4.1.444) - continued

2048

Depth of sample (feet)	Percentages of sample by volume			
	Gravel	Very coarse and coarse sand	Medium and fine sand	Very fine sand, silt, and clay
	>2.0 mm.	2.0 - 0.5 mm.	0.5 - 0.125 mm.	<0.125 mm.
230-240	63	28	8	1
240-250	39	34	19	8
250-260	32	45	20	3
260-270	29	42	22	7
270-280	12	59	26	3
280-290	12	52	33	3
290-300	36	42	18	4
300-310	31	41	24	4
310-320	59	28	12	1
320-330	45	37	13	5
330-340	57	27	12	4
340-350	44	36	16	4
350-360	61	28	10	1
360-370	82	15	2	1
370-380	46	31	18	5
380-390	48	34	15	3
390-400	32	42	22	4
400-410	23	40	32	5
410-418	-	-	-	-
418-430	19	42	32	7

Table 7.--Logs of wells in the Headquarters area - continued

Test well T-1 (22.4.1.444) - continued

Depth of sample (feet)	Percentages of sample by volume			
	Gravel >2.0 mm.	Very coarse and coarse sand 2.0 - 0.5 mm.	Medium and fine sand 0.5 - 0.125 mm.	Very fine sand, silt, and clay <0.125 mm.
430-440	20	45	31	4
440-450	32	41	20	7
450-460	35	38	22	5
460-470	24	43	28	5
470-480	22	39	31	8
480-490	35	38	21	6
490-500	29	43	25	3
500-510	19	42	35	4
510-520	19	48	30	3
520-530	18	42	31	9
530-540	20	41	32	7
540-550	22	40	30	8
550-560	14	34	39	13
560-570	18	36	37	9
570-580	21	37	34	8
580-590	16	35	41	8
590-600	22	29	36	13
600-610	20	29	34	17
610-620	23	32	31	14
620-630	23	30	34	13

Table 7.--Logs of wells in the Headquarters area - continued

Test well T-1 (22.4.1.444) - continued

Depth of sample (feet)	Percentages of sample by volume			
	Gravel >2.0 mm.	Very coarse and coarse sand 2.0 - 0.5 mm.	Medium and fine sand 0.5 - 0.125 mm.	Very fine sand, silt, and clay <0.125 mm.
630-640	38	25	24	13
640-650	35	29	27	9
650-660	42	25	24	9
660-670	58	25	12	5
670-680	65	20	11	4
680-690	37	39	19	5
690-700	25	25	38	12
700-710	20	45	27	8
710-720	30	41	24	5
720-730	20	49	25	6
730-740	19	49	26	6
740-750	41	39	16	4
750-760	39	38	18	5
760-770	37	35	21	7
770-780	33	35	23	9
780-790	30	45	20	5
790-800	24	45	24	7
800-810	18	55	24	3
810-820	24	31	25	20
820-830	21	34	27	18

Table 7.--Logs of wells in the Headquarters area - continued

Test well T-1 (22.4.1.444) - concluded

Depth of sample (feet)	Percentages of sample by volume			
	Gravel	Very coarse and coarse sand	Medium and fine sand	Very fine sand, silt, and clay
	>2.0 mm.	2.0 - 0.5 mm.	0.5 - 0.125 mm.	<0.125 mm..
830- 840	8	44	36	12
840- 850	13	44	33	10
850- 860	19	44	28	9
860- 870	14	43	33	10
870- 880	11	37	40	12
880- 890	11	34	37	18
890- 900	13	36	36	15
900- 910	12	32	33	23
910- 920	18	32	30	20
920- 930	13	29	36	22
930- 940	23	25	21	31
940- 950	25	26	27	22
950- 960	24	27	24	25
960- 970	41	25	17	17
970- 980	22	27	30	21
980- 990	33	26	22	19
990-1,000	28	28	26	18

Table 7.--Logs of wells in the Headquarters area - continued

Test well T-2 (22.4.13.223)

6 of 48

Depth of sample (feet)	Percentages of sample by volume			
	Gravel >2.0 mm.	Very coarse and coarse sand 2.0 - 0.5 mm.	Medium and fine sand 0.5 - 0.125 mm.	Very fine sand, silt, and clay <0.125 mm.
0- 23	50	30	15	5
23- 33	65	20	10	5
33- 43	55	30	10	5
43- 53	45	30	20	5
53- 63	65	20	10	5
63- 73	65	20	10	5
73- 83	60	20	20	10
83- 93	60	20	20	10
93-103	65	20	10	5
103-113	65	20	10	5+
113-123	65	15	15	5+
123-133	60	15	15	10
133-143	70	20	10-	5-
143-153	62	13	16	9
153-163	42	13	25	20
163-173	66	16	11	6
173-183	57	14	17	12
183-193	62	25	11	2
193-203	62	21	11	6

Table 7.--Logs of wells in the Headquarters area - continued

Test well T-2 (22.4.13.223) - continued

Depth of sample (feet)	Percentages of sample by volume			
	Gravel	Very coarse and coarse sand	Medium and fine sand	Very fine sand, silt, and clay
	>2.0 mm.	2.0 - 0.5 mm.	0.5 - 0.125 mm.	<0.125 mm.
203-213	64	22	10	4
213-223	50	23	19	8
223-233	39	36	19	6
233-243	47	32	18	3
243-253	57	13	23	7
253-263	34	38	22	6
263-268	13	13	55	19
268-273	15	29	39	17
273-278	32	29	28	11
278-283	37	40	18	5
283-293	37	33	22	8
293-303	36	39	21	4
303-313	32	38	24	6
313-318	43	30	20	7
318-323	34	24	30	12
323-328	31	31	32	6
328-338	28	26	34	12
338-343	36	34	23	7
343-348	46	34	16	4

Table 7.--Logs of wells in the Headquarters area - continued

Test well T-2 (22.4.13.223) - continued

8 of 48

Depth of sample (feet)	Percentages of sample by volume			
	Gravel >2.0 mm.	Very coarse and coarse sand 2.0 - 0.5 mm.	Medium and fine sand 0.5 - 0.125 mm.	Very fine sand, silt, and clay <0.125 mm.
348-356	48	30	18	4
356-361	53	32	11	4
361-366	31	34	28	7
366-375	26	36	30	8
375-385	46	18	20	16
385-395	52	15	18	15
395-405	48	27	20	5
405-415	76	13	7	4
415-425	41	30	23	6
425-435	61	25	11	3
435-445	56	21	18	5
445-455	26	28	35	11
455-465	52	29	15	4
465-475	25	34	35	6
475-485	64	15	16	5
485-495	68	19	9	4
495-505	50	24	21	5
505-510	52	25	17	6
510-515	60	19	15	6
515-525	49	21	20	10

Table 7.—Logs of wells in the Headquarters area - continued

Test well T-2 (22.4.13.223) - continued

9 of 48

Depth of sample (feet)	Percentages of sample by volume			
	Gravel >2.0 mm.	Very coarse and coarse sand 2.0 - 0.5 mm.	Medium and fine sand 0.5 - 0.125 mm.	Very fine sand, silt, and clay <0.125 mm.
525-535	52	22	17	9
535-545	60	22	12	6
545-550	68	14	12	6
550-560	47	23	20	10
560-570	51	21	20	9
570-580	63	17	14	6
580-590	57	25	14	4
590-600	23	22	41	14
600-610	49	28	17	6
610-620	34	32	25	9
620-630	31	28	27	14
630-640	27	22	33	18
640-650	16	24	42	18
650-660	26	40	27	7
660-670	37	35	23	5
670-680	36	33	22	9
680-690	34	36	22	8
690-700	21	35	33	11
700-710	29	40	26	5
710-720	23	35	34	8

Table 7.--Logs of wells in the Headquarters area - continued

Test well T-2 (22.4.13.223) - continued

Depth of sample (feet)	Percentages of sample by volume			
	Gravel >2.0 mm.	Very coarse and coarse sand 2.0 - 0.5 mm.	Medium and fine sand 0.5 - 0.125 mm.	Very fine sand, silt, and clay <0.125 mm.
720-730	29	42	24	5
730-740	22	34	35	11
740-750	23	37	30	10
750-760	35	32	26	7
760-770	47	37	14	2
770-780	42	29	23	6
780-790	46	34	18	2
790-800	42	33	21	4
800-810	11	41	41	7
810-820	7	40	47	6
820-830	21	35	36	8
830-840	20	35	36	9
840-850	23	43	29	5
850-860	6	27	54	13
860-870	-	-	-	-
870-880	51	23	19	7
880-890	30	36	27	7
890-900	47	32	17	4
900-910	48	34	14	4
910-920	48	28	16	8

Table 7.--Logs of wells in the Headquarters area - continued

Test well T-2 (22.4.13.223) - concluded

Depth of sample (feet)	Percentages of sample by volume			
	Gravel >2.0 mm.	Very coarse and coarse sand 2.0 - 0.5 mm.	Medium and fine sand 0.5 - 0.125 mm.	Very fine sand, silt, and clay <0.125 mm.
920- 930	42	35	18	5
930- 940	48	31	17	4
940- 950	49	33	14	4
950- 960	41	25	26	8
960- 970	50	33	12	5
970- 980	56	24	18	2
980-1,000	65	13	14	8

Table 7.--Logs of wells in the Headquarters area - continued

Test well T-3 (22.4.14.211)

Depth of sample (feet)	Percentages of sample by volume			
	Gravel >2.0 mm.	Very coarse and coarse sand 2.0 - 0.5 mm.	Medium and fine sand 0.5 - 0.125 mm.	Very fine sand, silt, and clay <0.125 mm.
0- 10	32	37	29	2
10- 20	27	53	18	2
20- 30	14	45	34	7
30- 40	92	2	4	2
40- 50	89	5	4	2
50- 60	93	2	3	2
60- 70	90	3	5	2
70- 80	82	9	6	3
80- 90	87	7	4	2
90-100	90	3	4	3
100-110	91	4	3	2
110-120	81	9	7	3
120-130	82	10	5	3
130-140	95	3	1	1
140-150	81	11	5	3
150-160	88	6	4	2
160-170	57	17	19	7
170-180	49	29	19	3
180-190	48	3	16	5
190-200	50	30	17	3

Table 7.--Logs of wells in the Headquarters area - continued

Test well T-3 (22.4.14.211) - continued

Depth of sample (feet)	Percentages of sample by volume			
	Gravel >2.0 mm.	Very coarse and coarse sand 2.0 - 0.5 mm.	Medium and fine sand 0.5 - 0.125 mm.	Very fine sand, silt, and clay <0.125 mm.
200-210	34	39	22	5
210-220	28	43	22	7
220-230	33	41	21	5
230-240	46	36	14	4
240-250	48	31	17	4
250-260	47	29	19	5
260-270	29	38	26	7
270-280	43	32	20	5
280-290	34	35	27	4
290-300	26	38	28	8
300-310	37	34	22	7
310-320	41	39	15	5
320-330	36	29	25	10
330-340	38	36	18	6
340-350	39	39	19	3
350-360	75	15	6	4
360-370	62	19	12	7
370-380	61	17	13	9
380-390	56	20	15	9
390-400	53	21	18	8

Table 7.--Logs of wells in the Headquarters area - continued

Test well T-3 (22.4.14.211) - continued

14 of 48

Depth of sample (feet)	Percentages of sample by volume			
	Gravel >2.0 mm.	Very coarse and coarse sand 2.0 - 0.5 mm.	Medium and fine sand 0.5 - 0.125 mm.	Very fine sand, silt, and clay <0.125 mm.
400-410	58	23	13	6
410-420	43	26	21	10
420-430	48	30	15	7
430-440	47	24	19	10
440-450	59	19	15	7
450-460	53	21	19	7
460-470	52	27	16	5
470-480	49	29	16	6
480-490	27	34	29	10
490-500	35	43	18	4
500-510	36	36	22	6
510-520	41	37	17	5
520-530	41	35	17	7
530-540	43	31	21	5
540-550	41	35	17	7
550-560	35	29	27	9
560-570	48	28	18	6
570-580	41	35	19	5
580-590	26	34	32	8
590-600	36	36	24	4

Table 7.--Logs of wells in the Headquarters area - continued

Test well T-3 (22.4.14.211) - concluded

15548

Depth of sample (feet)	Percentages of sample by volume			
	Gravel >2.0 mm.	Very coarse and coarse sand 2.0 - 0.5 mm.	Medium and fine sand 0.5 - 0.125 mm.	Very fine sand, silt, and clay <0.125 mm.
600-610	36	37	23	4
610-620	39	36	21	4
620-630	27	35	32	6
630-640	8	34	49	9
640-650	19	43	32	6
650-660	17	42	33	8
660-670	12	48	35	5
670-680	13	48	32	7
680-690	14	56	25	5
690-700	26	42	24	8
700-710	16	34	41	9
710-720	18	46	27	9
720-730	29	36	30	5
730-740	17	46	31	6
740-750	16	45	32	7
750-760	8	31	51	10
760-770	5	46	41	8
770-775	7	40	44	9

Table 7.—Logs of wells in the Headquarters area - continued

Test well T-4 (22.5.16.111)

Depth of sample (feet)	Percentages of sample by volume			
	Gravel — <2.0 mm.	Very coarse and coarse sand — 2.0 - 0.5 mm.	Medium and fine sand — 0.5 - 0.125 mm.	Very fine sand, silt, and clay — <0.125 mm.
0-10	-	-	-	-
10-20	70	11	12	7
20-30	88	6	4	2
30-40	34	14	34	18
40-50	67	14	13	6
50-60	71	8	13	8
60-70	70	9	16	5
70-80	42	17	24	17
80-90	29	19	34	18
90-100	34	18	34	14
100-110	34	18	29	19
110-120	10	-	-	-
120-130	10	-	-	-
130-140	10	-	-	-
140-150	10	-	-	-
150-160	5	-	-	-
160-170	5	-	-	-
170-180	5	-	-	-
180-190	5	-	-	-
190-200	5	-	-	-

Table 7.--Logs of wells in the Headquarters area - continued

Test well T-4 (22.5.16.111) - continued

17 of 48

Depth of sample (feet)	Percentages of sample by volume			
	Gravel >2.0 mm.	Very coarse and coarse sand 2.0 - 0.5 mm.	Medium and fine sand 0.5 - 0.125 mm.	Very fine sand, silt, and clay <0.125 mm.
200-210	15	-	-	-
210-220	15	-	-	-
220-230	10	-	-	-
230-240	5	-	-	-
240-250	2	-	-	-
250-260	2	-	-	-
260-270	2	-	-	-
270-280	2	-	-	-
280-290	2	-	-	-
290-300	2	-	-	-
300-310	2	-	-	-
310-320	5	-	-	-
320-330	7	-	-	-
330-350	5	-	-	-
350-360	5	-	-	-
360-370	5	-	-	-
370-380	27	27	40	6
380-390	50	25	19	6
390-400	7	-	-	-
400-410	5	-	-	-

Table 7.--Logs of wells in the Headquarters area - continued

Test well T-4 (22.5.16.111) - continued

18 of 48

Depth of sample (feet)	Percentages of sample by volume			
	Gravel > >2.0 mm.	Very coarse and coarse sand 2.0 - 0.5 mm.	Medium and fine sand 0.5 - 0.125 mm.	Very fine sand, silt, and clay <0.125 mm.
410-420	5	-	-	-
420-430	5	-	-	-
430-440	7	-	-	-
440-450	5	-	-	-
450-460	5	-	-	-
460-470	5	-	-	-
470-480	5	-	-	-
480-490	7	-	-	-
490-500	7	-	-	-
500-510	3	-	-	-
510-520	5	-	-	-
520-530	5	-	-	-
530-540	5	-	-	-
540-550	7	-	-	-
550-555	10	25	57	8
555-560	11	33	52	4
560-565	22	31	41	6
565-570	20	28	45	7
570-575	26	29	40	5
575-580	5	-	-	-

Table 7.--Logs of wells in the Headquarters area - continued

Test well T-4 (22.5.16.111) - continued

19 of 48

Depth of sample (feet)	Percentages of sample by volume			
	Gravel	Very coarse and coarse sand	Medium and fine sand	Very fine sand, silt, and clay
	>2.0 mm.	2.0 - 0.5 mm.	0.5 - 0.125 mm.	<0.125 mm.
580-590	5	-	-	-
590-600	3	-	-	-
600-610	12	21	65	2
610-620	7	13	75	5
620-630	3	-	-	-
630-640	3	-	-	-
640-650	3	-	-	-
650-660	28	19	45	8
660-680	5	-	-	-
680-690	5	-	-	-
690-700	5	-	-	-
700-710	5	-	-	-
710-720	5	-	-	-
720-740	5	-	-	-
740-750	5	-	-	-
750-760	5	-	-	-
760-770	3	-	-	-
770-780	5	-	-	-
780-790	5	-	-	-
790-800	19	25	48	8

Table 7.—Logs of wells in the Headquarters area - continued

Test well T-4 (22.5.16.111) - concluded

20 of 48

Depth of sample (feet)	Percentages of sample by volume			
	Gravel	Very coarse and coarse sand	Medium and fine sand	Very fine sand, silt, and clay
	>2.0 mm.	2.0 - 0.5 mm.	0.5 - 0.125 mm.	<0.125 mm.
800-810	13	16	64	7
810-820	16	26	47	11
820-830	16	27	49	8
830-840	16	16	57	11
840-850	11	8	70	11
850-860	17	17	54	12
860-870	32	18	41	9
870-880	34	17	37	12
880-890	25	20	45	10
890-900	27	20	43	10
900-910	16	11	59	14
910-920	9	9	68	14
920-930	16	14	56	14
930-940	20	13	59	8
940-950	22	14	50	14
950-960	23	16	46	15
960-970	16	12	56	16
970-980	10	7	69	14
980-990	6	5	73	16
990-1,000	11	11	67	11

Note: Predominantly calcareous clay from 110 to 370, 390 to 550, 575 to 600, 620 to 650, and 660 to 790 feet.

Table 7.--Logs of wells in the Headquarters area - continued

Test well T-5 (22.5.20.111)

Depth of sample (feet)	Percentages of sample by volume			
	Gravel > 2.0 mm.	Very coarse and coarse sand 2.0 - 0.5 mm.	Medium and fine sand 0.5 - 0.125 mm.	Very fine sand, silt, and clay <0.125 mm.
0-20	93	3	2	2
20-30	89	8	2	1
30-40	67	15	12	6
40-50	70	18	7	5
50-60	77	13	7	3
60-70	75	10	9	6
70-80	67	13	14	6
80-90	80	7	9	4
90-100	75	11	11	3
100-110	78	10	8	4
110-120	80	10	6	4
120-130	79	11	6	4
130-140	62	16	18	4
140-150	56	18	20	6
150-160	65	14	13	8
160-170	61	17	17	5
170-180	51	21	20	8
180-190	57	16	20	6
190-200	60	21	14	5
200-210	64	17	12	7

Table 7.--Logs of wells in the Headquarters area - continued

Test well T-5 (22.5.20.111) - continued

22 of 48

Depth of sample (feet)	Percentage of sample by volume			
	Gravel >2.0 mm.	Very coarse and coarse sand 2.0 - 0.5 mm.	Medium and fine sand 0.5 - 0.125 mm.	Very fine sand, silt, and clay <0.125 mm.
210-220	55	20	18	7
220-230	50	21	22	7
230-240	41	26	27	6
240-250	56	28	13	3
250-260	42	27	25	6
260-270	47	22	22	9
270-280	34	21	30	15
280-290	15	29	45	11
290-300	23	27	37	13
300-310	32	29	30	9
310-320	26	23	32	19
320-330	12	17	55	16
330-340	14	18	43	25
340-350	21	18	37	24
350-360	28	19	32	21
360-370	33	20	28	19
370-380	24	32	31	13
380-390	23	34	30	13
390-400	26	29	30	15
400-410	28	31	28	13

Table 7.--Logs of wells in the Headquarters area - continued

Test well T-5 (22.5.20.111) - continued

23 of 48

Depth of sample (feet)	Percentages of sample by volume			
	Gravel >2.0 mm.	Very coarse and coarse sand 2.0 - 0.5 mm.	Medium and fine sand 0.5 - 0.125 mm.	Very fine sand, silt, and clay <0.125 mm.
410-420	23	30	32	15
420-430	28	22	32	18
430-440	35	31	25	9
440-450	16	10	32	42
450-460	21	23	31	25
460-470	30	24	30	16
470-480	24	22	40	14
480-490	29	25	33	13
490-500	24	17	36	23
500-510	22	25	38	15
510-520	25	25	35	15
520-530	14	33	37	16
530-540	16	35	35	14
540-550	20	35	31	14
550-560	10	34	43	13
560-570	29	19	20	15
570-580	32	23	27	18
580-590	38	24	25	13
590-600	22	26	33	19
600-610	12	21	38	29

Table 7.--Logs of wells in the Headquarters area - continued

Test well T-5 (22.5.20.111) - continued

24 of 48

Depth of sample (feet)	Percentages of sample by volume			
	Gravel >2.0 mm.	Very coarse and coarse sand 2.0 - 0.5 mm.	Medium and fine sand 0.5 - 0.125 mm.	Very fine sand, silt, and clay < 0.125 mm.
610-620	23	26	33	18
620-630	22	26	39	13
630-640	32	27	27	14
640-650	28	25	22	25
650-660	29	24	21	26
660-670	10	-	-	-
670-680	7	-	-	-
680-690	7	-	-	-
690-700	7	-	-	-
700-710	10	-	-	-
710-720	10	-	-	-
720-730	7	-	-	-
730-740	7	-	-	-
740-750	5	-	-	-
750-760	10	-	-	-
760-770	6	-	-	-
770-780	7	-	-	-
780-790	25	26	33	16
790-800	18	21	46	15
800-810	14	21	54	11

Table 7.--Logs of wells in the Headquarters area - continued

Test well T-5 (22.5.20.111) - concluded

25 of 48

Depth of sample (feet)	Percentages of sample by volume			
	Gravel >2.0mm.	Very coarse and coarse sand 2.0 - 0.5 mm.	Medium and fine sand 0.5 - 0.125 mm.	Very fine sand, silt, and clay <0.125 mm.
810-820	19	31	38	12
820-830	20	31	36	13
830-840	29	32	27	12
840-850	17	26	43	14
850-860	14	27	45	14
860-870	16	30	44	10
870-880	17	27	44	12
880-890	21	32	36	11
890-900	14	28	43	15
900-910	8	13	68	11
910-920	3	9	76	12
920-930	9	18	58	15
930-940	10	18	57	15
940-950	20	25	42	14
950-960	15	25	45	15
960-970	10	17	53	20
970-980	16	28	42	14
980-1,000	16	19	36	29

Note: Predominantly red clay from 660 to 780 feet.

Table 7.--Logs of wells in the Headquarters area - continued

Test well T-6 (22.4.14.133)

Material	Thickness (feet)	Depth (feet)
Sand, fine to very coarse, granitic debris	15	15
Sand, fine to very coarse, and bit-cut fragments of larger rocks	10	25
Sand, fine to very coarse	5	30
Sand, fine to very coarse, and bit-cut fragments larger rocks	5	35
Sand, fine to very coarse, some silt, and bit-cut fragments of larger rocks	5	40
Sand, fine to very coarse	10	50
Sand, very fine- to very coarse, and silt	5	55
Sand, fine to very coarse, and some bit-cut fragments of larger rocks	5	60
Sand, fine to very coarse, some red clay or silt, and bit-cut fragments of larger rocks	20	80
Sand, fine to very coarse	5	85
Sand, fine to very coarse, and some bit-cut fragments of larger rocks	5	90
Sand, fine to very coarse, some red clay or silt, and bit-cut fragments of larger rocks	5	95
Sand, fine to very coarse	5	100
Sand, fine to very coarse, and some bit-cut fragments of larger rocks	5	110
Sand, fine to very coarse, several pebbles, and some bit- cut fragments of larger rocks	5	115

Table 7.--Logs of wells in the Headquarters area - continued

Test well T-6 (22.4.14.133 - continued

Material	Thickness (feet)	Depth (feet)
Sand, fine to very coarse, andbit-cut fragments of larger rocks	10	125
Sand, fine to very coarse	15	140
Sand, fine to very coarse, and bit-cut fragments of larger rocks	10	150
Sand, fine to very coarse	5	155
Sand, fine to very coarse, and small bit-cut flakes of larger rocks	10	165
Sand, fine to very coarse	5	170
Sand, fine to very coarse and bit-cut fragments of larger rocks. Grain size mainly coarse	5	175
Sand, coarse, with small amounts of fine- to very coarse sand	15	190
Sand, mainly coarse, and bit-cut fragments of larger rocks	10	200
Sand, fine to very coarse, and bit-cut fragments of larger rocks	5	205
Sand, fine to very coarse, some small pebbles and bit-cut fragments of larger rocks	25	230
Sand, fine to very coarse, and bit-cut fragments of larger rocks	5	235
Sand, medium to coarse	5	240
Sand, very fine to coarse	35	275
Sand, very fine to coarse and some bit-cut fragments of larger rocks	5	280

Table 7.--Logs of wells in the Headquarters area - continued

Test well T-6 (22.4.14.133) - continued

Material	Thickness (feet)	Depth (feet)
Sand, very fine to very coarse	5	285
Sand, very fine to very coarse, and some bit-cut fragments of larger rocks	5	290
Sand, very fine to coarse	10	300
Sand, very fine to coarse, and some bit-cut fragments of larger rocks	5	305
Sand, very fine to coarse, bit-cut fragments of larger rocks, and small bits of steel from drill bit	5	310
Sand, fine to medium, and bits of steel	5	315
Sand, fine to medium, small pebble, and bits of steel	5	320
Sand, fine to coarse, and bits of steel	5	325
Sand, fine to coarse, and bit-cut fragments of larger rocks	10	335
Sand, fine to coarse, bit-cut fragments of larger rocks, and bits of steel	5	340
Sand, fine to coarse, bit-cut fragments of larger rocks, and a little brown clay	5	345
Sand, fine to coarse, and bits of steel	5	350
Sand, fine to coarse, bit-cut fragments of larger rocks, and bits of steel	10	360
Sand, fine to coarse, much bit-cut rock, and bits of steel	5	365
Sand, fine to coarse, bit-cut rock, and bits of steel	5	370
Sand, fine to coarse, much bit-cut rock, and bits of steel	10	380
Sand, mainly very coarse, and much bit-cut fragments of of larger rocks	35	415

Table 7.--Logs of wells in the Headquarters area - continued

Test well T-6 (22.4.14.133) - concluded

Material	Thickness (feet)	Depth (feet)
Sand, medium, and much bit-cut roack	5	420
Sand, mainly very coarse, and much bit-cut rock	25	445
Sand, mainly very coarse, and much bit-cut rock. Samples have a uniform dark gray-brown color. Many larg bit-cut chips from 490 to 500 feet	55	500
Igneous rock, mainly bit-cut chips of brown, fine; many chips have distinct conchoidal fracture	15	515
		Total depth

Note: During course of drilling it was observed that much very fine sand and apparently some clay was carried away in the drilling mud. Almost all sand grains are angular to subangular because the parent rock is nearby. Grain sizes from 325 to 372 probably were reduced from original size by slow grinding from a worn and broken bit. Rock chips, noted as "bit-cut" are the result of the reduction of boulders and other large particles in the fan debris; these larger particles increased in number with depth to the vicinity of the bedrock top at about 490 feet, thus the increase in the amount of bit-cut material. A part of the erosional debris apparently was partly cemented, as shown by the relatively clean hole prior to setting casing.

Table 7.--Logs of wells in the Headquarters area - continued

Production well 1 (22.5.32.131)

30 of 48

Material	Thickness (feet)	Depth (feet)
Soil	4	4
Sand and rock	5	9
Gravel, sand, and dirt	227	236
Gravel, carrying water	21	257

Table 7.--Logs of wells in the Headquarters area - continued

Production well 2 (25.5.31.244)

Material	Thickness (feet)	Depth (feet)
Soil	3	3
Sand and rock	5	8
Sand, gravel, and dirt	232	240
Gravel, carrying water	50	290
Red shale	4	294

Table 7.--Logs of wells in the Headquarters area - continued

Production well 4 (22.5.32.311)

31 of 48

Material	Thickness (feet)	Depth (feet
Loose gravel	7	7
Shell	5	12
Gravel and clay	215	227
Water sand	44	271
Red shale	11	282
Gravel	5	287
Gray shale	18	305
Red shale	21	326
Gray shale	4	330
Red shale	6	336
Gravel, sand, clay, and boulders	81	417
Red shale	23	430
Sandy shale	17	447
Red shale	5	452

Table 7.--Logs of wells in the Headquarters area - continued

Production well 5 (22.5.32.313)

Material	Thickness (feet)	Depth (feet)
Red gravel wash	25	25
Gravel and brown clay	210	235
Water sand and gravel	12	247
Red shale	20	267

Table 7.--Logs of wells in the Headquarters area - continued

Production well 5 (22.5.32.313)

Material	Thickness (feet)	Depth (feet)
Red clay and gravel	158	158
Gray shale	22	180
Brown shale	45	225
Gravel and clay (water yielding)	8	233
Red shale	7	240
Sand	5	245
Red shale	18	263
Blue shale	25	288
Brown shale	11	299
Brown sandy shale	5	304
Red sandy shale (water yielding)	20	324
Red shale	8	332
Red sandy shale	6	338

Table 7.--Logs of wells in the Headquarters area - continued

Production well 7 (22.5.32.323)

Material	Thickness (feet)	Depth (feet)
Gravel and red clay	54	54
Gravel, clay, and boulders	21	75
Gravel and red clay	84	159
Gray shale	29	188
Gravel and red clay	7	195
Gray shale	5	200
Red shale	21	221
Blue shale	4	225
Gravel and red clay (water-bearing)	3	228
Red shale	23	251
Gray sand (water-bearing)	14	265
Sandy shale	25	290
Brown shale	14	304

Table 7.--Logs of wells in the Headquarters area - continued

Production well 8 (22.5.32.332)

34 448

Material	Thickness (feet)	Depth (feet)
Sand and clay	31	31
Sand and brown clay	19	50
Gravel and brown clay	60	110
Gravel and sand	20	130
Gravel and brown sand	40	170
Red shale	20	190
White shale	10	200
Brown gravel	8	208
Red rock and shale	17	225
Red sand	5	230
Gravel and water	8	238
Blue shale	18	256

Table 7.--Logs of wells in the Headquarters area - continued

Production well 9 (22.5.31.424)

Material	Thickness (feet)	Depth (feet)
Gravel	78	78
Clay and red gravel	181	259
Gravel (water-yielding)	14	273
Gravel and clay	19	292
Gravel	3	295
Gravel and clay	11	306
Gravel (water-yielding)	5	311
Shale	4	315
Gravel and clay	13	328
Gray shale	7	335
Blue shale	13	348

Table 7.--Logs of wells in the Headquarters area - continued

Production well 11 (22.4.13.333)

Material	Thickness (feet)	Depth (feet)
Top soil and caliche	17	17
Caliche, sand, gravel, and boulders	23	40
Gravel, sand, and layers of clay	140	180
Clay, gravel, and fine sand	83	263
Sand, clay, and gravel - lots of sand	25	288
Coarse sand and gravel (water)	20	308
Boulder	1	309
Sand and coarse gravel	111	420
Boulder	1	421
Sand and gravel	25	446
Boulder	2	448
Sand and gravel	32	480
Hard rock	4	484
Sand and gravel	39	523

Table 7.--Logs of wells in the Headquarters area - continued

Production well 12 (22.4.23.214)

Material	Thickness (feet)	Depth (feet)
Surface formation - gravel and adobe clays -----------	17	17
Boulder bed in sand and adobe ------------------------	3	20
Adobe clay and dry gravel conglomerate ---------------	29	49
Heavy boulders ---------------------------------------	5	54
Beds of sand, gravel, and some conglomerate, not very hard - some soft places ------------------	136	190
Sand, gravel and clay cemented into a hard conglomerate -----------------------------------	88	278
Hard packed sandy formation - slow drilling ----------	52	330
Loose fine sand (water-bearing) ----------------------	12	342
Loose coarse water sand (some clay streaks) ----------	18	360
Hard dense sand (very slow drilling) -----------------	67	427

Table 7.--Logs of wells in the Headquarters area - continued

Production well 13 (22.4.13.311)

38 of 48

Material	Thickness (feet)	Depth (feet)
Top soil and sand	23	23
Coarse sand with some clay	24	47
Rocks and boulders	4	51
Coarse sand and gravel with some layers of clay	105	156
Cemented sand and boulders	13	168
Coarse sand and gravel	68	236
Coarse sand - hard drilling	19	255
Medium coarse sand	119	374
Coarse sand - water	15	389
Hard sand, boulders	21	410
Hard sandy clay	62	472
Coarse sand - water	55	527
Hard cemented sand	7	534

Table 7.--Logs of wells in the Headquarters area - continued

Production well 14 (22.4.13.411)

39 4/48

Material	Thickness (feet)	Depth (feet)
Sand, very fine to fine, silt, and clay	40	40
Gravel and medium sand	50	90
Gravel, medium sand, and boulders	30	120
Gravel, medium	20	140
Gravel, coarse	20	160
Gravel, medium to coarse, and fine to medium sand	30	190
Sand, fine to medium, and gravel	20	210
Sand, fine to medium, silt, and clay	10	220
Sand, medium, fine gravel, silt, and clay	10	230
Sand and fine gravel	10	240
Clay, some fine to medium sand	40	280
Sand, coarse	10	290
Clay, some fine sand	100	390
Sand, fine to medium, silt, and clay	30	420
Sand, fine to medium, gravel, silt, and clay	50	470
Sand, medium to coarse, gravel, silt, and clay	20	490

Table 7.--Logs of wells in the Headquarters area - continued

Production well 14 (22.4.13.411) - concluded

Material	Thickness (feet)	Depth (feet)
Sand, medium to coarse, and fine gravel --------------	10	500
Sand, fine to medium, silt, and clay ----------------	10	510
Sand, medium to coarse ------------------------------	40	550
Clay, some medium to coarse sand --------------------	10	560
Sand, medium to coarse ------------------------------	60	620
Sand and gravel --------------------------------------	10	630
Sand, medium to coarse ------------------------------	20	650
Sand, fine, silt, and clay --------------------------	20	670
Clay and little sand ---------------------------------	20	690
Sand, coarse gravel, silt, and clay -----------------	30	720
Clay, some sand and gravel --------------------------	100	820
Clay and fine sand -----------------------------------	20	840
Sand, fine to medium, silt, and some clay streaks ----	70	910
Sand, fine to medium, little gravel -----------------	20	930
Sand, fine to medium, silt, and clay ----------------	75	1,005

Table 7.--Logs of wells in the Headquarters area - continued

Production well 15 (22.4.13.424)

Material	Thickness (feet)	Depth (feet)
Clay and very fine to fine sand	10	10
Sand, fine to medium, and some gravel	10	20
Gravel, medium to coarse, and some sand	10	30
Coarse gravel	10	40
Sand, medium to coarse, and fine gravel	20	60
Gravel, medium to coarse, silt, and clay	20	80
Sand, medium to coarse, and fine gravel	84	164
Boulder	1	165
Gravel, medium to coarse	25	190
Sand, medium to coarse, and gravel	10	200
Coarse gravel; some sand and clay	10	210
Sand, fine to medium, silt, and clay	30	240
Sand, medium to coarse, clay, some gravel	10	250
Clay, silt, and fine sand	70	320
Sand, fine to medium, and clay	60	380
Sand, fine to medium, clay and some gravel	10	390
Gravel, medium to coarse, fine sand, and little clay	20	410

Table 7.--Logs of wells in the Headquarters area - continued

Production well 15 (22.4.13.424) - continued

Material	Thickness (feet)	Depth (feet)
Clay and fine to medium sand	80	490
Sand, medium to coarse, gravel, and clay	10	500
Clay and fine to medium sand	10	510
Sand, medium to coarse, gravel and clay	20	530
Sand, medium, silt, and clay	10	540
Sand, medium, gravel and clay	30	570
Sand, fine to medium, silt and clay	20	590
Sand, medium to coarse, and gravel	10	600
Sand, fine to medium, silt, and clay	20	620
Sand, medium to coarse, and gravel	10	630
Sand, medium, and some gravel	10	640
Clay and fine to medium sand	30	670
Sand, medium to coarse, and some gravel	10	680
Sand, fine, silt, and clay	20	700
Clay	10	710
Clay and fine to medium sand	10	720
Clay	10	730
Clay and fine to medium sand	60	790

Table 7.--Logs of wells in the Headquarters area - continued

Production well 15 (22.4.13.424) - concluded

Material	Thickness (feet)	Depth (feet)
Clay	10	800
Gravel, fine to medium, and sand	20	820
Clay and gravel	20	840
Clay, sand, and some gravel	30	870
Sand, fine to medium, and some gravel	10	880
Clay and sand	10	890
Sand, fine to medium, clay, and some gravel	30	920
Sand, medium, and clay	40	960
Clay and sand, medium	10	970
Sand, medium, and clay	10	980
Sand, medium, clay, and some gravel	10	990
Sand, fine to medium, and clay	20	1,010

Table 7.--Logs of wells in the Headquarters area - continued

Production well 16 (22.4.13.432)

44 of 48

Material	Thickness (feet)	Depth (feet)
Sand, fine to medium	20	20
Sand, fine to coarse	10	30
Sand, medium to very coarse	10	40
Sand, very coarse	10	50
Sand, coarse to very coarse	20	70
Sand, very coarse, and very fine gravel	10	80
Gravel, very fine, and coarse to very coarse sand	10	90
Gravel, very fine to fine, and coarse to very coarse sand	10	100
Sand, coarse to very coarse, and very fine gravel	10	110
Sand, coarse to very coarse	60	170
Sand, coarse to very coarse, and very fine gravel	10	180
Sand, medium to very coarse	10	210
Sand, coarse to very coarse, and very fine gravel	40	250
Sand, coarse to very coarse	10	260

Table 7.--Logs of wells in the Headquarters area - continued

Production well 16 (22.4.13.432) - continued

Material	Thickness (feet)	Depth (feet)
Sand, coarse to very coarse, and very fine gravel ----	10	270
Sand, medium to very coarse ------------------------	30	300
Sand, coarse to very coarse -------------------------	10	310
Sand, medium to very coarse -------------------------	70	380
Sand, coarse to very coarse -------------------------	10	390
Sand, coarse to very coarse, and very fine gravel ----	60	450
Sand, medium to very coarse, and very fine gravel ----	30	480
Sand, medium to very coarse -------------------------	10	490
Sand, medium to very coarse, silt and clay ----------	10	500
Sand, medium to very coarse, and very fine gravel ----	20	520
Sand, medium to very coarse ------------------------	80	600
Sand, fine to very coarse ---------------------------	4[illegible]	640
Sand, coarse and very coarse ------------------------	10	650
Sand, fine to coarse --------------------------------	10	660
Sand, fine to very coarse ---------------------------	10	670
Sand, very fine to coarse, silt and clay ------------	10	680

Table 7.--Logs of wells in the Headquarters area - continued

Production well 16 (22.4.13.432) - continued

46 of 48

Material	Thickness (feet)	Depth (feet)
Sand, fine to very coarse	20	700
Sand, fine to coarse	10	710
Sand, very fine to coarse	10	720
Sand, very fine to coarse, silt and clay	10	730
Sand, very fine to medium, silt and clay	20	750
Sand, very fine to coarse, silt and clay	20	770
Sand, very fine to very coarse, silt and clay	40	810
Sand, medium to very coarse, and very fine gravel	10	820
Sand, very fine to very coarse	10	830
Sand, very fine to very coarse, silt and clay	20	850
Silt, clay, and very fine to fine sand	10	860
Silt, clay, very fine and coarse sand	10	870
Sand, very fine to coarse, silt and clay	10	880

Table 7.--Logs of wells in the Headquarters area - concluded

Production well 16 (22.4.13.432) - concluded

Material	Thickness (feet)	Depth (feet)
Sand, very fine to very coarse, silt and clay	20	900
Sand, very fine to coarse, silt and clay	10	910
Sand, very fine to very coarse, silt and clay	20	930
Sand, medium to very coarse	10	940
Sand, very fine to very coarse	10	950
Sand, fine to very coarse	10	960
Sand, fine to coarse	20	980
Sand, fine to coarse, silt and clay	10	990
Sand, fine to coarse	10	1,000
Sand, silt and clay	10	1,010
Sand	10	1,020

Table 7.--Logs of wells in the Headquarters area - concluded

Production well 17 (22.4.13.234)

48 of 45

Material	Thickness (feet)	Depth (feet)
Surface sand	4	4
Hard sand, layers of rock and gravel	57	61
Sandy clay and layers of gravel	151	212
Hard sand, gravel and layers of rock	59	271
Sand and gravel	30	301
Sand, clay and streaks of gravel	60	361
Sand and clay	58	419
Sand and layers of clay	63	482
Sand and layers of rock	60	542
Sand, sandy clay and clay	90	632
Sand and clay with a few streaks of gravel	74	706
Sand and clay	30	736
Sand, gravel and layers of clay	135	871
Sand, gravel and clay	29	900

Table 8.--Well test data, Headquarters area

Well	Date	Average yield (gallons per minute)	Drawdown during test (feet)	Pumping time (hours)	Specific capacity			Transmissibility of formation indicated by test (gallons per day per foot)
					6 hours	12 hours	24 hours	
5 a/	Apr. 1948	70 R/	13 R/	-	-	-	-	-
9 a/	Apr. 1953	35 R/	23	6.5	1.5	-	-	800
10 a/	Aug. 1953	350 E/	17	72	28.0	25.9	24.1	61,600
11	Aug. 1953	366	57	29.5	13.1	9.4	6.9	2,500
12 a/	Sep. 1953	212	-	-	-	-	-	-
13	Sep. 1953	209	72	50	3.9	3.5	3.3	5,000
14	Jan. 1954	600	76.5	48	10.6	9.2	8.5	7,900
15	Feb. 1954	750	35	40.5	24.2	23.4	21.4	28,300
16	Oct. 1954	600	25	48	33.3	30.3	30.0	33,000

a/ Abandoned

R/ Reported

E/ Estimated

Table 9.--Construction data for water-supply wells, Headquarters area

Well	Date completed	Depth (feet)	Diameter (inches)	Casing and screen			Air cleanout pipes	
				Depth of setting (feet)	Length (feet)	Description	Depth of setting (feet)	Description
10	Aug. 1948 Use as production well terminated 1965; replaced by well 10a.	505	21 to 456 feet 14 from 456 to 505 feet	10	10	30-inch diameter	348	2-inch diameter pipe, lower 4 feet perforated
				267	267	12-inch diameter blank steel casing	458	Do.
				497	230	12-inch diameter slotted steel casing		
10a	July 1965	805	36	50	50	42-inch CMP surface casing		
				400	400	Two 8-inch gravel feed lines		
				405	405	16-inch steel casing		
				805	400	16-inch slotted steel casing		
11	May 1950	500	24 to 12	40	40	26-inch diameter steel welded surface casing	400	$2\frac{1}{2}$-inch diameter pipe.
				380	380	12-inch diameter blank steel casing	490	Do.
				498	8	Do.		
				490	110	12-inch diameter slotted steel casing		
				500	2	Set nipple with back-wash valve		

Table 9.--Construction data for water-supply wells,

Headquarters area - continued

Well	Date completed	Depth (feet)	Diameter (inches)	Casing and screen			Air cleanout pipe	
				Depth of setting (feet)	Length (feet)	Description	Depth of setting (feet)	Description
12	Jan. 1952	570	24 to 12	50	50	24-inch diameter corrugated metal surface pipe	360	$2\frac{1}{2}$-inch diameter pipe
				330	330	12-inch diameter blank steel casing	480	Do.
				425	65	do.	560	Do.
				500	20	do.		
				360	30	12-inch diameter slotted steel casing		
				480	55	do.		
				560	60	do.		
13	Aug. 1951	534	24 to 12	50	50	24-inch diameter corrugated metal surface pipe	390	$2\frac{1}{2}$-inch diameter meter pipe
				373	373	12-inch diameter blank steel casing	531 3/4	
				470	77	do.		
				393	20	12-inch diameter slotted steel casing		
				534	64	do.		

Table 9.--Construction data for water-supply wells

Headquarters area - Continued

Well	Date completed	Depth (feet)	Diameter (inches)	Casing and screen: Depth of setting (feet)	Casing and screen: Length (feet)	Casing and screen: Description	Air cleanout pipes: Depth of setting (feet)	Air cleanout pipes: Description
14	Dec. 1953	810	26 to 12	50	50	26-inch diameter steel surface casing	760	$2\frac{1}{2}$-inch diameter pipe perforated at each screen section
				370	370	12-inch diameter blank steel casing		
				398	8	do.	760	Do.
				454	36	do.		
				480	16	do.		
				510	10	do.		
				538	8	do.		
				554	6	do.		
				584	10	do.		
				632	38	do.		
				650	8	do.		
				680	10	do.		
				700	10	do.		
				728	18	do.		
				760	12	do.		
				390	20	12-inch diameter louvered steel screen		
				418	20	do.		
				464	10	do.		
				500	20	do.		
				530	20	do.		
				548	10	do.		
				574	20	do.		

Table 9.--Construction data for water-supply wells - :

Headquarters area - continued

Well	Date completed	Depth (feet)	Diameter (inches)	Casing and screen			Air cleanout pipes	
				Depth of setting (feet)	Length (feet)	Description	Depth of setting (feet)	Description
14 Cont.	Dec. 1953	810	26 to 12	594	10	12-inch diameter louvered steel screen		
				642	10	do.		
				670	20	do.		
				690	10	do.		
				710	10	do.		
				748	20	do.		
				810	50	do.		
15	Feb. 1954	820	26 to 12	50	50	26-inch diameter steel surface casing	770	$2\frac{1}{2}$-inch diameter pipe, perforated at each screen section
				350	350	12-inch diameter blank steel casing		
				486	46	do.	770	Do.
				508	12	do.		
				525	7	do.		
				598	33	do.		
				670	32	do.		
				690	10	do.		
				710	10	do.		
				800	50	do.		
				440	90	12-inch diameter louvered steel screen		

Table 9.--Construction data for water-supply wells -

Headquarters area - continued

Well	Date completed	Depth (feet)	Diameter (inches)	Casing and screen: Depth of setting (feet)	Casing and screen: Length (feet)	Casing and screen: Description	Air cleanout pipes: Depth of setting (feet)	Air cleanout pipes: Description
15 Cont.	Feb. 1954	820	26 to 12	496	10	12-inch diameter louvered steel screen		
				518	10	do.		
				565	40	do.		
				638	40	do.		
				680	10	do.		
				700	10	do.		
				750	40	do.		
				820	20	do.		
16	Sept. 1954	890	26 to 12	50	50	26-inch diameter steel surface casing	420	2½-inch diameter pipe, lower 6 feet perforated
				370	370	12-inch diameter blank steel casing		
				415	5	do.	840	
				443	8	do.		
				459	6	do.		
				486	7	do.		
				508	12	do.		
				542	14	do.		
				588	6	do.		
				606	8	do.		
				642	6	do.		
				657	5	do.		
				678	11	do.		

Table 9.--Construction data for water-supply wells

Headquarters area - concluded

Well	Date completed	Depth (feet)	Diameter (inches)	Casing and screen			Air cleanout pipes	
				Depth of setting (feet)	Length (feet)	Description	Depth of setting (feet)	Description
16 Cont.	Sept. 1954	890	26 to 12	708	20	12-inch diameter louvered steel screen		
				724	6	do.		
				742	8	do.		
				784	12	do.		
				804	10	do.		
				866	32	do.		
				890	4	do.		
				410	40	do.		
				435	20	do.		
				453	10	do.		
				479	20	do.		
				496	10	do.		
				528	20	do.		
				582	40	do.		
				598	10	do.		
				636	30	do.		
				652	10	do.		
				667	10	do.		
				688	10	do.		
				718	10	do.		
				734	10	do.		
				772	30	do.		
				794	10	do.		
				834	30	do.		
				886	20	do.		

Recharge

The source of all the ground water in the Headquarters area is precipitation within the reentrant and in the nearby mountains, an area of about 40 square miles. The average annual precipitation in the entire area of the reentrant west of the access highway probably is about 13 inches. According to Herrick (1960) the average annual natural recharge to the bolson deposits within the Headquarters reentrant probably is in the order of 2,000 acre-feet.

Discharge

Within the Headquarters area the only appreciable discharge of ground water from the bolson deposits is by transpiration and, artifically, by pumping. Most of the ground water is discharged outside the area.

The total amount of ground water pumped in the Headquarters area in 1954 was about 300 million gallons, or about 1,000 acre-feet, equal to approximately 50 percent of the estimated average recharge of 2,000 acre-feet. However, water levels in the area are declining and will continue to decline (see figs. 10, 11, and 12). The pumpage from the Headquarters well field is shown by the graph on figure 15.

Figure 15 (caption on next page) belongs near here.

Figure 15.--Pumpage in the Headquarters area well field, million of gallons, 1953-63.

Quality of water

All the wells supplying water to the housing and cantonment areas of the Headquarters area produce water of exceptionally good chemical quality. (See table 4 and figure 3.) The wells within the reentrant produce water containing an average concentration of about 240 ppm of dissolved solids. Although the deeper water obtained from wells 14 and 15 during drilling contained more dissolved solids than the shallow water, the deeper water is of a chemical quality well within potable limits.

Eastward from the cantonment area the ground water contains increasing amounts of dissolved solids, the deeper water having the higher concentrations. In June 1953 shallow water from test well T-4, 2 miles east of the access highway, contained only 329 ppm of dissolved solids, but a water sample obtained from a depth between 956 and 1,003 feet in the same well contained 7,480 ppm of dissolved solids, mostly sodium chloride. The electric log of test well T-4 indicates that the ground water at that site is saline below a depth of approximately 760 feet. The shallow water farther east in the central part of Tularosa Basin is highly saline, unfit for watering stock, and probably similar in quality to water from the Gregg site wells.

East of the headquarters area the fresh water mixes with saline water moving to the south and southwest through the main part of Tularosa Basin. Immediately east of the reentrant the fresh water apparently overrides the saline water (fig. 14).

The data indicate that south and north of the Headquarters area fresh water probably is confined to a relatively narrow belt close to the base of the mountains.

Possibilities of encroachment of saline water

The bolson deposits in the vicinity of the wells consist of clay, silt, sand, and some gravel. In general, the deposits in that part of the re-entrant are fairly well stratified. The vertical movement of ground water within the zone of saturation is considerably more restricted than lateral movement. The interface between fresh and saline ground water is sharply defined in the places where data were obtained, indicating that vertical mixing is slight under natural conditions.

Saline ground water may not extend beneath the wells north of the cantonment area. Saline water has not been sampled from wells west of the access highway, but samples of water from wells 15 and 16 should be analyzed chemically at about 6-month intervals as a precautionary measure. Even if saline water should eventually reach the wells, it would be in small quantities compared to the amount of fresh water with which it would be diluted during pumping. The dissolved solids content of the water presently produced by the wells is so low that considerable saline contamination could be tolerated without the water becoming nonpotable.

A few miles east of the reentrant, near T-4, where the shallow ground water is reported to be highly saline, the water table is about the same level as the present lowest nonpumping water levels in wells in the eastern part of the well field (fig. 9). It is apparent from figure 9 that a low mound of water is present between T-4 and the well field and that the pumping levels in the well field must be lowered further before saline water will move toward the well field. Such movement would be slow, probably less than a few hundred feet per year. Water quality in test wells basinward of the pumped area is monitored by periodic sampling; precise rate of water movement is one of the objectives of the well field evaluation study now under way.

Transmissibility of bolson deposits

The coefficient of transmissibility of the bolson deposits has been computed from data obtained from several pumping tests. Analysis of a pumping test of well 9 in the old well field indicated a coefficient of transmissibility of only 800 gpd per foot. This test was of short duration, and it was not possible to make other tests in that area. Examination of pump-test data and available drillers' logs of wells in that area indicates that the average transmissibility of the bolson deposits is much lower in the old well field than it is in the present well field north of the cantonment area. Coefficients of transmissibility obtained from pumping tests made in the present well field ranged from 2,500 at well 11 to 60,000 gpd per foot at well 10. The computed average coefficient of transmissibility in the vicinity of wells in the present well field is about 15,000 gpd per foot, although the average throughout the reentrant may be less than that.

Effects of pumping

Declines of water levels have been as much as 89 feet from 1954 to 1964 (fig. 12). If pumping is distributed uniformly among the wells declines of the water levels will be spread throughout the well field and the danger of an excessive decline at any one well will be reduced to a minimum. An accurate record of water-level fluctuations in all the wells should be maintained and measurements should be made at least once every 2 months. This information is needed to accurately evaluate the effects of pumping and thereby plan most efficient use of the ground-water resources.

Small Missile Range area

(Reference: Hood, 1963)

The principal work area in the Small Missile Range is sec. 15, T. 21 S., R. 5 E. The potable water supply for the area in 1961 came from a shallow well (21.5.11.411) that had been yielding water since 1952. The original yield of the well was 15 gpm. However, by 1961, the yield was only 10 gpm and was inadequate for the needs of the area. Attempts to rehabilitate the well were unsuccessful.

Well 21.5.15.411 is shallow and the water from it is potable. Reportedly the aquifer is fine sand. However, a deep well at this location probably would yield water inferior to that from the shallow zone. Investigations were made upslope towards the mountains to the west in sections 16 and 17, where the probability of obtaining potable water from coarse sand and gravel is greater. (See figs. 3 and 4.)

The locations for test drilling were about a mile east of a fault scarp that extends northeastward through the NE cor. sec. 21, T. 21 S., R. 5 E. West of the fault a pediment slope extends into a reentrant in the mountain front through which arroyos carry runoff to the flats. The pediment is cut on granite and is covered by only a few feet of overburden. East of the fault, which has a vertical displacement of more than 1,000 feet, the bolson fill is thick. Two wells, SMR 1 (21.5.17.244) and SMR 2 (21.5.17.424) were drilled. SMR 1 was completed as a production well. The well yields 75 to 100 gpm. However, this is not the maximum capacity of the well.

Drilling of well SMR-1 began June 3 and was completed June 25, 1960. The first water was found at 285-90 feet. The hole was drilled to 600 feet but was cased with 6-inch casing only to 473 feet below land surface. A total of one hundred twenty-eight feet of the casing was slotted opposite selected zones. The slots were cut approximately one-eighth inch wide and 4 inches long, staggered in rows, 12 slots per foot.

Well SMR-1 was equipped as a production well with a submersible pump in the Spring of 1962. Yield of the well ranges from 75 to 90 gpm.

Drilling of well SMR-2 began at the end of June 1960, and was finished at the end of September. The first water was found at 305 feet below land surface. Total depth was 765 feet.

The well was cased with 8-inch casing to about 608 feet below land surface and 6-inch casing from 598 to 747 feet. These casings were perforated from 295 to 588 feet, and from 608 to 715 feet.

The annular space between the 8-inch casing and the wall of the hole was filled with gravel by pouring the gravel into the space at the surface and then bailing the well to settle the gravel. The well initially required about 9 cubic yards of gravel.

The saturated bolson fill at the test sites is more than 450 feet thick. The top of the saturated zone is about 3,890 feet above mean sea level at test well SMR-1 and about 3,894 feet at SMR-2. The source of water in the Small Missile Range area is west of the well sites. Ground water moves east-southeastward from the well sites toward the flats of the Tularosa Basin and then moves southward. Recharge to the Small Missile Range area comes partly from absorption of precipitation and subsequent underground transmission from the reentrant above the test well area, and partly from absorption of precipitation and arroyo flow in the vicinity of the test wells.

The quantity of recharge can be estimated from the slope of the water surface, the coefficient of transmissibility of the bolson fill, and the width of the area concerned. The water levels in the area had not been disturbed prior to test drilling so the flow of water through the area should represent the amount of water entering the aquifer. The slope from SMR-1 to the production well at the Small Missile Range work area is 51 feet in 1.29 miles, or about 40 feet per mile. The coefficient of transmissibility was about 20,000 gpd per foot, as determined by the aquifer test at SMR-2. For a mile width of the aquifer the rate of flow = 20,000 x 40 = 800,000 gallons per day per mile, or about 900 acre-feet per year per mile.

The coefficient of transmissibility at test well SMR-1 is about 7,900 gpd per foot for a saturated section approximately 200 feet thick. The coefficient of transmissibility at test well SMR-2 is about 20,000 gpd per foot for a saturated section about 450 feet thick. These figures are approximately comparable when related to thicknesses. The specific capacity for SMR-2 after pumping about 12 hours at 116 to 180 gpm was nearly 12 gpm per foot of drawdown. The specific capacity for SMR-1 was computed to be about 5.9 gpm per foot.

Well logs of SMR-1 and 2 are given in table 10.

Table 10.--Log of wells in the Small Missile Range.

Production well SMR-1 (21.5.17.244) - (formerly Test well SMR-1)

Material	Thickness (feet)	Depth (feet)
Soil, full of sand and gravel. Fragments are angular	5	5
Gravel, pebbles, and some very coarse sand	5	10
Sand, fine- to very coarse-grained, and gravel	5	15
Sand, coarse- to very coarse-grained, gravel and small pebbles	5	20
Sand, very fine- to very coarse-grained, gravel, and small pebbles	5	25
Sand, very fine- to very coarse-grained, and small gravel. Pebbles at 35 and 55 feet	30	55
Sand, very fine- to very coarse-grained, very small gravel and some tan clay	15	70
Sand, fine- to very coarse-grained, and small gravel partly bit-cut	15	85
Sand, fine- to very coarse-grained, gravel, and small pebbles	20	105
Sand, fine- to very coarse-grained, small gravel and a large pebble or two	10	115
Sand, fine- to very coarse-grained, and small bit-cut gravel	10	125
Clay, silty brown, very fine- to very coarse-grained sand and some small gravel	5	130

Production well SMR-1 - continued

Material	Thickness (feet)	Depth (feet)
Sand, very fine- to very coarse-grained, silty brown clay and some small gravel	10	140
Clay, silty, yellow-brown, very fine- to very coarse-grained sand, and small bit-cut gravel	5	145
Sand, fine- to very coarse-grained, small bit-cut gravel, and yellow-brown clay	5	150
Clay, silty yellow-brown, and very fine- to very coarse-grained sand	5	155
Sand, coarse-grained, gravel, and small pebbles	5	160
Sand, fine- to very coarse-grained, gravel and small pebbles	5	165
Sand, very fine- to very coarse-grained, some small pebbles, and silty clay	5	170
Clay, silty, yellow-brown, very fine- to very coarse-grained sand, and a few pebbles	5	175
Clay, silty yellow-brown, very fine- to very coarse-grained, and few small gravel	5	180
Sand, coarse- to very coarse-grained, and bit-cut gravel. Some silt	15	195
Clay, silty, yellow-brown, very fine- to very coarse-grained sand, and bit-cut gravel	10	205

Table 10.--Log of wells in the Small Missile Range - continued

Production well SMR-1 - continued

Material	Thickness (feet)	Depth (feet)
Sand, very fine- to very coarse-grained, small gravel, and some clay	5	210
Sand, fine- to very coarse-grained and some clay	10	220
Sand, very fine- to very coarse-grained, small gravel, and some clay	10	230
Clay, yellow-brown, some sand, and very small bit-cut gravel	10	240
Clay, sandy yellow-brown	5	245
Clay, sandy yellow-brown, and very fine- to very coarse-grained sand	10	255
Sand, very fine- to very coarse-grained and some clay	5	260
Sand, fine- to very coarse-grained, and gravel	5	265
Sand, fine to very coarse-grained, gravel and small pebbles	5	270
Clay, sandy tan	10	280
Sand, medium- to very coarse-grained, pebbles, and tan clay	5	285
Clay, sandy tan	5	290
Sand, medium- to coarse-grained, bit-cut pebbles, and tan clay	5	295
Sand, fine-grained to fine-grained gravel, and bit-cut pebbles	5	300

Table 10.--Log of wells in the Small Missile Range - continued

Production well SMR-1 - continued

Material	Thickness (feet)	Depth (feet)
Silt, tan, and fine- to coarse-grained sand	5	305
Sand, coarse-grained	5	310
Sand, coarse-grained, gravel, and small pebbles	20	330
Gravel and pebbles	5	335
Sand, coarse-grained, gravel, small pebbles, and tan clay	10	345
Sand, coarse-grained, gravel, and pebbles	5	350
Sand, medium-grained to medium bit-cut gravel	10	360
Sand, medium-grained to medium bit-cut gravel, and tan silt	10	370
Clay, silty tan, and fine- to medium-grained sand	10	380
Sand, fine- to medium-grained, and silty tan clay. About 50% each	10	390
Clay, silty tan	5	395
Sand, medium- to coarse-grained, and tan silt	5	400
Sand, medium- to coarse-grained, tan silt, and some small gravel	20	420
Clay, silty tan, and medium- to very coarse-grained sand	5	425
Clay, silty tan, medium- to very coarse-grained sand, and small pebbles	5	430
Clay, silty tan, and medium- to very coarse-grained sand	5	435

Table 10.--Log of wells in the Small Missile Range - continued

Production well SMR-1 - concluded

Material	Thickness (feet)	Depth (feet)
Clay, sandy tan, and bit-cut gravel	5	440
Clay, sandy tan, bit-cut gravel, and large pebbles	5	445
Gravel, bit-cut, small pebbles, and sandy brown clay	15	460
Clay, sandy brown, sand, and bit-cut gravel	10	470
Clay, sandy brown, sand, bit-cut gravel, and small pebbles	15	485
Clay, sandy brown, sand, bit-cut gravel, and large pebbles	5	490
Clay, sandy tan, and fine-grained gravel	5	495
Clay, sandy tan	5	500
Clay, sandy brown, sand and bit-cut gravel	10	510
Sand, bit-cut gravel, and large pebbles	5	515
Clay, brown, bit-cut gravel, and large pebbles	5	520
Clay, brown, sand, and small gravel (bit-cut at 540 feet)	30	550
Clay, sandy brown	5	555
Clay, sandy brown, and some coarse-grained sand	20	575
Clay, sandy brown, coarse-grained sand, and some small gravel	20	595
Clay, sandy brown, coarse-grained sands, small gravel, and large pebbles	5	600

Table 10.--Log of wells in the Small Missile Range - continued

Test well SMR-2 (21.5.17.424)

Material	Thickness (feet)	Depth (feet)
Silt, reddish-brown. Complete grain-size range through pebbles. Much sub-angular debris	15	15
Silt, reddish-brown, sand and gravel, with more silt and clay in lower part of section	15	30
Gravel, small sub-angular silt and clay	5	35
Gravel, small sub-angular, very coarse-grained sand and tan clay	5	40
Gravel, small sub-angular, pebbles, very coarse-grained sand, and tan clay	5	45
Pebbles, bit-cut, gravel, and very coarse-grained sand	5	50
Pebbles, bit-cut, gravel, very coarse-grained sand, and tan clay	5	55
Sand, very coarse-grained, small gravel, and tan clay	5	60
Sand, fine- to very coarse-grained, and small gravel	15	75
Sand, fine- to very coarse-grained, small gravel, pebbles and tan silt	10	85

Table 10.--Log of wells in the Small Missile Range - continued

Test well SMR-2 (21.5.17.424) - continued

Material	Thickness (feet)	Depth (feet)
Sand, fine- to very coarse-grained and small gravel	5	90
Sand, fine- to very coarse-grained, small gravel, small pebbles, and tan silt	20	110
Sand, fine- to very coarse-grained, small gravel, and tan silt	10	120
Sand, fine- to very coarse-grained, small gravel, and small pebbles	5	125
Sand, fine- to very coarse-grained, small gravel and tan silt. Sample 135-140 feet missing	25	150
Sand, very coarse-grained, small gravel and a pebble	10	160
Silt, tan, very coarse-grained sand, small gravel and pebbles	10	170
Gravel, small, with some silt and fine-grained sand	10	180
Gravel, small, small pebbles, and some silt and fine-grained sand	5	185
Gravel, small, silt, fine-grained sand, and brown clay	5	190
Silt, brown, and fine- to very coarse-grained sand	5	195
Sand, coarse- to very coarse-grained, and brown silt	5	200

Table 10.--Log of wells in the Small Missile Range - continued

Test well SMR-2 (21.5.17.424) - continued

Material	Thickness (feet)	Depth (feet)
Sand, coarse- to very coarse-grain cemented, and brown silt	5	205
Silt, tan to brown, very coarse-grained sand, and pebbles	5	210
Sand, fine- to very coarse-grained, small gravel and silt	10	220
Sand, fine- to very coarse-grained, small gravel, silt and very small pebbles	5	225
Sand, fine- to very coarse-grained, small gravel, silt, and large pebbles	5	230
Sand, very coarse-grained, gravel, and small pebbles	5	235
Sand, very coarse-grained, gravel, small pebbles, and much tan silt	10	245
Silt, tan, very fine-grained sand, small pebbles	5	250
Silt, tan, and very coarse-grained sand	15	265
Silt, tan, very coarse-grained sand, and small pebbles	5	270
Silt, tan, and very coarse-grained sand	10	280
Samples missing	15	295
Silt, tan, and very coarse-grained sand	5	300
Clay, yellow-brown, in lumps	5	305
Sand, medium- to coarse-grained small gravel, pebbles, and small amount of clay	5	310
Clay, sandy yellow-brown, in lumps	5	315

Table 10.--Log of wells in the Small Missile Range - continued

Test well SMR-2 (21.5.17.424) - continued

Material	Thickness (feet)	Depth (feet)
Clay, with much included small gravel, and a pebble	10	325
Clay, very sandy brown, and small gravel	5	330
Clay, very sandy, brown, in lumps, and a pebble	5	335
Clay, sandy brown, and medium- to coarse-grained sand	5	340
Clay, sandy brown, in lumps, and fine-grained gravel	5	345
Sand, silty, medium- to coarse-grained, and small gravel	5	350
Clay, yellow-brown, and medium- to coarse-grained sand	5	355
Clay, sandy, light-brown, stiff	5	360
Clay, sandy, light-brown, stiff, and fine-grained gravel	10	370
Clay, sandy, light-brown, in lumps	5	375
Sand, medium- to coarse-grained, fine-grained gravel, and a lump of sandy brown clay	10	385
Clay, sandy brown	5	390
Clay, and coarse-grained sand	5	395
Clay, sandy light-brown, in lumps, and some pebbles	5	400

Table 10.--Log of wells in the Small Missile Range - continued

Test well SMR-2 (21.5.17.424) - continued

Material	Thickness (feet)	Depth (feet)
Clay and fine- to coarse-grained sand	5	405
Clay, sandy light-brown, in lumps	5	410
Clay, yellow-brown. Almost no coarser material	5	415
Clay, light-brown, coarse-grained sand and small gravel	15	430
Sand, medium- to coarse-grained and some yellow clay	5	435
Clay, light brown, and coarse-grained sand. Clay firmer than above. A few pebbles	15	450
Clay, light brown, some coarse-grained sand, and fine gravel	5	455
Clay, yellow-brown	5	460
Clay, yellow	5	465
Clay, brown, and very fine- to coarse-grained sand	5	470
Clay, yellow-brown, and very fine- to coarse-grained sand	15	485
Clay, yellow-brown, very fine- to very coarse-grained sand, small gravel, and small pebbles	10	495
Clay, yellow-brown, fine-grained sand to fine-grained gravel	5	500
Clay, brown and fine-grained gravel	10	510

Table 10.--Log of wells in the Small Missile Range - continued

Test well SMR-2 (21.5.17.424) - continued

Material	Thickness (feet)	Depth (feet)
Sand, very fine- to very coarse-grained, small gravel, and tan clay	10	520
Clay, brown, and very fine-grained sand to fine-grained gravel	10	530
Clay, sandy brown	5	535
Clay, sandy brown, and very coarse-grained sand	5	540
Gravel, fine-grained, and sandy brown clay	5	545
Sand, medium- to very coarse-grained, fine-grained gravel, and brown clay	30	575
Clay, sandy brown	15	590
Sand, fine- to very coarse-grained, and sandy brown clay	5	595
Clay, sandy brown	5	600
Sand, medium- to very coarse-grained, and sandy brown clay	5	605
Clay, sandy brown	5	610
Sand, medium- to very coarse-grained, small gravel, and brown clay	5	615
Clay, sandy brown, medium- to very coarse-grained sand, and small gravel	10	625
Sand, very fine- to very coarse-grained, small gravel, and silty brown clay	10	635

Table 10.--Log of wells in the Small Missile Range - concluded

Test well SMR-2 (21.5.17.424) - continued

Material	Thickness (feet)	Depth (feet)
Clay, brown, sand, and small gravel-one pebble	20	655
Clay, sandy brown. Caliche fragments at 710 feet	60	715
Clay, sandy reddish-brown	15	730
Clay, brown, and very fine- to coarse-grained sand	5	735
Clay, sandy brown	10	745
Clay, brown, and very fine- to coarse-grained sand	5	750
Clay, sandy brown, medium- to very coarse-grained sand, and fine-grained gravel	5	755
Clay, sandy brown, and very coarse-grained sand	5	760
Sandstone, well-cemented, arkosic. Driller called this bedrock because of the hardness of the rock and the slowness of drilling	5	765

The water obtained from wells SMR-1 and SMR-2 is very hard, but the concentration of dissolved solids is about 500 ppm and individual constituents are low in concentration.

Hazardous Test Area

(Reference: Hood, 1963)

In July 1960, the Geological Survey was requested to investigate the possibility of obtaining 10 to 15 gpm of water in the northern part of the Hazardous Test Area. The water was intended to supply domestic needs for a planned small installation in the NW$\frac{1}{4}$SW$\frac{1}{4}$NW$\frac{1}{4}$ sec. 24, T. 21 S., R. 4 E. Only the area north and northwest of the point of use was studied, because of its favorable topographic position..

During July and August 1960, brief reconnaissance in the Hazardous Test Area revealed only two wells that might supply the required amount of water. Other wells and the springs in the area were inoperative, dry, or yielded less than the required amount of water. Several old mine shafts in the area which might supply the required amount of water were not investigated because the water from mines generally is polluted.

Ground water in the area

The few control points indicate that the overburden in the area does not contain water. Water in wells and other excavations is from igneous rock. The water table in the Hazardous Test Area slopes steeply southeastward in the same direction as the land surface. Although the depth to water is not uniform throughout the area, no well has a water level greater than about 120 feet below land surface. Most, if not all, of the water is stored in the near-surface zones of shattered and weathered rock. The amount of water stored in the area probably is small, because the granite contains water only in joints and other fractures. The overburden and the fractures in the granite have a large intake capacity, and water, when available, enters the system readily. Maximum yield of wells probably would not exceed 25 gpm. The yields of heavily-pumped wells in the Hazardous Test Area probably would diminish substantially during drought, a time when water generally is most needed, because the storage capacity of the aquifer is low and the recharge is irregular.

Wells investigated

Construction data were collected and performance tests made on wells 21.4.11.311 and 21.4.22.222. Both wells are used from time to time to supply water for wildlife in the area; both wells are equipped with windmills. Supplementary data from Alamo Springs (S21.5.7.431), obtained during a visit prior to the Hazardous Test Area study, also was used in evaluating the water resources of the area.

Well 21.4.11.311, on the east side of the Drop Test Tower site, was equipped both with a windmill and a gasoline engine. The well had 6-inch casing and was 198 feet deep. Depths to water in the well were as follows:

Date	Depths to water below land surface (feet)
2-12-53	110.9
7-12-60	70.6
7-14-60	70.7

The well was tested July 14, 1960 by pumping approximately 3 hours, at the end of which time the water level had declined to the bottom of the pump intake. Pumping for 3 hours at 3 gpm produced 68 feet of drawdown or about 0.04 gpm per foot of drawdown. The well was not considered further because the yield was inadequate for the intended purpose.

Well 21.4.22.222 is west of the test houses in the Nike Warhead Test Area and near the north end of Mineral Hill. In August 1961, the well was equipped only with a windmill. The well contained about 10 feet of 8-inch surface casing; below the pipe to a depth of 80 feet the granite in the wall of the well was stable and required no support.

The well was test pumped at a rate of 3 gpm for $5\frac{1}{2}$ hours August 5, 1960, and the drawdown was 2.4 feet (fig. 16). The results of the test indicated

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Figure 16 (caption on next page) belongs near here.

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that the well might meet the requirements of 10-15 gpm, and further work was planned. In addition to a longer, better-controlled pumping test, it was proposed that the well be deepened, because more of the fracture system in the granite might be penetrated and the yield of the well increased.

Prior to deepening, the well was tested by bailing at a rate of about 32 gpm and measuring the rate of recovery. Figure 17 shows

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recovery measurements after the bailing test. The residual drawdown was 0.45 foot 20 minutes after the very short period of bailing.

The deepening of well 21.4.22.222 began October 8, 1960, and ended October 12. The log of the well (table 11) indicated the rock penetrated was granite from 80 to 125 feet and a dark, fine-grained, igneous rock from 125 to 130 feet. The deepening of the well caused no change in the water level in the well.

Figure 16.--Preformance test of well 21.4.22.222, Hazardous Test Area, White Sands Missile Range, N. Mex., Aug. 5, 1960.

17.--Recovery of water level after bailing well 21.4.22.222, Hazardous Test Area, White Sands Missile Range, N. Mex., Oct. 6, 1960.

Table 11.--Log of well 21.4.22.222, Hazardous Test Area

(Stock well deepened from 80 to 130 feet, October 1960)

Material	Thickness (feet)	Depth (feet)	Drilling time (minutes)
Bottom of existing well	-	80	-
"Granite", mainly quartz and feldspar with a low percentage of ferromagnesian minerals	10	90	210
"Granite", as above. Drill cuttings finer	5	95	95
"Granite", quartz and feldspar, with increased ferromagnesian mineral content. Cuttings coarser	15	110	300
"Granite", as from 95 to 110 feet. Cuttings very fine-grained	5	115	120
"Granite", as from 110 to 115	10	125	110
Igneous rock, dark gray. Texture very fine-grained but rock is holocrystalline. Approximately 50% ferromagnesian minerals	5	130	50

The well was test pumped for 12 hours October 13, 1960. Measurements during the test are shown in figure 18. The depths to

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water shown in the figure have been corrected so as to be comparable with depths to water shown in figures 16 and 17.

Data in figure 18 show that well 21.4.22.222 can produce approximately 10 gpm for periods of at least 12 hours, or about 7,200 gallons, without a large drawdown. The well, however, cannot yield much more than 10 gpm without large drawdown and probable temporary exhaustion of the supply after a few hours of pumping. Twelve hours pumping at an average rate of about 12 gpm produced a drawdown of 12.2 feet, a specific capacity of 0.9 gpm per foot of drawdown. This figure for specific capacity is comparable with that obtained from the test on August 5, 1960 and shows that deepening the well did not increase the productive capacity of the well.

Figure 18.--Water levels during drawdown and recovery and rate of discharge during performance test of well 21.4.22.222, Hazardous Test Area, White Sands Missile Range, N. Mex., Oct. 13-14, 1960.

The residual drawdown, approximately 17 hours after pumping stopped, was about 1.6 feet, a significant part of the total drawdown. The residual drawdown still was relatively large several days after the test. The storage area contributing water to the well is limited, and continuous day-to-day pumping of well 21.4.22.222 might seriously deplete the water in storage during dry periods.

Chemical quality of water

Two samples of water were obtained from well 21.4.22.222, one sample before and one after deepening the well. The analyses of water from well 21.4.22.222 show that deepening the well did not change significantly the chemical character of the water. The water is chemically suitable for drinking but contains about 5 ppm fluoride and about 20 ppm nitrate. The water should not be consumed by persons whose teeth still are developing. The waters probably should be examined for bacteriological purity because the nitrate content is so high.

Gregg site

(Reference: Hood, 1963)

The Gregg site optical laboratory is in the NW¼SE¼ sec. 8, T. 22 S., R. 6E.

Two wells were drilled at Gregg site, a test well and later a production well. The test well was drilled during August 9-12, 1961, to a depth of 1,010 feet. The well log is given in table 12. A water sample was obtained through the drill stem from the interval 281-300 feet. The test well was cased with 8-inch casing to a depth of 500 feet and performance tested. The specific capacity was about 11.5 gpm per foot of drawdown and the pumping rate was about 175 gpm. A water sample was collected at the end of the pumping period.

A production well was drilled about 4 feet south of the test well and was completed to a depth of 478 feet. The hole was 27-3/4 inches in diameter and was cased with 14-inch casing perforated in the same zones as used in the test well. The annular space between the casing and the wall of the hole was gravel-packed.

Table 12.--Log of Gregg test well (22.6.8.414)

Materials	Thickness (feet)	Depth (feet)
Samples missing	130	130
Sand, tan, silty, very fine to coarse, and some caliche	10	140
Sand, tan, silty, very fine	10	150
Silt and very fine sand, tan	10	160
Sand, tan, silty, very fine, with some caliche and a few very small gravel	30	190
Sand, tan, silty, very fine, with some caliche, very small gravel, and tan clay	30	220
Clay, brown, sandy, and small particles of caliche	30	250
Clay, brown, sandy, partly plastic, with greenish reduction spots, and few very small gravel	10	260
Clay, brown sandy, partly plastic, with greenish reduction spots	10	270
Sand, very fine to medium, and brown-red clay	10	280
Clay, red, sandy, and fragments of caliche	10	290
Clay, red-brown, very sandy, and fragments of caliche	20	310
Sand, very fine to medium, with fragments of caliche and lumps of clay	50	360
Clay, brown-red, very sandy	30	390
Sand, very fine to medium, much tan to red clay, and small grains of caliche	40	430

Table 12.--Log of Gregg test well (22.6.8.414) - Continued

Materials	Thickness (feet)	Depth (feet)
Clay, brown, sandy	10	440
Sand, very fine to medium or very sandy clay, with fragments of caliche and pieces of red to brown clay. Very sandy 470-80 ft.	40	480
Clay, brown, plastic, slightly sandy with greenish reduction spots	30	510
Clay, brown sandy	10	520
Clay, brown to tan, with fragments and lumps of red and greenish-gray clay; some very fine-grained sand and a fragment of limestone gravel	20	540
Clay, as from 520-to 540, but sandier; fragment of small gravel	10	550
Clay, as from 520 to 540	10	560
Clay, as from 540 to 560	10	570
Note: Most, if not all, rock types noted probably are in strata 6 inches thick, or more. Drill bit moves downward sporadically, first slowly, then very fast. The rapid drilling is in the soft clay, and the slow rate in the occassional beds of hard caliche.		
Clay, red to brown, compact, some greenish clay and considerable amount of very fine sand	20	590
Clay, very soft, and fragments of compact red clay. Rapid drilling rate	20	610
Clay, soft, and some very fine gravel	10	620
Clay, soft, slightly sandy	10	630
Clay, soft, and very fine gravel	10	640

Table 12.--Log of Gregg test well (22.6.8.414) - concluded

Materials	Thickness (feet)	Depth (feet)
Clay, tan, with small lumps and flakes of greenish and dark brown compact clay, and considerable amount of very fine sand.	10	650
Clay, tan, very sandy	20	670
Clay, red, very compact, and some caliche	10	680
Clay, tan, soft, sandy, with some lumps of compact red clay and chips of sandy caliche	60	740
Clay, slightly sandy	40	780
Clay, tan, sandy, very soft	10	790
Clay, tan, sandy, very soft, and small hard-fragments of caliche (?). Little change	110	900
Clay, tan, very sandy, soft	10	910
Clay, tan, sandy, soft and some green clay fragments	10	920
Clay, tan slightly sandy, soft, with greenish reduction spots	30	950
Clay, red, compact, with greenish reduction spots. Some clays are almost dry in appearance	60	1,010
		Total depth

The static water level in the Gregg test well was about 213 feet below land surface. The water-surface altitude was 3,807 feet. The water surface at Gregg Site is lower than at test well T-5 (22.5.20.111), altitude 3,880 feet, and test well T-4 (22.5.16.111), altitude 3,828 feet, which are to the west between the Headquarters area and Gregg Site. The difference between the altitude of the water at Gregg Site and at test wells T-4 and T-5 establishes a continuous slope of the water table from the Headquarters well field to the main part of the Tularosa Basin near Gregg Site. No reliable data are available east of Gregg Site, but the water table in the vicinity of Gregg Site probably is the lowest in the basin at the latitude of the White Sands Headquarters.

A performance test was made on the production well at Gregg Site October 30 from 9:50 a.m. to 8:50 p.m. The results of the several measurements are shown in figures 19, 20, and 21.

Figure 19 (caption on next page) belongs near here.

20 (caption on next page) belongs near here.

21 (caption on next page) belongs near here.

Figure 19.--Drawdown and residual drawdown in Gregg well (22.6.8.414), White Sands Missile Range, N. Mex., during performance test on Oct. 30, 1961.

20.--Rate of discharge and sand content of water pumped from Gregg well (22.6.8.414), White Sands Missile Range, N. Mex., during performance test on Oct. 30, 1961.

21.--Coefficient of transmissibility of the bolson fill in the vicinity of Gregg well, White Sands Missile Range, N. Mex. using residual drawdown after pumping test on Oct. 30, 1961.

The specific capacity of the production well was 12.4 gpm per foot at the end of the pumping period, while the well was being pumped at a rate of about 740 gpm. The coefficient of transmissibility (fig. 21) is 19,600 gpd (gallons per day) per foot. These data indicate that the well can sustain pumping rates of several hundred gallons per minute for prolonged periods of time. The figure for transmissibility shows that the formation can transmit large amounts of water to the well when the water level is lowered by pumping. At a pumping rate of 600 gpm, the well could be pumped for prolonged periods with a pump setting of about 300 feet.

The well produced sand throughout the performance test. The amount produced was generally less than 5 ml per liter. Even in these quantities, however, it would be best to pump the well to waste for a short period each time the pump is started, to avoid filling the storage reservoir or plugging the distribution system.

Ground water from the Gregg Site area is unsuitable for most uses. The analyses of samples of water from the test well and the production well show that water as shallow as 300 feet, or about 90 feet below the water table, contains about 8,900 ppm of dissolved solids and that water from below 500 feet contains about 15,000 ppm of dissolved solids.

Rhodes Canyon Range Camp (pole 1788) area

(Reference: Hood, 1963)

Ground water at Rhodes Canyon Range Camp (pole 1788) is nonpotable.

The water in the fill for several miles east and south of the camp probably is saline, as evidenced by the saline residue in the low areas. Potable water probably is present to the west and northwest of the camp.

A well about 4 miles south of the camp and shown on the Black Top Mountain topographic map as the G Henderson well (14.5.8.321), yields water containing about 6,000 ppm of dissolved solids of which about 2,400 ppm is chloride. The depth to water is reported to be 54 feet below land surface.

The McDonald South well (13.5.29.341) has a reported water level of 100 feet below land surface. Soldiers from Rhodes Canyon Camp reportedly used water from the well before potable water was trucked to the camp. The inferred potable water at well 13.5.29.341 and the runoff from the mountains indicate the large composite fans reaching from Rhodes Canyon northward to the base of Salinas Peak may contain coarse-grained debris that will yield an appreciable quantity of potable water.

Rhodes Canyon Wells

Two test wells (RC-1, 12.5.31.433 and RC-2, 12.5.28.432) were drilled in the Rhodes Canyon-Salinas Peak area in 1964. Well 12.5.28.432 was drilled with a rotary drill to a depth of 358 feet and a water sample collected. The water was saline and the well was abandoned. Well 12.5.31.433 was drilled by cable tool to a depth of 942 feet. A seep of water was obtained when the well was about 530 feet deep and the water rose to about 484 feet below land surface. Although the water obtained was potable, the well would yield only about 2 gallons per minute or less, and the yield did not increase as the well was deepened.

The test wells in the Rhodes Canyon-Salinas area did not obtain an adequate supply of water. However, the water obtained from well 12.5.31.433 was potable and a well drilled farther up the fan slope might obtain a larger yield.

Salinas Peak area

(Reference: Hood, 1963)

Data relating directly to the occurrence of ground water in the Salinas Peak area was obtained for 11 wells and 2 springs. All these sources are on the backslope of the mountains. Water sources on the east face of the mountains were not visited because they are relatively inaccessible.

The potential yield of the formations to wells cannot be estimated accurately. The only wells in the area are stock wells that are pumped at rates of only 1 to 5 gpm.

The only potable ground water sampled in the Salinas Peak area was that from Grapevine Spring (S12.4.2.141). Wells and springs elsewhere in the area yield water containing from 1,500 to more than 2,000 ppm of dissolved solids, of which the sulfate content amounts to 500 ppm or more. All the water is very hard and the overall chemical quality of water deteriorates from the crest of the mountain to the northwest, toward the Jornada del Muerto.

The ground water sampled, with the exception of that from Grapevine Spring, is not suitable for human consumption, owing to the sulfate content of the water.

Water suitable for use by military personnel probably is not present in the Salinas Peak area in quantities adequate for the needs of Salinas Peak Site and Salinas Camp.

Exploration for ground-water supplies

The immediate area of Salinas Camp (NW$\frac{1}{4}$SE$\frac{1}{4}$SE$\frac{1}{4}$ sec. 36, T. 11 S., R. 4 E. does not seem promising; however, a test well there would determine the aquifer possibilities, and if water were obtained, the supply would be at the point of use. A test well 500 feet deep probably would be adequate.

One test well farther down Grapevine Canyon in the SW$\frac{1}{4}$NE$\frac{1}{4}$SW$\frac{1}{4}$ sec. 35, T. 11 S., R. 4 E. would determine aquifer possibilities in the general area. The site is on the access road at its intersection with the side canyon that contains Grapevine Spring, offers adequate room off the road for drilling, and is on or adjacent to one of the major transverse faults that cross the mountain range. A test well of 500 feet probably would be adequate.

Mockingbird Gap area

(References: Herrick and others, 1960; Weir, 1964)

The Mockingbird Gap well (9.5.15.143), derives potable water containing less than 100 ppm of sulfate from a fracture zone in the Bursum Formation and yields approximately 30 gpm with a drawdown of 5 to 9 feet in about 8-hours time. The water level continues to decline if the well is pumped continuously during the periods of no rainfall, and the pumping water level is lowered to the pump intake, about 135 feet below the land surface. The nonpumping water level in the Mockingbird Gap well has been as high as 25 feet below the land surface after heavy rains in the area, and reportedly this well occasionally has flowed. When the water level is 25 feet or less below the land surface, about 3 million gallons (about 9 acre-feet) of water can be pumped from storage above the level of the pump setting.

The water level in Mockingbird Gap well rises within a few days after water flows in the arroyo near the well. The fracture-aquifer is recnarged in the immediate vicinity of the well, probably in an area less than 100 yards upstream. Longer periods of storm flow in the arroyo cause far more effective recharge to the aquifer than do brief freshets. Impounding runoff with check dams along the arroyo upstream from Mockingbird Gap well would increase the amount of recharge from rainwater that normally runs off quickly.

In the area around Mockingbird Gap Hills and Oscura Gap, ground water in usable quanity and qualitv has been obtained from onlv one source; the Murrav well (8.5.32.431). Several holes have been drilled between Mockingbird Gap Hills and the northern end of the San Andres Mountains, including one dry 400-foot test hole drilled 0.5 mile south of George MacDonalds's Murray well. The Murray well is completed in a fault zone. Pumping tests of the well indicate a specific capacity of about 5 gpm per foot of drawdown at a pumping rate of 100 gpm. The static water level in the Murrav well is 192 feet below land surface. Water from the well contains 298 ppm of sulfate and 684 ppm of dissolved solids.

Water from the Murray well has been used to supplv water for domestic use to areas in the northern and central range since 1956. The Murray well obtains water from a small reservoir in consolidated rocks. The reservoir can be depleted quicklv bv pumping.

Malpais area

(References: Herrick and others, 1960; Weir, 1964)

The alluvium is the principal aquifer in the Malpais area. The Yeso Formation of Permian age also might yield water to deep wells in the central basin, but no wells are known to penetrate the Yeso there.

Water of reasonably good chemical quality is known to occur in only a very few, relatively small localities within the northern part of the Malpais area. Most of these are along the east side of the area. In a small area north and east of the village of Oscura relatively shallow wells yield as much as 50 gpm of water containing less than 300 ppm of sulfate. Deep wells in the Carrizozo area reportedly yield as much as 50 gpm of water similar in chemical quality to water from wells at Oscura. Aquifers containing saline water in the central part of the Malpais basin are capable of yielding 500 to 1,000 gpm or more.

Malpais Spring (12.7.8.422), at the south end of the malpais, has a low flow of more than 1,000 gpm of water containing, according to one analysis, 5,100 ppm of dissolved solids, including 1,910 ppm of sulfate and 1,200 ppm of chloride. A well at Oscura Range Camp will yield 500 gpm of water containing about 4,000 ppm of dissolved solids, including 1,900 ppm of sulfate and 640 ppm of chloride. Most of the stock-watering wells in the basin yield less than 10 gpm.

Chupadera Mesa-Transmalpais Hills area

(References: Herrick and others, 1960; Weir, 1964)

The Transmalpais Hills, an outlier of Chupadera Mesa, lie adjacent to and west of the malpais, and are geologically and hydrologically similar to Chupadera Mesa. Here the San Andres is dry and water occurs in the Yeso Formation at depths of 200 to about 700 feet, depending on the topography. All water analyzed from the Yeso Formation in this area contained 3,000 ppm or more of dissolved solids, including 2,000 ppm or more of sulfate. A 700-foot well near Red Canyon Range Camp yields 100 gpm per foot of drawdown from solution channels in the Yeso Formation. Most of the wells in the area supply water for livestock and yield less than 20 gpm; however, near the north end of the Transmalpais Hills, one irrigation well (5.9.25.333) approximately 90 feet deep yields enough water for irrigating about 100 acres of forage crops. The well reportedly yielded 2,000 gpm originally, but soon after it was put into use the yield declined to about 300 gpm.

Steven Tank well (7.8.29.144) on Chupadera Mesa yields water of fair quality (678 ppm of sulfate). No data are available as to the capacity of the well, but it probably will yield about 10 gpm.

Sierra Oscura backslope area

(References: Herrick and others, 1960; Weir, 1964)

The backslope of Sierra Oscura is here considered to include the area from the crest of the range eastward to Red Canyon.

Almost all the ground water in the rocks of Pennsylvanian age occurs in fractures in the limestone and appears in springs, shallow wells, and collection galleries on the backslope. These sources yield only very small quantities of water, but the water is potable.

Known sources of water from rocks of Permian age in the Sierra backslope area yield small quantities of water that is generally poor in quality. The Bursum Formation, the oldest Permian formation in the area, yields potable water at two localities, Brush Tank Canyon and near R. C. Withers Tank in sec. 18, T. 7 S., R. 7 E. A well at each of these places yields less than 5 gpm of potable water; however, an upper water-bearing zone in the Brush Tank Canyon area yields 7 to 15 gpm. Analyses of water from two wells indicate the water in this upper zone contains more than 100 ppm of nitrate, but is otherwise of good quality. The single well near R. C. Withers Tank reportedly is very weak, but the water from the well is of good quality, containing only 205 ppm of sulfate. The yield of this well might be increased by treatment with acid

Red Canyon Spring (S7.7.15.421) yields about 3 gpm of water containing 1,880 ppm of sulfate. The spring water issues from cracks in the Abo Sandstone of Permian age.

Atlas Project area, Holloman Air Force Base

(References: Hood, 1960; Rapp, 1957)

Test drilling for process water for the Atlas Project at Holloman Air Force Base consisted of drilling, developing, and test pumping three test wells: T-1, T-2, and T-4. The work extended over a period of about 4 months; drilling of test well T-1 began on April 19, and the final measurements of the water level in test well T-4 were made on August 24, 1956. The logs of the wells are given in table 13.

Atlas test well T-1

Drilling of test well T-1 (16.8.13.400) at the planned site of the Atlas Project commenced on April 19, 1956 and was completed on May 6, 1956.

The water from Atlas test well T-1 is very saline, containing about 1,800 ppm dissolved solids.

As the final yield of test well T-1 was only 50 gpm, which was below the minimum requirement of 75 gpm, the casing was removed and the well was plugged and abandoned. On the basis of this performance of test well T-1 and of several wells in the vicinity, 50 gpm is generally about the maximum yield that can be expected from wells in the area from test well T-1 westward to the eastern margin of the White Sands dunes area.

Atlas test well T-2

After test well T-1 had been abandoned test well T-2 (16.9.4.441) was drilled. Several rather distinct beds of sand and gravel were penetrated (table 13). The more permeable beds are thin and scattered through the clay and silt that make up most of the section drilled.

On July 5 the test well was pumped for 4 hours at a rate of 60 gpm with a drawdown of about 40 feet. The pumping rate was then increased to 90 gpm for 45 minutes, at the end of which time some air was being pumped with the water. The discharge rate was then decreased to 75 gpm and pumping was continued for a period of 7 hours and 15 minutes. The specific capacity for the test well was a little less than 0.5 gpm per foot of drawdown.

The water from test well T-2 is quite hard and fairly saline, containing about 1,110 ppm dissolved solids, but it is of much better quality than water from test well T-1.

Atlas test well T-4

Drilling of test well T-4 (16.9.8.100) began on August 3, 1956, and was completed at a depth of 403 feet August 7, 1956. Most of the material penetrated was silt and clay. Only two zones, between depths of 67 and 77 feet and 90 and 99 feet, appeared to be somewhat permeable. The well was cased with about 400 feet of 8-inch casing, of which more than 250 feet was perforated with 1/8 by 4-inch slots. Perforated sections of casing were set at the following depths: 44 to 142 feet, 170 to 250 feet, and 270 to 350 feet. Static water level in the well on August 21, 1956 was 50.6 feet below land surface. The log is given in table 13.

Table 13.—Logs of wells in the Atlas Project area

Atlas test well T-1 (16.8.13.442)

Material	Thickness (feet)	Depth (feet)
Silt, buff to white gypsiferous, and caliche -----------	5	5
Caliche, buff to white, and some chalky silt -----------	8	13
Caliche and reddish-brown clay-------------------------	2	15
Clay, variegated (red, green, and tan) with caliche ----	5	20
Caliche --	3	23
Clay with some caliche ------------------------------	7	30
Clay, brown, some caliche and coarse sand ------------ (lost circulation at 35 ft)	5	35
Sand, very fine to fine, red, clayey -----------------	5	40
Clay, red, sandy ------------------------------------	10	50
Sand, very fine to fine, red, slightly consolidated ---	5	55
Sand, fine, red, clayey ------------------------------	10	65
Clay, red, may be sandy ------------------------------	3	68
Silt, with clay breaks, containing scattered pebbles of gypsiferous caliche -----------------------------	5	73
Clay, red, containing silty zones, and pebbles of gypsiferous caliche --------------------------------	7	80
Clay, red, sandy, containing pebbles of gypsiferous caliche --	15	95
No sample --	8	103
Clay, red, silty, with caliche fragments -------------	2	105
No sample --	5	110

Table 13.--Logs of wells in the Atlas Project area - continued

Atlas test well T-1 (16.8.13.442) - continued

Material	Thickness (feet)	Depth (feet)
Clay, red, soft, with very few caliche fragments ------	25	135
Clay, red, soft, silty ------------------------------	5	140
Sand, very fine to fine -----------------------------	5	145
Clay, red, silty with fragments of green gypsum -------	15	160
Sand, very fine to fine, clayey ---------------------	10	170
Sand, light gray, slightly consolidated, with soft red clay --	10	180
Clay, red, soft -------------------------------------	5	185
Clay, red, soft, with darker red and light gray to green streaks ---------------------------------------	10	195
Clay, red, soft, containing fragments of light gray silt and caliche --------------------------------	15	210
Clay, red, very soft --------------------------------	5	215
Clay, dark red, soft --------------------------------	10	225
Clay, dark red, with light green streaks -------------	5	230
Clay, dark red and green ----------------------------	30	260
Clay, brown, some red and gray ----------------------	5	265
No sample ---	5	270
Clay, red, with green silt --------------------------	10	280
Clay, brown ---	5	285
Clay, dark red --------------------------------------	5	290
Clay, red to brown, silty ---------------------------	20	310
Clay, red, soft -------------------------------------	2	312

Table 13.--Logs of wells in the Atlas Project area - continued

Atlas test well T-1 (16.8.13.442) - concluded

Material	Thickness (feet)	Depth (feet)
Clay, red, with caliche fragments	3	315
Clay, green and red, silty, with caliche	5	320
Clay, green and red, soft	5	325
Clay, variegated (light to dark red, light to dark green), silty	5	330
Clay, red, soft, with blue clay and caliche fragments	10	340
Clay, red and blue, silty	10	350
Clay, blue; little red clay	10	360
Clay, red, soft; little blue clay	25	385
Clay, red and green, soft	5	390
Clay, variegated (light to dark red, green, blue and gray)	12	402

Table 13.--Logs of wells in the Atlas Project area - continued

Atlas test well T-2 (16.9.4.441)

Material	Thickness (feet)	Depth (feet)
Clay, reddish, soft	30	30
Clay, reddish, soft, sandy; contains caliche fragments	10	40
Clay, reddish, soft, and greenish-blue clay fragments; contains some sand	5	45
Clay, reddish, gypsiferous, soft; contains caliche fragments	15	60
Sand and fine gravel	10	70
Clay, reddish, silty, gypsiferous	5	75
Clay, reddish, gypsiferous, soft, with greenish, silty pieces	5	80
Clay, mainly reddish with some brown pieces	20	100
Clay, reddish, soft	5	105
Sand, very fine	5	110
Clay, reddish to brown, sandy	6	116
Clay, reddish, soft; contains gravel	4	120
Clay, reddish, soft	10	130
Gravel, with some soft, reddish, clay	5	135
Clay, reddish, soft	7	142
Clay, reddish, sandy	6	148
Clay, reddish, soft; contains silt lenses	24	172
Gravel, fine to medium, mainly greenish limestone	5	177

Table 13.--Logs of wells in the Atlas Project area - continued

Atlas test well T-2 (16.9.4.441) - continued

Material	Thickness (feet)	Depth (feet)
Clay, reddish, sandy-------------------------------	8	185
Clay, reddish, soft--------------------------------	6	191
Sand, fine, clayey---------------------------------	11	202
Clay, reddish, soft--------------------------------	12	214
Gravel, with some grayish and brownish clay-------	8	222
Clay, mainly brownish, with some grayish----------	15	237
Sand, fine, with brownish and grayish clay--------	17	254
Clay, silty; brownish to about 265, then reddish--	26	280
Sand and gravel; contains clay--------------------	12	292
Clay, reddish to brownish red; contains thin lenses of silt----------------------------------	41	333
Sand, fine--	4	337
Clay, brownish red--------------------------------	3	340
Sand, fine--	4	344
Silt, clayey--------------------------------------	9	353
Sand, fine--	5	358
Clay, reddish-brown-------------------------------	5	363
Sand, fine--	5	368
Clay, reddish-brown, with some greenish, clayey silt-------------------------------------	14	382
Sand, very fine to fine and brownish clay---------	10	392
Clay, mainly grayish with some brownish, soft-----	4	396

Table 13.--Logs of wells in the Atlas Project area - continued

Atlas test well T-2 (16.9.4.441) - concluded

Material	Thickness (feet)	Depth (feet)
Sand, fine--	5	401
Clay, reddish-brown with red and green pieces-----	9	410

Table 13.--Logs of wells in the Atlas Project area - continued

Atlas test well T-4 (16.9.8.140)

Material	Thickness (feet)	Depth (feet)
Caliche and tan to brown silt---------------------	5	5
Sand, light brown, very fine to fine--------------	5	10
Sand, becoming darker brown, very fine to fine; contains lenses of brownish clay----------------	10	20
Sand, reddish, very fine; contains thin beds of clay, silt, and caliche-------------------------	10	30
Clay, reddish, silty; contains caliche------------	8	38
Sand, reddish, very fine and silt; contains caliche---	10	48
Clay, reddish; contains silt and caliche----------	17	65
Clay, tan---	2	67
Sand, fine to coarse, and angular gravel consisting mainly of limestone fragments--------	10	77
Clay, red, soft, becoming gray at base------------	12	89
Sand, fine to coarse, and angular gravel consisting mainly of limestone fragments--------	10	99
Clay, red, soft; contains sand and gravel---------	16	115
Sand and fine gravel------------------------------	6	121
Clay, reddish, soft-------------------------------	4	125
Clay, brownish, some tan; soft--------------------	8	133
Sand, very fine; contains caliche-----------------	8	141
Clay, mainly brownish to brownish red, soft-------	32	173
Clay, mainly light brown to light reddish brown, silty near base, soft; contains caliche---------	28	201

Table 13.--Logs of wells in the Atlas Project area - concluded

Atlas test well T-4 (16.9.8.140) - concluded

Material	Thickness (feet)	Depth (feet)
Clay, brownish to red, soft----------------------	17	218
Silt to very fine sand---------------------------	7	225
Clay, mainly light brown, some red; soft----------	13	238
Sand, very fine----------------------------------	4	242
Clay, red, gypsiferous, soft; contains some caliche---	18	260
Clay, red to brown, gypsiferous, soft; contains silty lenses------------------------------------	23	283
Clay, variegated-red, brown, green and gray; gypsiferous, soft------------------------------	8	291
Sand, very fine----------------------------------	7	298
Clay, mainly reddish brown with red, brown, gray, and green; gypsiferous, soft--------------	22	320
Clay, mainly light brown with some red and green, silty, gypsiferous, soft-----------------	8	328
Sand, very fine----------------------------------	5	333
Clay, brownish with red and green; silty, gypsiferous-------------------------------------	2	335
Clay, gray, silty, gypsiferous, soft; contains caliche---	7	342
Clay, brownish with some red and green; gypsiferous, soft------------------------------	44	386
Clay, reddish, gypsiferous-----------------------	6	392
Clay, brownish with red and green; gypsiferous, soft--	11	403

Tularosa-Alamogordo area

(References: Herrick and others, 1960; Meinzer, 1915)

The Tularosa-Alamogordo area extends west from the foothills of the Sacramento Mountains for about 12 miles, north from Tularosa about 10 miles, and south from Alamogordo about 7 miles.

In the Tularosa-Alamogordo area the valley fill can be divided into two parts, a thick section of older alluvium and an overlying, relatively thin section of younger alluvium.

Ground water in moderate to large quantities is available in much of the area, but water of good quality is scarce. Most of the ground water is highly saline, containing particularly calcium, sodium, chloride, and sulfate. Sulfate in the ground water is sufficient to render the water unfit for domestic or livestock use.

The quality of ground water in the vicinity of the Boles well field differs vertically as well as laterally. Two distinct water-bearing zones in the younger alluvium can be differentiated -- a deep, thick zone containing potable water and a shallow, thin zone containing water of inferior quality.

Water from the deeper part of the older alluvium is probably of poor quality. Meinzer (1915, p. 133) stated that water from a depth of 890-1,200 feet in a deep well near Dog Canyon (south of the Boles well field) was reported to be salty. Presumably this well tapped the lower part of older alluvial fill, but did not penetrate to the bedrock.

Water from the bedrock underlying the valley fill is generally saline. A sample of water from well 18.8.5.431, about 6 miles southwest of Holloman Air Force Base, which probably taps the Yeso Formation, contained about 8,400 ppm of dissolved solids, including about 3,000 ppm of sulfate, and about 2,500 of chloride, and it had a hardness of about 2,600 ppm.

Carrizozo area

(References: Herrick and others, 1960)

The Carrizozo area extends from the vicinity of Carrizozo southeast to Nogal and southwest to Oscura. This area of about 150 square miles is a part of the Tularosa Basin and lies between the Sierra Blanca on the east and the malpais (lava flow) on the west. (See fig. 22, in pocket).

Figure 22 (caption on next page) belongs near here.

Large quantities of ground water are available from the alluvium in a part of the area. Generally the water is very hard and high in dissolved solids, a large part of which is sulfate. A considerable quantity of ground water containing about 600 ppm or less of sulfate could be obtained from the alluvium near Carrizozo.

No quantitative data are available on the hydrologic characteristics of the valley fill. Information is needed on the trend of nonpumping and pumping water levels, specific capacities of wells, transmissibility of the aquifers, and interference between pumped wells.

Evidence indicates that the thickest sections of alluvium in the area are a few miles south and southwest of Carrizozo. Near the center of the plain a few miles east and southeast of Carrizozo the alluvium generally is slightly more than 100 feet thick; however, it is not improbable that the alluvium is thicker at some places in that general area. The remainder of the area is not considered favorable for the occurrence of saturated alluvium that would yield large quantities of water to wells.

Figure 22.--Map of the Carrizozo area, Lincoln County, N. Mex., showing geology, wells and altitude of the water table, April 1957.

Three Rivers area

(References: Hood and Herrick, 1962)

The Three Rivers area includes about 150 square miles between the west slope of Sierra Blanca and U.S. Highway 54, at the boundary between Otero and Lincoln Counties about 20 miles north of Tularosa, New Mexico (fig. 23, in pocket). The area is drained by Three Rivers

Figure 23 (caption on next page) belongs near here.

and its tributaries. Two of the tributaries, Three Rivers Canyon and Indian Creek, have perennial flows in their upper reaches at the west side of Sierra Blanca.

The depth to water in Three Rivers area ranges from less than a foot in parts of the creek beds to as much as 150 feet. In the lower parts of the reentrant, in the northwestern part of T. 11 S., R. 10 E., and the southwestern part of T. 10 S., R. 10 E., the range in depth to water is between about 20 and 50 feet.

As indicated by the water-table contours on figure 23, the ground water moves southwestward from the reentrant area toward the main part of Tularosa Basin. Several small springs issue where eastward-dipping impermeable beds force the ground water to the surface.

Figure 23.--Map of the Three Rivers area, Otero and Lincoln Counties, N. Mex., showing well and spring data and contours on the water table, 1957.

The water resources of the Three Rivers area can be most fully and most economically developed by mixing waters of inferior chemical quality with potable water to yield a product of potable or near-potable quality to the pipeline. This may be accomplished in several ways. For example, data indicate that wells producing at least 100 and possibly as much as 200 gpm can be developed in the vicinity of test well 11.10.7.232. Although the ground water in that area may be expected to contain from 300 to 500 ppm of sulfate, by mixing this water with less saline surface and ground water, the final product would be of reasonably good quality. The base flows of Three Rivers and Indian Creek probably have an average sulfate content of about 100 ppm. Such water mixed in equal proportion with ground water containing an average of as much as 400 ppm of sulfate would produce water containing about 250 ppm of sulfate for delivery to the pipeline.

A dependable supply of at least 1,000 acre-feet per year of water containing an average of not more than 250 ppm of sulfate can be developed in the Three Rivers area, if both surface-water and ground-water sources are utilized. This estimate includes diversions on both Three Rivers and Indian Creek and approximately six wells. More than 1,000 acre-feet per year can be developed if more wells are drilled or a somewhat inferior water is permitted.

Area southeast of Valmont and north of Orogrande pipeline

(References: Herrick and others, 1960)

An area about 12 miles south of the Boles well field and along the east side of Tularosa Basin, southeast of Valmont and north of the Orogrande pipeline, has been suggested as a possible source of potable ground water. The area includes about 150 square miles adjacent to the Sacramento Mountains and northeast of the Jarilla Mountains, in the central part of Otero County, N. Mex. (See fig. 24) in pocket.)

Figure 24 (caption on next page) belongs near here.

Figure 24.--Map of an area southeast of Valmont and north of Orogrande pipeline, Otero County, N. Mex., showing contours on the water table, depth to water, and sulfate content of ground water, 1956.

Ground water in the bolson fill moves southwestward and westward from the mountains toward the lower part of the basin, as indicated by the water-table contours on figure 24. The water-table gradient ranges from about 25 feet per mile in the southeastern part of T. 19 S., R. 9 E., to about 50 feet per mile in the southwestern part of T. 18 S., R. 10 E. Data are not available with which to determine the configuration of the water table in the southern part of T. 19 S., R. 10 E., and T. 20 S., R. 10 E. The ground water in these areas is moving westward at gradients of 25 to 30 feet per mile. The depth to water in the bolson fill in the area shown on figure 24 ranges from less than 30 feet in the northwestern part of the area, the vicinity of Valmont, to at least 200 feet in the southern part of T. 19 S. and the northern part of T. 20 S., Rs. 9 and 10 E.

Boles well field area

(Reference: Hood, 1959)

The Boles well field is on bolson fill of which the most permeable zones are the first 200 to 300 feet below the land surface. Production wells drilled in the area need not be more than 300 feet deep. Wells drilled within about one-half mile of the mountains possibly can be drilled to somewhat greater depths because the coarse-grained bolson fill is thicker closer to the mountains but not necessarily more productive. The permeability of the aquifer in the Boles well field, and consequently the yields of wells, increases from east to west, as a result of the better sorting of the fill at increasing distance from the mountains.

At the 1955 rate of production from the existing production wells, it is estimated that the water level in the center of the well field will decline in the order of 30 feet in 5 years, 40 feet in 10 years, and 50 feet in 20 years. To minimize lowering of water levels in the well field, and thus reduce the possibility of migration of saline water from the west, it is suggested that future wells be considered in the eastern three-fourths of sec. 19, the northern half of sec. 30, excepting the northwest 40 acres, and possibly the southwest part of sec. 20, T. 17 S., R. 10 E. Generally a well spacing of 1,000 feet seems adequate. The optimum distribution of wells in this new area seems to be a straight line extending southward from Boles well 5.

Logs of wells drilled in the Boles well field area are given in table 14.

Table 14.--Logs of wells and test wells drilled in 1954 and 1955 in vicinity of Boles well field

Test well 22 (17.9.13.244)

1 of 54

Material	Thickness (ft)	Depth (ft)
Soil, sandy	3	3
Sand, gravel, cobbles and boulders	7	10
Sand, and gravel	1	11
Clay, very sandy, and gravel, grading downward to sandy clay	9	20
Clay, firm, sticky, sandy, brown	20	40
Clay, firm, sticky, sandy, brown, with medium-grained gravel of black limestone	10	50
Clay, firm, brown, with little gravel	10	60
Clay, sandy, brown, with some sand and gravel	20	80
Sand and gravel, with some sandy, brown clay	10	90
Sand and gravel, with smaller amounts of clay	30	120
Clay, sandy, brown, with some sand and gravel	60	180
Sand and gravel, 50 percent and 50 percent brown clay	10	190
Clay, brown, with slightly less sand and gravel than from 180 to 190 feet	10	200
Clay, brown, and sand	20	220
Clay, brown, sand, and gravel; exceptionally slow drilling from 241 to 245 feet	40	260
Clay, brown, with little sand or gravel	50	310

Table 14.--Logs of wells and test wells drilled in 1954 and 1955 in vicinity of Boles well field - Continued

Test well 3 (17.9.23.333) 2/54

Material	Thickness (ft)	Depth (ft)
Caliche and a little clay	11	11
Sand and clay; sand appears to be mostly evaporites	5	16
Clay, red	4	20
Clay, red; crystalline gypsum; and some coarse-grained quartz sand	3	23
Clay, red, and crystalline gypsum	7	30
Sand, very fine- to medium-grained; caliche; crystalline gypsum; and a little red clay	5	35
Sand of caliche, very fine- to coarse-grained, and gypsum, with little clay	3	38
Missing	3	41
Caliche and flakes or grains	4	45
Clay, red	5	50
Clay, red and white, and caliche, becoming sandy toward bottom	5	55
Clay, white, and caliche	6	61
Clay, red	4	65
Clay, silty red	8	73
Caliche	3	76
Clay, sandy red, and caliche	6	82

Table 14.--Logs of wells and test wells drilled in 1954 and 1955 in vicinity of Boles well field - Continued

Test well 3 (17.9.23.333) - Concluded

3 of 54

Material	Thickness (ft)	Depth (ft)
Caliche, hard	1	83
Caliche, thin, strata of, intercalated with sandy, red clay. Minor amounts of red sand and crystalline gypsum	12	95
Caliche and red, sandy clay	10	105
Caliche, very fine-grained sand, and silty red clay	10	115
Clay, sandy, brown	6	121
Caliche, fine-grained sand and some white clay	4	125
Clay, white, and caliche, with minor amounts of sand and red clay	10	135
Clay, tan, with minor amounts of sand and caliche	10	145
Clay, brown, with minor amounts of sand and caliche	25	170
Clay, brown, with thin, intercalated strata of caliche	10	180
Clay, brown	20	200
Clay, brown, with minor amounts of sand and caliche	8	208

Table 14.--Logs of wells and test wells drilled in 1954 and 1955 in vicinity of Boles well field - Continued

Test well 1 (17.9.23.431)

4 of 54

Material	Thickness (ft)	Depth (ft)
Soil gypsiferous	10	10
Clay, brown, and caliche	10	20
Clay, silty, brown, and small gravel	20	40
Clay, silty, brown, very fine-grained sand, and small gravel	9	49
Sand, very fine- to fine-grained, and some brown clay	21	70
Clay, sandy, brown, and caliche	16	86
Clay, brown, and caliche	19	105
Clay, sandy, brown, and caliche	10	115
Clay, sandy, brown, and caliche with minor amount of gravel	10	125
Sand, fine- to very fine-grained; finely divided caliche; and minor amount of brown clay	20	145
Sand, very fine-grained; brown clay; and minor amount of caliche	11	156
Caliche, and very sandy, brown clay	10	166
Caliche, and very fine-grained sand	9	175
Caliche, and sandy, brown clay	8	183
Clay, sandy, brown, and caliche	17	200
Clay, brown; very fine-grained sand; and caliche	10	210
Clay, brown, and caliche	10	220

Table 14.--Logs of wells and test wells drilled in 1954 and 1955 in vicinity of Boles well field - Continued

Test well 1 (17.9.23.431) - Concluded

Material	Thickness (ft)	Depth (ft)
Clay, sandy, brown, with minor amounts of caliche and small gravel	10	230
Clay, brown, caliche and minor amount of small gravel	10	240
Clay, sandy, brown, with minor amount of caliche	10	250
Clay, brown, with minor amount of caliche	20	270
Caliche, and sandy, brown clay	10	280
Caliche, fine- to very fine-grained sand, and minor amount of brown clay	10	290
Clay, sandy, brown; caliche; and minor amount of gravel	10	300

Table 14.--Logs of wells and test wells drilled in 1954 and 1955 in vicinity of Boles well field.- Continued

Test well 8 (17.9.24.142)

Material	Thickness (ft)	Depth (ft)
Clay, red-brown; sandy at surface, becoming slightly sandy with caliche near bottom	20	20
Clay, sandy, brown, with a little gravel	10	30
Clay, sandy, and caliche	10	40
Clay, soft, sandy, brown, with some gravel	10	50
Sand, very fine- to medium-grained; very small gravel; and sandy, brown clay	10	60
Clay, brown	4	64
Sand, very fine- to medium-grained; very small gravel; and sandy, brown clay	6	70
Clay, soft, brown, with some sand and gravel, becoming very sandy in thin zones	20	90
Clay, soft, red-brown, with some sand and gravel, gravel predominantly of black limestone, becoming less sandy near bottom	30	120
Clay, soft, sandy, red-brown; becoming very sandy with medium-grained sand near bottom	10	130
Sand, and small gravel, mostly of black limestone, and sandy, reddish clay	10	140
Clay, sandy, red, with a little sand and small gravel	40	180
Clay, sandy, red-brown; very sandy clay in thin strata below 200 feet	30	210

Table 14.--Logs of wells and test wells drilled in 1954 and 1955 in vicinity of Boles well field - Continued

Test well 8 (17.9.24.142) - Concluded

Material	Thickness (ft)	Depth (ft)
Clay, sandy to very sandy, red-brown, with minor amount of small gravel	50	260
Clay, sandy, brown	40	300
Clay, soft, brown, and very small gravel	12	312

Table 14.--Logs of wells and test wells drilled in 1954 and 1955 in vicinity of Boles well field - Continued

Test well 9 (17.9.24.222)

Material	Thickness (ft)	Depth (ft)
Soil, sandy, chocolate-brown, with much sand and gravel and some reddish clay	10	10
Sand and gravel, and red clay in alternating beds about 2 feet thick	10	20
Clay, silty, red, with included gravel	9	29
Sand, and small gravel	1	30
Gravel, mostly bit-cut	3	33
Clay, red, and bit-cut, gravel	7	40
Clay, silty, brown, with some gravel	20	60
Clay, sandy, red-brown, with small amount of very coarse sand	10	770
Clay, sandy, brown, with very small gravel	20	90
Clay, sandy, red-brown, with small gravel	20	110
Clay, sandy, firm, red-brown, and bit-cut gravel	10	120
Clay, sandy, brown, with small gravel and minor amount of large gravel	10	130
Clay, sandy, brown, and minor amount of gravel	10	140
Clay, sandy, brown, and clayey sand	10	150
Clay, sandy, brown, and small gravel	20	170
Clay, red-brown to brown, and sandy clay, with minor amount of gravel and white clay	10	180
Sand and gravel, 75 percent; sandy clay, 25 percent	7	187

Table 14.--Logs of wells and test wells drilled in 1954 and 1955 in vicinity of Boles well field - Continued

Test well 9 (17.9.24.222) - Concluded

Thickness	Thickness (ft)	Depth (ft)
Sand, and small gravel, 50 percent; sandy clay, 50 percent. (Rocks drilled from 180 to 200 feet alternated in beds from 6 inches to 2 feet thick)	13	200
Clay, sandy, red, 50 percent; gravel, 50 percent; with minor amount of caliche; with very large, bit-cut gravel from 200 to 203 feet	20	220
Gravel, bit-cut, 85 percent; and sandy, red clay. (Formation was very hard, with slow drilling from 228 to 230 feet, and moderately hard from 230 to 236 feet)	20	240
Clay, red-brown, with a minor amount of sand and gravel at bottom; some of clay appears to dissolve into the drilling mud	10	250
Clay, red-brown, with minor amount of gravel, occurring as very thin strata	20	270
Clay, red-brown, with minor amount of gravel. (Extremely hard stratum at 275 to 278 feet, either of cemented gravel or of cobbles and boulders. All returns were completely bit-cut)	10	280
Clay, firm, red-brown, with a few thin strata of gravel	10	290
Clay, red-brown, with little gravel	10	300
Clay, red-brown, grading into next stratum	5	305
Sand and clay	3	308
Clay and gravel	6	314

Table 14.--Logs of wells and test wells drilled in 1954 and 1955 in vicinity of Boles well field - Continued

Test well 34 (17.9.24.343)

Material	Thickness (ft)	Depth (ft)
Soil, silty clay; and caliche	10	10
Clay, soft, silty yellow-tan	10	20
Clay, sandy, tan, and gravel	10	30
Sand, very fine- to fine-grained, with minor amount of clay and gravel	10	40
Clay, firm, slightly silty, red-brown, with minor amount of gravel	20	60
Clay, soft, very sandy, tan, with minor amount of gravel and caliche	10	70
Clay, silty, brown	10	80
Clay, sandy, brown, and some large, black limestone gravel	10	90
Clay, firm, brown with minor amount of gravel	10	100
Clay, firm, brown, and nodular caliche	10	110
Clay, soft, tan, with minor amount of very small gravel	5	115
Clay, firm, silty, brown, and nodular caliche	15	130
Clay, silty, brown, with minor amounts of caliche and small gravel	10	140
Clay, silty, brown, and white calcareous clay	10	150
Clay, brown; caliche; and minor amount of gravel	10	160

Table 14.--Logs of wells and test wells drilled in 1954 and 1955 in vicinity of Boles well field - Continued

Test well 34 (17.9.24.343) - Concluded

Material	Thickness (ft)	Depth (ft)
Clay, plastic, red-brown	10	170
Clay, brown; white calcareous clay; and minor amount of small gravel	10	180
Clay, soft, very sandy, tan; very small gravel; and minor amount of caliche	10	190
Clay, firm, plastic; caliche; and minor amount of gravel	30	220
Caliche and gravel with some brown clay	3	223
Clay, tan	7	230
Clays, brown and white	10	240
Clay, soft, very sandy, tan, and caliche	10	250
Clay, firm, red-brown, and caliche	10	260
Clay, silty, brown, with minor amount of gravel	10	270
Clay, firm, red-brown, and caliche	10	280

Table 14.--Logs of wells and test wells drilled in 1954 and 1955 in vicinity of Boles well field - Continued

Test well 21 (17.9.25.123)

Material	Thickness (ft)	Depth (ft)
Clay, silty, with minor amount of caliche	10	10
Clay, silty, brown, with minor amount of gravel	3	13
Clay, soft, gray to white	4	17
Clay, silty, brown, with inclusions having a limonitic appearance	3	20
Clay, firm, brown, with minor amount of caliche near bottom	10	30
Clay, brown, with several thin, hard strata of caliche	10	40
Clay, red-brown, with caliche, and with minor amount of sand at about 48 feet	10	50
Clay, red-brown, with some sand and gravel	10	60
Clay, sandy, red-brown; minor amount of gravel; and thin strata of very fine-grained sand	10	70
Clay, silty, red, intercalated with strata of caliche and fine-grained sand	20	90
Clay, silty, red	10	100
Clay, silty, red, and caliche	10	110
Clay, red, and sandy caliche	10	120
Clay, red; caliche; and a very compact red clay, called "shale" by driller; becoming much softer and sandier toward bottom	20	140

Table 14.--Logs of wells and test wells drilled in 1954 and 1955 in vicinity of Boles well field - Continued

Test well 21 (17.9.25.123) - Concluded

Material	Thickness (ft)	Depth (ft)
Clay, silty, red to brown; caliche; and minor amount of sand and gravel	10	150
Clay, red and white	6	156
Caliche	4	160
Clay, red; sand in very thin strata; and some very small gravel or very coarse sand	10	170
Sand, very fine- to medium-grained, and sandy clay	7	177
Clay, red, and gravel	3	180
Clay, sandy, and sand, grading into clay and caliche at bottom	10	190
Clay, red, and caliche	20	210
Clay, red-brown, and caliche; with thin strata of sand from 218 to 220 feet	20	230
Clay, sticky, silty, red, and caliche	20	250
Clay, red-brown, with minor amount of caliche	62	312

Table 14.--Logs of wells and test wells drilled in 1954 and 1955 in vicinity of Boles well field - Continued

Boles well 35 (17.9.25.212)

Material	Thickness (ft)	Depth (ft)
Clay, brown	20	20
Clay, brown, with sand and gravel of black limestone	10	30
Clay, tan; very fine-grained sand; and gravel of tan limestone	10	40
Clay, brown; small gravel; and minor amount of caliche	10	50
Clay, silty to sandy, brown, with minor amount of gravel	20	70
Clay, firm, plastic, brown	10	80
Clay, firm, plastic, brown; gravel; and pebbles	20	100
Clay, sandy, brown; very fine-grained sand; and gravel	10	110
Clay, silty, brown, and gravel	10	120
Clay, brown, with minor amount of gravel	10	130
Clay, tan, with minor amount of gravel	20	150
Clay, silty, tan, and caliche	10	160
Clays, silty, red-brown and tan, and caliche	10	170
Clay, slightly silty, brown	20	190
Clay, red-brown; caliche; and minor amount of gravel	10	200
Clay, red-brown, and caliche	10	210
Clay, firm, brown; a few pebbles; and a minor amount of caliche	30	240
Clay, firm, brown, and caliche	10	250
Clay, tan	10	260
Clay, tan, and minor amount of caliche	10	270

Table 14.--Logs of wells and test wells drilled in 1954 and 1955 in vicinity of Boles well field - Continued

Test well 7 (17.9.25.324)

Material	Thickness (ft)	Depth (ft)
Soil, black-brown, clayey	6	6
Caliche	1	7
Clay, brittle, red and white	3	10
Clay, silty, brown, with grains of caliche and minor amount of very small gravel or very coarse-grained sand; becoming siltier toward botton	10	20
Clay, sandy, yellow-brown, and sand	10	30
Sand, very fine- to medium-grained, limestone; and minor amount of tan clay	10	40
Sand and caliche with minor amount of clay	10	50
Clay, sandy, red, with included grains of caliche	10	60
Clay, sandy red, becoming sandier toward	10	70
Clay, sandy, tan, with thin stratum of caliche at 70 feet	10	80
Sand, very fine- to coarse-grained, with minor amount of caliche and clay	5	85
Sand, medium- to very coarse-grained	10	95
Clay, sandy, tan, with some caliche and very coarse-grained sand	7	102
Clay, silty, red	3	105
Silt, silty clay or clayey	10	115

Table 14.--Logs of wells and test wells drilled in 1954 and 1955 in vicinity of Boles well field - Continued

Test well 7 (17.9.23.324) - Continued

Material	Thickness (ft)	Depth (ft)
Clay, and very coarse-grained sand or very small gravel, mostly of limestone. Clay is very silty from 125 to 135 feet	20	135
Clay, soft, silty, tan, with very small gravel	20	155
Clay, firm, tan, with much very small gravel in some zones	10	165
Clay, sandy, tan, and caliche	10	175
Clay, sandy to silty, red and tan; caliche; and some very small gravel	10	185
Clay, slightly sandy, with some gravel and caliche (Stratum of caliche from 190½ to 191 feet)	10	195
Clay, red to red-brown, and large amounts of caliche, either as granules or as thin strata 1 to 2 inches thick. Minor amount of gravel and little or no sand	75	265
Clay, red-brown, with less caliche than from 195 to 265 feet	30	295
Clay, light red-brown, with minor amount of caliche	10	305
Clay, red, and caliche. Some of clay very compact and brittle	20	325
Clay, firm, red and brown	10	335
Clay, brown, with some sand and very small gravel; less gravel toward bottom	20	355

Table 14.--Logs of wells and test wells drilled in 1954 and 1955 in vicinity of Boles well field - Continued

Test well 7 (17.9.25.324) - Concluded

Material	Thickness (ft)	Depth (ft)
Clay, sandy or silty, red and gray	30	385
Clay, sandy or silty, red to brown and gray, with minor amount of gravel and caliche. Nearly all clays in last 40 to 50 feet appear partly to dissolve into the drilling mud	40	425
Clay, slightly sandy, tan, which appears to dissolve into the drilling mud	66	491
Clay, dense, hard, red, and sand	26	517

Table 14.--Logs of wells and test wells drilled in 1954 and 1955 in vicinity of Boles well field - Continued

Test well 11 (17.9.25.444)

Material	Thickness (ft)	Depth (ft)
Clay, firm, tan, becoming softer toward bottom -------	20	20
Clay, soft, silty, tan, with minor amount of gravel --	10	30
Clay, firm, tan, with some silt or sand near top -----	10	40
Clay, slightly sandy, tan ----------------------------	10	50
Clay, sandy, tan, intercalated with thin strata of very fine-grained sand. Partial loss of circulation when 60 feet reached ------------------------------	10	60
Clay, slightly silty, tan, containing yellow-brown spots	20	80
Clay, slightly gritty, red-brown --------------------	35	115
Clay, red-brown, with some caliche ------------------	5	120
Clay, soft, tan to brown, with some caliche ----------	10	130
Clay, soft, silty, brown, and caliche ---------------	22	152
Clay, silty and silt --------------------------------	8	160
Clay, silty, and caliche; clay became red at about 260 feet --	147	307

Table 14.--Logs of wells and test wells drilled in 1954 and 1955 in vicinity of Boles well field - Continued

Test well 4 (17.9.26.431)

Material	Thickness (ft)	Depth (ft)
Soil, tan	3	3
Clay with large amount of caliche	7	10
Clay, red; sandy near top and becoming full of caliche at about 15 feet	13	23
Caliche, gray clay, and crystalline gypsum	5	28
Clay, red and gray	2	30
Sand, very fine-grained	2	32
Clay, red, becoming very sandy at 39 feet	8	40
Clay and sand	1	41
Sand, very fine-grained, and minor amount of caliche	2	43
Sand, very fine- to fine-grained, becoming clayey toward bottom	7	50
Sand, with minor amount of clay	1	51
Clay, soft, red-brown and white; very sandy at top and grading downward to a gritty clay at bottom	9	60
Clay, sandy, with large amount of very fine-grained sand	5	65
Clay, gritty, red, containing grains of caliche or very small gravel, and becoming redder and more compact toward bottom	12	77
Clay, sandy, tan	4	81
Clay, red, intercalated with strata of very hard sandy caliche	5	86

Table 14.--Logs of wells and test wells drilled in 1954 and 1955 in vicinity of Boles well field - Continued

Test well 4 (17.9.26.431) - Concluded

Material	Thickness (ft)	Depth (ft)
Sand, clayey, and caliche, with a hard stratum at 89 feet	5	91
Clay, soft, sandy, and very small gravel	3	94
Clay, compact, gritty, red	1	95
Clay, soft, sandy	3	98
Clay, soft, gritty, red	12	110
Clay, sandy, and sand	10	120
Clay, sandy, white	10	130
Clay, sandy, white, grading downward into very sandy, red-brown clay	10	140
Clay, firm, red	2	142
Clay, soft, slightly gritty, brown, becoming very gritty toward bottom	8	150
Clay, soft, brown, with very small gravel, fine-grained sand and a few thin strata of caliche-cemented sand	9	159
Clay, soft, gritty, brown	4	163
Clay, soft, gritty, red and white	2	165
Clay, firm, brown, with much small gravel	2	167
Clay, soft, gritty, brown, becoming very gritty and sticky from 170 to 180 feet and very soft from 185 to 187 feet	23	190
Clay, soft, gritty, brown and white	10	200
Clay, moderately firm, red-brown	9	209

Table 14.--Logs of wells and test wells drilled in 1954 and 1955 in vicinity of Boles well field - Continued

Test well 20 (17.9.36.414)

Material	Thickness (ft)	Depth (ft)
Soil, silty, clayey	5	5
Clay, red	22	27
Clay, silty, brown	3	30
Clay, silty, brown, and caliche, with white clay near bottom	10	40
Clay, white, and caliche	6	46
Caliche, hard	1	47
Clay, white, and caliche	3	50
Sand, and sandy red and white clay	6	56
Clay, firm, red	4	60
Clay, sandy, red	5	65
Clay, sandy, red, and caliche	35	100
Clay, sandy, red, and caliche; sandier near bottom; with some very small black gravel	10	110
Sand, sandy white clay, very small, black gravel and minor amount of caliche	10	120
Clay, sandy, red, with some black gravel and minor amount of caliche	10	130
Clay, red; caliche; minor amount of gravel; and some thin strata of sand	20	150
Clay, sandy, red; some thin strata of sand; and minor amount of caliche	10	160

Table 14.--Logs of wells and test wells drilled in 1954 and 1955 in vicinity of Boles well field - Continued

Test well 20 (17.9.36.414)- Concluded

Material	Thickness (ft)	Depth (ft)
Clay, red, very sandy in some zones, with thin, hard strata of caliche at 166 and 168 feet	10	170
Clay, red, 50 percent; and caliche, 50 percent	10	180
Clay, silty, brown, and caliche, becoming somewhat sandy toward bottom	30	210
Clay, sandy, red, intercalated with thin strata of medium- to coarse-grained sand and caliche, with minor amount of gravel near bottom	20	230
Clay, red-brown, and caliche with thin stratum of caliche at 243 feet	60	290
Clay, red-brown	10	300
Clay, red-brown, with caliche and minor amount of black gravel	12	312

Table 14.--Logs of wells and test wells drilled in 1954 and 1955 in vicinity of Boles well field - Continued

State Engineer Alamogordo well, 1930 (16.9.8.432)

Material	Thickness (ft)	Depth (ft)
Soil	1	1
Gyp	1	2
Red clay	61	63
Water-bearing gyp. 30 gpm	2	65
Grayish-red clay	132	197
Gyp	2	199
Red clay and gyp	146	345
Gyp	3	348
Red clay and gyp	177	525

Table 14.--Logs of wells and test wells drilled in 1954 and 1955 in vicinity of Boles well field - Continued

Well 16.9.23.240

Material	Thickness (ft)	Depth (ft)
Soil	3	3
Red clay	15	18
Gray clay	4	22
Red clay, and water	40	62
Red clay, gravel and water	8	70
Red clay	13	83
Red clay and gravel	8	91
Gray clay	7	98
Red clay, gravel, and water	16	114
Red clay, gravel, and some sand	13	127
Red clay and water	15	142
Red clay and gravel	9	151
Pea gravel and water	9	160
Gray clay	13	173
Red clay	1	174
Gray clay	28	202
Red clay	8	210

Table 14.--Logs of wells and test wells drilled in 1954 and 1955 in vicinity of Boles well field - Continued

Fig. 11, WSP 343 well 16.9.26.210

Material	Thickness (ft)	Depth (ft)
Red clay	15	15
Gypsum	5	20
Stratified red clay and claystone	71	91
Red clay and gravel	35	126
Limerock	6	132
Yellow clay and claystone	80	212
Red clay	25	237
Sticky red clay	69	306
Red clay	152	458
Yellow clay	10	468
Red clay	6	474
Blue clay	9	483
Yellow clay	20	503
"Clayey material"	501	1,004

Table 14.--Logs of wells and test wells drilled in 1954 and 1955 in vicinity of Boles well field - Continued

-2 of 5

New Mexico School for Visually Handicapped well 16.10.18.241

Material	Thickness (ft)	Depth (ft)
Soil	5	5
Red sandy clay	35	40
Gravel, gyppy water	2	42
Red sandy clay	38	80
Sand, water	3	83
Red sandy clay	29	112
Gravel, water	1	113
Red sandy clay	3	116
Gravel, water	1	117
Sand	2	119
Clay	1	120
Coarse, water-bearing gravel	8	128

Table 14.--Logs of wells and test wells drilled in 1954 and 1955 in vicinity of Boles well field - Continued

City of Alamogordo test well No. 2, 1945 (16.10.33.340)

Material	Thickness (ft)	Depth (ft)
Gravel and boulders	29	29
Boulders	11	40
Boulders and gravel	80	120
Boulders	20	140
Boulders and gravel	32	172
Boulders and layers of clay	38	210
Boulders and layers of clay and gravel	28	238
Boulders and layers of clay	32	270
Boulders and clay	6	276
Sand	5	281
Boulders, clay, and gravel	34	315
Sand	13	328
Rock	10	338
Sand, boulders, and layers of clay and boulders	25	363
Boulders and layers of clay	29	392
Sand, gravel, boulders, and layers of clay	29	421
Hard boulders	16	437
Boulders and clay	41	478
Boulders and layers of clay	25	503
Boulders and clay, partly soft	24	527
Boulders and clay	31	558

Table 14.--Logs of wells and test wells drilled in 1954 and 1955 in vicinity of Boles well field - Continued

City of Alamogordo test well No. 2, 1945 (16.10.33.340) - Con.

Material	Thickness (ft)	Depth (ft)
Rock, boulders and layers of clay	15	573
Hard rock	10	583
Boulders	1	584
Rock, boulders, and layers of clay	8	592
Clay boulders	6	598
Clay	47	645
Boulders	3	648

Table 14.--Logs of wells and test wells drilled in 1954 and 1955 in vicinity of Boles well field - Continued

City of Alamogordo test well No. 1, 1945 (16.10.33.440)

Material	Thickness (ft)	Depth (ft)
Boulders	53	53
Boulders and soft layers	24	77
Boulders	1	78
Rock	2	80
Boulders and soft layers	102	182
Boulders	65	247
Boulders and sand layers	25	272
Boulders	8	280
Rock	2	282
Boulders	139	421
Rock	23	444
Rock and boulders	31	475
Boulders	62	537
Rock and boulders	25	562
Boulders	82	644
Rocks and boulders	3	647

Table 14.--Logs of wells and test wells drilled in 1954 and 1955 in vicinity of Boles well field - Continued

Boles well 33 (17.9.24.342)

Material	Thickness (ft)	Depth (ft)
Soil	8	8
Red clay	10	18
Gray clay	8	26
Gray lime rock	1	27
Gray clay	7	34
Red clay	18	52
Red clay and gravel. Water at 70 feet	30	82
Gray clay	7	89
Sand and clay	8	97
Clay, sand and gravel	23	120
Sand	9	129
Clay	6	135
Hard, lumpy clay	7	142
Red and gray clay	47	189
Clay and gravel	9	198
Red clay	33	231

Table 14.--Logs of wells and test wells drilled in 1954 and 1955 in vicinity of Boles well field - Continued

Holloman Air Force Base Swimming Pool well (17.8.13.311)

Material	Thickness (ft)	Depth (ft)
Gypsum rock	20	20
Red clay	14	34
Sand, briny water	1	35
Red clay	28	63
Sand, briny water	4	67
Red clay	36	103
Sand, briny water	10	113
Red clay	1	114
Sand, briny water	1	115
Red clay	45	160

Table 14.--Logs of wells and test wells drilled in 1954 and 1955 in vicinity of Boles well field - Continued

City of Alamogordo test well 1, 1953 (17.9.25.112) 32 of 54

Material	Thickness (ft)	Depth (ft)
Soil	10	10
Gray clay	40	50
Red clay	5	55
Brown clay	10	65
Brown clay, gravel, and water	15	80
Red clay	5	85
Red clay, sand, gravel, and water	30	115
Light-gray clay, some gravel, and water	22	137
Caliche	1	138
Light-gray clay, and water	17	155
Red clay, and water	10	165
Light-gray clay, and water	12	177
Red clay	7	184
Brown clay	30	214
Gray clay	6	220
Red clay	8	228
Gray clay and some sand	12	240
Pale-red clay	10	250

Table 14.--Logs of wells and test wells drilled in 1954 and 1955 in vicinity of Boles well field - Continued

City of Alamogordo test well No. 2, 1953 (17.9.25.132) 33 of 54

Material	Thickness (ft)	Depth (ft)
Soil	4	4
Gray clay	31	35
Gray clay and some sand	32	67
Gray clay, sand, and water	58	125
Brown clay, and water	15	140
Pale-gray clay	22	162
Pale-red clay, and water	11	173
Light-gray clay	44	217
Red clay, gravel, and water	28	245
Gray clay and some sand	5	250

Table 14.--Logs of wells and test wells drilled in 1954 and 1955 in vicinity of Boles well field - Continued

Boles well 16 (17.9.25.222)

Material	Thickness (ft)	Depth (ft)
Soil	10	10
Red clay and small gravel, first water at 78 feet	68	78
Fine sand and red clay, very soft	34	112
Red clay, and gravel, mixed	68	180
Clay, and sand, mixed	7	187
Red clay	13	200
Brown sand	6	206
Red clay	20	226
Gray clay, and gravel, mixed	15	241
Red clay	20	261

Table 14.--Logs of wells and test wells drilled in 1954 and 1955 in vicinity of Boles well field - Continued

City of Alamogordo Production well No. 1, 1954 (17.9.35.242)

Material	Thickness (ft)	Depth (ft)
Caliche	28	28
Sandy clay, and gravel	22	50
Boulders	3	53
Sandy clay	38	91
Sand and gravel. First water	4	95
Clay	12	107
Boulders	4	111
Soft clay	21	132
Gravel and boulder	3	135
Clay	48	183
Gravel	2	185
Clay	14	199
Gravel	3	202
Clay	28	230
Clay and small streaks of sand and gravel	17	247
Clay	16	263
Gravel	3	266
Clay	3	269
Gravel	6	275
Hard clay	11	286
Boulders	2	288
Clay	2	290
Gravel. Lost mud	7	297
Clay	1	298

Table 14.--Logs of wells and test wells drilled in 1954 and 1955 in vicinity of Boles well field - Continued

City of Alamogordo Production well No. 2, 1954 (17.9.35.444)

Material	Thickness (ft)	Depth (ft)
Caliche	4	4
Clay and chalk rock	14	18
Soft clay and some gravel	22	40
Clay and small boulders	4	44
Soft clay and strata of caliche	21	65
Boulders	2	67
Hard clay	19	86
Gravel	1	87
Clay	27	114
Gravel and boulders	6	120
Clay	9	129
Gravel	7	136
Clay	7	143
Sand	1	144
Clay	27	171
Coarse gravel and boulders	13	184
Clay	39	223
Gravel	7	230
Clay	44	274
Gravel	23	297

Table 14.--Logs of wells and test wells drilled in 1954 and 1955 in vicinity of Boles well field - Continued

State Engineers' Valmont test hole, 1930 (17.9.36.120) 37 of 5

Material	Thickness (ft)	Depth (ft)
Soil	3	3
Sandy brown clay	57	60
Gyp, with water under it at 5 gpm	2	62
Sandy clay	23	85
Red clay	5	90
Water sand. 50 gpm	5	95
Red clay	53	148
Gyp shell	2	150
Red clay	30	180
Gyp shell	5	185
Red clay	30	215
Gyp. Water at 10 gpm	10	225
Red clay and gyp	75	300
Blue clay	10	310
Gray clay	50	360
Red clay	42	402

Table 14.--Logs of wells and test wells drilled in 1954 and 1955 in vicinity of Boles well field - Continued

Boles well 8 (17.10.18.343)

Material	Thickness (ft)	Depth (ft)
Sandy loam	13	13
Sand and clay	39	52
Sandy clay	148	200
Clay	62	262

Table 14.--Logs of wells and test wells drilled in 1954 and 1955 in vicinity of Boles well field - Continued

Boles well 3 (17.10.18.424)

Material	Thickness (ft)	Depth (ft)
Sandy loam	11	11
Hardpan clay	33	44
Clay with trace of sand, trace of moisture at 54 feet	55	99
Solid blue limestone	7	106
Coarse sand with large gravel	9	115
Sandy clay	10	125

Table 14.--Logs of wells and test wells drilled in 1954 and 1955 in vicinity of Boles well field - Continued

Boles well 28 (17.10.18.432a)

Material	Thickness (ft)	Depth (ft)
Clay	10	10
Clay and sand rock	10	30
Fine sand	10	40
Sand and lime streaks	10	50
Sandy clay	20	70
Sand and clay	20	90
Sand and sticky clay	10	100
Sand and some clay	30	130
Sand and lime	10	140
Sand	30	170
Sand and hard gravel	5	175
"Shells" and shale	5	180
Sandy clay and shale	10	190
Fine sand, clay and shale	10	200
Streaks of sand; clay and shale	10	210
Lime shells, clay, and sandy shale	10	220
Broken lime shells, sand, and clay	10	230
Sand, broken clay and shale	10	240
Broken lime shells and clay	5	245
Hard, sharp lime shells	2	247
Shells, clay, and streaks of shale	13	260

Table 14.--Logs of wells and test wells drilled in 1954 and 1955 in vicinity of Boles well field - Continued

Boles well 6 (17.10.18.433)

Material	Thickness (ft)	Depth (ft)
Clay loam	6	6
Clay hardpan	6	12
Clay with trace of sand	10	22
Sand and gravel	2	24
Clay	10	34
Sand and gravel	2	36
Clay	6	42
Sand and gravel	2	44
Clay	22	66
Sandy clay	32	98
Fine sand with very little water. Water level at 89 feet	26	124
Sandy clay	24	148
Large clay(?)	2	150
Sandy clay	25	175
Clay	53	228

Table 14.--Logs of wells and test wells drilled in 1954 and 1955 in vicinity of Boles well field - Continued

Boles well 26 (17.10.18.442a)

Material	Thickness (ft)	Depth (ft)
Clay	10	10
Shale	20	30
Clay and gravel	30	60
Hard clay	10	70
Sand and clay	10	80
Clay and sand	10	90
Shale, clay, and sand	10	100
Clay	10	110
Sandy shale and sand	10	120
Shale and sand	10	130
Shale and sandy clay	10	140
Shale, shells, and clay	20	160
Shale and shells	10	170
Sand streaks, shale, and shells	10	180
Lime shells, shale, and clay	42	222
Sand, some gravel and lime shells	12	234
Clay	6	240
Shale and gravel	10	250

Table 14.--Logs of wells and test wells drilled in 1954 and 1955 in vicinity of Boles well field - Continued

Boles well 10 (17.10.19.121a)

Material	Thickness (ft)	Depth (ft)
Sandy loam	8	8
Clay	95	103
Fine sand and gravel. Water level at 80 feet	9	112
Sandy clay(?)	28	140
Shale	6	146
Clay	19	165
Fine sand	10	175
Clay	85	260

Table 14.--Logs of wells and test wells drilled in 1954 and 1955 in vicinity of Boles well field - Continued

Boles well 11 (17.10.19.121b)

Material	Thickness (ft)	Depth (ft)
Sandy loam	9	9
Clay	93	102
Water-bearing formation (sand?). Water level at 82 feet	3	105
Clay	35	140
Shale	4	144
Clay	274	418
Gravel	4	422
Clay	148	570

Table 14.--Logs of wells and test wells drilled in 1954 and 1955 in vicinity of Boles well field - Continued

Boles well 7 (17.10.19.132)

Material	Thickness (ft)	Depth (ft)
Sandy loam	8	8
Clay hardpan	11	19
Clay with trace of sand	11	30
Clay	18	48
Sandy clay	22	70
Shale	4	74
Clay	50	124
Shale	11	135
Clay	31	166
Gravel	3	169
Clay	8	177
Sand	3	180
Clay	35	215
Shale	5	220
Clay	30	250
Shale	3	253

Table 14.--Logs of wells and test wells drilled in 1954 and 1955 in vicinity of Boles well field - Continued

Boles well 5 (17.10.19.144)

Material	Thickness (ft)	Depth (ft)
Sandy loam	4	4
Hardpan clay	6	10
Clay and sand	16	26
Sandy clay	26	52
Clay	38	90
Water-bearing formation (sand?). Water level at 73 feet	6	96
Sandy clay	66	162
Water-bearing formation (sand?)	3	165
Sandy clay	17	182
Clay	38	220

Table 14.--Logs of wells and test wells drilled in 1954 and 1955 in vicinity of Boles well field - Continued

Boles well 4 (17.10.19.214)

Material	Thickness (ft)	Depth (ft)
Sandy loam	13	13
Hardpan clay	29	42
Clay	43	85
Sandy clay	26	111
Fine sand and small gravel. Water level at 86 feet	4	115
Sandy clay	104	219
Fine sand	3	222
Sandy clay	93	315

Table 14.--Logs of wells and test wells drilled in 1954 and 1955 in vicinity of Boles well field - Continued

Boles well 27 (17.10.19.321)

Material	Thickness (ft)	Depth (ft)
Soil	5	5
Brown clay	15	20
Brown clay with streak of embedded gravel	10	30
Brown clay	10	40
Brown clay with embedded gravel; struck water at 90 feet	75	115
Very fine, silty sand. Water level at 80 feet	5	120
Silty clay with embedded gravel	10	130
Silty clay, clay lumps and embedded gravel	10	140
Not logged	10	150
Silty clay with embedded gravel and sand	10	160
Silty clay with embedded sand. Well caving	10	170
Clay with embedded gravel	10	180
Clay and fine sand. Water level at 78 feet	10	190
Clay with embedded gravel	10	200
Silty clay with sand and gravel	10	210
Silty clay with sand, gravel, and sandstone	10	220
Silty clay with streaks of sand	10	230
Silty clay with embedded sand and gravel. Water level at 81 feet	20	250

Table 14.--Logs of wells and test wells drilled in 1954 and 1955 in vicinity of Boles well field - Continued

Boles well 30 (17.10.19.321a)

Material	Thickness (ft)	Depth (ft)
Sand and clay	10	10
Gravel and boulders	20	30
Sand, gravel, and clay	20	50
Sand and clay	30	80
Sand, gravel, and shale	10	90
Sand	20	110
Sand and clay	10	120
Sand, clay, and gravel	40	160
Clay, shale and shells	40	200
Sandy clay	10	210
Gravel, clay, and sand	10	220
Sand and clay	20	240
Sandy clay	10	250
Gravel and sandy clay	10	260

Table 14.--Logs of wells and test wells drilled in 1954 and 1955 in vicinity of Boles well field - Continued

Boles well 29 (17.10.19.323)

Material	Thickness (ft)	Depth (ft)
Soil	5	5
Brown clay	45	50
Brown clay with embedded sand	30	80
Silty clay with embedded sand	50	130
Brown clay with embedded sand	10	140
Silty clay with embedded sand	40	180
Brown clay with embedded sand	20	200
Silty clay with embedded sand	60	260
Silty clay with streaks of white clay	3	263

Table 14.--Logs of wells and test wells drilled in 1954 and 1955 in vicinity of Boles well field - Continued

Boles well field (17.10.19.323a)

Material	Thickness (ft)	Depth (ft)
Clay	10	10
Sand, boulders, and clay	10	20
Fine sand	10	30
Clay and coarse sand	10	40
Sandy clay	30	70
Sand	40	110
Sandy clay	10	120
Sand	30	150
Sandy clay	10	160
Clay and shale	20	180
Clay	20	200
Sandy clay	20	220
Clay and rough shells	10	230
Rough gravel, and sandy clay	10	240
Clay	5	245

Table 14.--Logs of wells and test wells drilled in 1954 and 1955 in vicinity of Boles well field - Continued

White Sands National Monument, Garton Well (18.8.5.431) 5-2 of 5

Material	Thickness (ft)	Depth (ft)
Valley fill, clay and gyp	783	783
Red sandstone	14	797
Clay and gypsum	5	802
Limestone	19	821
Red lime	25	846
Hard, red lime	12	858
Soft, green shale; gas pocket	31	889
Open cavity; artesian water	3	892
Missing	10	902
Brown shale; show of oil and gas	5	907
Light, thin limes	2	909
Brown and greenish clays	4	913
Red limestone; gas	13	926
Hard, red limestone	4	930
Limestone	7	937
Red shale and thin lime	8	945
Hard lime	7	952
Soft, brown shale; show of oil	1	953
Tough, gray shale	36	989

Table 14.--Logs of wells and test wells drilled in 1954 and 1955 in vicinity of Boles well field - Continued

Fig. 12; WSP 343 (18.9.14.200)

Material	Thickness (ft)	Depth (ft)
Gypsiferous adobe	10	10
Gypsum	11	21
Red clayey material	18	39
Sand and gravel	11	50
Red clayey material	25	75
Sand and gravel	10	85
Red clayey material	75	160
Sand and gravel	11	171
Red clayey material	118	289
Sand and gravel	20	309
Red clayey material	256	565
Sand and gravel	20	585
Red clayey material	305	890
Sand and gravel	20	910
Red clayey material	290	1,200
Sand and gravel	17	1,217
Red clayey material	18	1,235

Table 14.--Logs of wells and test wells drilled in 1954 and 1955 in vicinity of Boles well field - Concluded

Well 18.10.6.234

Material	Thickness (ft)	Depth (ft)
Silt	8	8
Boulders	7	15
Silt	80	95
Gravel and water	5	100
Silt, gravel, sand, and water	55	155
Clay and gravel	40	195

Jornada del Muerto Apollo site

(Reference: Doty, 1963)

Geology and ground water occurrence

The Jornada del Muerto is a topographic basin whose southern extremity, in which the Apollo PSD facility lies, is between the Dona Ana and San Andres Mountains. The rocks exposed in these mountains on either side of the basin have been eroded, filling the basin to an unknown depth with bolson fill.

The bolson deposits consist of irregular beds and lenses of unconsolidated to semi-consolidated clay, silt, sand, and gravel, and mixtures of these particle sizes. Wells in the Jornada del muerto obtain water, which is unconfined or semiconfined, from permeable beds of sand and gravel in the bolson deposits. The bolson deposits and the saturated zone within the deposits thin toward the mountains: thus the probability of obtaining an adequate supply of water decreases with nearness to the mountains. Apollo Site wells C, D, G, and H apparently did not penetrate a sufficient thickness of saturated bolson deposits to yield the required quantity of water. Wells I and J penetrated 682 and 602 feet of saturated bolson deposits, respectively, and when cased as water wells, each had 400 feet of slotted casing open to the saturated sections. (See table 15.)

Table 15.--Records of wells drilled at Apollo PSD facility

Well C

Location: NW¼NW¼NE¼ sec. 4, T. 21 S., R. 3 E., Dona Ana County, N. Mex.

Altitude: Land-surface altitude 4,590 feet interpolated from USGS topographic maps.

Depth: 1,011 feet below land surface datum.

Date completed: April 22, 1963 (Plugged and abandoned).

Drilling contractor: Layne-Texas Co., El Paso, Tex.

Drilling method: Hydraulic rotary

Casing and well record: 8-inch test well drilled to 1,011 feet December 6-18, 1962. Well reamed to 16-inch and cased full depth with 12 3/4-inch casing March 27 to April 15, 1963. Casing perforated with 3/16 x 2-inch mill-cut slots, 12 slots around, staggered rows, from 350-460, 590-650, 690-720, and 800-1,000 feet. 24-inch surface casing cemented to 30 feet.

Well completion record: 12 3/4-inch casing pulled and well plugged with heavy mud and abandoned April 22, 1963. Steel cap welded on surface casing.

Table 15.--Records of wells drilled at Apollo PSD facility - continued

Well C - concluded

Geologic source: Probably bolson deposits, from 360 to 450 feet. Water level was lowered from 362 to 752 feet by bailing at a rate of about 38 gpm with 90-gallon bailer indicating that the well was incapable of producing the desired yield.

Summary of material penetrated:

Material	Thickness (ft.)	Depth (ft.)
Bolson deposits ----------------------------------	453	453
Igneous rock (weathered) ------------------------	50	503
Igneous rock (unweathered) ----------------------	508	1,011

Table 15.--Records of wells drilled at Apollo PSD facility - continued

Well D

Location: NE$\frac{1}{4}$SW$\frac{1}{4}$SW$\frac{1}{4}$ sec. 12, T. 20 S., R. 5 E., Dona Ana County, N. Mex.

Altitude: Land-surface altitude 4,900 feet interpolated from USGS topographic maps.

Depth: 1,321 feet below land surface datum

Date completed: January 24, 1963

Drilling contractor: Layne-Texas Co., El Paso, Tex.

Drilling method: Hydraulic rotary

Casing and well record: 8-inch well to 1,321 feet, not cased.

Well completion record: Plugged and abandoned

Geologic source: Unknown. Yield insufficient to justify further development.

Summary of material penetrated:

Material	Thickness (ft.)	Depth (ft.)
Bolson deposits ----------------------------------	265	265
Older sedimentary rocks -----------------------	1,054	1,319

Table 15.--Records of wells drilled at Apollo PSD facility - continued

Well G

Location: NE¼NE¼SE¼ sec. 15, T. 20 S., R. 3 E., Dona Ana County, N. Mex.

Altitude: Land-surface altitude 4,740 feet interpolated from USGS topographic maps.

Depth: 578 feet below land surface datum

Date completed: February 8, 1963

Drilling contractor: Layne-Texas Co., El Paso, Tex.

Drilling method: Hydraulic rotary

Casing and well record: 8-inch well to 578 feet, not cased.

Well completion record: Plugged and abandoned.

Geologic source: Unknown. Yield insufficient to justify further development.

Summary of material penetrated:

Material	Thickness (ft.)	Depth (ft.)
Bolson deposits	180	180
Volcanic rocks	80	250
Limestone and shale	318	578

Table 15.--Records of wells drilled at Apollo PSD facility - continued

Well H

Location: $SW\frac{1}{4}SW\frac{1}{4}NE\frac{1}{4}$ sec. 16, T. 20 S., R. 5 E., Dona Ana County, N. Mex.

Altitude: Land-surface altitude 4,590 feet interpolated from USGS topographic map.

Depth: 1,445 feet below land-surface datum

Date completed: March 2, 1963

Drilling contractor: Layne-Texas Co., El Paso, Tex.

Drilling method: Hydraulic rotary

Casing and well record: 10-inch well to 1,445 feet. 6-inch casing wedged in well at 350 feet, and could not be pulled or driven.

Well completion record: Plugged and abandoned

Geologic source: Probably bolson deposits. Water level lowered from 272 to 739 feet by pumping at 35 gpm with submergible pump.

Summary of material penetrated:

Material	Thickness (ft.)	Depth (ft.)
Bolson deposits	285	285
Igneous rock (weathered)	50	335
Igneous rock (unweathered)	1,110	1,445

Table 15.--Records of wells drilled at Apollo PSD facility - continued

Well I

Location: SW$\frac{1}{4}$SW$\frac{1}{4}$SW$\frac{1}{4}$ sec. 30, T. 20 S., R. 3 E., Dona Ana County, N. Mex.

Altitude: Land surface altitude, 4,385 feet interpolated from USGS topographic map.

Depth: 862 feet below land surface

Date completed: May 2, 1963

Drilling contractor: Layne-Texas Co., El Paso, Tex.

Drilling method: Hydraulic rotary

Casing and well record: 8-inch test well drilled to 1,000 feet. 30 feet of 18-inch surface casing cemented in and well reamed to 16-inch to 862 feet. Well cased full depth with 862 feet of 12 3/4-inch casing perforated from 430-660 and 680-850 feet with 3/16 x 2-inch mill cut slots, 12 slots around, alternate rows staggered.

Well completion record: Fitted with temporary steel cap.

Geologic source: Bolson deposits. Water level lowered from 318 to 391 feet by pumping for 24 hours at rate of 1,000 gpm.

Summary of material penetrated:

1,000 feet of bolson deposits.

Table 15.--Records of wells drilled at Apollo PSD facility - concluded

Well J

Location: $NW\frac{1}{4}SE\frac{1}{4}NW\frac{1}{4}$ sec. 31, T. 20 S., R. 3 E., Dona Ana County, N. Mex.

Altitude: Land surface altitude 4,410 feet interpolated from USGS topographic map.

Depth: 850 feet below land surface

Date completed: May 31, 1963

Drilling contractor: Layne-Texas Co., El Paso, Texas

Drilling method: Hydraulic rotary

Casing and well record: 10-inch test well drilled to 939 feet. 30 feet o 18-inch surface casing cemented in and well rea 16-inch to 850 feet. 12 3/4-inch casing instal to full depth. Casing perforations: mill-cut 3/16 x 2-inch slots. 12 slots around, staggere rows. Perforated intervals: 400-700, 740-840

Well completed record: Fitted with temporary steel cap.

Geologic source: Bolson deposits. Water level lowered from 337 to 388 fe by pumping at rate of 1,000 gpm for 24 hours.

Summary of material penetrated:

939 feet of bolson deposits.

Aquifer test

Wells I and J were test pumped at approximately 1,000 gpm for 24 hours. A semi-log plot of water-level recovery versus time indicates the coefficient of transmissibility is about 48,000 gpd per ft for well I and about 80,000 gpd per ft for well J. The coefficient of transmissibility are on the order of those expected from bolson deposits, and the relatively small drawdown of water levels indicates that the wells are in good hydraulic connection with the aquifer.

Chemical quality of water

The sulfate content of water from all the wells except C was more than the U.S. Public Health Service recommended limit of 250 ppm. The water from wells I and J contains about 300 ppm sulfate. The water is extremely hard; the hardness as $CaCO_3$ of water from wells I and J is 378 and 418 ppm, respectively. Water of appreciably better quality probably cannot be obtained within about 10 miles of the facility.

Bosque del Apache Wildlife Refuge

(Reference: Weir, 1964)

This area includes a strip along the Rio Grande through a 10-mile reach south of San Antonio, N. Mex. (fig. 1). In this area the Recent flood-plain deposits constitute the major aquifer.

Generally water from wells east of the Rio Grande in the Bosque del Apache is inferior to impotable owing mainly to the movement of mineralized ground water into this area from the northern Jornada del Muerto. This water of poor quality comes from wells tapping the flood-plain deposits as well as older unconsolidated basin fill although wells tapping the flood-plain deposits at the edge of the river yield somewhat better water, apparently owing to dilution by the river water in the shallowest part of the aquifer.

Except for a small grassy marsh area along U.S. Highway 85 from 1 to 3 miles south of the northern boundary of the wildlife refuge in the Bosque del Apache Grant (west of map area), wells west of the river yield potable water from both the flood-plain deposits and the Santa Fe Group. Shallow wells in the grassy marsh area yield inferior water because of a concentration of salts in the marsh area by evapotranspiration. This inferior water may exist only in the shallowest part of the aquifer.

Stallion Range Center

(Reference: Weir, 1964)

Stallion Range Center is a small administrative and service installation in the northern part of the Jornada del Muerto. Water levels in wells in the Stallion Range Center area range from 150 to 450 feet below the land surface, from east to west and the depth to water is 327 feet in well 6.3.5.232 at Stallion Range Center (see table 16 for log). Well 6.3.5.232 supplies nonpotable water to the Range Center. The water is too saline for domestic use; calcium, magnesium, and sulfate are the principal chemical contaminants.

The results of the chemical analyses of water from wells drilled in 1956 indicate that the western and northern flanks of the Cerro Colorado volcanic mass are underlain by water of potable and near-potable quality. The sulfate content in the ground water underlying this part of the area ranges from about 220 to about 900 ppm. Yields from three test wells drilled in secs. 1, 4, and 10, T. 6 S., R. 2 E, range from 2 to 40 gpm.

Table 16.--Log of well 6.3.5.232, Stallion Range Center

Material	Thickness (feet)	Depth (feet)
Samples missing	20	20
Sand, very fine to medium, and small gravel of volcanic rocks	20	20
Sand, very fine to medium, small gravel of volcanic rocks, and some clay	10	50
Sand, fine to very coarse, and small gravel of volcanic rocks	40	90
Clay, silty, tan, and very small gravel of volcanic rocks	20	110
Sand, medium to very coarse, small volcanic gravel, and tan silt	10	120
Clay, tan	10	130
Sand, medium to very coarse, small volcanic gravel, and tan silt	10	140
Clay, tan, sand, medium to very coarse, small volcanic gravel, and tan silt. Less gravel.	20	160
Clay, red to tan, small gravel and large pebbles of volcanic rocks	10	170
Silt, tan, some very coarse sand, and a small pebble	10	180
Clay, red to tan, and pebbles	10	190
Sand, very fine and red-brown silt, with a small amount of very coarse sand and small gravel	10	200
Clay, red-brown silty	20	220
Clay, red, and included crystals of selenite	10	230
Clay, red, and included crystals of selenite with some gravel	10	240
Clay, very silty tan, and very coarse sand	10	250

Table 16.--Log of well 6.3.5.232, Stallion Range Center - continued

Material	Thickness (feet)	Depth (feet)
Sand, very coarse, very small gravel, and tan silt	10	260
Clay, red, very coarse sand, very small gravel and tan silt	10	270
Clay, white, very coarse sand, very small gravel, and tan silt	5	275
Clay, tan and white, silty	5	280
Clay, tan silty, and a small amount of very coarse sand	14	294
Silt, tan to cream	6	300
Clay, tan silty	20	320
Silt, brown, and very fine sand. Some very coarse sand	18	338
Silt, brown, very fine sand,some very coarse sand, and small volcanic gravel	9	347
Clay, tan, very silty	5	353
Clay, tan very silty, very coarse sand and small gravel	22	375
Silt, very fine sand, and very silty tan clay	5	380
Sand, very fine to very coarse, and small gravel	20	400
Sand, very fine to very coarse, small gravel, and brown silt. Some clay 430-435.	50	450
Samples missing	58	508
Sand, medium to very coarse, and small gravel	4	512
Sand, medium- to very coarse-grained, small gravel and small pebbles	11	523
Sand, very coarse and gravel	5	528
Sand, fine to coarse	5	532

Table 16.--Log of well 6-3.5.232, Stallion Range Center - concluded

Material	Thickness (feet)	Depth (feet)
Sand, medium to coarse, and brown clay	7	539
Sand, fine to very coarse	5	544
Sand, fine to very coarse and small gravel	31	575
Clay, brown, fine to very coarse sand and small gravel	5	580
Silt, brown and very fine to coarse sand	30	610
Sand, very coarse, and small gravel	5	615
Sand, very coarse, small gravel, and brown silt	5	620
Sand, very coarse, gravel and small pebbles	15	635
Sand, fine to very coarse, and brown clay	30	665
Sand, very coarse, small gravel and brown silt. Some clay from 693-to 700, and a large pebble 705-10	45	710
Sand, very coarse, gravel and small pebbles. General grain sizes somewhat smaller 725-30, and one large pebble 735-740	30	740
Sand, medium to very coarse and gravel	10	750

Notes: All clays were calcareous. Clay, silt, and sand below 400 feet are uniformly coffee-brown in color All gravel and pebbles observed are detritus of "volcanics"; some are holocrystalline but very fine-grained, and some are glassy with very small phenocrysts. The general appearance of the volcanics is red-brown when wet, but a dusty lavendar when dry.

Red Canyon Range Camp

(Reference: Weir, 1964)

Well 7.8.8.322, the second of two wells drilled at Red Canyon Range Camp to supply nonpotable water to the camp, was test pumped for 48 hours in November 1956.

Red Canyon well 2 (7.8.8.322) was pumped at approximately 200 gpm and the water level decline was observed in the pumped well and in Red Canyon well 1 (7.8.8.412), 1,000 feet east of the pumped well, where the water level declined 1.25 feet during the test. The decline in the pumped well was 2.12 feet during the pumping period. The specific capacity of the pumped well is approximately 100 gpm per foot of drawdown. Transmissibility is about 45,000 gpd per ft.

MAR facility water supply

(References: Doty, 1964, 1964a)

Three test wells (19.5.17.333, 19.5.28.443, and 19.5.21.111) were drilled near Lucero Ranch in 1963 to find potable water for the MAR facility. All three wells produced potable water but only test well 1 (19.5.17.333) produced an adequate quantity of water for the facility. Two production wells (19.5.17.331 and 19.5.17.334) were drilled late in 1963 and put in service in the Spring of 1964.

MAR 1 test well was drilled to 1,000 feet and plugged back to 650 feet because water quality depreciates below that depth. The test well was pumped for 12 hours at 165 gpm with a drawdown of about 40 feet below the nonpumping depth to water at 225 feet. The pumped water had a specific conductance of 809 micromhos and contained 42 ppm chloride and 162 ppm sulfate.

MAR 1 (19.5.17.331) and MAR 2 (19.5.17.334) production wells were completed at 550 and 650 feet respectively. **The wells drilled were of** 20-inch diameter, cased with 10-inch pipe mill-slotted, 1/8 x $2\frac{1}{4}$ inch slots, 9 slots around, below the water level, and gravel packed. The wells are designed to pump about 100 gpm. The quality of water obtained from the wells is similar to that from the test well.

The log of MAR test well 1 (19.5.17.333) is given in table 17. This log is representative of other wells drilled in the MAR facility area.

Table 17.--Log of MAR-1 test well

(19.5.17.333)

Material	Thickness (ft)	Depth (ft)
[illegible] [illegible] limestone, dolomite, chert, vein quartz and [illegible] rock. Some caliche cement	0	112
Clay, tan, gravel, and coarse sand	18	130
Clay, tan, some fine to very fine sand	15	145
Clay, tan	10	155
Clay, tan and large gravel	5	160
Gravel, little clay	5	165
Clay, tan, with imbedded pebbles	5	170
Clay, tan, and granule to pebble gravel	30	200
Gravel, pebble, and some clay	10	210
Clay, tan, and some gravel	5	215
Clay, tan	10	225
Clay, tan, and pebble gravel, some sand	30	255
Gravel, pebble, tan clay and some coarse sand	15	270
Clay, tan and pebbles	10	280
Clay, tan	5	285
Gravel and some clay	55	290
Gravel, pebble	10	300
Clay, tan, and some pebbles	5	305

Table 17.--Log of MAR-1 test well - Continued

(19.5.17.333)

Material	Thickness (ft)	Depth (ft)
Clay, tan and pebble gravel	15	320
Gravel and clay	10	330
Clay and gravel	25	355
Gravel, and tan and white clay	10	365
Clay, tan, granules and some coarse sand	20	385
Gravel and clay	10	395
Clay, tan and some granule to pebble gravel	55	450
Gravel and white, green, and tan clay	10	460
Clay and some granules to pebble gravel	75	535
Gravel, granule to pebble, and clay	10	545
Clay, tan, and a few granules	45	590
Gravel and clay in beds 4 to 5 inches thick	10	600
Clay, tan, and a few granules	20	620
Gravel, granule to pebble, and clay	10	630
Clay, and a few granules	40	670
Clay, tan, with streaks of white sandy, silty clay	5	675
Clay, tan, and a few granules	45	720
Clay	30	750
Clay and gravel	35	785
Clay	20	805
Clay and some gravel	35	840
Clay	20	860
Clay and fine sand	55	915

Table 17.--Log of MAR-1 test well - Continued

(19.5.17.333)

Material	Thickness (ft)	Depth (ft)
Clay	30	945
Clay and very fine sand, and few granules of limestone	5	950
Clay	10	960
Clay, hard	20	980
Clay	10	990
Clay and gravel	10	1,000

Upper Sacramento River canyon

(Reference: Mourant, 1959)

The Sacramento River originates in the Sacramento Mountains in central Otero County, N. Mex., about 10 miles southeast of Alamogordo. The upper part of the Sacramento River flows southeastward through canyons several hundred feet deep. The valley floor is extremely narrow except in the cienega (marshy) areas, where it is several hundred feet wide. The river has a perennial flow only in cienega areas. The Southern Pacific Co. was diverting about 250 gpm of water from two of the cienega areas in December 1956 which was transported by pipeline to Orogrande, about 35 miles southwest.

Ground water in the Sacramento River canyon area occurs mainly in the upper part of the Yeso Formation. The depth to water in two wells in sec. 34, T. 17. S., R. 11 E., which furnish water to the installation at Sacramento Peak, is about 200 feet. In many places in the Sacramento River canyon in T. 18 S., Rs. 11 and 12 E., the ground water discharges through springs (fig. 25). The depth to

Figure 25 (caption on next page) belongs near here.

water in well 19.12.15.144 at the Circle Cross Ranch, is about 170 feet. The wells in sec. 34, T. 17 S., R. 11 E., are reported to yield 50 gpm. each. Well 19.12.15.144 is not equipped with a pump, and the yield of the well is not known. The Yeso Formation probably contains one or more zones of saturation throughout this part of the Sacramento Mountains, and wells drilled in most of the upper part of the Sacramento River canyon will yield at least 50 gpm and possibly as much as 100 gpm. The development of wells a short distance upstream from the spring area probably would cause the yields of the springs to decline rapidly.

Figure 25.--Map of the upper Sacramento River Canyon, Otero County, N. Mex., showing wells, springs and part of Orogrande pipeline.

The Hueco Bolson

(Reference: Knowles and Kennedy, 1958)

The Hueco Bolson is in the extreme western part of Texas and south-central New Mexico, covering parts of El Paso County, Tex., and Dona Ana and Otero Counties, N. Mex. (See fig. 1.) Wells tapping the bolson deposits furnish the major part of the water supply for the city of El Paso, Ciudad Juarez, Fort Bliss, Biggs Air Force Base, and private industries in the area. The progressively-increasing demand for water made it obvious that a comprehensive investigation of the quantity and quality of water in storage in the entire Hueco Bolson would be essential for the proper planning of future water supplies. A test-drilling program was started in 1953, jointly sponsored by the city of El Paso, the United States Army, the United States Air Force, and the Texas Board of Water Engineers. The drilling was supervised by the United States Geological Survey.

Thirty-three deep test wells were drilled, comprising a total footage of 32,456 feet. Water samples for chemical analysis were obtained by means of drill-stem tests at most of the wells. An electric log was made after each test well was completed, water-level measurements were made in each well, and pumping tests were made at several selected wells. In addition to the test-drilling program, all available information was collected for existing wells in the area, and chemical analyses were made of water samples collected from many of the wells. Records of the wells and explanatory text and illustrations are contained in U.S. Geological Survey Water-Supply Paper 1426 (Knowles and Kennedy, 1958). The data from Water-Supply Paper 1426 are not included in this report, but illustrations showing the altitude of water levels and saturated thickness of fresh-water-bearing material (Knowles and Kennedy, 1958, pls. 2 and 10 are included herein as figures 26 and 27 (pls. 2 and 10 of Water-Supply Paper 1426)

Figure 26 (caption on next page) belongs near here.

27 (caption on next page) belongs near here.

Figure 26.--Map showing water-level contours in the Hueco Bolson area, Texas and New Mexico, January 1954.

27.--Map showing saturated thickness of fresh-water-bearing deposits (chloride content less than 250 parts per million) in the Hueco Bolson area, Texas and New Mexico.

The Hueco Bolson is an intermontane lowland sparsely covered with low vegetation. The bolson is traversed by the Rio Grande Valley (figs. 26 and 27), the portion of which south of El Paso, known locally as the Lower Valley, is reached by an abrupt drop of 200 to 300 feet from the bolson surface, which is known locally as the Mesa. No well-developed drainage channels are on the Mesa, and the precipitation on it either infiltrates or is lost by evapotranspiration.

The bedrock that underlies the bolson deposits and makes up the surrounding mountains is relatively impermeable and will not supply large quantities of water to wells. The Franklin and Organ Mountains, which form part of the western boundary of the Hueco Bolson (figs. 26 and 27), consist largely of granitic and porphyritic rocks that were the source beds for much of the bolson deposits. The latter consist of lenticular layers of clay, sand, and gravel, which cannot be correlated for long distances. The sands and gravels are thickest and coarsest near the Franklin and Organ Mountains and become progressively thinner and finer grained toward the east. The maximum known thickness of the bolson deposits is 4,920 feet. Caliche lying nearly everywhere beneath the surface of the bolson affords a rather effective barrier to recharge from above. The caliche beds are partly or completely missing beneath depressions in the bolson, however, and recharge takes place when water collects in the depressions during periods of heavy rainfall.

Contours of water levels in the Hueco Bolson (fig. 26) show that the principal area of recharge is along the east edge of the Franklin and Organ Mountains, where the runoff from the mountains infiltrates into the coarse gravel of alluvial fans. The water in the bolson deposits in the Mesa is unconfined and almost everywhere is of good quality. The bolson deposits in El Paso Valley contain fresh water but are overlain and underlain by alluvial deposits containing mineralized water. The lowering of the artesian head in the bolson deposits in places has permitted the infiltration of salt water into the fresh-water-bearing beds. Two large cones of depression, one in El Paso Valley and one in the Mesa, have been formed by large withdrawals of ground water.

Pumpage from deep wells in the El Paso area has increased steadily since 1906. The average withdrawal in 1953 was 27.9 mgd (million gallons per day), of which 13.1 mgd was pumped from wells in the Mesa and 14.7 mgd was pumped from wells in the El Paso Valley.

The fresh water--defined as that containing less than 250 ppm (parts per million) of chloride--in the Hueco Bolson is in a trough of irregular width and depth roughly parallel to the Franklin and Organ Mountains (fig. 27). Salt water--defined as that containing more than 750 ppm of chloride--is present in the bolson sediments that lie beneath and east of the fresh-water-bearing beds and in the younger alluvium in the El Paso Valley. A body of inferior water is present between the fresh and salt water and differs in thickness from place to place.

Pumping tests at wells in the Hueco Bolson showed that the coefficient of transmissibility ranged from 38,000 to 164,000 gpd (gallons per day) per foot. Because of the shortness of the tests, the coefficient of storage of the bolson deposits could not be determined accurately.

The volume of the saturated bolson deposits in Texas is at least 31.6 million acre-feet and in New Mexico at least 24.8 million acre-feet. Of this, about 7.4 million acre-feet in Texas and 6.2 million acre-feet in New Mexico is available for recovery by wells. On the basis of about 50-percent recovery of the available water, 30 mgd could be withdrawn from storage for a period of 110 years. Artificial recharge would extend this period. Suggested methods of artificial recharge are by means of wells on the Mesa and a system of ditches and detention dams in the arroyos along the mountain fronts.

Although a large quantity of water is available in the bolson deposits, detailed planning and proper development will be necessary to secure maximum recovery from the reservoir without serious salt-water encroachment.

Conclusions and suggestions

The data and maps in this report show that potable water underlies narrow belts of land at the foot of the Franklin and Organ Mountains and the southern part of the San Andres Mountains in the western part of the area and the Sacramento Mountains in the eastern part. The belt of potable water is bounded basinward by a narrow belt of inferior water. The major part of the Tularosa Basin and Hueco Bolson contain non-potable water. Removal of large quantities of potable water locally from ground storage causes water levels in wells to decline, and at places the water-table gradient has been reversed from the normal basinward slope. Eventually, the removal of large quantities of potable water from storage will induce movement of inferior and non-potable water into the areas now containing potable water.

Figure 4 shows areas of potable water having little development both north and south of the headquarters area. Unfortunately, these areas have not been adequately explored to define accurately the amount of potable water in storage.

The expected long-term need for increasingly larger supplies of potable water in the White Sands Missile Range and adjacent areas can be met only by additional evaluation and development. The following program of evaluation is suggested:

1. Continue the present program of monitoring pumpage, water levels in wells, and quality of water in production and observation wells. Extend the monitoring to keep pace with new development of water supplies.

2. Drill additional test and observation wells in the potable water areas to determine more accurately what is happening in heavily-pumped centers and the quantity of potable water in storage.

   a. At least three more observation wells are needed northwest, west, and southwest of the headquarters well field.

   b. Additional wells northward from the headquarters to a few miles north of the MAR wells in the potable water belt would be desirable. Larger yields from a thicker zone of fresh water might be possible between the MAR wells and the mountain front.

   c. Several wells should be drilled in the potable water belt southward from the headquarters area several miles into the Fort Bliss Military Reservation.

   d. At least one deep test well (to bedrock at a depth of 1,000 to 5,000 feet) should be drilled 6 to 10 miles east of the headquarters to evaluate differences in pressure head and chemical quality of water. We know that the water increases in salinity with depth to the depths tested, but we do not know that the salinity continues to increase to bedrock. In some similar basins of New Mexico, water of good quality has been found below zones of saline water.

   e. One or two additional test wells should be drilled northwest of Rhodes Canyon to further explore for potable water.

f. Drill test wells to locate new sources of potable water near areas of need. Small areas of potable water surely must exist at some unexplored places. Our increasing knowledge of the geology and hydrology of the missile range increases the chances of finding additional supplies of potable water.

3. A geophysical survey should be made in each area before the test drilling is started. The geophysical work should be a combination of surveying, for accurate control, and gravity survey, for economical coverage of large areas.

4. Investigate the quantity of surface water available for artificial ground-water recharge in the potable water areas. Also, evaluate the efficiency and cost of collecting water for direct use or artificial recharge from areas coated with asphalt. A small coated watershed (9 acres) is currently being studied. Gaging stations to measure the natural runoff from three watersheds near the headquarters are being planned. Construction of artificial recharge facilities may be feasible in the future, especially in the headquarters area.

5. Ground-water recharge with treated sewage effluent up-gradient from the headquarters well field would be a safe, sanitary method of supplementing the supply of potable water in the well field. This recharge could be accomplished with properly constructed infiltration pits. Movement of this water vertically through a hundred feet or more of the zone of aeration and a mile or more horizontally in the zone of saturation after treatment would assure its safety and even its esthetic value.

6. A large saline-water conversion plant may become feasible in the future. A very large volume of saline ground water is stored in the Tularosa basin. Conversion of this saline water to fresh water could supply the missile range indefinitely, even after large increases in water demand.

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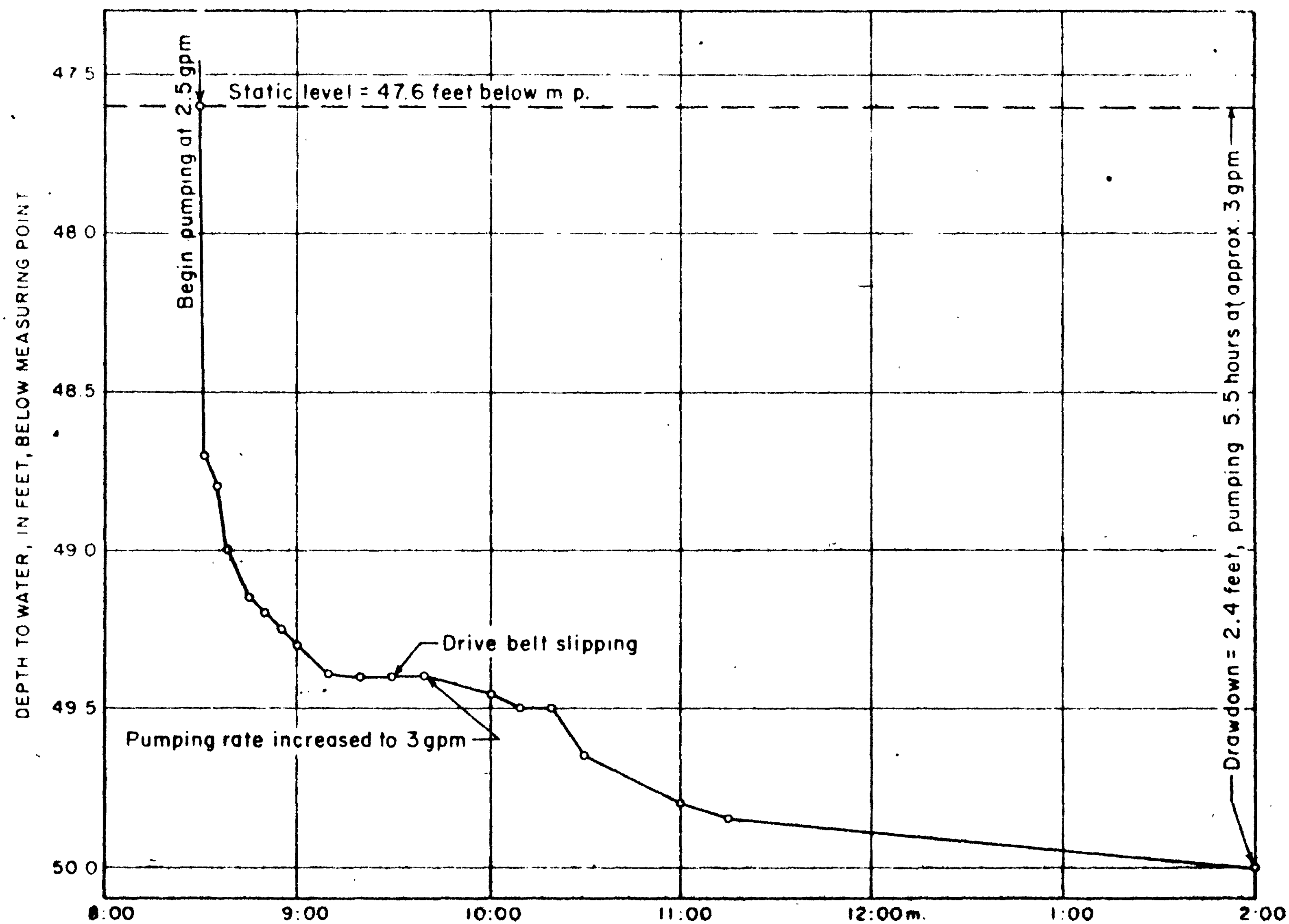


Figure 16.--Performance test of well 21.4.22.222, Hazardous Test Area, White Sands Missile Range, N. Mex., August 5, 1960.

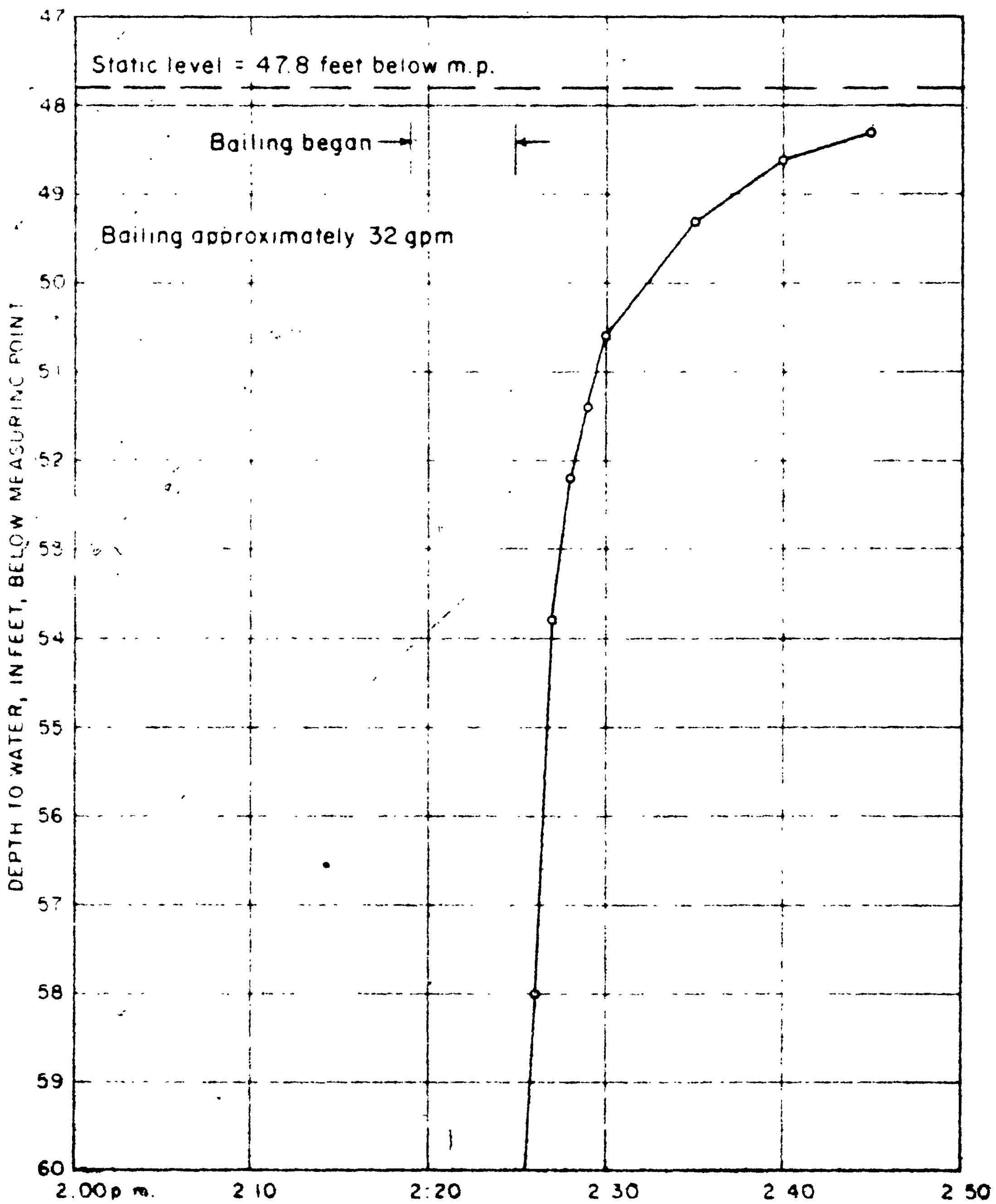


Figure 17.--Recovery of water level after bailing well 21.4.22.222, Hazardous Test Area, White Sands Missile Range, New Mexico, October 6, 1960.

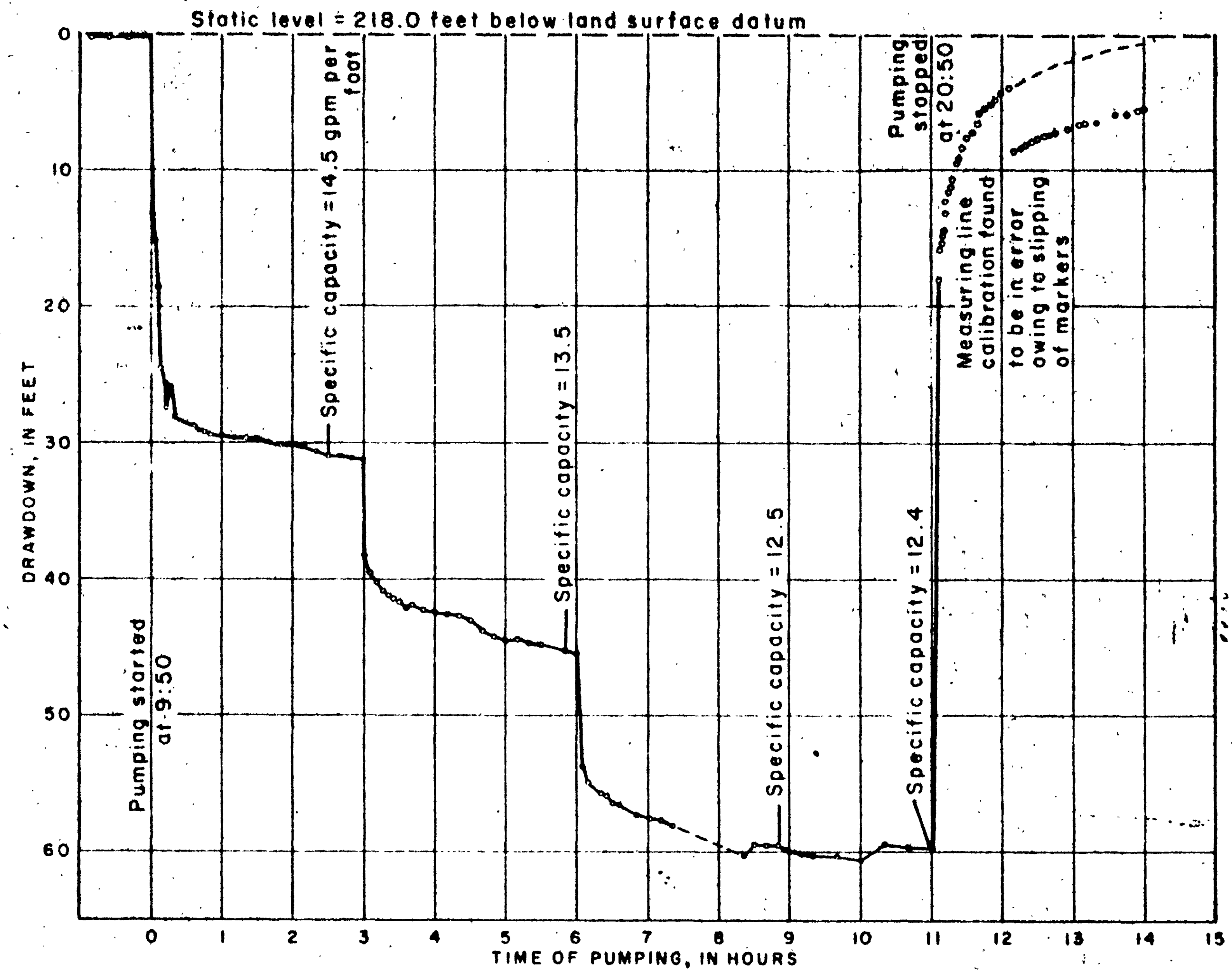


Figure 19.--Drawdown and residual drawdown in Gregg well (22.6.28.414), White Sands Missile Range, N. Mex., during performance test on Oct. 30, 1961.

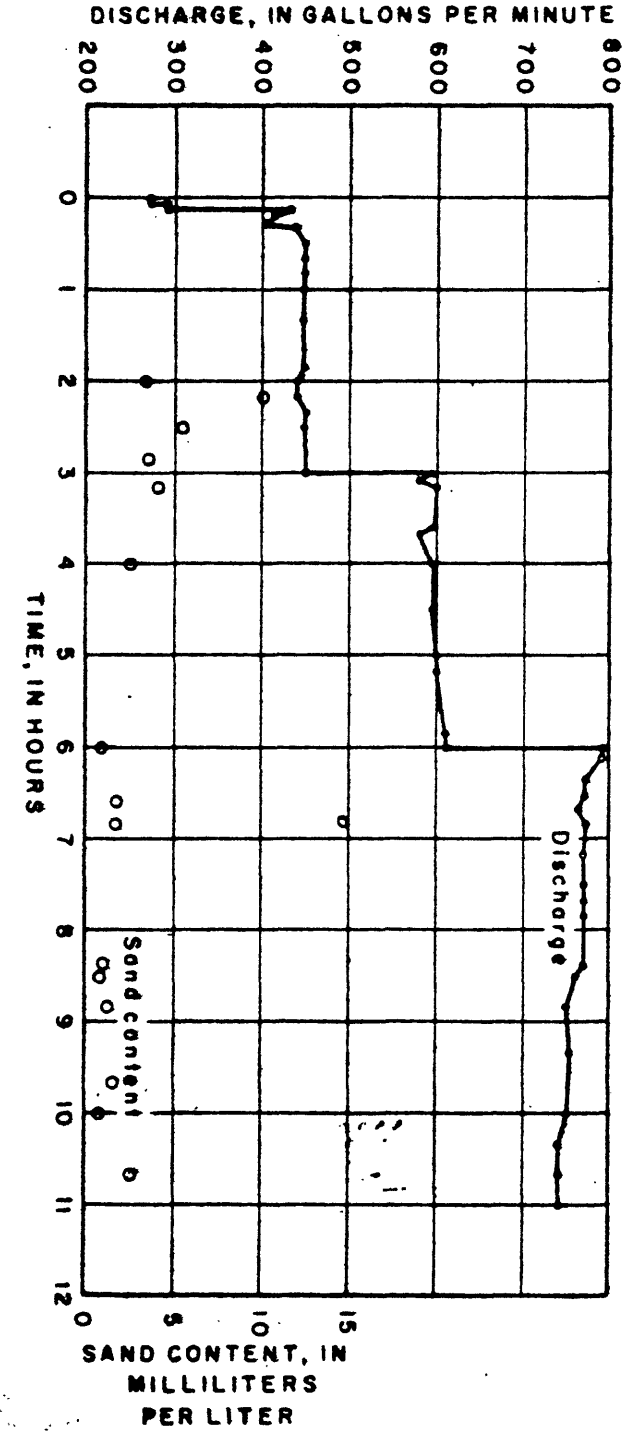


Figure 20.--Rate of discharge and sand content of water pumped from Gregg well (22.6.8.414), White Sands Missile Range, N. Mex., during performance test on Oct. 30, 1961.

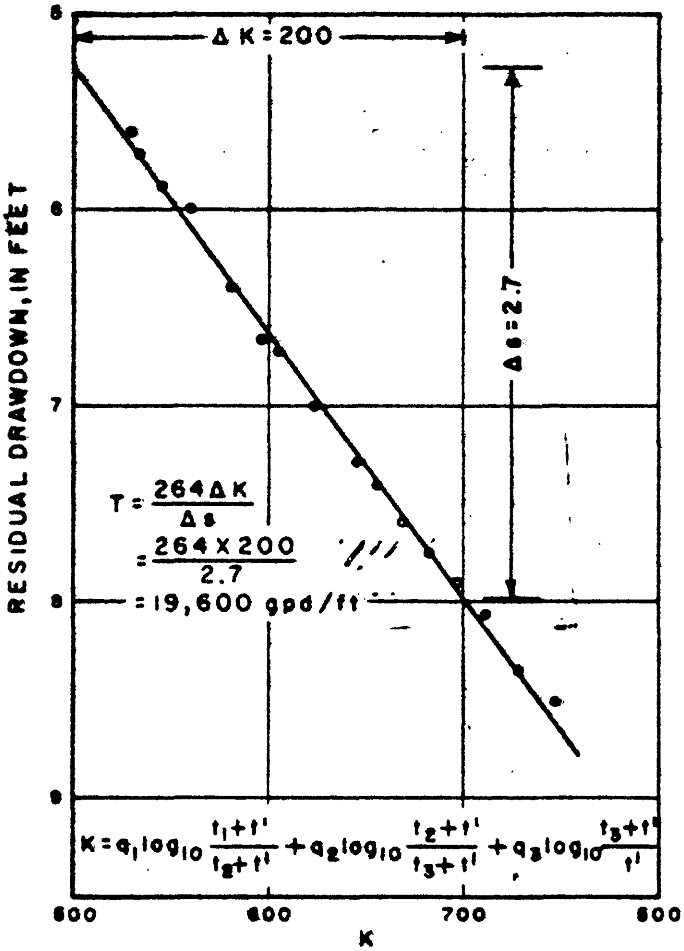


Figure 21.--Computation of the coefficient of transmissibility of the bolson fill in the vicinity of Gregg well, White Sands Missile Range, N. Mex. using residual drawdown after pumping test on Oct. 30, 1961.

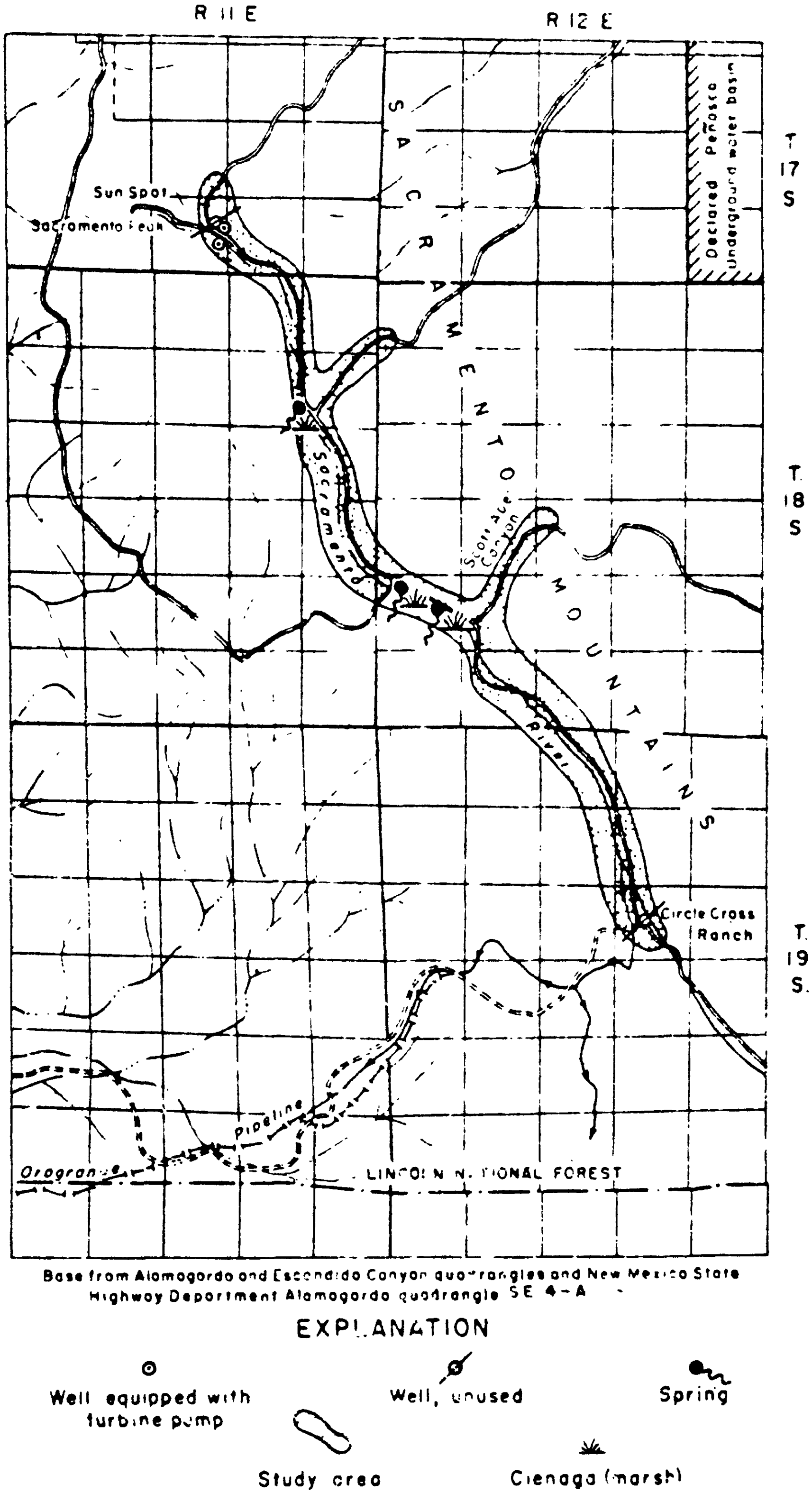


Figure 25

MAP OF THE UPPER SACRAMENTO RIVER CANYON, OTERO COUNTY, N MEX.,
showing wells, springs and part of Orogrande pipeline

0 1 2 3 Miles

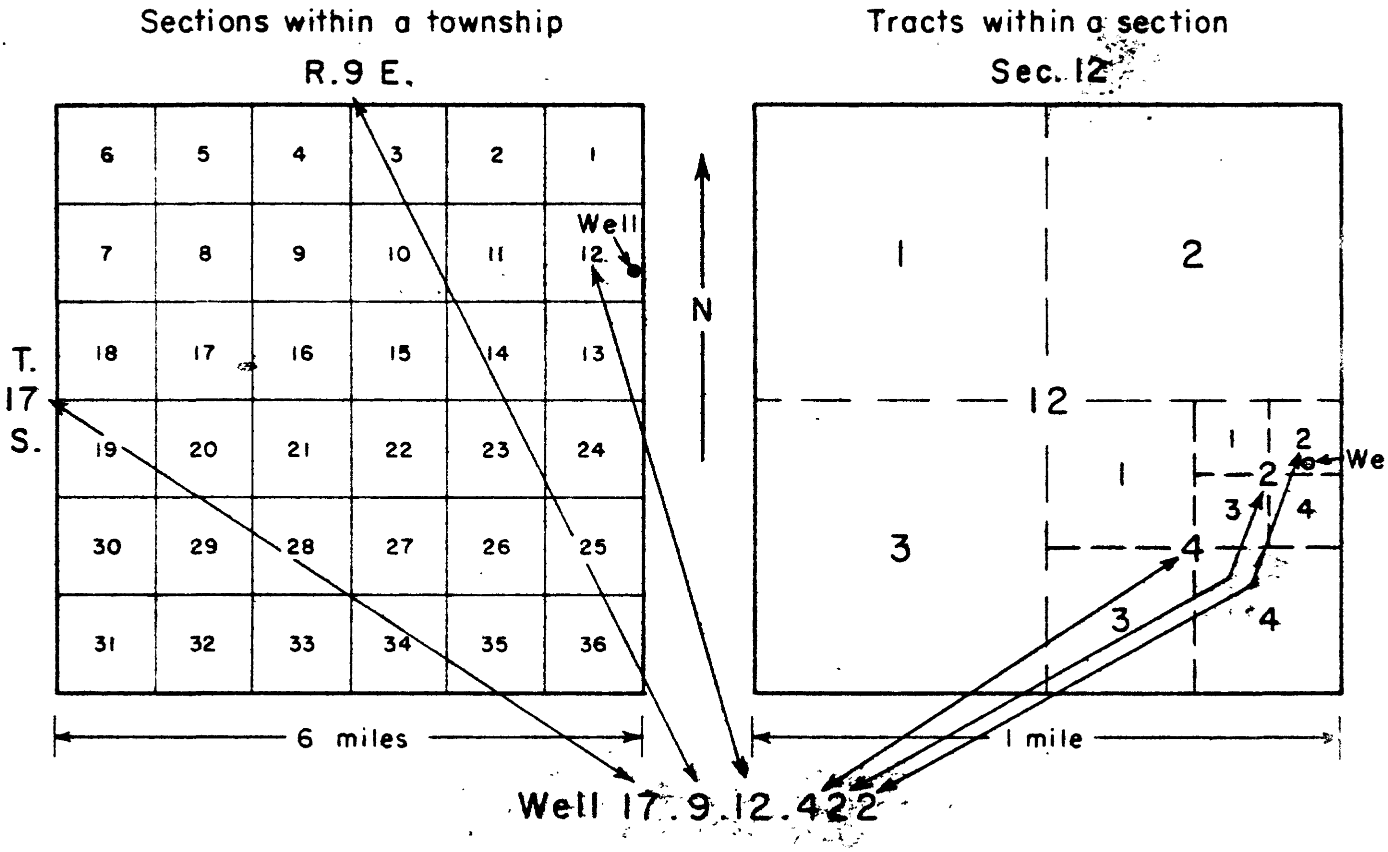
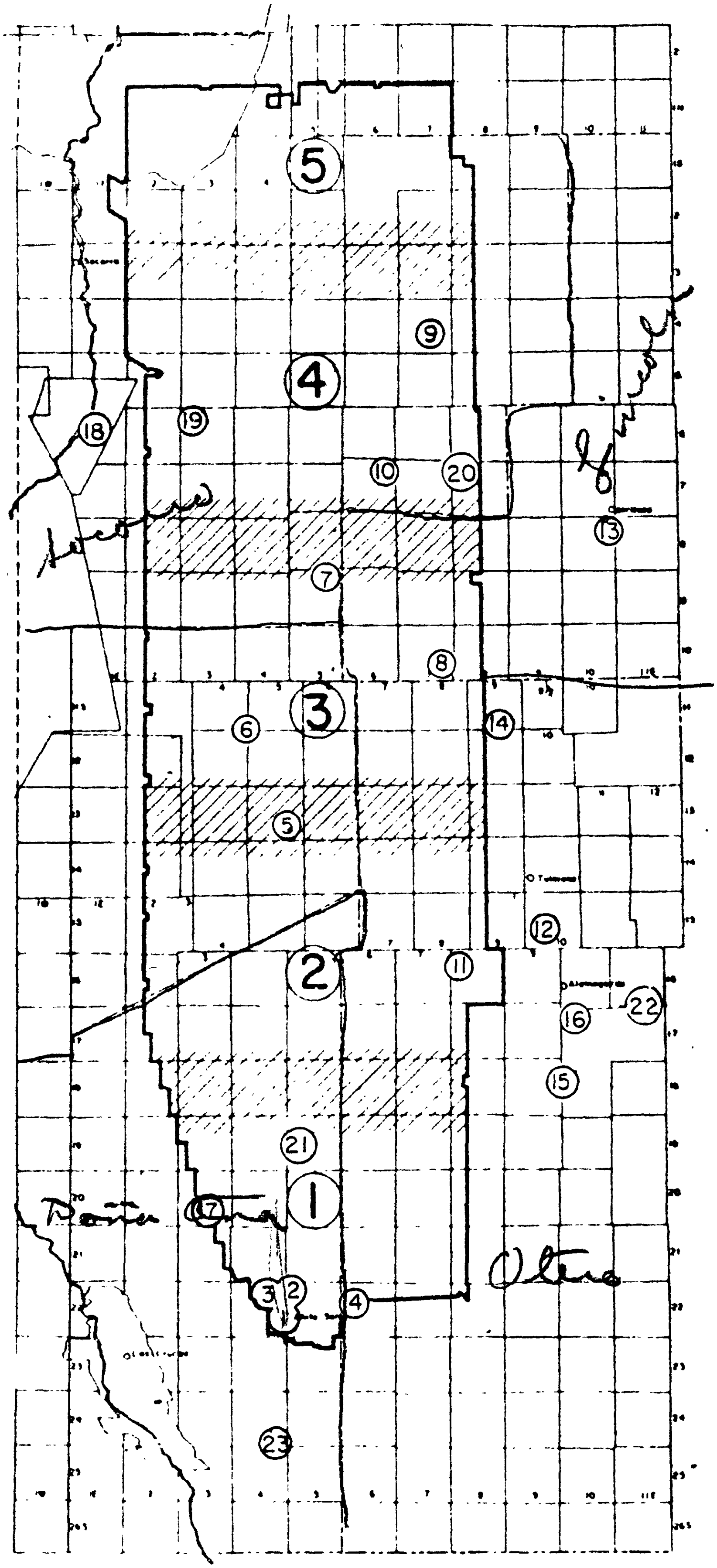


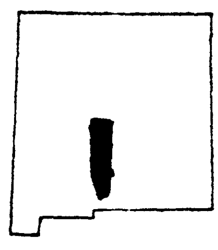
Figure 2.--System of numbering wells and springs in New Mexico

(S in front of number indicates a spring)



Areas mentioned in text

1. Headquarters (WSMR)
2. Small Missile Range
3. Hazardous test
4. Gregg site
5. Rhodes Canyon Range Camp
6. Salinas Peak
7. Mockingbird Gap
8. Malpais
9. Chupadera Mesa-Transmalpais
10. Sierra Oscura backslope
11. Atlas Project
12. Tularosa-Alamogordo
13. Carrizozo
14. Three Rivers
15. Valmont
16. Boles well field
17. Jornada del Muerto Apollo site
18. Bosque del Apache
19. Stallion Range Center
20. Red Canyon Range Camp
21. MAR facility water supply
22. Upper Sacramento River Canyon
23. Fillmore Pass area -- See USGS WSP 1426



LOCATION OF WHITE SANDS MISSILE RANGE IN NEW MEXICO

Figure 1.--Index map showing White Sands Missile Range. Large circled numbers indicate areas of separate sheets of figures 4 and 5; hachured areas are overlap between sheets. Small circled numbers refer to areas mentioned in text and listed at upper right of this map.