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Drilling, construction, and testing of water-supply wells 21 and 22, White Sands Missile Range, Dona Ana County, New Mexico

By Clyde A. Wilson, Robert R. White,
Raymond G. Roybal, and Jose L. Gonzales

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U.S. customary to metric unit conversion factors

In this report figures for measurements are given in U.S. customary units only. The following table contains factors for converting to metric units.

Multiply U.S. customary units	By	To obtain metric units
inch (in)	25.4	millimeter (mm)
foot (ft)	.3048	meter (m)
cubic foot per day per foot [(ft^3/d)/ft]	.0929	cubic meter per day per meter [(m^3/d)/m]
cubic foot per day per foot squared [(ft^3/d)/ft^2]	.3048	cubic meter per day per meter squared [(m^3/d)/m^2]
mile (mi)	1.609	kilometer (km)
gallon (gal)	3.785	liter (L)
gallon per minute (gal/min)	.06309	liter per second (L/s)
gallon per minute per foot [(gal/min)/ft]	.2070	liter per second per meter [(L/s)/m]
gallon per day per foot [(gal/d)/ft]	12.418	liter per day per meter [(L/d)/m]
pound (lb)	.4536	kilogram (Kg)

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Abstract

During the spring and summer of 1976, two municipal-supply wells (designated as well 21 and well 22) were drilled at the Post Headquarters area of White Sands Missile Range, New Mexico. The design specifications for both wells called for 24-inch diameter surface casing cemented in place to a depth of about 430 feet, with 16-inch liner and slotted casing from the surface to a depth of about 700 feet.

After an extensive development program, each well was pumped continuously for 32 hours in a step-drawdown test. This test consisted of four steps, with discharge rates varying from about 500 to 1,150 gallons per minute.

The drawdown test for well 21 gave an estimated transmissivity of 2,300 cubic feet per day per foot (17,300 gallons per day per foot), and a final specific capacity of slightly less than 11 gallons per minute per foot of drawdown. The step-drawdown test and a later drawdown and recovery test on well 22 gave an average transmissivity of 4,400 cubic feet per day per foot (32,600 gallons per day per foot), and a final specific capacity of about 15 gallons per minute per foot of drawdown. All the data collected during the drilling and pumping tests indicate that the aquifer in the vicinity of well 22 is more permeable than the aquifer around well 21.

Both wells furnish a satisfactory quantity of excellent-quality water. The dissolved-solids content of water from wells 21 and 22 is 232 and 301 milligrams per liter respectively.

Introduction

In April 1976, drilling began on the first of two new wells at the Post Headquarters area (fig. 1), White Sands Missile Range. These wells, designated as well 21 and well 22, will be used as water-supply wells for the base. They were designed for a capacity of 800 gal/min each. The contract for these wells was awarded to John Lavis, a general contractor of El Paso, Texas; the actual drilling was subcontracted by Lavis to Layne Western Co., also of El Paso.

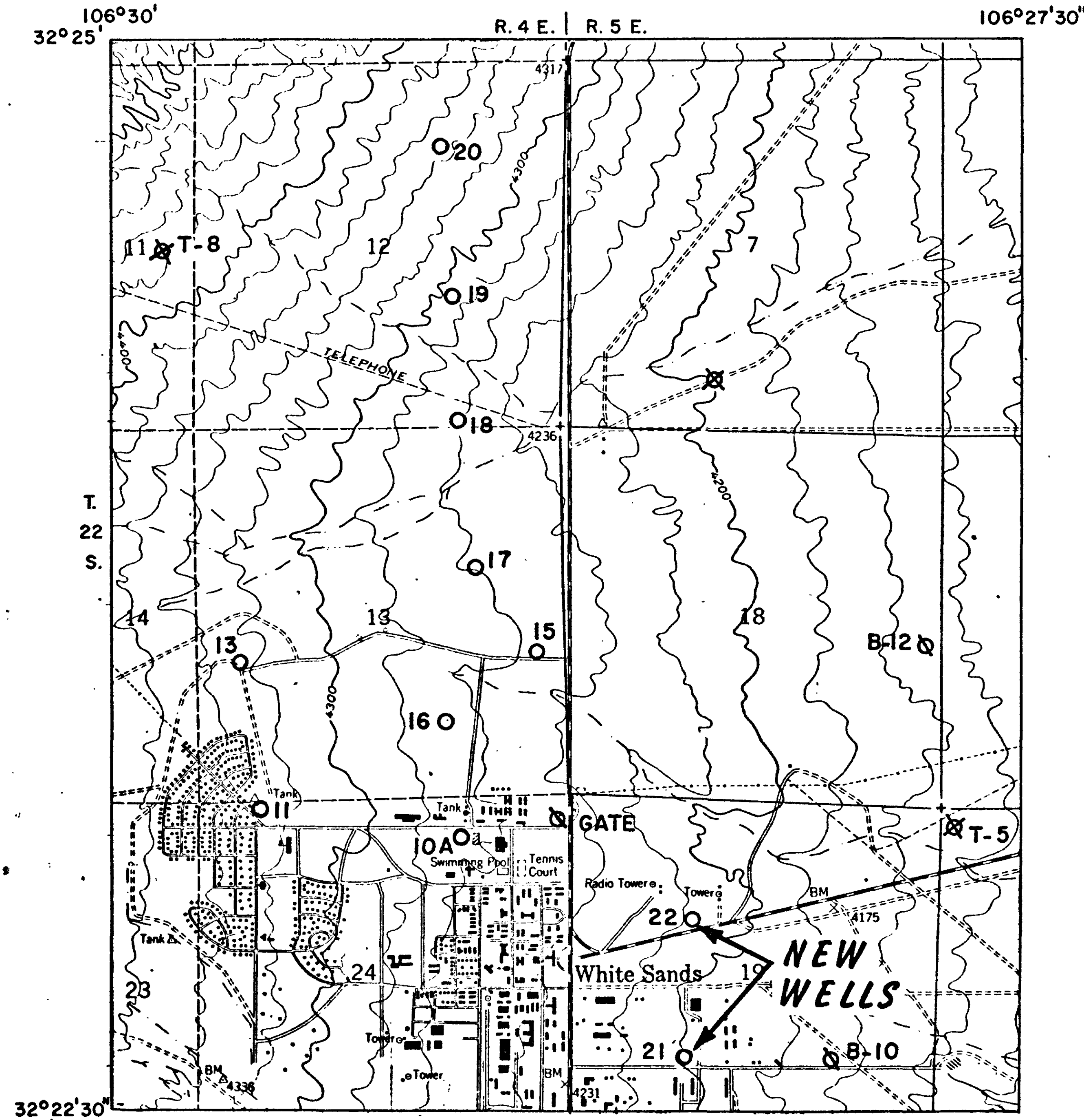
This report describes briefly the drilling and construction of the two wells and the subsequent development and production tests. In general, the U.S. Army Corp of Engineers' design specifications called for drilling a 9 5/8-inch diameter pilot hole to a depth of about 730 feet and running borehole geophysical logs at each site.[1/]

[1/] White Sands Missile Range Specification of Water Wells, 1976, U.S. Army Corps of Engineers, Fort Worth, Texas, written commun.)

At well-site 21, two water samples were to be collected upon completion of the logging. The pilot holes were then to be reamed out to a diameter of 28 inches to a depth of about 430 feet, and 24-inch diameter surface casing cemented in place. The interval from 430 to about 700 feet was to be reamed and under-reamed to 30-inch diameter, a 16-inch diameter slotted casing and blank liner emplaced, and the well gravel packed.

Well 21

Drilling began on the test hole for well 21 on April 15 using a rotary drilling rig, and by April 22 a depth of 730 feet was reached. The U.S. Geological Survey monitored the drilling continuously and collected cutting samples (a summary geologic log is shown in table 1). In general, the sample lithology was much the same for the entire hole--mostly sand, ranging in grain size from very fine to very coarse, with some gravel up to 1/4-inch diameter. Particles were generally rounded to subangular. As drilling progressed, lenses of a sticky, very soluble brown clay were frequently encountered. Although the clay occurred in thin lenses, it would occasionally constitute most of a sample. The borehole geophysical logs indicate more clay than was noted during drilling and sampling.



Base from
U.S. geological Survey
White Sands 1:24000, 1955

0 1/2 1 MILE
0 1 KILOMETER

CONTOUR INTERVAL 20 FEET
DATUM IS MEAN SEA LEVEL

EXPLANATION

O 22 Water Supply Well
⊠ T7 Test Well
⊘ B-10 Bore Hole

Figure 1.--Location of water-supply wells.

Table 1.--Summary geologic log of Well 21

[Numbers and letters in parentheses, such as (10R 4/6), refer to the rock color chart, distributed by the Geological Society of America, New York, N. Y.]

Sample description	*Thickness (feet)*	*Depth (feet)*
Clay, sand, silt, and small gravel; clay is moderate reddish brown (10 R 4/6). Sand is very fine to very coarse. Particles are generally angular to rounded. Sand is about 40 percent quartz, 50 percent feldspars, and 10 percent dark igneous rocks. Some biotite flakes present. Some gravel greater than ¼ inch in diameter. Less clay below 15 feet --	112	112
Sand, size ranges from very fine to very coarse. Grains are subangular to well rounded. Mineral composition same as above. Sample generally indicates clean, medium-sorted sand ----------------	70	182
Sand and gravel; sand is very similar to above interval. Gravel is made up of mostly orthoclase and plagioclase. Most particles are about ¼ inch in diameter and are subangular to rounded ----------	91	273
Sand, clayey, with gravel, silt. There are very few clay "pieces" in the washed or unwashed samples, indicating that clay was very soluble. Pieces found were a medium brown with a slight orange hue. Sample about 80 percent sand of similar mineralogy as before. Presence of clay was indicated by thickening of circulating mud and change in color. Gravel is usually smaller than ¼ inch in diameter -------------------	30	303
Sand, gravel, silt, and clay. Sand ranges from very fine to very coarse and gravel is less than ¼ inch in diameter. The clay is a moderate brown (5 YR 4/4). The clay content ranges in alternating layers, from about 20 to 70 percent of sample. From 331-335 feet the drilling was very slow, indicating a well consolidated layer. Clean sand layer with very little clay from about 312-320 feet ----------------------	109	412

Table 1.--Summary geologic log of Well 21 - Concluded

Sample description	*Thickness (feet)*	*Depth (feet)*
Sand, (estimated 70-80 percent) with majority in fine-to-coarse-grain size. Mineral composition same as before. Virtually no gravel found in this interval. Small amount of clay (≃ 15 percent) and silt --------	16	428
Sand and gravel, ranging from very fine to coarse and of same mineral composition as before. Gravel grains are usually less than ¼ inch in diameter, but some are nearly ½ inch in diameter -----------------------	30	458
Sand and silt, (95 percent is sand) of same mineral composition as before. The grain size is mostly in the medium-to-coarse range. The over-all color (wet) is moderate yellowish brown (10 YR 5/4) -------	17	475
Clay, very sandy, light brown (5 YR 6/4). A relatively clay-free sand layer occurs between 490-495 feet ----	30	505
Sand with clay, alternating layers or lenses. The sand is same mineral composition as before and is mostly in medium-to-coarse grain size. Sample shows about 90 percent sand. Some small gravel present (from less than ¼ to 1 inch diameter) -------	105	610
Clay, very soluble, sticky, pale yellowish-brown (10 YR 6/2) to dark yellowish-brown (10 YR 4/2). There are some sand lenses. Sand is very fine to coarse grained. Some gravel present -------------	45	655
Sand, with some clay lenses alternating throughout interval. Traces of small gravel (less than ¼ inch in diameter). Sand varies from 50-70 percent of total sample. Size and mineralogy same as before. Some very small gravel present ---------------	45	700
Sand, light brown (5 YR 6/4, dry); very fine grained. Same mineralogy as above -----------------------------	30	730

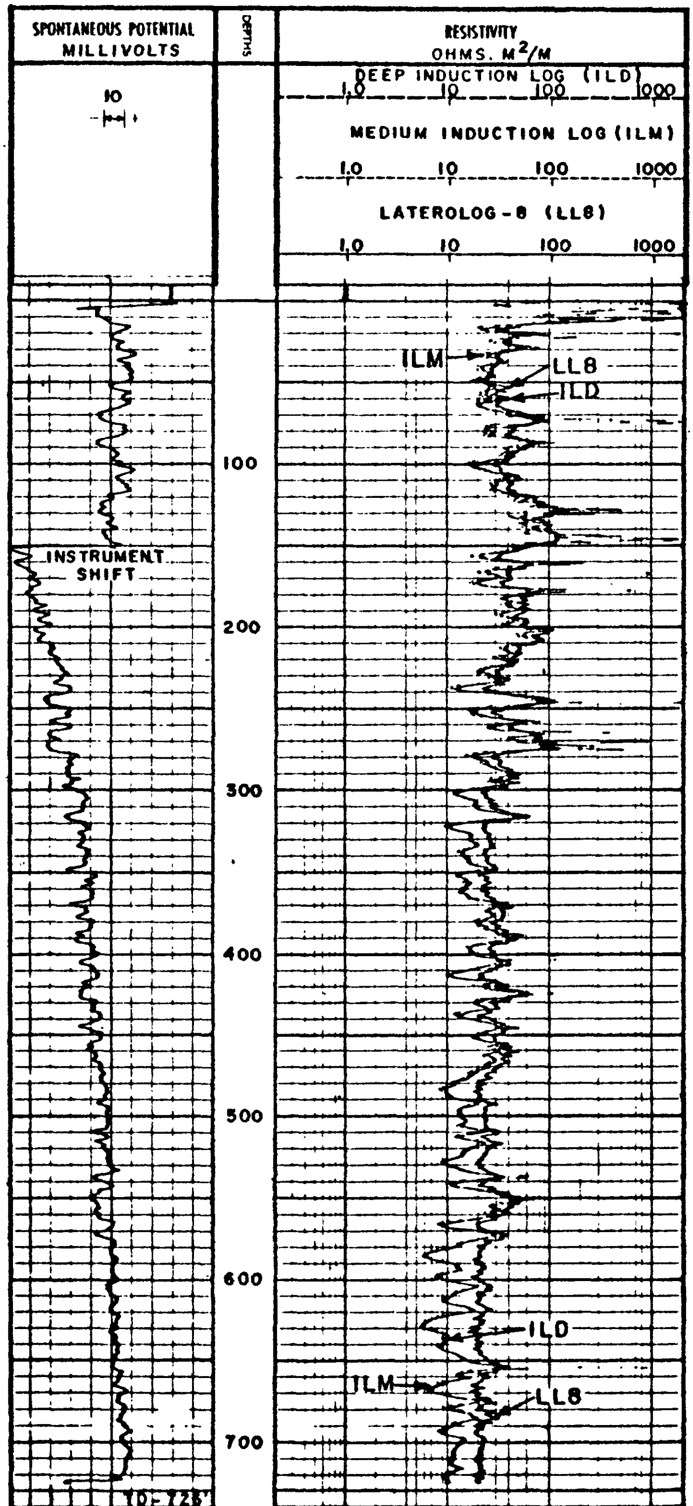
After completion of the pilot hole, drilling mud was circulated overnight, and on April 23 the tools were removed from the hole and the well was logged by Schlumberger well-logging service, Hobbs, New Mexico. Copies of the dual induction-laterolog logs are shown on figure 2.

Test-hole sampling

On April 26, work was begun to collect the first water sample. The interval selected for sampling was about 710 to 730 feet. A 20-foot length of slotted 2-inch pipe was attached to the drill stem and set at 730 feet. Gravel was placed around and above the slotted section so that only the formation water directly across from the openings could enter the pipe. An airline was run inside the stem, to permit jetting of a water sample. At first there was some drilling mud leakage from above through the gravel. Additional gravel was placed in the hole and allowed to settle overnight. This enabled an uncontaminated sample of formation water to be jetted the following day. The sample had a field specific conductance of 360 μmhos (micromhos per cm at 25°C); the chemical analysis of the formation water is given in table 2. Immediately upon completing the water sampling, the air compressor was shut-off, and water-level recovery measurements were taken for the next 100 minutes. These data were used to estimate a transmissivity of 300 $(ft^3/d)/ft$ [2,200 (gal/d)/ft] for the 20 feet of formation opposite the sampled interval. The estimated hydraulic conductivity is 30 $(ft^3/d)/ft^2$ [220 $(gal/d)/ft^2$] assuming development of ten feet of sand within the perforated zone (fig. 3). On April 29 an attempt was made to collect a water sample from the 460-480 foot interval. This effort was unsuccessful, however, presumably because of insufficient submergence of the jetting pipe below the water table.

Well construction

The pilot hole was reamed out to a diameter of 28 inches down to 415 feet, and 24-inch surface casing was set to this depth. The space between the casing and the wall of the hole was completely cemented. The hole below the surface casing was then underreamed to a 30 inch diameter to a depth of 700 feet. Next, 16-inch galvanized slotted casing was set from 455 to 690 feet with blank 16-inch casing set from 690 to 700 feet, and from the top of the screen to land surface. Gravel was placed outside the screen, and the well was then ready for development. Lithology and construction details are shown on figure 4 and are described in tables 1 and 2 respectively.



Resistivity of mud was 11.5 ohm-meter squared per meter at 73°F.

Figure 2.--Dual induction-laterolog of well 21.

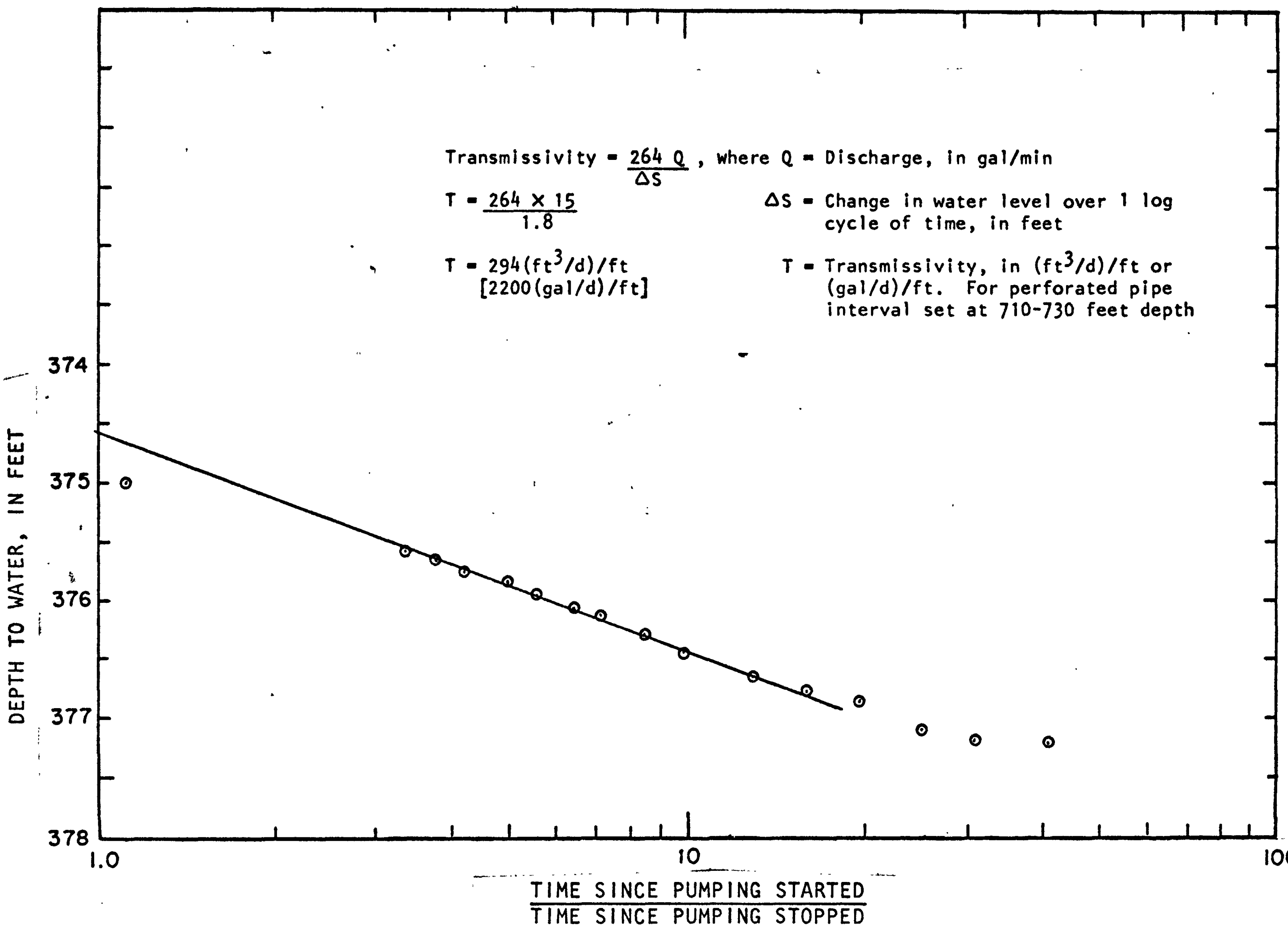


Figure 3.--Water-level recovery in test hole at well-site 21, April 27, 1976.

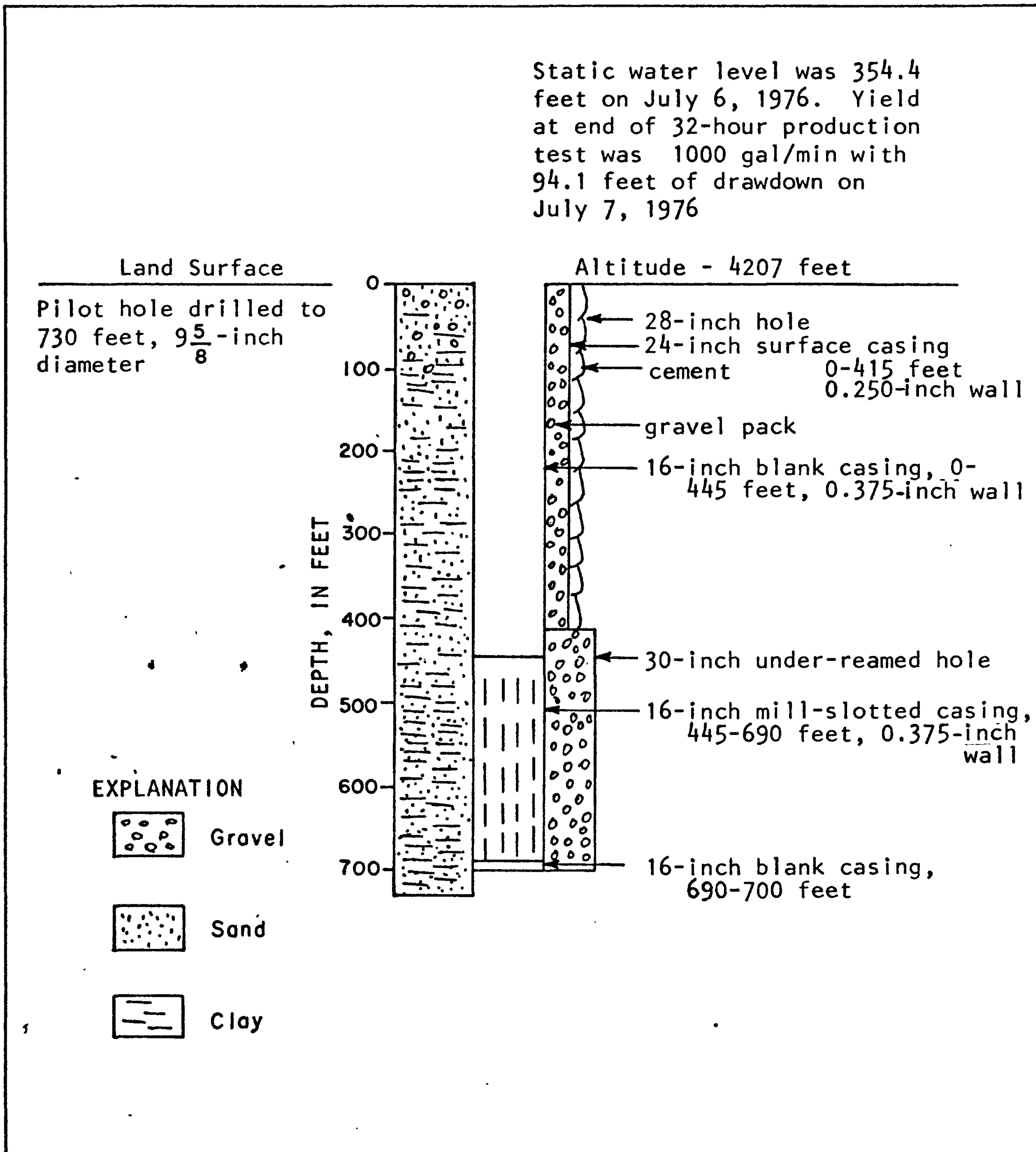


Figure 4.--Construction and lithology of well 21.

Table 2.--Summary record of well 21

Post Headquarters Area
White Sands Missile Range
Dona Ana County, New Mexico

LOCATION: SW¼NE¼SW¼ sec. 19, T.22 S., R.5 E. USGS no. 22.5E.19.323

LATITUDE: 32°22'37" LONGITUDE: 106°28'28" ALTITUDE: 4,207 feet

DEPTH: Drilled to 730 feet, completed well at 700 feet.

DATE COMPLETED: July 1976 DRILLING METHOD: Hydraulic rotary

DRILLING CONTRACTOR: Layne-Western Co., El Paso, Texas

CASING AND HOLE RECORD: Pilot hole diameter 9 5/8-inch to 730 feet. Twenty-eight-inch diameter hole reamed to 415 feet with 24-inch diameter casing cemented in place; 30-inch diameter, underreamed hole from 415 to 700 feet. Set casing string (all 16-inch diameter) consisting of 0-455 feet blank casing, 455 to 690 feet galvanized mill-slotted casing and 690-700 feet blank casing. Slots are 1/8-inch by 2 3/4-inch, well is gravel packed.

YIELD: Step-drawdown production test run for 32 hours. Final yield was 1,000 gal/min with 94.1 feet of drawdown on July 7, 1976. Recovery test made after completion of pumping.

NONPUMPING WATER LEVEL: 354.4 feet on 7-6-76
351.4 feet on 4-12-77

CHEMICAL QUALITY:

Depth interval (feet)	Conductance (micromhos)	Sulfate (mg/L)	Chloride (mg/L)	Date
710-730	347	75	8.4	4-27-76
455-690	305	48	8.1	7- 8-76

FORMATION LOGS: (1) Sample description; (2) Dual induction-laterolog; (3) Formation density log; (4) Microlog-caliper; (5) Resistivity log.

GEOLOGIC SOURCE: Bolson fill

USE AND REMARKS: Water-supply well for Post Headquarters.

Development and test pumping

The development program for this well consisted of three phases. Phase 1, which began on June 28, consisted of adding 150 pounds of a mud-cutting chemical "Laynite"[2] to the well (in a mixture of two

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[2]The use of the brand name in this report is for identification purposes only and does not imply endorsement by the U.S. Geol. Survey.

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pounds of chemical per gallon of water), flushing with 150 gallons of water, and using a surge block to surge for 10 cycles throughout the screened section. This procedure was repeated until 900 pounds of Laynite had been added. Approximately 1,000 gallons of water was then added and surging was continued for one hour. The well was then rested, but with surging for 10 cycles at the end of each hour during the next 8-hour period. Following the surging, the well was bailed continuously for 8 hours.

Phase 2 began immediately after phase 1 ended, and was identical to phase 1. Following phase 2, a variable capacity test-pumping unit was installed.

Phase 3 was very similar to phases 1 and 2 except that instead of using a surge block to agitate the water-chemical mixture, the test pump was used to lift a column of water up the casing, and was then shut off allowing the column of water to drop, thereby causing agitation and back pressure. Instead of bailing as done in previous phases, the well was pumped for short intervals. After an 8-hour rest period, a sequence was begun in which the water was surged eight times and then pumped at a discharge of 800 gal/min for 30 minutes; the surging was then begun again and the cycle was repeated for a total of 8 hours (White Sands Missile Range Specifications for Water Wells, 1976, U.S. Army Corps of Engineers, Fort Worth, Texas, written commun.).

Test pumping began on July 6 after a 3-day rest period following development. The geophysical logs and recovery test data gathered previously were evaluated. The results indicated a lower transmissivity of the aquifer than had been anticipated. Therefore, a decision was made not to use the original discharge rates as listed in the specifications, but rather to pump at rates of 500, 700, 900, and 1,000 gal/min. Each rate was for an 8-hour period of pumping, with no shutdown until the end of the 32-hour pumping period. There was a deviation from the pumping schedule during the first 2 hours of the pumping test, as the initial rate of discharge was set at about 740 gal/min. This was caused by an erroneous reading of the discharge manometer when originally setting the discharge rate. However, the error presented no major obstacle to the interpretation of data. All other phases of the test pumping went smoothly and according to specifications. Measurements of pumping level, discharge, and specific conductance were made during pumping. Immediately after the test pumping was completed, the pump was shut off and water-level recovery measurements were taken continuously for the next 24 hours. Figure 5 shows a graphic plot of depth to water in the pumped well with the corresponding time of measurement, and also specific capacity and pumping rate. The specific capacity decreased slightly with time (a normal response), but with no sudden changes that could indicate increased well loss due to well-construction problems. Specific capacity after 6 hours of pumping was 14 (gal/min)/ft of drawdown, and at the end of the 32-hour test the figure was slightly below 11 (gal/min)/ft.

Figure 6 shows the depth to water in the pumped well versus the logarithm of time since pumping started. Figure 7 shows the depth to water in the pumped well versus the logarithm of the ratio of the time since pumping started to the time since pumping stopped (recovery test). These two plots are used to estimate the transmissivity of the part of the aquifer contributing water to the pumped well. The slope of lines connecting the plotted points varies continuously, due to aquifer conditions, the position of the perforated interval, and variations in discharge. The aquifer is composed of alternating layers of sand and clay; the sand layers easily transmit water, whereas the clay layers are much less permeable but may store considerable water and allow vertical leakage of water into the sand units. The perforated interval begins almost 100 feet below the water table, but the pumping level during this test dropped to within 7 feet of the perforations. It is suggested that aquifer units in the deeper parts of the perforated zone behave as a confined aquifer, whereas those units near the top of the perforated interval may react as a confined aquifer during short periods of pumping, but tend to behave as an unconfined or water-table aquifer after long periods of pumping. These conditions make estimation of transmissivities difficult.

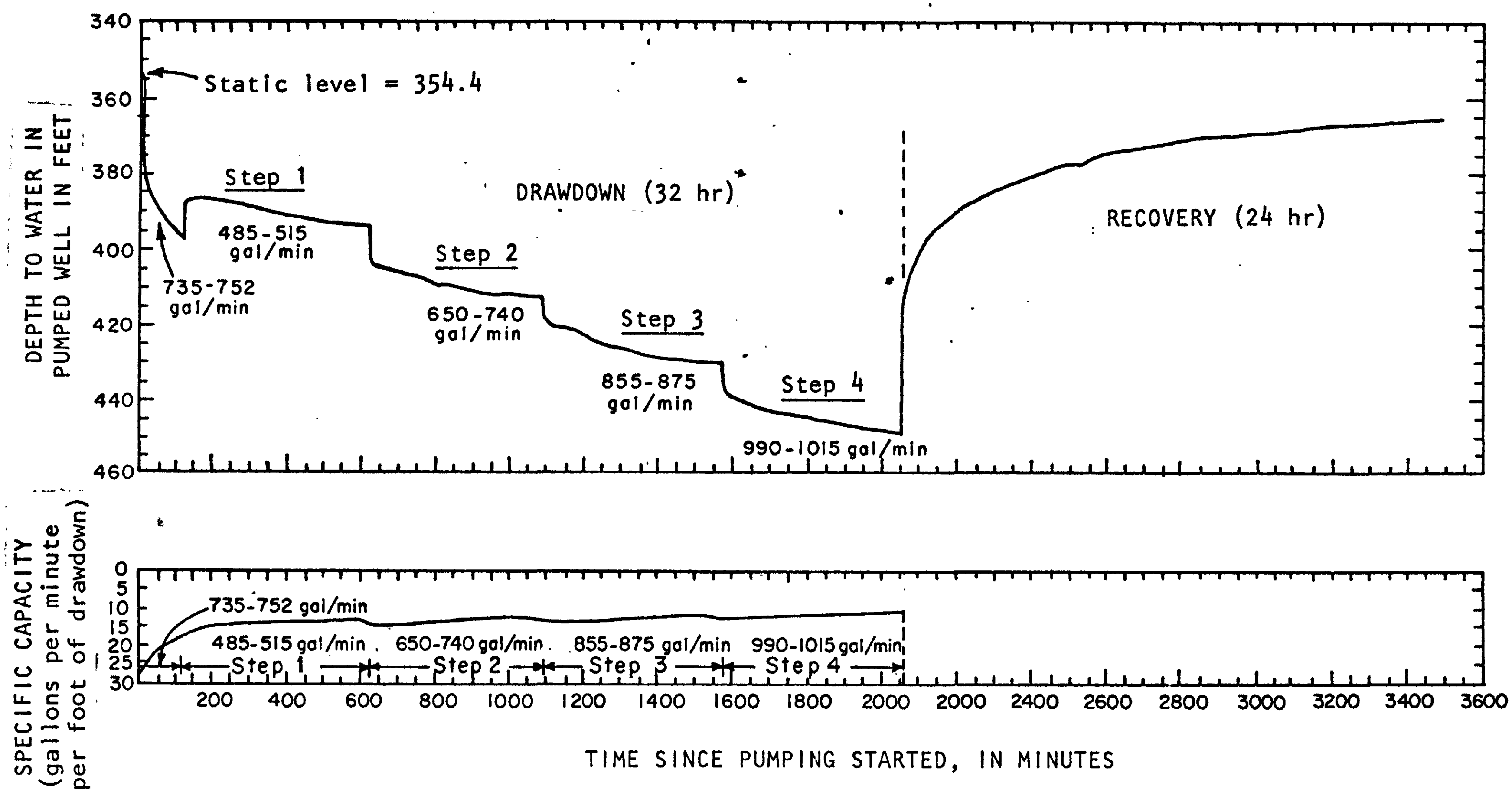


Figure 5.--Drawdown, recovery, and specific capacity in well 21, July 6-9, 1976.

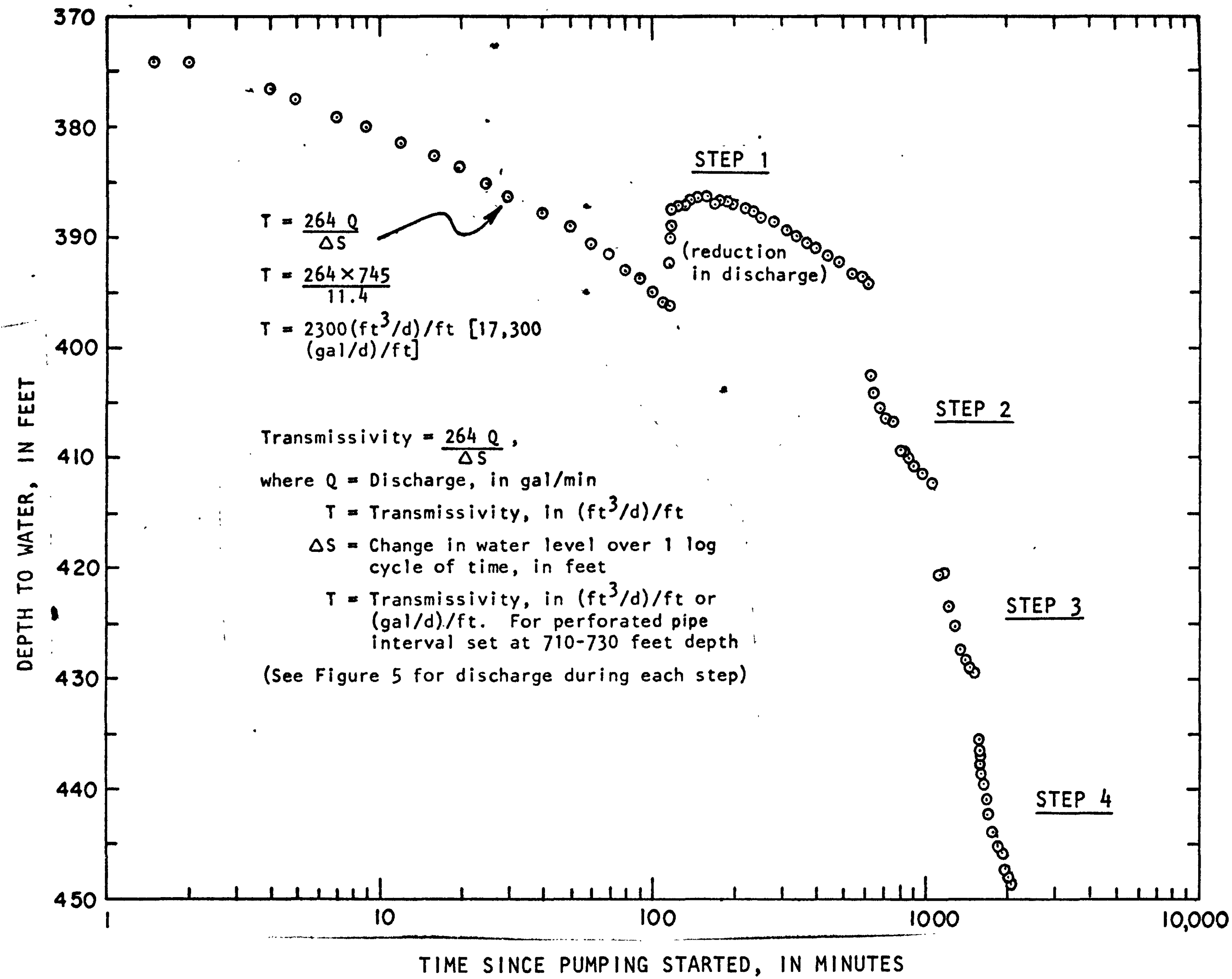


Figure 6.--Drawdown in well 21, July 6-8, 1976.

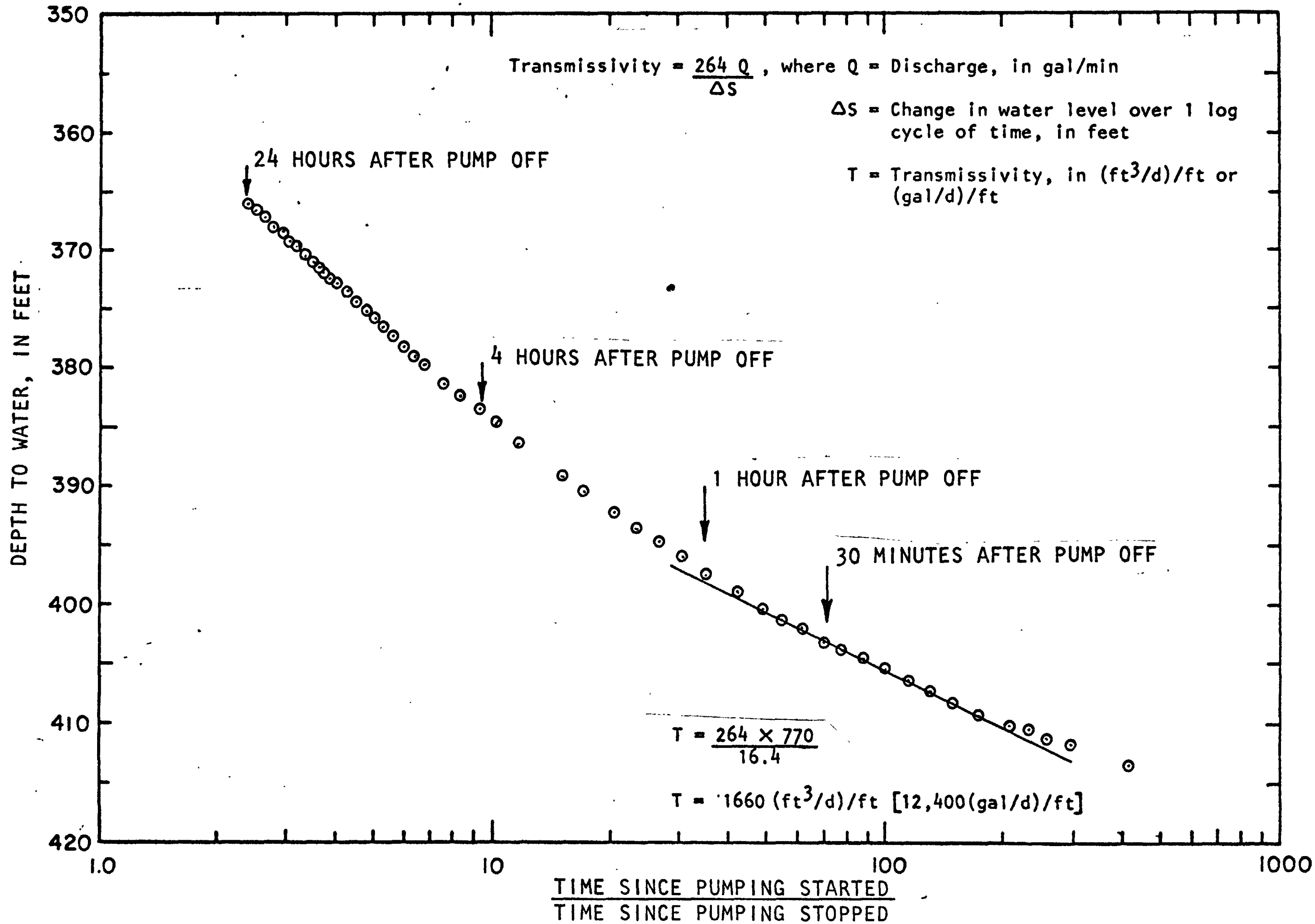


Figure 7.--Water-level recovery in well 21, July 8-9, 1976.

It is generally believed that the initial or early measurements of water-level changes made during pumping tests more accurately reflect aquifer response; therefore, calculations of transmissivities are based on the early part of pumping-test data. Transmissivity calculated during drawdown is about 2,300 $(ft^3/d)/ft$ [17,300 (gal/d)/ft], and the transmissivity calculated from recovery data is 1,660 $(ft^3/d)/ft$ [12,400 (gal/d)/ft]. Transmissivity calculated from drawdown data for this test is considered more representative than that which is calculated from the recovery data because four different pumping rates need to be considered in the recovery calculations. The transmissivity calculated from drawdown data divided by the total thickness of sand in the perforated interval of about 94 feet gives an average hydraulic conductivity of 25 $(ft^3/d)/ft^2$ [180 $(gal/d)/ft^2$]. This compares generally with the hydraulic conductivity calculated during the water-sampling procedure from the 710-730 foot interval of 15 $(ft^3/d)/ft^2$ [(110 $(gal/d)/ft^2$], a zone which contains both sand and clay. Water-level decline in test hole T-5, located about 4,500 feet northeast of well 21 was less than 0.1 foot during pumping.

Another aquifer test was attempted on April 12, 1977, after the well was equipped with pump and motor. However, the test was terminated after pumping 352 minutes when a circuit breaker opened. Results of the test were adversely affected by the pumping of well 22 the previous day; however, the indicated transmissivity was in the range of 2,000 $(ft^3/d)/ft$ [15,000 (gal/d)/ft]. Specific capacity after pumping six hours was about 16 (gal/min)/ft.

Water quality

During the production test, the specific conductance of the water was monitored and water samples collected. The conductance was 280 μmhos at beginning of pumping, and 310 μmhos near the end of the test. Results of the chemical analysis of water taken during the pumping test are shown in table 3. The concentration of major constituents in all four analyses is very similar, and indicates no significant change in water quality during the test. Comparison of analyses from the sample taken at a depth of 710-730 feet in the pilot hole (table 3) with the last sample during the production test (table 3, sample taken at 0530, July 8) shows large differences in quality. The formation water at the 710-730 foot interval is a sodium bicarbonate sulfate type, though the water from the entire screened interval (415-690 feet) is a sodium calcium bicarbonate type. Both samples contain less than 10 mg/L chloride; dissolved solids are about the same, 217 and 225 mg/L. Comparison of the analyses with recommended limits for municipal waters shows no constituent which exceeds the recommended standards.[3/]

[3/] U.S. Environmental Protection Agency, 1969, Manual for evaluating Public Drinking Water supplies: U.S. Environmental Protection Agency, 1975 reprint, Office of Water and Hazardous Materials, Water Supply Division, Report 430-9-75-011, p. 7.

Well 22

Drilling began July 9, 1976, on WSMR well 22, which is 2,000 feet (about 0.4 mile) north of well 21 (fig. 1). The design, testing, and development specifications were about the same as those for well 21. The test hole was continuously monitored during drilling by the U.S. Geological Survey, and a geologic log was made (table 4). The lithology was much the same as in well 21, with some increase in the amount of sand. The test hole drilling was completed on July 15 at 730 feet. A dual induction-laterolog was made in the hole and is shown in figure 8.

Table 3.--Chemical analyses of water from wells 21 and 22
[Analyses by Geological Survey, United States Department of the Interior.]

[Amounts in milligrams per liter (mg/L), micrograms per liter (μg/L), or as indicated.]

Well number	Well 21	Well 21	Well 21	Well 21	Well 21	Well 22	Well 22
Laboratory number	135050	208055	208056	208054	205019	286022	117008
Date of collection	4-27-76	7-6-76	7-7-76	7-7-76	7-8-76	8-27-76	8-28-76
Time of collection	1745	2050	0110	1320	0530	0115	0658
Depth of interval perforated (ft)	710-730	455-690	455-690	455-690	455-690	459-725	459-725
Remarks	Test hole						
Alkalinity, total, (as $CaCo_3$)(mg/L)	77	95	102	101	95	126	90
Arsenic (dissolved)(As)(μg/L)	1	-	-	-	2	5	-
Barium (dissolved)(Ba)(μg/L)	0	-	-	-	100	0	-
Bicarbonate (HCO_3)(mg/L)	94	116	124	123	116	154	110
Boron (dissolved)(B)(μg/L)	50	-	-	-	20	30	20
Cadmium (dissolved)(Cd)(μg/L)	0	-	-	-	1	0	-
Calcium (dissolved)(Ca)(mg/L)	12	25	25	25	29	17	18
Carbonate (CO_3)(mg/L)	0	0	0	0	0	0	0
Chloride (dissolved)(Cl)(mg/L)	8.4	7.3	7.4	7.8	8.1	11	12
Chromium (dissolved)(Cr)(μg/L)	0	-	-	-	0	0	-

Table 3.--Chemical analyses of water from wells 21 and 22 - Continued

Well number - Continued	Well 21	Well 21	Well 21	Well 21	Well 21	Well 22	Well 22
Chromium (hexavalent)(µg/L)	0	-	-	-	0	0	-
Copper (dissolved)(Cu)(µg/L)	1	-	-	-	2	2	-
Fluoride (dissolved)(F)(mg/L)	.6	-	-	-	.4	.8	.7
Hardness (noncarbonate)(mg/L)	0	0	0	0	5	0	0
Hardness (total)(mg/L)	34	90	88	89	100	51	54
Iron (dissolved)(Fe)(µg/L)	10	-	-	-	140	10	20
Lead (dissolved)(Pb)(µg/L)	1	-	-	-	9	1	-
Lithium (dissolved)(Li)(µg/L)	-	-	-	-	10	-	-
Magnesium (dissolved)(Mg)(mg/L)	1.0	6.6	6.3	6.5	6.6	2.0	2.3
Manganese (dissolved)(Mn)(µg/L)	20	-	-	-	20	0	0
Mercury (dissolved)(Hg)(µg/L)	.0	-	-	-	.0	.0	-
Nitrate plus Nitrite as Nitrogen (dissolved)(mg/L)	.60	-	-	-	.91	.82	.88
pH (field value)	8.2	7.0	7.5	7.5	7.5	7.5	7.4
Ortho Phosphate as Phosphorous (dissolved)(mg/L)	.01	-	-	-	1.1	11	2.3

Table 3.--Chemical analyses of water from wells 21 and 22 - Concluded

Well number - Concluded	Well 21	Well 21	Well 21	Well 21	Well 21	Well 22	Well 22
Phosphate (dissolved)(Ortho)(mg/L)	0.03	-	-	-	3.4	34	7.1
Potassium (dissolved)(K)(mg/L)	1.5	-	-	-	1.9	1.6	1.5
Residue, calculated sum (dissolved)(mg/L)	229	-	-	-	232	301	249
Residue (dissolved 180°C)(mg/L)	217	-	-	-	225	346	-
Sodium Absorption Ratio (SAR)	4.5	1.3	1.5	1.5	1.2	3.7	3.5
Selenium (dissolved)(µg/L)	1	-	-	-	1	1	-
Silica (dissolved)(SiO_2)(mg/L)	21	-	-	-	45	27	26
Silver (dissolved)(Ag)(µg/L)	0	-	-	-	0	0	-
Sodium (dissolved)(Na)(mg/L)	60	28	33	32	28	60	59
Sodium (percent)	78	-	-	-	37	71	70
Specific Conductance, field (micromhos per cm at 25°C)	360	280	310	310	300	420	340
Specific conductance, laboratory, (micromhos per cm at 25°C)	347	293	311	313	305	447	-
Sulfate (dissolved)(SO_4)(mg/L)	75	34	34	49	48	68	64
Temperature (°C)	25.5	25.0	24.0	26.0	25.0	28.0	28.5
Zinc (dissolved)(Zn)(µg/L)	20	-	-	-	150	80	-

Table 4.--Summary lithologic log of Well 22

[Numbers and letters in parentheses, such as (10 R 4/6,) refer to the rock color chart, distributed by the Geological Society of America, New York, N. Y.]

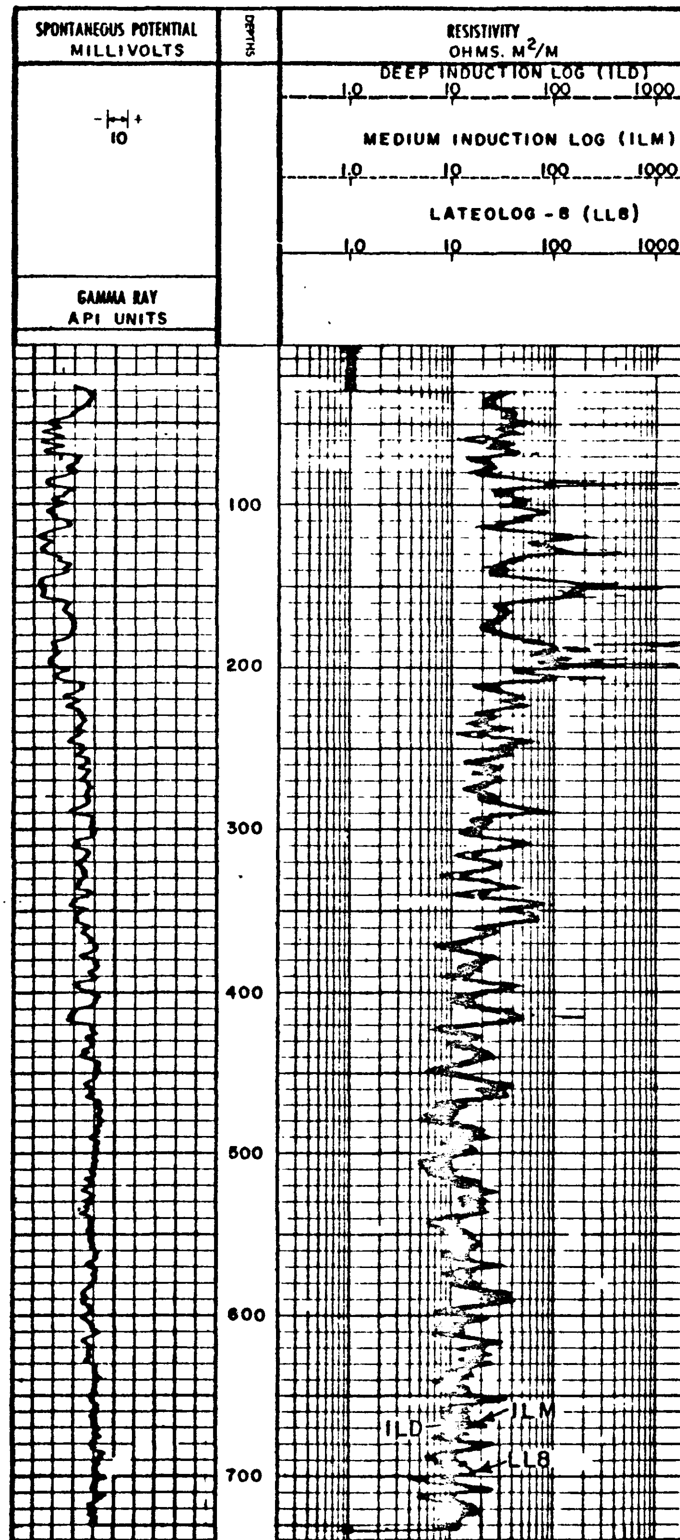
Sample description	*Thickness (feet)*	*Depth (feet)*
Sand, moderate brown (5 YR 4/4), very coarse to fine-grained, (mostly fine grained), subangular to rounded grains. Sand is about 45 percent quartz, ±45 percent feldspar, and 10 percent dark minerals, including many biotite flakes. Lower portion is finer grained, and has a more reddish tint ----------	30	30
Sand and gravel, color ranges from grayish-orange (10 YR 7/4) to moderate yellowish-brown (10 YR 5/4), very coarse to fine-grained sand (mostly very coarse), subangular to rounded. Quartz content about 30 percent, feldspar 60 percent, and 10 percent dark igneous rock fragments and some biotite flakes. Gravel less than ¼ inch in diameter (makes up 20 percent of sample). Some clay lenses near bottom ----------	50	80
Sand and gravel, with some silt; color similar to above. Sand has continuous size range from fine to very coarse; gravel up to ¼ inch in diameter. Particles are subangular to rounded. Mineral content resembles previous intervals ----------	23	103
Sand, gravel, and clay. Sand and gravel very similar to above, but with some clay lenses. Clay constitutes as high as ±50 percent of sample at times. Clay is soft, sticky, and highly soluble; its color is light brown (5 YR 6/4) with a slight reddish hue ----------	41	144
Gravel and sand. Mostly gravel of similar composition as before, up to ¼ inch in diameter. Sand is very coarse, subangular to rounded, and of same mineral composition as before. Gravel is monzonite or latite composition ----------	16	160

Table 4.--Summary lithologic log of Well 22 - Continued

Sample description	*Thickness (feet)*	*Depth (feet)*
Clay, sand, and gravel; gravel up to ¼ inch in diameter, of similar mineral composition as before; sand ranges from very fine to very coarse, and is subangular to well rounded. Clay is slightly softer and more soluble than clay previously encountered. Color of clay is a pale yellowish-brown (10 YR 6/2). In places clay is about 60 percent of sample. Some lenses of clay encountered in this interval were reddish brown (5 YR 5/6) -------------------------	22	182
Sand, appearance same as previous samples but size is medium to very coarse. Mineral content same as before. Slight trace of clay ----------------------	26	208
Sand, gravel, and clay; sand very similar to above in size and composition. Gravel less than ¼ inch in diameter. Clay 10 percent of sample, and is very soft and soluble; color light brown (5 YR 5/6) with slight reddish tint. Clay occurs in lenses, especially 270-284 feet --------------------------------------	97	305
Gravel, sand, and clay. Gravel is greater than ¼ inch in diameter and made up of latite or monzonite composition. Sand is very fine to very coarse-grained and of similar composition as above. Gravel ±50 percent of sample, sand ±40 percent, and clay about 10 percent --	33	338
Sand, gravel, and clay. Sand very fine to very coarse, subangular to rounded, of same mineral composition as previously encountered. Sand ±50 percent of sample. Gravel ranges from very small to over ¼ inch in diameter and is ±30 percent of sample. Clay is very soft, soluble, sticky, ranging in color from light brown (5 YR 5/6) to moderate brown (5 YR 4/4). Clay found in lenses which, in some places, consists of 40-50 percent of interval ----------------------	54	392

Table 4.--Summary lithologic log of Well 22 - Concluded

Sample description	*Thickness (feet)*	*Depth (feet)*
Sand, gravel, clay, and silt. Same mineralogy as before. Sand is very fine to very coarse, with traces of gravel (up to ¼ inch in diameter) and silt. Clay ranges from 10 to 40 percent throughout the interval, and ranges in color from light brown (5 YR 5/6) to moderate brown (5 YR 4/4) ------------	74	466
Sand, clay, and gravel. Same mineralogy as before. Sand very fine to very coarse. Many lenses of gravel and clay. The overall color of sample is moderate yellowish-brown (10 YR 5/4). Clay is very soluble but estimated to be more abundant than previous sample --------------------------------	50	516
Clay, sand, gravel, and silt. Same mineralogy as before. Clay is of two colors--one a moderate brown (5 YR 4/4) with a pinkish tint, and the other a light brown (5 YR 6/4). The latter is more abundant. Clay content is about 20 percent at top of interval and increases to about 50 percent toward the bottom. Less gravel than previous sample. Traces of silt --------------------------------------	68	584
Sand, gravel, and clay. Mineralogy same as before. Size ranges from silt to very coarse sand with some ¼-inch diameter gravel. Subangular to rounded. Traces of clay ----------------------------	56	640
Sand, fine to very coarse. Mineral composition same as before. Clay is about 15 percent and a light brown (5 YR 6/4). Traces of gravel --------	60	700
Sand, gravel, and clay. Sand is same as above; gravel has many pebbles up to ¼-inch diameter. The clay is of two types--one a light brown (5 YR 6/4) found predominantly in the top half of the interval; the other a moderate brown (5 YR 4/4) and found mostly at bottom of interval. The clay content increases from ±20 percent at top to ±40 percent at bottom ----------------------------	30	730



Resistivity of mud was 3.29 ohm-meter squared per meter at 82°F.

Figure 8.--Dual induction-laterolog of well 22.

Well construction

After the test hole was drilled and logged, the well was reamed to a diameter of 28 inches to 426 feet, and 24-inch surface casing was set to this depth. The space between the casing and the wall of the hole was cemented. The hole below the surface casing was underreamed to a diameter of 30 inches and 16-inch diameter mill-slotted casing was set from 459 to 725 feet. Blank casing of 16-inch diameter extended from the top of the screen to land surface. The annular space outside the screen was filled with gravel. Lithology and construction details are shown on figure 9, and are described in tables 4 and 5.

Development and test pumping

On August 16, the development period began on well 22. It consisted of the same three phases with the same procedures and quantities as described for well 21. The development period was completed by August 25. After a 24-hour rest period, test pumping began on August 26. As on well 21, this was to be a four-step drawdown test. The discharge rates selected (for 8-hour intervals each) were about 530, 780, 990, and 1,150 gal/min. Two plots showing depth to water during pumping versus time, and specific capacity versus time, are shown on figure 10. A semilogarithmic plot of depth to water versus time of pumping is shown on figure 11. Figure 12 shows a plot of the recovery water level versus the logarithm of the ratio of the time since pumping started to the time since pumping stopped. It is believed that early measurements of drawdown or recovery water-levels are more representative of aquifer performance to pumping stresses. Transmissivity calculated from drawdown data is about 3,920 (ft^3/d)/ft [29,300 (gal/d)/ft] and transmissivity based on recovery measurements is 2,870 (ft^3/d)/ft [21,500 (gal/d)/ft]. Leakage from adjacent clay units along with possible changes in aquifer conditions from confined to unconfined, and variations in the pump discharge rates caused changes in the drawdown or recovery measurements, which, in turn, produced the nonlinear data plots. Specific capacity for well 22 was about 21 (gal/min)/ft after 6 hours, and about 15 (gal/min)/ft at the end of the 32-hour test--somewhat greater than those for well 21 (figs. 5 and 10). Both figures show only gradual increases in well losses with increases in discharge.

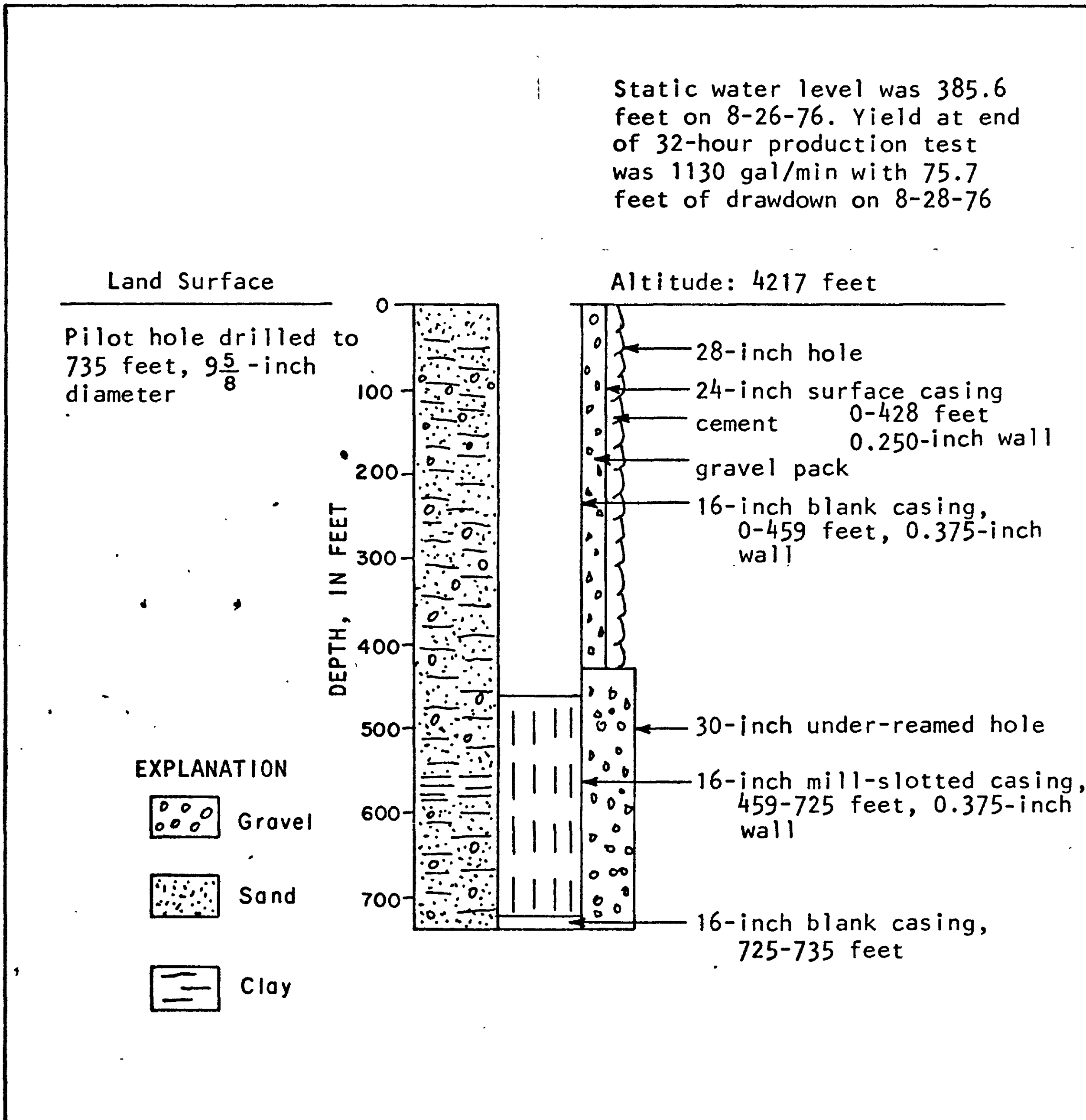


Figure 9.--Construction and lithology of well 22.

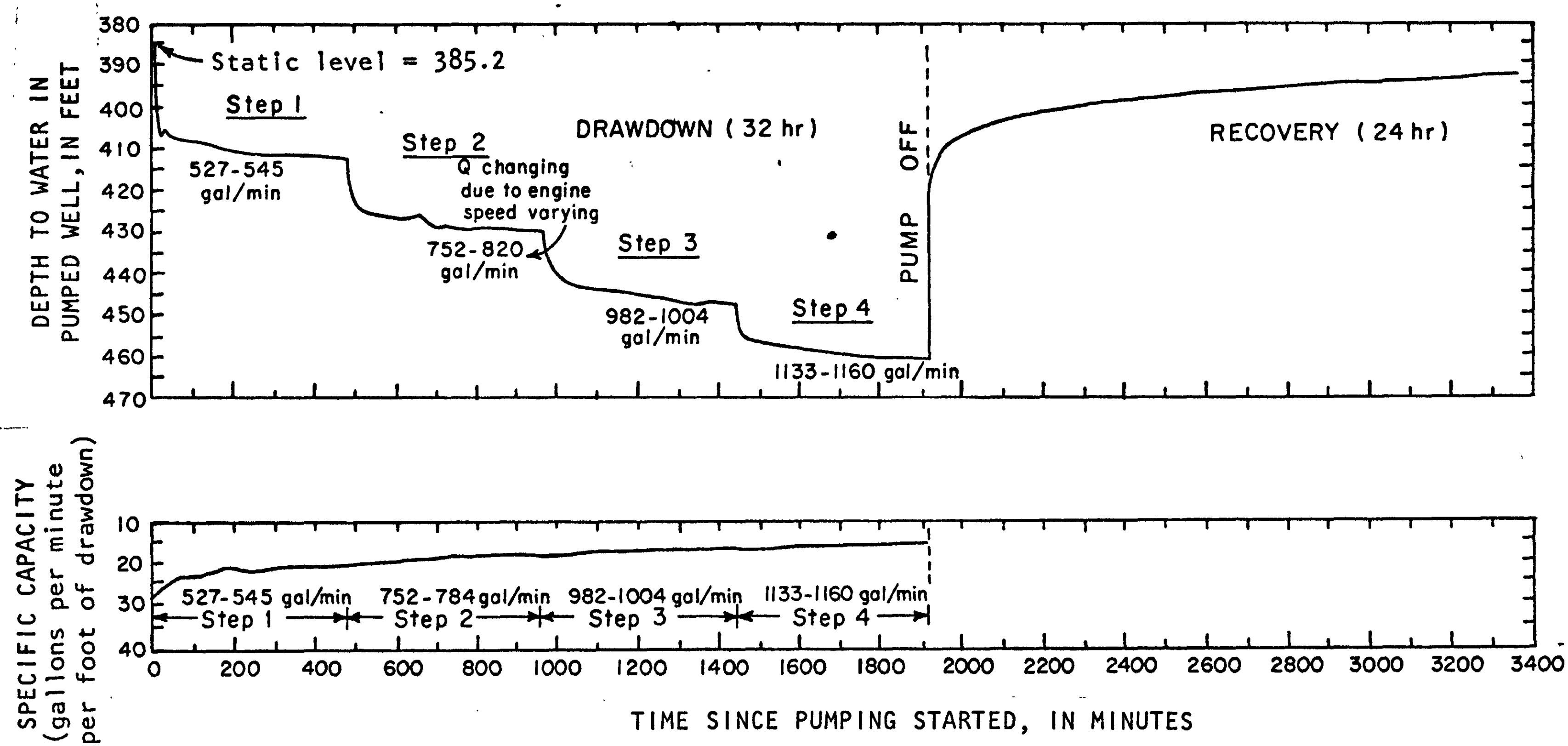


Figure 10.--Drawdown, recovery, and specific capacity in well 22, August 26-29, 1976.

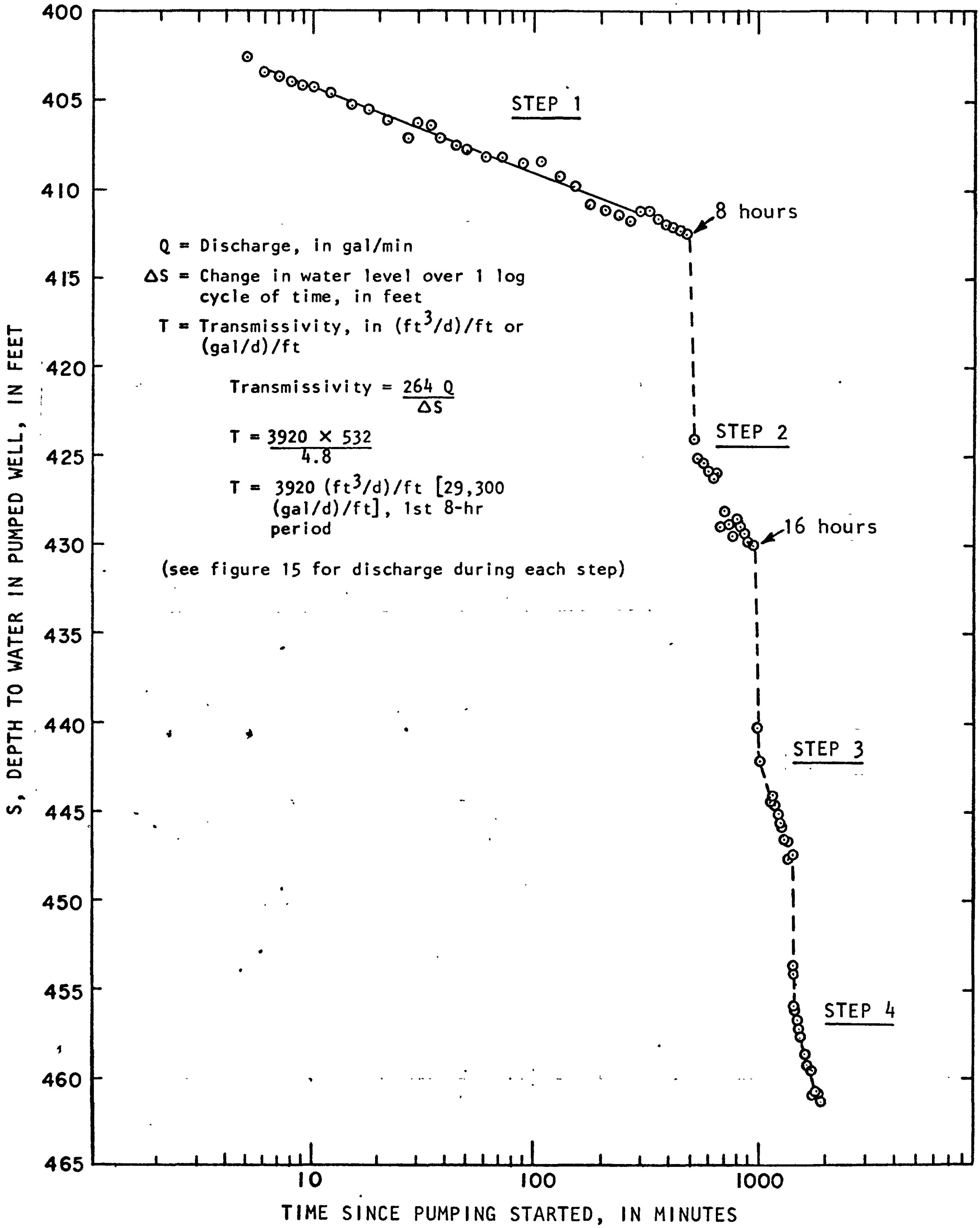


Figure 11.--Drawdown in well 22, August 26-28, 1976.

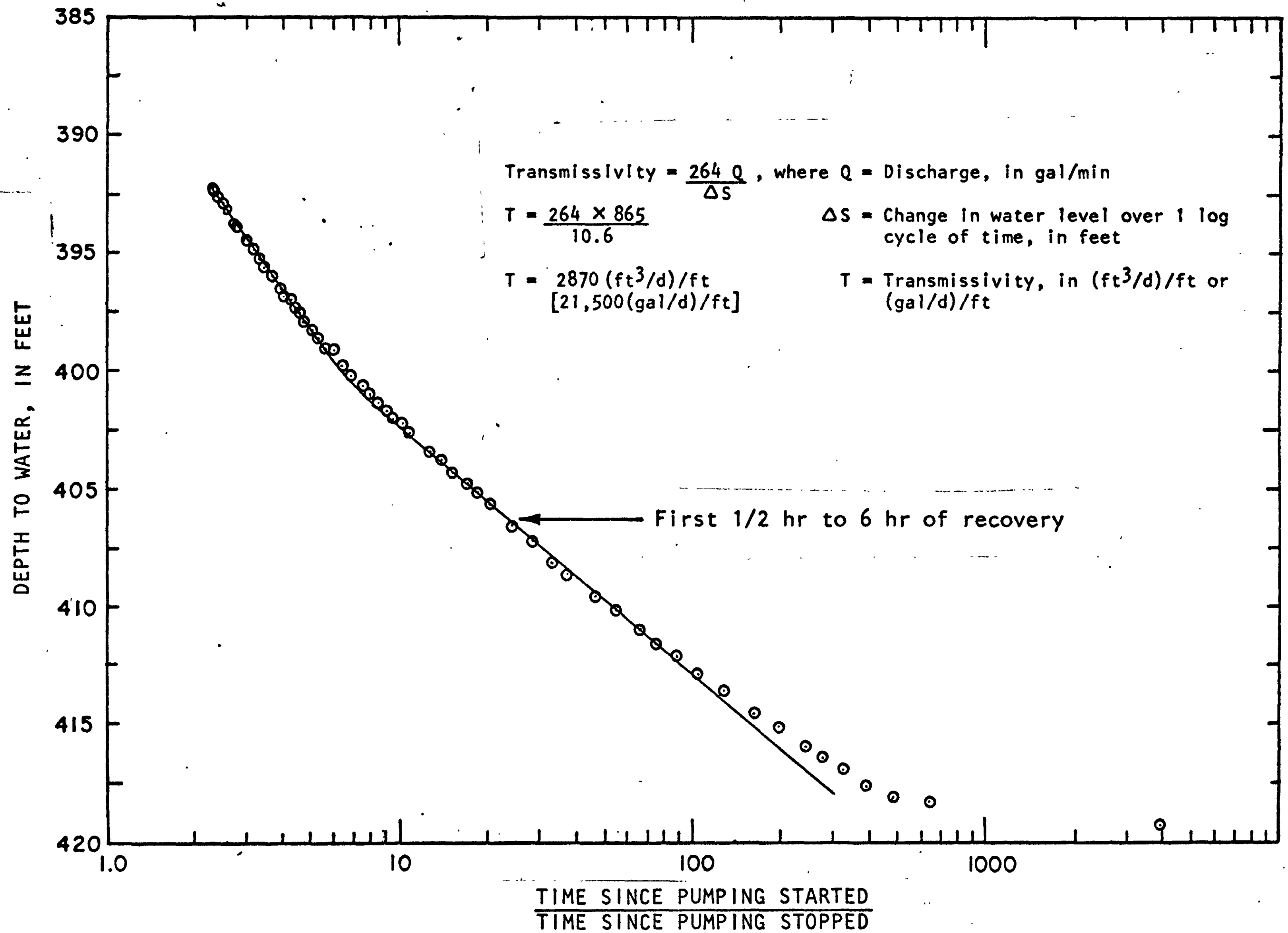


Figure 12.--Water-level recovery in well 22, August 28-29, 1976.

Table 5.--Summary record of well 22

Post Headquarters Area
White Sands Missile Range
Dona Ana County, New Mexico

LOCATION: NW¼SE¼NW¼ sec. 19, T.22 S., R.5 E. USGS no. 22.5E.19.141

LATITUDE: 32°22'56" LONGITUDE: 106°28'26" ALTITUDE: 4,217 feet

DEPTH: Drilled and completed at 733 feet

DATE COMPLETED: August 1976 DRILLING METHOD: Hydraulic rotary

DRILLING CONTRACTOR: Layne-Western Co., El Paso, Texas

CASING AND HOLE RECORD: Pilot hole of 9 5/8-inch diameter to 735 feet. Twenty-eight-inch diameter hole reamed to 428 feet with 24-inch diameter casing cemented in place. Thirty-inch diameter under-reamed hole from 428 to 735 feet. Set casing string (all 16-inch diameter) consisting of 0-459 feet blank casing, 459-725 feet galvanized mill slotted casing, and 725-735 feet blank casing. Slots are 1/8-inch by 2 3/4-inch; well is gravel packed.

YIELD: Step-drawdown production test ran for 32 hours. Final yield was 1,130 gal/min with 75.7 feet of drawdown on August 28, 1976. Recovery test made after completion of pumping.

NONPUMPING WATER LEVEL: 385.6 on 8-26-76
370.5 on 4-11-77

CHEMICAL QUALITY:

Depth interval (feet)	Conductance (micromhos)	Sulfate (mg/L)	Chloride (mg/L)	Date
459-725	447	68	11	8-27-76

FORMATION LOGS: (1) Sample description; (2) Dual induction-laterolog; (3) Formation density log; (4) Microlog-caliper

GEOLOGIC SOURCE: Bolson fill

USE AND REMARKS: Water-supply well for Post Headquarters.

The design turbine pump and electric motor were installed after the production test in August. On April 11, 1977, a second pumping test was conducted on well 22. Drawdown and recovery graphs for this test are shown on figures 13 and 14. Transmissivity calculated from drawdown data is 4,610 $(ft^3/d)/ft$ [34,500 (gal/d)/ft], and from recovery data is 4,560 $(ft^3/d)/ft$ [34,100 (gal/d)/ft]. Specific capacity after 8 hours of pumping is about 19.7 (gal/min)/ft. The results of the April 11 test are believed to be more reliable because discharge was relatively constant during pumping. The transmissivity around well 22 is estimated to be about 4,600 $(ft^3/d)/ft$ [34,400 (gal/d)/ft]. This value, when divided by the total sand thickness in the perforated interval (about 110 feet), gives a hydraulic conductivity of about 42 $(ft^3/d)/ft^2$ [310 $(gal/d)/ft^2$]. The drilling at well 22 was easier and faster than at well 21; the aquifer is probably less cemented around well 22.

Water-level measurements were made in four other wells and test holes during the August pumping test of well 22. The water level in well 21 declined about 1.3 feet during the test period, borehole B-10 showed a decline of 0.26 foot, and test hole T-5 had a 0.15 foot possible decline. No decline was observed in borehole B-12.

Water quality

Water samples were taken at selected times during the pumping period; results of chemical analyses are shown in table 3. Specific conductance was monitored during pumping; it ranged from 340 to 450 μmhos. The lower conductance occurred toward the end of the test. The sample which was taken near the beginning of the production test contained unusually large amounts of orthophosphate. A sample taken near the end of pumping demonstrated considerable reduction in orthophosphate, although the concentration remained at a somewhat high level. It is believed that some amount of Laynite was present in the formation at the time of sampling. The analysis also indicates the water is a sodium bicarbonate type, which is different than water from well 21. Dissolved solids are 301 mg/L, also greater than in water from well 21.

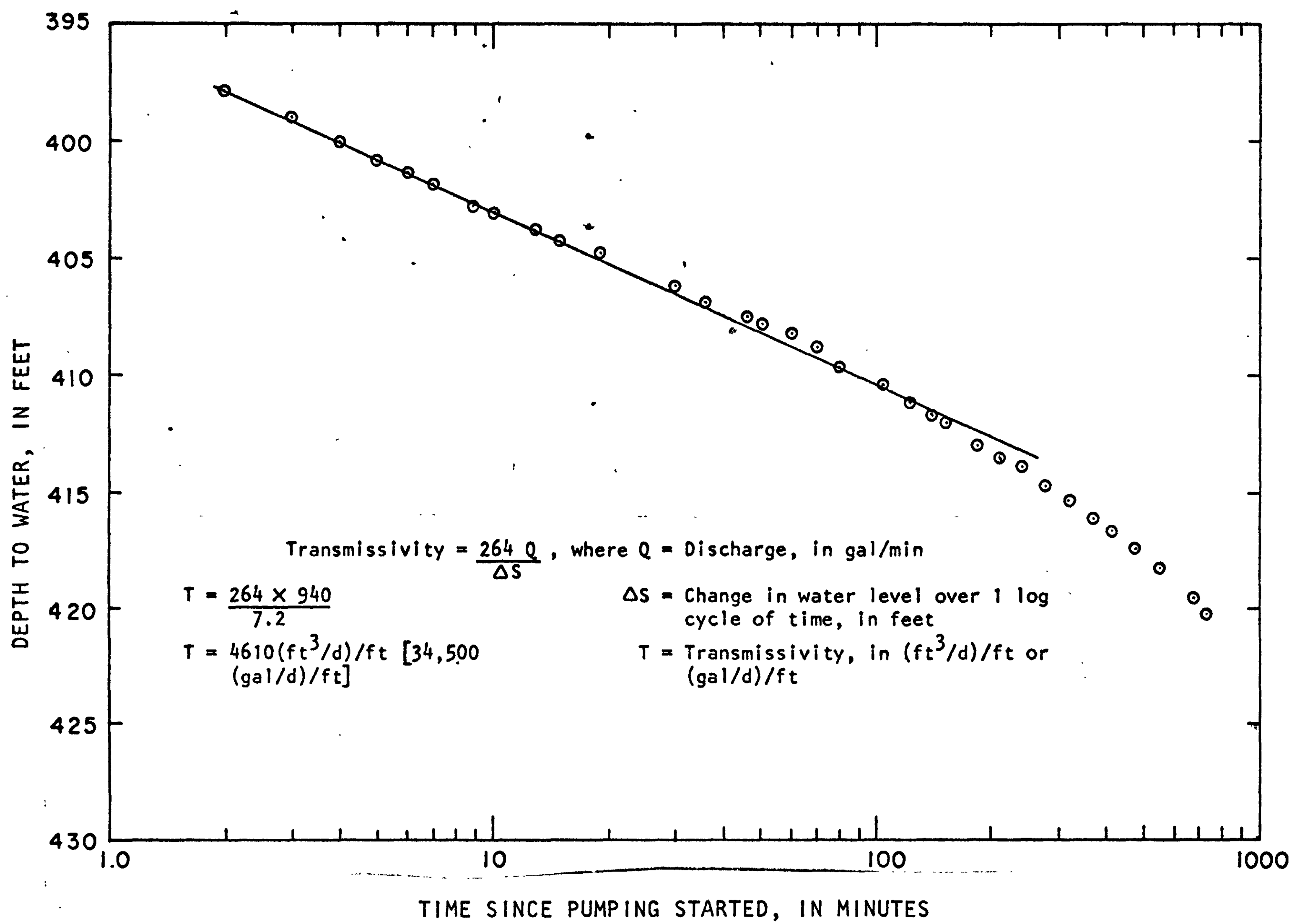


Figure 13.--Drawdown in well 22, April 12, 1977.

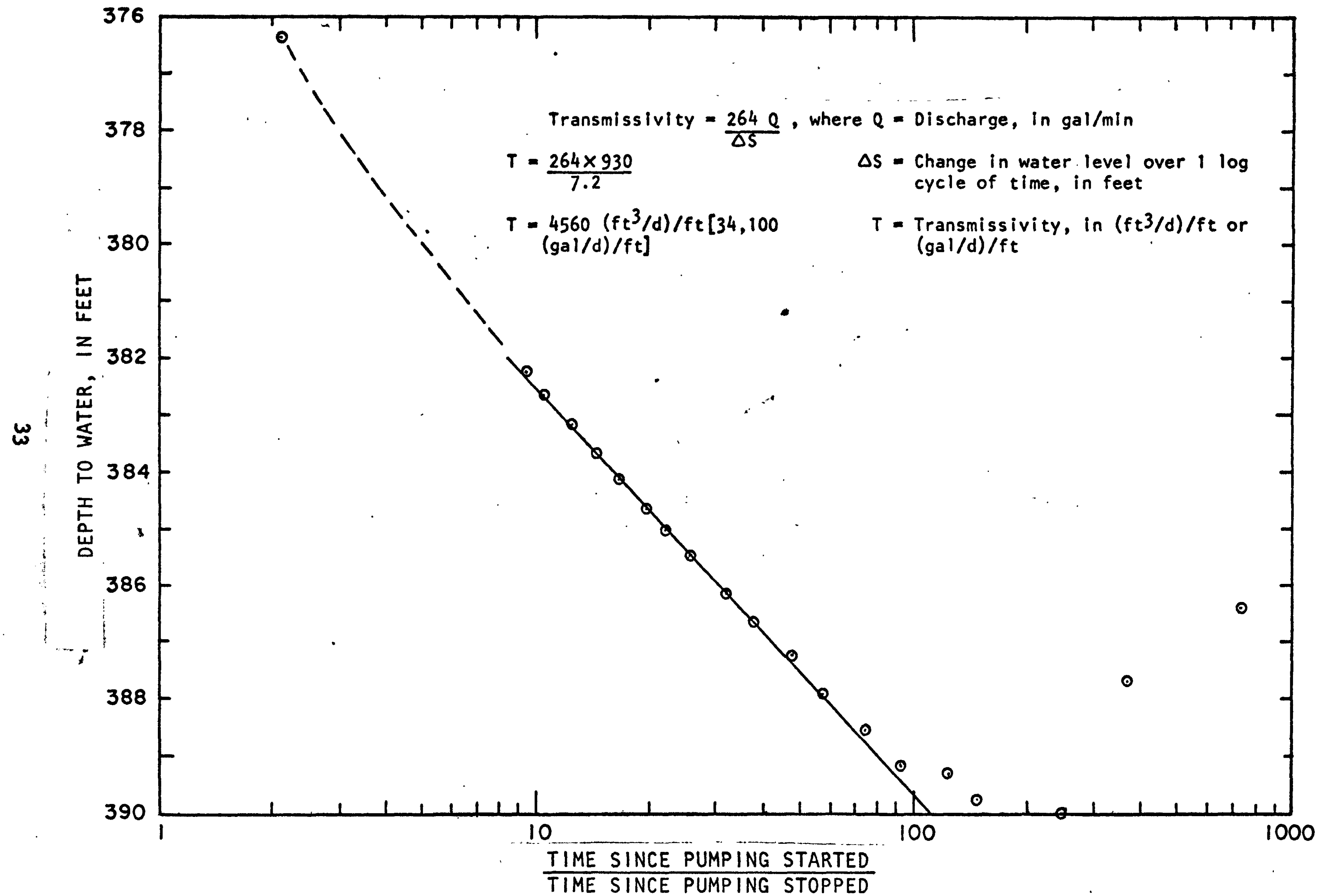


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Figure 14.--Water-level recovery in well 22, April 12, 1977.

Conclusions

Conclusions based on the testing of the wells are listed below:

1. The water from both wells is of good quality and suitable for municipal use. Dissolved-solids content for well 21 is 232 mg/L and for well 22 it is 301 mg/L. Total hardness is 100 mg/L and 51 mg/L, respectively.

2. The aquifer is not as permeable in this area (especially around well 21) as it is to the west in the center of the headquarters well field. Cementation of sands and increased clay content may be the cause of this decrease. Above-average decline in the water table may occur as the wells are used. Transmissivity for well 21 is about 2,300 $(ft^3/d)/ft$ [17,300 (gal/d)/ft], and for well 22 is about 4,600 $(ft^3/d)/ft$ [34,400 (gal/d)/ft].

3. Specific capacities of the wells are moderate for municipal-designed wells and seem to indicate small well losses and good well construction. Specific capacity for well 21 is 16 (gal/min)/ft after 6 hours pumping. Specific capacity for well 22 is 21 (gal/min)/ft after 6 hours pumping.

4. Traces of drilling mud still remain in the formation and discharge water, possibly caused by the large amounts of the mud-removing chemical used in developing the well. The dissolved solids, sodium, and orthophosphate concentrations in water from well 22 will probably decrease as the well becomes completely developed.

5. A few feet of additional water-level drawdown will occur in wells 21 and 22 when both are pumping due to mutual interference caused by intersection of the cones-of-depression around each well.

6. Decline in both static and pumping water levels can be expected to occur slowly with time and amount of pumpage.

7. Additional long-term pumping tests may provide data to refine estimates of aquifer transmissivity.