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UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

GROUND WATER TEST WELL A, NEVADA TEST SITE, NYE COUNTY, NEVADA*

A summary of lithologic data, aquifer

By

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Report TEI-800

This report is preliminary and
has not been edited for conformity
with Geological Survey format.

* Prepared on behalf of the U.S. Atomic Energy Commission.

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GROUND-WATER TEST WELL A, NEVADA TEST SITE
NYE COUNTY, NEVADA

By C. E. Price and William Thordarson

ABSTRACT

Ground-water test well A was drilled to a depth of 1,870 feet with rotary and cable-tool equipment. Only alluvial materials were penetrated. These were saturated below 1,605 feet (altitude 2,402.5 feet).

Pumping and bailing tests indicate that the minimum transmissibility of the alluvium is about 800 gallons per day per foot. The specific capacity was 1.9 gallons per minute per foot of drawdown after 1 hour of pumping at rates of both 41 and 60 gallons per minute.

A suite of geophysical logs, a summary of contract costs, and a detailed description of the drilling equipment and casing record are presented.

INTRODUCTION

The Nevada Test Site is about 70 miles northwest of Las Vegas, Nev., and has been the scene of several nuclear detonations carried out by the U.S. Atomic Energy Commission. The possibility that radioactive fission products may contaminate the ground water and thereby create a hazard to the public is a matter of great concern to the Commission. To appraise this problem for the Commission, the U.S. Geological Survey is studying the ground-water hydrology of the Test Site, and especially the hydrology of Yucca Flat. Test wells penetrating 100 feet or more below the water table provide a major part of the information needed for this study. They also yield much information that cannot practically be incorporated in the final report on the investigation but which shall be recorded and preserved in interim reports, of which this is the first of a series.

In detail the objectives sought through the drilling of test wells are:

1. To determine the character, subsurface distribution, and water-bearing properties of the rocks and sediments from the land surface downward into the zone of saturation.

2. To obtain samples of these materials for laboratory analysis and study.

3. To determine the location, depth beneath the surface, quantity, temperature, and chemical and radiochemical quality of the ground water.

4. To determine the configuration and slope of the water table as one step in ascertaining the direction and rate of movement of the ground water.

5. To establish a network of wells in which observations of water-level fluctuations can be made and from which samples can be taken for chemical and radiochemical monitoring.

Purpose and scope

This report records the work done at ground-water test well A, which is one of six wells that were put down especially to ascertain the direction and rate of ground-water movement beneath Yucca Flat. Included are descriptions of the drilling, casing, development, and geophysical logging of the well, the materials penetrated, and the bailing and pumping tests that were made.

The report is largely a compilation of data. Valid interpretations must await the accumulation of data from other test wells. The section of this report dealing with the lithology of the materials penetrated in the hole was written by the junior author; the remainder of the report was written by the senior author.

Location

Ground-water test well A is in the central part of an enclosed intermontane valley known as Yucca Flat, which is about 20 miles long and 7 miles wide. The well site is about 2 miles south-southeast of B J Junction at Nevada State coordinates N 833,000 and E 684,000 (fig 1). The altitude of the land surface at the site is about 4,006 feet.

Acknowledgments

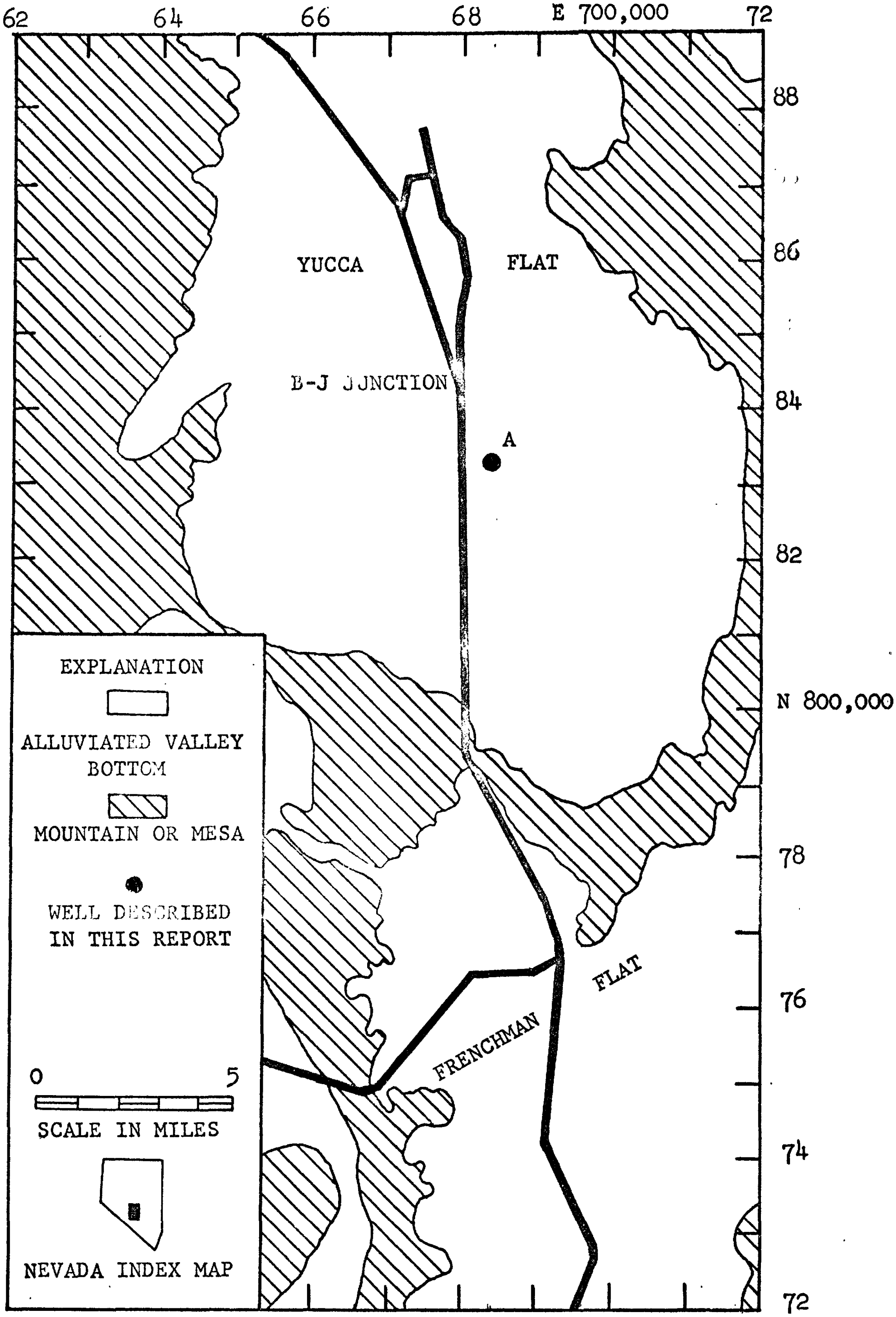
The writers are grateful for the cooperation and assistance given by Mr. Victor McCann, of B and B Drilling Company; Mr. C. A. Stephenson and Mr. Kyle Chaney, both of C. A. Stephenson and Son; and H. B. Woodworth, then of Holmes and Narver, Inc. Bruce Blackerby and Robert Scott, both formerly with the U.S. Geological Survey, collected much of the field data.

CONSTRUCTION RECORD

Drilling of test well A was begun on May 24, 1960, and was completed on August 29. The subsequent installation of the liner, surging to remove loose mud and sand, and hydrologic testing completed on September 21, 1960. Details of the work follow:

Specifications and contract

The specifications for hole A were presented in AEC Invitation 292-60-21, February 1960. The work was performed under contract No. AT(29-2)989, which was awarded to the Mac Exploration Co., Milford, Utah. This company subcontracted part of the work to the B and B Drilling Co., Beaver, Utah, and part to C. A. Stephenson and Son, Grants, New Mexico. The engineering inspection was



Coordinates: Nevada State System, central zone.

FIGURE 1.--MAP SHOWING LOCATION OF TEST WELL DESCRIBED IN THIS REPORT

provided by Holmes and Narver, Inc., Los Angeles, Calif.

General construction plans

Hole A was drilled to 1,600 feet--a point just above the water table--with rotary equipment, and was deepened to 1,870 feet with cable-tool equipment. Cable tools were specified for drilling into the saturated zone so that zones having different heads and permeabilities might be identified and so that water samples collected from the well would not be contaminated by drilling mud.

Drilling equipment

The rotary drilling equipment was truck mounted, and consisted of a 40-foot mast having a rated capacity of 50,000 pounds, a Hutchins MAXI drawworks, and a Gardner-Denver FD-FXX 5-inch by 8-inch mud pump.

A cable-tool drilling equipment was trailer mounted, and consisted of a Bucyrus-Erie 36-L machine having a 54-foot derrick. The rated capacity of the derrick was 120,000 pounds.

Detailed information on both the rotary and the cable-tool equipment is given in appendix I.

Contract cost

The contractor was paid $59,745 for the materials and labor required to drill, case, and develop the hole and to aid in collecting geophysical, bailing, pumping, and other information. This cost is slightly less than $32.00 per foot. Payments under the contract are itemized in appendix II.

Rotary drilling

Drilling by the rotary method started on May 24, 1960, but stopped on the following day at the depth of 383 feet when a drill-pipe tool joint broke. Left in the hole were the following: two collars, each 8 inches in diameter and 18 feet long; a collar 6 inches in diameter and 22 feet long; and three lengths of drill pipe, each 22.5 feet long. In the next 6 days two attempts were made to fish the tools out of the hole, first by using a taper tap and then a wash-over string. Both attempts failed.

The hole, therefore, was abandoned on May 30, and a new one was started 4 feet to the west. On June 4, when the second hole had reached a depth of 840 feet, a key on the drawworks drum sheared off, causing a 2-day shutdown. After repairs were completed, an attempt was made to raise the drill string, but in only about 25 feet it became stuck. In a further attempt to free it, the discharge from a 5- by 6-inch mud pump mounted on a Portadrill was hooked in parallel with the mud pump of the drilling machine, but washing failed to dislodge the tools. Next, 2,400 gallons of diesel oil was circulated in the hole in the hope of lubricating the drill string sufficiently to free it, but this procedure alone was not adequate. By using jacks to supplement the foregoing procedure the drill pipe finally was dislodged. Eight days elapsed between the shearing of the key and the resumption of drilling.

No other major interruptions occurred, and the rotary drilling was completed on August 10, 1960, at a depth of 1,600 feet. The elapsed time between the starting and completion of drilling was 79 days.

A total of 187,600 gallons of water, 42,300 pounds of bentonite, and 990 pounds of quicklime were used to drill the hole (table 1). The drilling fluid passed through a mud sump having a capacity of about 6,000 gallons, and which had been excavated by means of a bulldozer.

Cable-tool work

The cable-tool machine was moved over well A on August 13, and drilling began with reaming and straightening of the hole using a 15-inch Mother Hubbard bit. This drilling lasted until August 19.

To test whether the hole was straight enough to be cased with 12 3/4-inch OD casing, a 42.5-foot length of casing of that diameter was lowered into the hole. However, it could be lowered only to 1,120 feet. Straightening the hole so that the test section of casing could be lowered to 1,555 feet required about 100 hours. The full string of 12 3/4-inch OD casing was installed from the surface to 1,555 feet without difficulty on August 24 and 25.

Table 1. Mud materials used in drilling pilot hole and reaming test well A

Depth interval (feet)	Bit diameter (inches)	Water (Gallons)	Bentonite (pounds)	Quicklime (pounds)
Pilot hole				
0-1,050	11	40,600	2,400	none
1,050-1,501	6	42,000	11,300	420
Reaming				
0- 601	16	17,000	7,400	90
601-1,600	10 5/8	88,000	21,200	480
Total	------	187,600	42,300	990

Drilling was resumed on August 26, and water was found at 1,608 feet. On August 29 the hole was bottomed at 1,870 feet. The lower part of the hole, below 1,547 feet was then cased with 10 3/4-inch casing, of which the lower 262 feet is slotted. The work of casing the hole required 6 days and was completed on September 5. The drilling and casing by the cable-tool machine required 24 days. Details of the casing and screen installed in the well are tabulated in appendix III.

Surging

After installation of the casing, the water in well A was agitated, or surged, with a solid surge block in order to loosen mud, silt, and fine sand and bring them into the well so that they might be bailed out. It was hoped that a natural gravel pack surrounding the screen would be created in this manner and that the quantity of sand in the water during pumping operations would thereby be reduced or eliminated.

Surging at a relatively gentle rate was started on September 6 opposite the zones believed to contain the coarser sand and gravel. These zones were chosen on the basis of the grain-size data which was summarized in table 3; and also on the basis of the section-gage log, inasmuch as the coarser materials had tended to cave into the well, causing the diameter of the hole to be larger opposite the coarser materials.

The objective in surging first opposite the coarser sediments was to make them slump against the screen and thus create a natural gravel pack not only opposite the coarser strata but perhaps also opposite the finer ones. Had the finer strata been disturbed first, the fine materials from them possibly could have sealed off the coarser beds, thereby decreasing the yield of the well and causing the well to yield troublesome quantities of sand when pumped.

Surging after the first day was as vigorous as was possible with the available equipment. By September 11 no more sand was being bailed from the well. Surging therefore was discontinued on September 12, after about 7 days of work. No sand was detected in the water when the well was pumped about a week later (September 19 and 20) but fine suspended matter made the water brown during the first few hours of pumping.

More than 2 cubic yards of sand, silt, and clay were bailed from the well during the surging work. Most of the grains in these materials were less than 0.024 inch in diameter.

GEOPHYSICAL LOGS

Geophysical logs were made in test well A to a depth of about 1,580 feet on July 30, when the hole was 1,600 feet deep, was uncased, and was filled with mud; and to a depth of about 1,870 feet on August 30, 1960, when all drilling had been completed, the hole was cased to 1,555 feet, and static water level was about 1,608 feet below top of the casing. Included are multi-electrode-electrical, lateral, gamma ray-neutron, sonic, directional and section-gage logs (figure 4.

The directional log shows that the well departed from the vertical to such an extent that 3 feet must be subtracted from measurements of static water level if the depth (neglecting instrument and operator errors) of the water level below the surface is desired (table 2).

Interpretation of the geophysical logs will be presented in a separate report.

Table 2.--Directional log of ground-water test well A, by Schlumberger Well Surveying Corp.

(Logged from 50 to 1,575 feet on July 30, 1960; and from 1,600 to 1,850 feet on August 30, 1960).

Depth (feet)	Drift angle	Deflection			Latitude		Departure		Coordinates			
		True bearing	Horizontal footage	Vertical footage	N	S	E	W	N	S	E	W
50	0°00'	------	0	50.00	----	----	----	----	----	----	----	----
100	0°00'	------	0	100.00	----	----	----	----	----	----	----	----
150	0°00'	------	0	150.00	----	----	----	----	----	----	----	----
200	0°15'	S 65 E	.22	200.00	----	.09	.20	----	----	.09	.20	----
250	0°15'	N 50 E	.22	250.00	.14	----	.17	----	.05	----	.37	----
300	0°30'	N 35 E	.43	300.00	.36	----	.25	----	.41	----	.62	----
350	0°15'	N 35 E	.22	350.00	.18	----	.13	----	.59	----	.75	----
400	0°30'	N 15 E	.43	400.00	.42	----	.11	----	1.01	----	.86	----
450	0°00'	------	0	450.00	----	----	----	----	1.01	----	.86	----
500	0°15'	S	.22	500.00	----	.22	----	----	.79	----	.86	----
550	0°00'	------	0	550.00	----	----	----	----	.79	----	.86	----
600	0°00'	------	0	600.00	----	----	----	----	.79	----	.86	----
650	0°15'	S 30 E	.22	650.00	----	.19	.11	----	.60	----	.97	----
700	0°30'	S 40 E	.43	700.00	----	.33	.28	----	.27	----	1.25	----
750	0°30'	S 40 E	.43	750.00	----	.33	.28	----	----	.06	1.53	----
800	0°30'	S 20 E	.43	800.00	----	.41	.15	----	----	.47	1.68	----
850	0°30'	S 10 W	.43	850.00	----	.43	----	.07	----	.90	1.61	----
900	1°00'	S	.87	899.99	----	.87	----	----	----	1.77	1.61	----
950	1°00'	S	.87	949.98	----	.88	----	----	----	2.65	1.61	----
1,000	1°15'	S 12 W	1.09	999.97	----	1.07	----	.23	----	3.72	1.38	----
1,050	1°15'	S 5 W	1.09	1,049.96	----	1.08	----	.09	----	4.80	1.29	----
1,100	1°30'	S	1.31	1,099.94	----	1.31	----	----	----	6.11	1.29	----
1,150	1°45'	S 3 E	1.53	1,149.92	----	1.52	----	.08	----	7.63	1.21	----
1,200	2°45'	S 6 W	2.40	1,199.86	----	2.38	----	.25	----	10.01	.96	----
1,250	3°30'	S 10 W	3.05	1,248.76	----	3.00	----	.53	----	13.01	.43	----
1,300	3°45'	S 2 E	3.27	1,297.60	----	3.27	.11	----	----	16.28	.54	----
1,350	4°15'	S 11 W	3.70	1,347.46	----	3.63	----	.70	----	19.91	----	.16
1,400	3°15'	S 6 E	2.83	1,397.38	----	2.82	.30	----	----	22.73	.14	----

Table 2.--Directional log of ground-water test well A, by Schlumberger Well Surveying Corp.

(Logged from 50 to 1,575 feet on July 30, 1960; and from 1,600 to 1,850 feet on August 30, 1960).

Depth (feet)	Drift Angle	Deflection			Latitude		Departure		Coordinates			
		True bearing	Hori-zontal footage	Vertical footage	N	S	E	W	N	S	E	W
1,450	4°30'	S	3.92	1,447.22	----	3.92	----	----	----	26.65	.14	----
1,500	3°30'	S	3.05	1,497.12	----	3.05	----	----	----	29.70	.14	----
1,550	3°00'	S 2 W	2.61	1,547.05	----	2.61	----	.09	----	32.31	.05	----
1,575	3°30'	S 6 E	1.52	1,572.00	----	1.52	.16	----	----	33.83	.21	----
1,600	0°00'	O	0	1,597.00	----	----	----	----	----	33.83	.21	----
1,650	0°15'	S 20 N	0.11	1,647.00	----	0.1	----	0.04	----	33.93	0.17	----
1,700	0°00'	O	0	1,697.00	----	----	----	----	----	33.93	0.17	----
1,750	0°15'	N 36 E	0.22	1,747.00	0.18	----	0.13	----	----	33.75	0.30	----
1,800	0°15'	N 21 E	0.22	1,797.00	0.21	----	0.08	----	----	33.54	0.38	----
1,850	0°30'	S 88 E	0.44	1,847.00	----	0.01	0.42	----	----	33.55	0.80	----

LITHOLOGY OF SEDIMENTARY DEPOSITS PENETRATED

Test well A penetrated only poorly sorted valley fill that consists predominantly of alluvial silt, sand, and gravel, together with some clayey deposits possibly of lacustrine origin. The silty sand portion of the alluvial deposits, hereafter called "sandy matrix," ranges from very pale orange to pale yellowish brown and commonly is cemented by calcium carbonate and clay (?). The gravel portion has various colors and consists of pebbles, cobbles, and boulders of many rock types. The major rock types in the gravel are welded tuff, pumiceous tuff, quartzite, chert, and argillite. The detrital welded and pumiceous tuffs are probably derived from the Oak Spring formation, of Tertiary age, and the detrital quartzite, chert, and argillite are probably derived from the Eleana Formation, of Mississippian to Pennsylvanian age. Both formations are widely exposed in the mountains that form the boundaries of the valley. The gravel shows no great changes in composition in the section that was drilled. Coatings of calcium carbonate are common on the gravel cuttings.

Collection and analysis of samples

The well was drilled by the rotary-hydraulic method from the land surface to a depth of 1,600 feet, and then was deepened to 1,870 feet by the cable-tool method. During the rotary drilling, the drillers collected 1-pint samples of the drill cuttings from the shale shaker at 5-foot depth intervals. During the cable-tool drilling, they collected 1-quart samples of the cuttings at 5- to 15-foot depth intervals, taking them from the bottom of a halved oil drum into which they emptied the bailer. Although the rotary drill reached a depth of 1,600 feet, it was necessary to redrill the lower part by the cable-tool method, and cable-tool cuttings therefore are available beginning at 1,580 feet. The cable-tool cuttings are believed to be better than those obtained by rotary drilling, and therefore were studied for the 20-foot zone where both were available (1,580 to 1,600 feet).

The Survey geologists washed the samples in the laboratory to free them of drilling mud, and then examined them by means of a binocular microscope. The colors of the samples were compared with the standard colors of the National Research Council rock color chart (Goddard and others, 1951). The footages logged by the several geologists follow: 0-160, 1,730-1,800-, 1,820-1,870 feet by George E. Walker; 160-290 feet by Robert B. Scott III; 290-1,580 feet by William Thordarson; 1,580-1,730 and 1,800-1,820 by Murray S. Garber. The procedures used in logging are described below.

First, estimates were made of the percentages of the various lithologies that compose the gravel fraction (table 2). This was followed by an examination of the silt- and sand-size particles making up the sandy matrix. The grain-size distributions in three size ranges were estimated visually from 1-quart samples of cable-tool cuttings that had been washed through an 0.6-millimeter sieve (table 3). The error in estimating the percentages of both the grain sizes and the gravel lithologies is 5 to 15 percent.

The cuttings were described, keeping their limitations in mind. That they do not closely represent the alluvium in place is obvious. In rotary drilling, for example, caving from the upper part of the hole, variability in the velocity and density of the drilling mud, the condition of the bit, and lag time make it difficult to obtain good samples of alluvium. In cable-tool drilling, caving of the hole and the crushing action of the bit adversely affect the samples of alluvial materials. In general, the cable-tool cuttings from test well A are believed to be more representative of the alluvium that the

1,550 feet of hole, which already had been cased, and second, because little or no bentonite was mixed with the cuttings.

The alluvium contains a wide range of grain sizes, rock types, and colors, but the differences between the strata tend to become lost in the wordiness of detailed descriptions. A conventional log of test well A would be a repetitious itemization in which variations in percentages of different constituents would be the principal differences between strata. Therefore tables 3 and 4 and figure 2 summarize the principal characteristics by depth. The main components of the alluvium are described in paragraphs that follow, beginning with the gravel.

Welded-tuff gravel

Most of the welded tuff has an aphanitic matrix and ranges from pale red to grayish-orange pink. About 25 percent of it is clear euhedral quartz and feldspar crystals as much as 2 mm across, and less than 1 percent is biotite. Less than 1 percent of the welded tuff is dark gray. It is composed of quartz and feldspar crystals (about 35 percent), biotite (3 to 5 percent) as much as 1 mm across, and black vitrophyre, black obsidian, and light and olive-gray to light greenish-gray glass. As much as 20 percent of the welded tuff is harder than 5.5 on the Mohs hardness scale.

Pumiceous-tuff gravel

The matrix of most of the pumiceous tuff is dense, zeolitized, and hard; some, however, is relatively soft. Commonly embedded in the matrix are fragments of zeolitized pumice as much as 3 mm across, which constitute as much as 30 to 50 percent of the whole. Other inclusions are small clear euhedral crystals of quartz and feldspar (10 to 20 percent), biotite (1 percent), and opaque black minerals (1 percent). Vitrophyric tuff, generally grayish red,

Table 3.--Major rock types in gravel in alluvial sediments penetrated in test well A. (Tr, trace; <, less than)

Bottom depth (feet)	Percentages of major rock types in gravel						Cuttings with carbonate coatings (percent)
	Welded tuff (pale red)	Pumiceous tuff		Quartzite	Chert	Argillite	
		Pink to red	Yellowish gray				
5	12	<5	20	5	Tr	60	1
10	16	5	23	5	Tr	50	1
20	6	12	75	Tr	0	6	1
30	25	8	35	<5	Tr	28	1
40	23	10	35	8	Tr	23	3
50	30	5	35	15	0	15	2
60	26	10	45	8	Tr	10	1
70	23	10	50	5	5	7	1
80	31	10	45	7	Tr	6	10
90	38	5	45	<5	Tr	8	3
100	36	5	35	8	<5	13	1
110	41	7	30	7	<5	13	1
120	37	5	40	5	<5	10	10
130	50	5	30	<5	5	7	2
140	25	<5	15	15	<5	40	5
150	30	7	40	10	Tr	12	25
160	20	15	42	10	Tr	12	3
170	25	10	35	15	5	10	5
180	25	10	40	5	<5	18	3
190	25	5	30	15	5	20	3
200	15	10	30	5	5	35	3
210	33	10	15	12	<5	28	5
220	25	5	15	18	6	31	5
230	20	5	20	20	5	30	5
240	25	<5	15	15	5	38	5
250	45	5	25	10	<5	13	5
260	30	5	20	15	5	25	5
270	35	5	20	12	5	23	5
280	25	5	15	20	5	30	5
290	28	5	25	15	<5	25	5
300	35	5	25	15	5	15	10
310	40	<5	30	10	<5	15	0

Table 3.--Major rock types in gravel in alluvial sediments penetrated in test well A. (Tr, trace; <, less than)

Continued.

Bottom depth (feet)	Percentages of major rock types of gravel						Cuttings with carbonate coatings (percent)
	Welded tuff (pale red)	Pumiceous tuff		Quartzite	Chert	Argillite	
		Pink to red	Yellowish gray				
320	25	<5	30	20	<5	17	1
330	45	5	20	10	<5	16	-
340	30	5	20	20	<5	21	5
350	40	8	20	15	5	12	3
360	30	5	25	20	5	15	2
370	20	5	30	15	5	25	3
380	30	10	25	20	5	10	5
390	30	5	30	10	5	20	2
400	40	10	30	<5	<5	15	2
410	40	10	30	5	Tr	14	20
420	30	5	25	25	5	10	1
430	30	5	35	15	<5	12	1
440	27	5	30	25	<5	10	1
450	40	5	20	20	5	10	0
460	35	5	30	15	5	10	0
470	40	5	25	15	5	10	0
480	40	5	25	15	5	10	0
490	25	5	35	15	5	15	3
500	30	5	25	20	5	15	0
510	35	5	30	10	5	15	0
520	35	5	30	15	5	10	1
530	30	5	15	30	10	10	5
540	35	5	30	10	10	10	5
550	35	<5	15	20	8	20	0
560	25	7	35	15	5	13	5
570	30	15	20	20	5	10	2
580	30	8	30	20	5	7	5
590	30	5	32	15	8	10	5
600	35	5	22	22	10	6	5
610	35	8	35	10	<5	8	3
620	20	7	37	20	10	6	5
630	32	<5	30	25	5	5	3
640	31	8	40	10	5	6	5

Table 3.--Major rock types in gravel in alluvial sediments penetrated in test well A. (Tr, trace; <, less than)

Continued

Bottom depth (feet)	Percentages of major rock types in gravel						Cuttings with carbonate coatings (percent)
	Welded tuff (pale red)	Pumiceous tuff		Quartzite	Chert	Argillite	
		Pink to red	Yellowish gray				
650	30	10	30	20	<5	6	2
660	47	5	30	10	<5	4	2
670	30	10	40	10	<5	6	2
680	20	<5	20	25	<5	28	10
690	35	5	29	20	5	6	10
700	25	5	40	20	<5	6	20
710	35	5	35	15	<5	6	5
720	35	5	30	20	<5	6	15
730	30	5	35	20	<5	6	5
740	30	10	45	10	<5	<5	5
750	10	10	70	<5	<5	<5	2
760	50	5	25	10	<5	6	3
770	40	10	30	10	<5	6	0
780	40	5	30	15	<5	6	2
790	35	5	35	15	<5	6	1
800	35	5	40	10	<5	6	1
810	35	5	45	5	<5	6	1
820	32	5	40	15	<5	<5	8
830	30	5	40	15	<5	6	
840	30	<5	35	20	10	<5	0
850	35	7	40	10	<5	6	1
860	30	8	40	13	<5	6	0
880	35	5	43	8	<5	6	2
890	30	10	40	12	<5	6	0
900	33	8	45	5	<5	7	0
910	30	10	40	10	<5	6	0
920	29	10	50	5	<5	<5	0
930	30	8	44	10	<5	6	0
940	30	10	20	20	5	15	0
950	20	8	40	15	5	12	5
960	20	10	45	15	5	5	8
970	30	10	40	10	5	5	5

Table 3.--Major rock types in gravel in alluvial sediments penetrated in test well A. (Tr, trace; <, less than) Continued.

Bottom depth (feet)	Percentages of major rock types in gravel						Cuttings with carbonate coatings (percent)
	Welded tuff (pale red)	Pumiceous tuff		Quartzite	Chert	Argillite	
		Pink to red	Yellowish gray				
980	25	5	45	5	5	15	3
990	25	5	30	15	10	15	2
1,000	30	5	42	10	5	8	2
1,010	20	10	30	20	10	10	2
1,020	20	10	40	10	8	12	0
1,030	20	5	30	20	5	20	0
1,040	30	5	35	10	5	15	0.5
1,050	30	5	35	10	5	15	0
1,060	20	22	45	5	<5	5	0.5
1,070	20	10	45	5	5	15	0.5
1,080	25	10	50	5	5	5	0.5
1,090	30	10	45	5	5	5	0
1,100	30	5	40	5	5	15	0
1,110	28	10	40	5	<5	15	5
1,120	30	5	45	5	<5	11	0
1,130	30	5	40	10	<5	12	0.5
1,140	29	5	30	10	5	21	2
1,150	30	5	30	5	5	25	1
1,160	30	<5	25	20	5	16	1
1,170	35	<5	25	10	5	21	2
1,180	30	<5	35	10	5	16	2
1,190	30	5	35	10	5	15	1
1,200	30	5	35	10	5	15	1
1,210	30	5	35	15	5	10	1
1,240	--	-	--	--	--	--	-
1,250	30	5	40	10	5	10	1
1,260	25	5	45	10	<5	11	1
1,270	25	5	45	10	<5	11	1
1,280	30	5	35	15	<5	11	
1,290	20	5	55	10	5	5	
1,300	20	5	50	10	5	10	
1,310	20	5	55	10	5	5	2
1,320	25	5	40	15	5	10	2

Table 3.--Major rock types in gravel in alluvial sediments penetrated in test well A. (Tr, trace; <, less than) Continued.

Bottom depth (feet)	Percentages of major rock types in gravel						Cuttings with carbonate coatings (percent
	Welded tuff	Pumiceous tuff		Quartzite	Chert	Argillite	
		Pink to red	Yellowish gray				
1,330	25	< 5	32	25	5	10	2
1,340	20	Tr	34	25	5	15	1
1,350	25	Tr	24	30	5	15	1
1,360	20	5	40	20	5	10	1
1,370	25	5	35	20	5	10	1
1,380	35	Tr	30	23	< 5	8	1
1,390	20	5	40	20	5	10	0
1,400	20	5	50	10	5	10	0
1,410	20	5	40	20	5	10	1
1,420	21	5	45	15	< 5	10	0
1,430	20	5	45	20	5	5	0
1,440	20	5	50	15	5	5	0
1,450	20	< 5	30	35	5	7	1
1,460	15	5	50	20	5	5	1
1,470	20	5	50	15	5	5	
1,480	20	5	40	20	5	10	1
1,490	20	5	50	15	5	5	1
1,500	20	5	50	15	5	5	1
1,515	20	5	50	15	5	5	1
1,520	25	5	30	25	5	10	0
1,530	25	5	30	25	5	10	0
1,540	20	< 5	50	17	5	5	0
1,550	20	5	50	15	5	5	0
1,570	20	5	50	15	5	5	0
1,580	20	5	55	10	5	5	0
1,585	23	< 5	65	5	< 5	Tr	5
1,600	10	5	68	10	< 5	< 5	5
1,610	10	5	70	7	< 5	5	
1,620	8	5	70	10	5	< 5	3
1,625	20	5	57	10	5	< 5	3
1,635	20	5	61	5	< 5	5	2
1,645	25	10	51	5	< 5	5	
1,655	11	< 5	60	12	< 5	10	5
1,665	20	< 5	63	< 5	< 5	10	

Table 3.--Major rock types in gravel in alluvial sediments penetrated in test well A. (Tr, trace; <, less than) Continued.

Bottom depth (feet)	Percentages of major rock types in gravel						Cuttings with carbonate coatings (percent)
	Welded tuff (pale red)	Pumiceous tuff		Quartzite	Chert	Argillite	
		Pink to red	Yellowish gray				
1,680	11	< 5	60	10	5	10	
1,690	17	5	72	< 5	Tr	< 5	
1,700	12	5	70	5	< 5	< 5	
1,720	13	< 5	72	5	< 5	< 5	
1,730	15	7	65	5	< 5	< 5	
1,745	30	5	55	5	< 5	< 5	1
1,750	20	5	54	8	6	7	1
1,765	30	5	46	5	< 5	10	1
1,775	26	5	60	< 5	< 5	Tr	
1,785	25	5	55	5	5	5	1
1,800	25	8	63	< 5	Tr	Tr	
1,805	25	Tr	65	< 5	< 5	Tr	
1,815	10	5	75	< 5	< 5	< 5	
1,820	10	< 5	75	< 5	< 5	< 5	
1,830	10	5	65	< 5	Tr	15	
1,845	18	5	65	Tr	Tr	10	
1,855	10	5	70	Tr	< 5	10	
1,870	18	5	65	Tr	Tr	70	

pale brown, and grayish yellow-green, and having a chert-like appearance, composes about 1 percent or less of the matrix. Some cuttings of the pumiceous tuff have black to dark-brown dendrites that probably are composed of manganese or iron oxide. The pumiceous tuff ranges from yellowish-gray to very pale orange, and some of it contains minor amounts of grayish yellow-green and pale-brown to pale yellowish-brown particles. For brevity in table 3 all these colors are summarized as yellowish gray. Minor amounts of the pumiceous tuff are grayish red, pale reddish brown, and moderate orange pink. In table 3 these reddish colors are grouped as pink to red.

Quartzite gravel

The quartzite in the gravel is of sedimentary origin and consists of grains of clear quartz and feldspar, most of which are subrounded to rounded and are very fine in texture. Some of the quartzite, however, is medium to very coarse grained. Included with the quartzite are small amounts of chert-granule conglomerate that contains clear quartz and feldspar grains together with subangular to rounded chert grains. The chert grains fall in the size range of very coarse sand and granules, and most of them are dark gray or are mottled. The quartzite itself is dark gray or variegated. Some of the rock is mottled light gray and light brown, and part of it is grayish red, pale brown, grayish brown, medium light gray, and light gray. Most of the brown coloration is probably due to iron oxide, perhaps limonite.

Chert gravel

Most of the chert probably was derived from chert-pebble conglomerates that had the same origin as the chert-granule conglomerates described above. The most abundant variety is grayish black to dark gray; other varieties are medium gray, pale-yellowish brown, grayish brown, and grayish red.

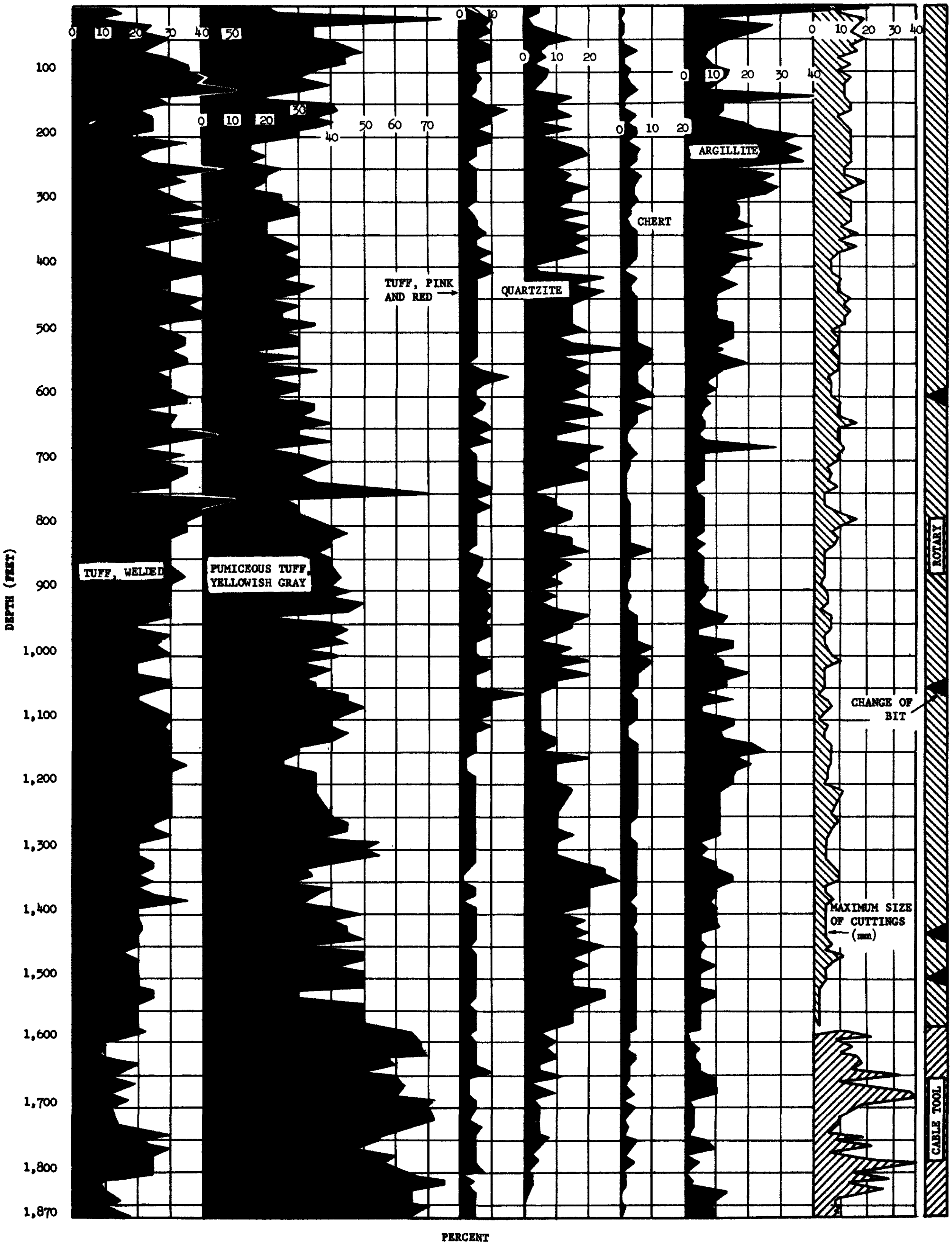


FIGURE 2. PERCENTAGE DISTRIBUTION OF ROCK TYPES IN CUTTINGS LARGER THAN 1 MILLIMETER IN DIAMETER (ESTIMATED)

Argillite gravel

Most of the pebbles of argillite recovered in the drill cuttings had been broken in the drilling, but a few were unbroken. These were rounded to well rounded. The argillite consists principally of silt-sized grains but generally includes a few clear quartz grains up to the size of very fine sand. About 90 percent of the argillite is pale yellowish brown, but minor amounts are light olive gray, medium gray, dark gray, grayish red, olive gray, and pale brown. The calcareous argillite is olive gray and pale brown, was found only in the lower 1,000 feet of the well, and as a rule constitutes no more than 3 percent of the argillite present. Most of the argillite is softer than about 5.5 on the Mohs scale, but some of the grayish-red, dusky yellowish-brown, and medium light-gray varieties, comprising less than 2 percent in any sample, are harder.

Minor gravels

Minor rock types found in the gravel include medium-gray to dary-gray limestone, dark-gray dolomite, and dusky-red basaltic scoria. The scoria was found only in samples from the lower 500 feet of the hole. Each of these rock types amounts to less than 1 percent of the gravel pebbles, and, therefore, they are not listed in table 3.

Coatings on gravel

Some of the drill currings that show the original gravel surfaces are coated with calcium carbonate or with clay. In most samples the cuttings showing calcium-carbonate coatings constitute between 1 and 5 percent of the sample (table 3), but in several samples they constitute 10 percent, and in one sample they constitute 25 percent.

Calcium -carbonate coatings are more abundant and thicker in the samples from the upper 800 feet of the well than in those from the lower 1,070 feet. The effect of caving in the upper part of the well on the distribution of these coatings in the lower part of the well is, of course, not known. Most of the coatings are less than 0.5 mm thick, but some of those from the upper part of the well are as much as 3 mm thick. Three-fourths of those thicker than 0.5 mm came from the upper 800 feet. The thicker calcium-carbonate coatings may be caliche. The color of the calcium-carbonate coatings ranges from very pale orange to white.

The coatings believed to consist of clay came from the upper 1,000 feet of the well and may have been derived from the clayey lake beds, discussed below. They are grayish orange and thin.

Lithologic changes with depth

The percentages of the different lithologic types in the alluvial gravel are plotted against depth in the six graphs of figure 2. These graphs show a general but irregular increase of the yellowish-gray pumiceous tuff from 25 or 30 percent near the top of the well to 55 or 65 percent near the bottom of the well; and a decrease of welded tuff and pink and red tuff through the same interval. The percentages of quartzite and chert pebbles also decrease with depth.

The changes in the lithologic composition of the gravel should be viewed with caution, however, because of the following factors: First, only sample constituents having diameters greater than 1 mm are considered, and among them the relatively resistent lithologic types, such as chert, quartzite, and welded tuff, may have become disproportionately concentrated. Second, some of the very sharp peaks of the graphs may indicate cuttings from a large boulder. Third, cuttings from beds of small pebbles may show percentages different from the percentages in cuttings from beds of cobbles and boulders. This is so because more resistant rock types are relatively more abundant among cobbles and boulders than they are in pebbles. In turn, large pebbles contain more resistant rock types than small pebbles or granules. Fourth, the drilling methods and equipment appear to influence the percentages. For example, the percentages of welded tuff and yellowish-gray pumiceous tuff change abruptly at 1,580 feet, the point at which the cable-tool cuttings were first obtained. Also, some of the other changes in the percentages of the welded tuff and the pumiceous tuff occur at depths where drilling bits were changed.

Sandy matrix

The character of the matrix of the gravelly alluvium is suggested imperfectly by the larger fragments and chunks of matrix that were brought to the surface during the rotary drilling. Few matrix particles were recovered during the cable-tool drilling because the blows of the bit broke them down into their granular components. However, the samples suggest the range in grain size of the materials.

The clusters of clay-, silt-, and sand-sized particles found intact in many of the rotary-drilled samples are cemented by calcium carbonate. Their composition differs considerably from sample to sample but in general they consist of clear quartz and feldspar (35 percent), fragments of tuff and other rock (25 percent), and silt or clayey silt (40 percent). The sand grains are commonly subangular to rounded. The colors are light shades of orange and brown; grayish orange or very pale orange in samples from the first 300 feet of the hole; between pale orange and pale yellowish brown in samples from 300 to 1,450 feet; and grayish orange or very pale orange in some of the cable-tool cuttings from 1,745 to 1,855 feet. The colors of the clusters probably represent the gross color of the alluvium at the depths at which the clusters occurred.

No stratigraphic significance can be attached to the differences in color of the matrix because, (1) the observed differences are slight, and (2), the record of color is incomplete owing to lack of chunks or clusters in many of the samples.

Grain-size distribution

Most of the rotary and cable-tool cuttings range from silt to pebble in size, suggesting that the valley fill consists predominantly of poorly sorted silt, sand, and gravel. In some samples, this wide grain-size distribution may be due to the mixing of fine and coarse materials from different strata. The grain-size distributions in both the rotary and cable-tool samples differ greatly from the grain-size distributions in the undisturbed sediments, principally for two reasons. First, unmeasurable portions of the clay, silt, and fine sand were washed away, either through the shale-shaker screen of the rotary drill, or when the bailer-fluid overflowed from the halved oil drum in which the cable-tool cuttings were collected. Second, some of the coarse sand and most of the pebbles, cobbles and boulders were crushed, thereby yielding cuttings of finer size which became mixed with the natural silty and sandy sediments in the samples. Only a few uncrushed small granules and small pebbles were recovered. The crushed gravel chips in the cuttings showed maximum diameters of less than 20 mm in the rotary samples (fig. 2) and less than 40 mm in the cable-tool samples (fig. 2, table 4). The grain-size distributions in the sandy matrix of the rotary portion of the hole and in the sandy matrix and gravel of the cable-tool portion of the hole are described below.

In the rotary portion of the hole, the particle sizes were not measured for entire samples. However, the size distributions of some of the sandy matrix were estimated by binocular examination of the intact clusters of clay-, silt-, and sand-sized particles (see section on "sandy matrix" above). These particles were seen in two-thirds of the samples between the surface and 1,280 feet. In this interval, the particle sizes ranged chiefly from silt to very coarse sand, but in 19 scattered samples the particle sizes ranged from silt to fine sand or from silt to medium sand. Only one sample below 1,280 feet contained clusters, and the clusters in it ranged from silt to medium sand. The above size ranges indicate that most of the sandy matrix is poorly sorted, but that some of the sandy matrix is moderately to well sorted.

The cuttings collected during the cable-tool drilling from 1,580-1,870 feet were analyzed for size in more detail than were the rotary-drill cuttings. The 1-quart samples of cable-tool cuttings were wet sieved through an 0.6 mm screen, and both the fine and coarse fractions were saved. Then the percentages of three size grades were estimated visually (table 4). The middle-size grade (0.6 to 5 mm) ranges from about coarse sand to granule; the other two grades include the sizes larger and smaller than the size range of the middle group. The results in table 4 are only an approximation at best, but they suggest that coarse sand and gravel intervals occur as follows:

Depth interval (feet)	Depth interval (feet)
1,585-1,590	1,745-1,750
1,620-1,635	1,755-1,765
1,645-1,655	1,775-1,815
1,675-1,730	1,825-1,840

The above intervals were made the basis for selecting the intervals to be perforated and surged during the development of the well.

Table 4.--Grain-size distribution in cable-tool samples from test well A from depths of 1,580 to 1,860 feet. (Tr. trace).

Depth interval (feet)	Grain size (percentages estimated)			Maximum diameter of cuttings, in mm
	Less than 0.6 mm	0.6 - 5 mm	Greater than 5 mm	
1,580-1,585	70	30	< 5	13
1,585-1,590	40	40	20	23
1,590-1,600	50	50	< 5	9
1,600-1,610	75	25	tr	15
1,610-1,620	80	20	tr	11
1,620-1,625	10	45	45	18
1,625-1,635	10	20	70	19
1,635-1,645	65	30	5	15
1,645-1,655	20	20	60	34
1,655-1,660	85	15	tr	10
1,660-1,675	--	--	--	--
1,675-1,680	20	65	15	26
1,680-1,690	20	70	10	28
1,690-1,700	10	70	20	19
1,700-1,712	--	--	--	--
1,712-1,720	15	75	10	11
1,720-1,730	15	75	10	10
1,730-1,745	30	70	tr	6
1,745-1,750	25	45	30	20
1,750-1,755	25	75	< 5	8

Table 4.--Grain-size distribution in cable-tool samples from test well A from depths of 1,580 to 1,860 feet. (Tr, trace) (Continued)

Depth interval (feet)	Grain size (percentages estimated)			Maximum diameter of cuttings, in mm
	Less than 0.6 mm	0.6 - 5 mm	Greater than 5 mm	
1,755-1,765	20	30	50	23
1,765-1,775	70	30	tr	6
1,775-1,785	25	30	45	24
1,785-1,790	20	50	30	41
1,790-1,800	10	55	35	26
1,800-1,805	10	45	45	16
1,805-1,815	15	50	35	30
1,815-1,820	10	70	20	14
1,820-1,825	80	20	tr	6
1,825-1,830	10	55	35	28
1,830-1,840	30	40	30	17
1,840-1,845	60	40	< 5	10
1,845-1,850	70	30	tr	9
1,850-1,855	50	50	< 5	8
1,855-1,860	50	50	< 5	10
1,860-1,870	65	35	< 5	9

Lacustrine deposits

Fragments that appear to be laminated clay were found in the drill cuttings from a depth of about 450 feet. These fragments were mixed with sand and gravel; therefore, the thickness of clay represented by them is not known other than that the whole sample represented an interval of no more than 5 feet. Similar clay was not observed in adjacent samples. If laminated clays should be found in other test wells in Yucca Valley at about the same depth, they would tend to confirm the lacustrine origin of the clay.

WATER TABLE

The lower 262 feet of the alluvium in test well A is saturated. The water level after completion of the well was about 1,608 feet below the top of casing measured along the hole (neglecting instrument and operator error). Owing to crookedness of the hole and the consequent deviation of the bore from the vertical as shown by a directional log of the well (table 2), the measurement along the bore is 3 feet greater than the vertical depth to water. The computed vertical depth to water below the top of the casing was about 1,605 feet.

The altitude of the land surface at the well is about 4,006 feet and the altitude of the top of the casing (used as measuring point) was 4,007.5 feet. Subtracting the vertical depth to water from the altitude of the measuring point gives the altitude of the water table at well A as 2,402.5 feet.

CHEMICAL QUALITY OF WATER

A sample of water from test well A was collected on September 21, 1960, during a pumping test and was analyzed by the Geological Survey in its laboratory at Denver. The sample was a sodium-bicarbonate water having a relatively high concentration of silica, and a hardness of 88 parts per million. The chemical and radiochemical analyses are given in table 5. The radiochemical analysis shows only natural, or back-ground concentrations.

AQUIFER TESTS

The hydraulic properties of the alluvial aquifer and of the well were tested three times by bailing and twice by pumping the well. The data from these tests are in appendix IV and are summarized below. The static water level prior to each test was about 1,608 feet below top of casing (after correction for deviation of the hole from the vertical, about 1,605 feet).

Description of tests

The first test by bailing was made on August 28, 1960, when the hole was 1,730 feet deep and was uncased below 1,555 feet. During the test, 40 bailerfuls totaling 3,000 gallons were removed. The average rate of water withdrawal was 12.3 gallons per minute.

The second test by bailing was made on the same day and under the same conditions except that only one bailerful (74 gallons) was removed.

The third test by bailing was made on September 6, 1960, when the well was 1,870 feet deep. The hole had been cased but the surging had not been done. only one bailerful, amounting to 33 gallons, was removed.

The first pumping test was made on September 20 and 21, 1960. The well was cased as in the third bailing test, and also had been surged. Information on the pump and other equipment used in this test and also in the second test is given in appendix V. Pumping lasted 38 hours and 10 minutes. The rate of discharge was constant at 60 gallons per minute, and a total of about 140,000 gallons of water was pumped. The drawdown after 1 hour of pumping was about 31 feet; and after 38 hours was 32.9 feet. The water level recovered to its

Table 5.--Chemical and radiochemical analyses of water from test well A, Nevada Test Site, by the U.S. Geological Survey

Date Collected: 9/21/60 — Water temperature: 79°F

Collected by: George Walker — Appearance: slightly cloudy.

Chemical components (ppm)	
Silica (SiO_2)	62
Aluminum (Al)	.1
Iron (Fe)	.11
Manganese (Mn)	.00
Calcium (Ca)	28
Magnesium (Mg)	4.6
Sodium (Na)	51
Potassium (K)	8.7
Bicarbonate (HCO_3)	212
Carbonate (CO_3)	0
Sulfate (SO_4)	18
Chloride (Cl)	6.0
Fluoride (F)	.6
Nitrate (NO_3)	3.8

Physical characteristics and computed values	
Dissolved solids (ppm):	
Residue on evap. at 180°C	301
Calculated	300
Hardness as $CaCO_3$ (ppm):	
Total	88
Noncarbonate	0
Specific conductance:	
(µmhos at 25°C	382
pH	7.6
Color	5

Radiochemical data	
Alpha activity (ug/l as uranium equivalent) as of 12-1-60	6.6 ± 3.9
Beta activity (pc/l) as of 11-15-60	15 ± 2
Radium (Ra) (pc/l)	0.5
Uranium (U) (ug/l)	4.7 ± 0.5
Extractable alpha activity (net) (pc/l)	4.3 ± 1.4
Strontium 90 (pc/l)	a/ 0.6

a/ None found down to this limit

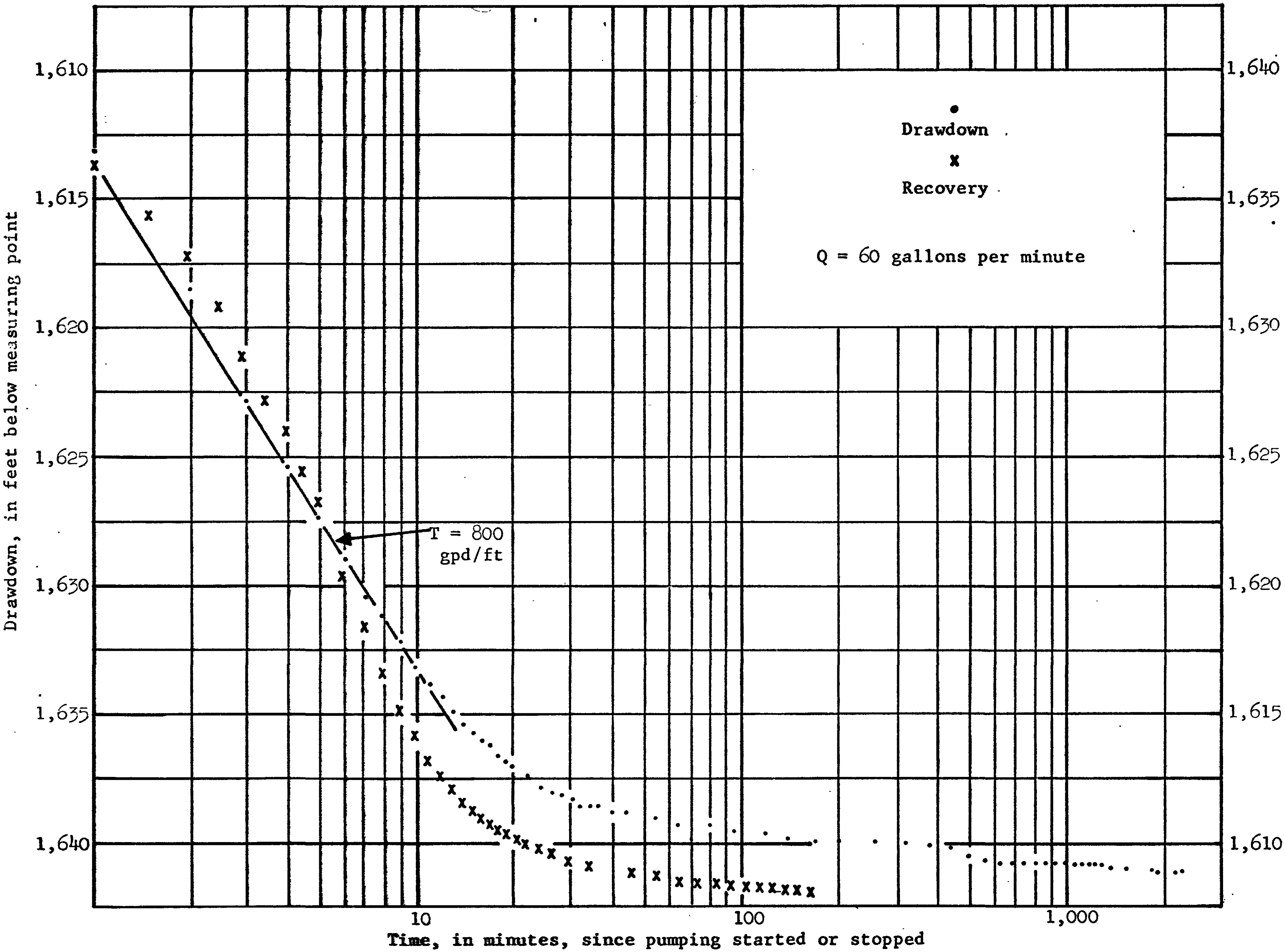


Figure 3.--Drawdown and recovery of water level in test well A in first pumping test.

initial static position in 2 hours 45 minutes after the pump was turned off. The drawdown and recovery of the water level are plotted in figure 3.

The second pumping test was a step drawdown test and was made on September 21, 1960. The pumping rate first was held at about 41 gallons per minute for 1 hour and 26 minutes; then was increased to 52 gallons per minute for about 1 hour and 10 minutes; and finally was increased to 64 gallons per minute for 1 hour and 2 minutes. The total pumping time was 3 hours and 38 minutes. The drawdown was 21.5 feet after 1 hour of pumping and 33.9 feet at the end of the test.

Coefficient of transmissibility

The three bailing tests and the first pumping test all provided data suitable for computing the coefficient of transmissibility of the part of the aquifer that was tapped by the well. The second pumping test was less suitable for this type of calculation because the pumping rate was varied, but the results are used in a subsequent section of this report for estimating the potential yield of the well.

Bailing test 1 and pumping test 1 were interpreted by the method of Cooper and Jacob (1946); bailing tests 2 and 3 were interpreted by a method suggested by Mr. H. E. Skibitzke (written communication, 1954). In the analysis of data from bailing tests 2 and 3 it is assumed that the bore is of uniform diameter. However, the section-gage log of the well suggests that this assumption may not be true for the interval in which drawdown occurred. Nevertheless, there is close agreement between the transmissibility values based on these two tests and those based on the other tests.

The values given below are the smallest values for the coefficient of transmissibility indicated by the tests and probably represent the order of magnitude of the true values.

Test	Hole depth (feet)	Thickness of aquifer (feet)	Minimum coefficient of transmissibility (gal per day per ft)
Bailing test 1	1,730	122	200
Bailing test 2	1,730	122	400
Bailing test 3	1,870	262	800
Pumping test 1	1,870	262	800

The transmissibility values indicated by the tests that were made when the aquifer had been penetrated 262 feet are greater than the values indicated when the aquifer had been penetrated only 122 feet, because transmissibility is a function of thickness of the aquifer.

Potential yield of test well A

The maximum yield of test well A is greater than the maximum discharge attainable with the pump used in the tests. This was 67 gallons per minute.

To estimate the potential yield of the well, a preliminary analysis of the step-drawdown pumping test was made by the method of Bruin and Hudson (1955, p. 29-35). This analysis suggests that the well is capable of yielding 150 gallons per minute with no more than 100 feet of drawdown after 1 hour of pumping. The applicability of the method is open to question, however, because the highest and lowest pumping rates, 20 gallons per minutes, is small.

On the other hand, the figures for the specific capacity of the well confirm the general validity of the result obtained. The specific capacity after 1 hour of pumping at both 41 and 60 gallons per minute was the same, namely

1.9 gallons per minute per foot of drawdown. Projected to a drawdown of 100 feet, this specific capacity would suggest a discharge of 190 gallons per minute; but because the specific capacity decreases somewhat with increasing drawdown, the rate of 190 gallons per minute would probably not be attainable. A rate of 150 gallons per minute, however, might be possible.

A drawdown of 100 feet would not be excessive at test well A. The thickness of saturated aquifer penetrated by the well is 260 feet. The suggested drawdown, therefore, would amount to only about 40 percent of the saturated thickness.

The data obtained in the step drawdown test are summarized in appendix IV.

CONCLUSION

Well A tests only the alluvium. The water level in it, measured vertically, is about 1,603.5 feet below the land surface, or about 2,402.5 feet above sea level. The minimum coefficient of transmissibility for the 262-foot saturated zone in the well is about 800 gallons per day per foot, and the potential yield of the well is more than 150 gallons a minute. The water is of the sodium-bicarbonate type and is relatively soft.

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Cooper, H. H., and Jacob, C. E., 1946, A generalized graphical method for evaluating formation constants and summarizing well-field history: Trans. Am. Geophys. Union, v. 27, p. 526-534.

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Appendix I. Drilling equipment

A. Rotary equipment.

The rotary-hydraulic machine used in drilling test well A belonged to the B and B Drilling Co. Assembled according to the company's own specifications and mounted on a General Motors truck, it consisted of the following:

Mast: 40 feet high, rated capacity about 50,000 pounds; vertical members of 2½-inch OD pipe cross braced with 1½-inch OD pipe.

Drawworks: Hutchins MAXI.

Rotary table: Brewster model OB 12, normal speeds 60 to 100 rpm.

Kelly: 4 inches square, 28 feet long.

Mud pump: Gardner-Denver FD-FXX duplex, reciprocating, 5-inch pistons, 8-inch stroke; rated at 43.3 hydraulic horsepower; normal speeds, 50-80 strokes per minute.

Water swivel: Hall, rated capacity 40,000 pounds.

Drill pipe and tool joints: two sets.

1. Interval-upset pipe, 3.5-inch diameter in 22-foot lengths having API regular 5-thread joints and weighing about 300 pounds each.

2. Same type and diameter as (1), above, but in 31-foot lengths weighing about 400 pounds each and reported to have Union Tool Full Hole 4-thread joints.

Drill collar: diameter 8 inches; length, 18 feet, weight about 2,000 pounds.

Bit: several makes and types. See table 6.

Appendix I. Drilling equipment -- Continued

Table 6.--Record of bits used in rotary drilling in test well A.

Dates	Depth interval (feet)	Manu-facturer	Type	Diameter (inches)
5-30 to 6- 2	0- 600	--------	3-cone	11
6-3 to 6- 4				
6-12 to 6-13	600-1,050	Smith	K2P (cross section)	11
6-17 to 6-20				
7-7 to 7-11	1,050-1,501	Hughes	OWS	6
7-12 to 7-14	0- 600	Reed	---------	16
7-15 to 7-20	601- 907	---do----	---------	15
7-20 to 7-22	907-1,316	Smith	K2P (cross section)	12 1/4
7-22 to 7-23	1,316-1,600	Security	3-cone	10 5/8
7-31	907-1,196	Reed	---------	15
8-3 to 8-10	1,196-1,546	Smith	3-point hole opener	15

Appendix I. Drilling equipment -- Continued

Shale shaker: Link Belt Co., NMR-145-S, 30-mesh.

B. Cable-tool equipment.

The cable-tool machine used in completing test well A was the property of C. A. Stephenson. It consisted of the following:

Manufacturer and model: Bucyrus-Erie 36-L mounted on semi-trailer.

Serial number: 62424

Power: Waukesha Model 145-GK Multi-Fuel (gas-gasoline) engine rated at 175 horsepower at 1,700 revolutions per minute.

Derrick: height, 54 feet; rated capacity, 120,000 pounds.

Wire rope: 7/8-inch drill line; 9/16-inch sand line; 1-inch casing line.

Rope socket: Prosser wire-line swivel.

Drilling jar: 18-inch stroke.

Drill stem: diameter, 6 inches; length, 24 feet, weight, 1,800 pounds.

Bailer: dart type; diameter, 0.8 foot; length, 18 feet; capacity, 74 gallons.

Appendix II. Contract cost

Following is an itemization of payments made to the contractors under the contract for the drilling of which test well A was a part. This list was prepared by George Willson, of Holmes & Narver, Inc., and is divided into two parts according to the type of drilling being done.

A. Payment units completed during work with rotary drilling machine.

B. Payment units completed during work with cable-tool drilling machine.

Appendix II. Contract cost -- Continued

	Description	Quantity	Amount
1.	Move in and set up rotary machine	1/10 mobilization	$ 250.00
2.	Rotary drilling 15-inch hole in alluvium	1,546 ft	19,325.00
3.	Rotary pilot-hole drilling in alluvium	54 ft	337.50
4.	Standing by, ready, for single-point electrical and gamma ray logs	7 hrs	112.00
5.	Logging-truck mileage	1 ea	400.00
6.	Electrical log	1 ea	450.00
7.	Laterolog	1 ea	300.00
8.	Gamma ray-neutron log	1 ea	300.00
9.	Sonic log	1 ea	300.00
10.	Directional survey	1 ea	300.00
11.	Section-gauge log	1 ea	350.00
12.	Shale-shaker rent	1.5 month	225.00
13.	Marsh funnel viscosimeter and graduated cup	1 ea	8.00
	SUBTOTAL		$22,657.50

Appendix II. Contract cost -- Continued

Description	Quantity	Amount
1. Dismantle drilling machine at previous hole set up at hole A.............	1 ea...............	$ 300.00
2. Move drilling machine to hole A......	5 mi...............	25.00
3. Reaming in alluvium...................	46 ft...............	335.50
4. Furnish and install 12 3/4-inch OD casing...........................	1,559 ft...............	12,861.75
5. Cementing 12 3/4-inch OD casing......	1 job..............	1,250.00
6. Drilling..........................	270 ft...............	3,915.00
7. Logging-truck mileage................	1 ea...............	400.00
8. Electrical log.....................	1 ea...............	500.00
9. Laterolog.........................	1 ea...............	250.00
10. Gamma ray-neutron log...............	1 ea...............	350.00
11. Sonic log.........................	1 ea...............	350.00
12. Directional survey.................	1 ea...............	400.00
13. Section-gauge log..................	1 ea...............	450.00
14. Furnish and install 10 3/4-inch OD slotted casing....................	262 ft...............	2,292.50
15. Furnish and install 10 3/4-inch OD plain casing.....................	61 ft...............	411.75
16. Bailing...........................	4 hrs...............	64.00
17. Surging and bailing.................	149.0 hrs..............	2,384.00
18. Furnish 3-inch tubing................	1,855.6 ft..............	3,989.54
19. Furnish 1-inch access pipe...........	1,830 ft.............	1,372.50
20. Furnish pump test measurement equipment.......................	1 lot..............	3,800.00

Appendix II. Contract cost -- Continued

	Description	Quantity	Amount
21.	Install submersible pump................	1 job..............	$ 1,200.00
22.	Test pumping..........................	45.0 hrs...........	630.00
23.	Remove submersible pump................	1 job..............	600.00
24.	Standing by, ready, for water-level measurements......................	41.5 hrs...........	664.00
25.	Standing by, secured, for water-level measurements......................	21 hrs...........	294.00
	SUBTOTAL...		39,089.54
	GRAND TOTAL..		$ 61,747.04

Appendix III. Casing record

Following is the record of the casing, screening, and cementing in well A. All casing is 0.375-inch thick electric-welded steel pipe (ASTM-A 139-58, grade B); joints welded with a minimum of two passes by electric arc.

Depth interval (feet)	Casing and cement
0-1,555	12 3/4-inch OD; bottom cemented with 25 sacks of commercial-type neat cement squeezed into the annular space by a wood and burlap plug; upper 10 feet cemented with 10 sacks of cement mixed with sand.
1,547-1,559	10 3/4-inch OD; upper 10 feet annealed and swedged out against 12 3/4-inch OD casing.
1,559-1,608	10 3/4-inch OD.
1,608-1,870	10 3/4-inch OD with saw-cut vertical slots, 0.125 by 3 inches, in rows consisting of 16 slots each; rows separated by 3 inches of blank casing; slots staggered so that those in alternate rows are in line. A 1-foot piece of split, blank, 10 3/4-inch, 0.375 inch casing is welded to inside bottom.

Appendix IV. Bailing and pumping tests

Records of the hydraulic tests performed in test well A are given below. In all tests, the static water level at the beginning of testing was about 1,608 feet below the top of the 12 3/4-inch OD casing which was 1.5 feet above the land surface. All water-level measurements were made electrically with a two-conductor cable and bronze-magnesium probe. The operator error involved in the use of this device is as much as 0.5 foot. That is, on two consecutive trips down and up the hole, the measurements of static level by the same operator could differ by as much as 1.0 foot. This error in a bailing test would be due in part to the necessity for moving the measuring device from the hole to permit the bailing to be done and then returning it to its previous position. For this reason the last water level, rather than the first, is taken as the static level in tests where only one bailerful was removed and a 1-foot error could represent a large proportion of the drawdown.

Other conditions and circumstances differed from test to test, and accordingly are itemized separately for each test, together with the measurements of water level, in tables 7, 8, 9, 10, 11. The equipment used in the pumping tests is listed in appendix V.

Appendix IV. Bailing and pumping tests -- Continued

Table 7.--Recovery of water level in test well A after bailing in first bailing test.

Date: August 28, 1960. Observer: I. J. Winograd. Well depth: 1,730 feet. Well cased to: 1,555 feet. Capacity of bailer: 74 gallons. Bailing started: 8:22 am; stopped, 12:17 pm. Number of bailerfuls removed: 40. Quantity of water removed: 3,000 gallons. Average bailing rate: 12.3 gpm.

Time since bailing stopped (minutes)	Depth to water (feet)	Time since bailing stopped (minutes)	Depth to water (feet)
7	1,613.8	17	1,608.8
8	1,612.9	18	1,608.5
9	1,612.1	19	1,608.4
10	1,611.8	20	1,608.3
11	1,610.8	22	1,608.1
12	1,610.5	24	1,607.9
13	1,610.1	28	1,607.7
14	1,609.7	32	1,607.6
15	1,609.3	40	1,607.5
16	1,609.0	60	1,607.4

Appendix IV. Bailing and pumping tests -- Continued

Table 8.--Recovery of water level in test well A after removal of one bailerful of water in second bailing test.

Date: August 28, 1960. Observer: I. J. Winograd. Well depth: 1,730 feet. Well cased to: 1,555 feet. Capacity of bailer: 74 gallons. Number of bailerfuls removed: 1. Quantity of water removed: 74 gallons. Hours: 1:34 p.m.

Time since bailing stopped (minutes)	Depth to water (feet)	Time since bailing stopped (minutes)	Depth to water (feet)
7	1,611.5	15	1,609.3
8	1,611.0	16	1,609.1
9	1,610.6	18	1,609.0
10	1,610.3	20	1,608.9
11	1,610.0	25	1,608.8
12	1,609.8	35	1,608.8
13	1,609.6	70	1,608.5
14	1,609.5	100	1,608.5

Appendix IV. Bailing and pumping tests -- Continued

Table 9.--Recovery of water level in test well A after bailing in third bailing test.

Date: September 6, 1960. Observer: C. E. Price. Well depth: 1,870 feet. Well cased to: 1,870 feet; screened from 1,608 feet to 1,870 feet. Capacity of bailer: 33 gallons. Number of bailerfuls removed: 1. Quantity of water removed: 33 gallons. Hour: 12:28 pm.

Time since bailer removed (minutes)	Depth to water (feet)	Time since bailer removed (minutes)	Depth to water (feet)
6.5	1,609.70	14	1,609.12
8.5	1,609.58	17	1,609.04
10.5	1,609.30	20	1,609.02
11.5	1,609.22	23	1,609.01
12	1,609.20	33	1,608.96
12.75	1,609.18	38	1,608.97
13.25	1,609.13	43.5	1,608.97

Appendix IV. Pumping and bailing tests -- Continued

Table 10.--Record of first pumping test in well A.

Date: September 20-21, 1960. Observers: I. J. Winograd, John E. Moore, W. A. Beetem, William Thordarson, and George E. Walker. Well depths, casing, and screen: same as in third bailing test. Pumping started, September 20, 12:05 am; stopped September 21, 2:15 pm. Pumping rate: 60 gpm. Note: difficulty in lowering the measuring probe through access line made it impractical to refer actual water-level measurements to a point at the land surface; all measurements, therefore, are relative to the first water level of the series, which is assumed to have been at the known static water level, 1,608 feet.

Time since pumping started (minutes)	Depth to water (feet)	Time since pumping started (minutes)	Depth to water (feet)
1	1,613.2	12	1,634.3
2	1,618.4	13	1,634.9
3	1,622.8	14	1,635.4
4	1,625.4	15	1,635.6
5	1,627.4	16	1,636.0
6	1,628.8	17	1,636.2
7	1,630.4	18	1,636.6
8	1,631.2	19	1,636.8
9	1,632.1	20	1,637.0
10	1,633.1	22	1,637.4
11	1,633.7	24	1,637.7

Appendix IV. Pumping and bailing tests -- Continued

Table 10.--Record of first pumping test -- Continued

Time since pumping started (minutes)	Depth to water (feet)	Time since pumping started (minutes)	Depth to water (feet)
26	1,638.0	560	1,640.6
28	1,638.1	620	1,640.7
30	1,638.3	680	1,640.7
32	1,638.5	740	1,640.7
34	1,638.5	800	1,640.7
36	1,638.5	860	1,640.6
40	1,638.8	920	1,640.6
45	1,638.8	980	1,640.6
55	1,639.0	1040	1,640.7
65	1,639.3	1100	1,640.7
80	1,639.3	1160	1,640.7
95	1,639.5	1220	1,640.8
120	1,639.6	1280	1,640.8
140	1,639.7	1340	1,640.9
170	1,639.7	1400	1,640.9
200	1,639.8	1460	1,640.9
260	1,639.9	1520	1,640.9
320	1,640.0	1580	1,640.9
380	1,640.1	1640	1,640.9
440	1,640.2	1700	1,640.9
500	1,640.5	1760	1,640.9

Appendix IV. Pumping and bailing tests -- Continued

Table 10.--Record of first pumping test -- Continued

Time since pumping started (minutes)	Depth to water (feet)
1820	1,640.9
1880	1,641.1
1940	1,641.1
2000	1,641.1
2060	1,641.1
2120	1,641.1
2180	1,641.1
2240	1,640.9 (?)
2280	1,640.9

Time since pumping stopped (minutes)	Depth to water (feet)
0.5	1,638.6
1	1,636.3
1.5	1,634.3
2	1,632.8
2.5	1,630.7
3	1,628.8
3.5	1,627.2
4	1,626.0
4.5	1,624.4
5	1,623.2
6	1,620.4
7	1,618.4
8	1,616.6
9	1,615.2
10	1,614.2
11	1,613.2
12	1,612.6
13	1,612.1
14	1,611.6
15	1,611.3
16	1,611.0
17	1.610.7
18	1,610.6
19	1,610.4
21	1,610.1
22	1,610.0
24	1,609.8
26	1,609.6
30	1,609.3
35	1,609.1

Appendix IV. Pumping and bailing tests -- Continued

Table 10.--Record of first pumping test -- Continued

Time since pumping stopped (minutes)	Depth to water (feet)	Time since pumping stopped (minutes)	Depth to water (feet)
45	1,608.8	115	1,608.2
55	1,608.6	125	1,608.2
65	1,608.5	135	1,608.1
75	1,608.5	145	1,608.1
85	1,608.4	155	1,608.1
95	1,608.3	165	1,608.0
105	1,608.2		

Appendix IV. Pumping and bailing tests -- Continued

Table 11.--Record of second pumping test well A (step-drawdown test)

Date: September 21, 1960. Observers, John E. Moore and W. A. Beetem. Well depth, casing and screen, same as in third bailing test. Pumping started: 6:34 pm; stopped, 10:12 pm. Pumping rate: from 40 to 64 gallons per minute by steps.

Time since pumping stopped (minutes)	Depth to water (feet)	Pumping rate (gpm)	Time since Pumping stopped (minutes)	Depth to water (feet)	Pumping rate (gpm)
13	1,626.4	41	76	1,629.3	41
15	1,626.6		86	1,629.3	41
17	1,626.8		88	1,631.2	
19	1,626.9		91	1,632.9	52
21	1,626.9	40	96	1,634.0	52
23	1,626.8		101	1,634.0	
25	1,627.3		106	1,634.9	52
27	1,627.6		111	1,635.3	52
29	1,627.6		116	1,635.6	
31	1,627.9		126	1,636.0	
36	1,628.5	41	136	1,635.8	52
41	1,629.1		146	1,635.7	52
46	1,629.3		151	1,635.7	
51	1,629.3	41	156		
58	1,629.5		157	1,635.7	
63	1,629.3		159	1,637.0	64
68	1,629.3		163	1,638.8	64

Appendix IV. Pumping and bailing test -- Continued

Table II.--Record of second pumping test well A (step-drawdown test)--Continued

Time since pumping stopped (minutes)	Depth to water (feet)	Pumping rate (gpm)	Time since pumping stopped (minutes)	Depth to water (feet)	Pumping rate (gpm)
168	1,640.1	64	196	1,641.7	
171	1,640.7	64	206	1,641.8	
176	1,641.1		216	1,641.9	
186	1,641.6				

Appendix V. Equipment for pumping tests

Details of the pump and other equipment used in connection with the pumping tests in well A are given below.

Pump assembly:

Pump manufactured by: Reda Pump Co.

Type: submersible turbine, model number 95D47E, serial no. 49104.

Protector: Reda, series 500 type SA, serial number 52109.

Motor: electric, 60 cycle, 3 phase, 440 volts, 72 amps; rated at 50 horsepower at 3,450 rpm.

Intake setting: 1,790 feet below top of well casing.

Power cable: number 000, length 1,800 feet, held to discharge line by Reda bands and saddles.

Check valves: (a) immediately above the pump, Reda 2.5-inch ball check valve; (b) 1,175 feet above the pump, Vogt 2-inch, 600 psi forged steel ball check valve (number 5-4858).

Discharge line: 3-inch nominal tubing, 1,785 feet long, non-upset, 2.922-inch ID, 10 threads per inch.

Access (air) line: 1-inch standard weight pipe, ASTM A-120, with threaded ends, fastened to the discharge line by means of clamps at about 24-foot intervals.

Generator: Buda, 1,200 rpm, 60 cycle, 3 phase, 480 volts, 70 amps. serial number G7AJ #9204.

Control panel: Allen-Bradley Co., Bulletin 1232, series 74676, 60 cycle, 3 phase, 440 volts, in a NEMA type-3 cabinet equipped with a size-3 starter and a bulletin-810 magnetic overload relay.

Pumping-rate control: 1.5-inch plug-type globe valve.

Pumping-rate measurement: 10-gallon can and stop watch.