UNITED STATES

DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

APPRAISAL OF SHALLOW GROUND-WATER RESOURCES, PUEBLO ARMY DEPOT, COLORADO

By

Frank A. Welder and R. Theodore Hurr

OPEN-FILE REPORT

~~1000~~

72·447

Prepared by the

U.S. Geological Survey

for the

Department of the Army

Pueblo Army Depot

Water Resources Division
Colorado District
Denver, Colorado

December 1971

CONTENTS

ILLUSTRATIONS

ILLUSTRATIONS--Continued

TABLES

APPRAISAL OF SHALLOW GROUND-WATER RESOURCES, PUEBLO ARMY DEPOT, COLORADO

By Frank A. Welder and R. Thoedore Hurr

ABSTRACT

The water supply for the Pueblo Army Depot, 15 miles east of Pueblo, Colo., is obtained from wells that tap an aquifer in terrace alluvium. Withdrawals have resulted in a water-level decline of 27 feet, which adversely affects the discharge rate of individual wells. Furthermore, excessive pumpage has resulted in progressive deterioration of water quality. Over a 20-year period, hardness has increased from 70 milligrams per liter to 135 milligrams per liter and dissolved-solids content has increased from 250 milligrams per liter to 370 milligrams per liter.

Two new supply wells were drilled in the southern part of the Depot and were tested to determine aquifer properties and probable production rate. The hydraulic conductivity determined from these tests ranged from about 350 to nearly 600 gallons per day per square foot. The transmissivity for the full thickness of the aquifer is in the range of 7,500 to 12,000 gallons per day per foot.

The two new supply wells can be pumped at a combined rate of about 140 gallons per minute. If pumpage in the existing well field is reduced by the same amount, some recovery of water levels in the field will occur and the trend in water quality deterioration may slow or even reverse.

INTRODUCTION

Purpose and Scope

In response to a request by the Department of the Army, the U.S. Geological Survey began a study in 1967 to evaluate the ground-water supply at the Pueblo Army Depot, 15 miles east of Pueblo, Colo. (fig. 1). The purpose of the evaluation was to determine the prospects of obtaining additional ground water and to assist Depot operators in developing the supply to meet existing and future water requirements. The purpose of this report is to present the results of the evaluation and to describe the physical and hydraulic properties of the alluvial aquifer that lies beneath the Pueblo Army Depot, in order to provide information that will aid in developing the additional water supplies.

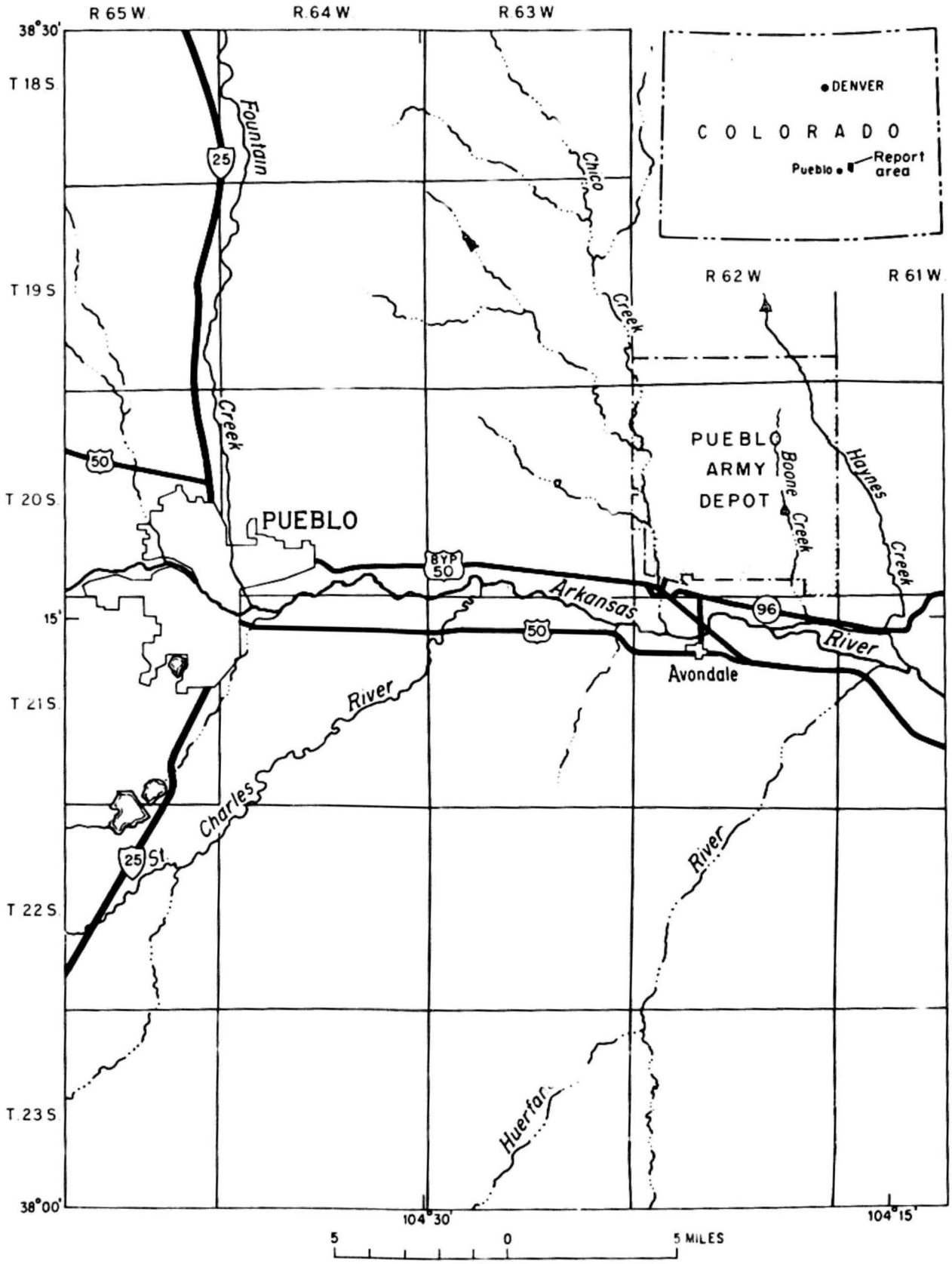


Figure 1. --Index map showing report area.

Geographic Setting

The Pueblo Army Depot, occupying about 40 square miles, is on a rolling upland terrace east of the Rocky Mountains in Pueblo County, south-central Colorado. The terrace, an erosional remnant of a much larger terrace, ranges from 4,650 to about 4,800 feet above mean sea level and slopes southward at about 25 feet per mile. The south edge of the terrace is about 150 feet above the Arkansas River. The terrace is drained on the west by Chico Creek, in the center by Boone Creek, both intermittent, and on the east by Haynes Creek. These creeks flow southward and are tributary to the Arkansas River (fig. 1). Erosion of the terrace by these creeks and by the Arkansas River has created local relief of about 100 feet.

The climate is semiarid. Nearby Pueblo receives about 12 inches of precipitation per year and has a mean annual temperature of 51°F. The soil is silt to fine sand and the native vegetation is grass and brush, typical of the climate and the region. A few trees grow in scattered areas where the roots can obtain sufficient water.

Method of Investigation

The investigation of the shallow ground-water resources of the Pueblo Army Depot was divided into several phases. The first phase included a geologic reconnaissance and test drilling to define the shape and extent of the aquifer and to delineate areas for more intensive investigation. The second phase consisted of testing existing wells and establishing an observation-well network for periodic measurements to determine seasonal and long-term fluctuations of water levels. The third phase was detailed drilling and testing in an area delineated by the first phase that also met utility requirements of the Depot. This drilling and testing included the collection of core samples for grain-size analysis, gamma-ray logging of two holes, and testing aquifer properties at two new supply wells drilled as a result of the investigation. Altogether, 44 test holes were drilled, of which 22 were converted to observation wells (pl. 1). Water samples were collected for analysis in order to determine the quality of water in the aquifer.

Acknowledgments

The assistance and cooperation of the engineering and technical personnel of Pueblo Army Depot aided the completion of the fieldwork, and is sincerely appreciated. Special thanks is extended to John Werme, Jr., and William Proudfoot, who provided administrative and engineering liaison during the investigation, and to Ray Aguirre, who provided shop facilities.

HYDROGEOLOGY

Geologic Setting

The Pueblo Army Depot is situated on an erosional remnant of an extensive alluvial terrace deposit. The moderately permeable terrace alluvium is underlain by nearly impermeable Pierre Shale. Erosion by Chico, Boone, and Haynes Creeks, and by the Arkansas River has exposed the Pierre Shale in many places along the west, south, and east edges of the terrace remnant. The Pierre Shale is the only bedrock formation that crops out in the report area. Below the Pierre Shale is a sequence of low permeability shale and limestone deposits underlain by the Dakota Sandstone. The Dakota Sandstone is the first water-bearing formation of any consequence below the terrace alluvium and is as much as 2,200 feet below land surface in the vicinity of the Depot.

Alluvium along the Arkansas River is water bearing and is the source of supply for many large-capacity irrigation wells. This alluvium is about 150 feet lower in elevation than the Depot. The lithologic and water-yielding characteristics of the geologic units in the area of the Pueblo Army Depot are summarized in table 1.

Terrace Alluvium and Aquifer

The terrace alluvium beneath the Depot is as much as 77 feet thick and lies on an irregular southward-sloping surface eroded on the Pierre Shale. The configuration of the bedrock surface as determined by test drilling and surficial mapping is shown in plate 2. The alluvium is thinnest along the edges of the terrace where it has been removed by erosion, and is thickest in bedrock troughs. One trough trends southward from near the center of the north Depot boundary to the other trough that trends generally westward through secs. 21 and 22, T. 20 S., R. 62 W.

The terrace alluvium contains the aquifer that supplies all the water used at the Pueblo Army Depot. The altitude and configuration of the water surface, which is the upper boundary of the aquifer, is shown on plate 3 and was determined from measurement of water levels in observation wells and from the position of springs around the edge of the terrace. The thickness of the aquifer is shown in plate 4 and was determined by the difference in altitude between the water-table surface and the bedrock surface. The aquifer is thinnest along the edges of the terrace, where it is drained by contact springs and thickest in the areas of the bedrock troughs (fig. 2).

Table 1.--Generalized section of the geologic units

System	Series	Geologic unit	Thickness (feet)	Physical character	Water supply potential
Quaternary	Holocene and Pleistocene	Terrace alluvium	0-77	Fine to coarse sand; very fine gravel, silt, clay, and some fine to coarse gravel and cobbles; poorly sorted.	Yields as much as 150 gallons per minute.
Cretaceous	Upper Cretaceous	Pierre Shale	2,200	Gray to black shale and sandy shale; contains iron concretions and thin limestone lenses.	Not a source of water in Depot area.
		Niobrara Formation	600-700	Gray to dark-gray sandy shale; contains concretionary zones and thick-bedded limestone at base.	Not a source of water in Depot area.
		Carlile Shale	150-250	Gray to dark-gray thin-bedded shale with light-tan to gray sandstone at top.	Not a source of water in Depot area.
		Greenhorn Limestone	80	Gray to dark-gray limestone separated by limy shale.	Not a source of water in Depot area.
		Graneros Shale	150-200	Gray to black bentonitic shale; contains thin clay beds.	Not a source of water in Depot area.
	Lower Cretaceous	Dakota Sandstone	80-150	Gray to white to yellow massive sandstone and dark-gray to black sandy shale.	Yields as much as 50 gallons per minute.
		Purgatoire Formation	150-250	Dark-gray to black shale at top and white to light-gray sandstone at base.	Yields as much as 50 gallons per minute.

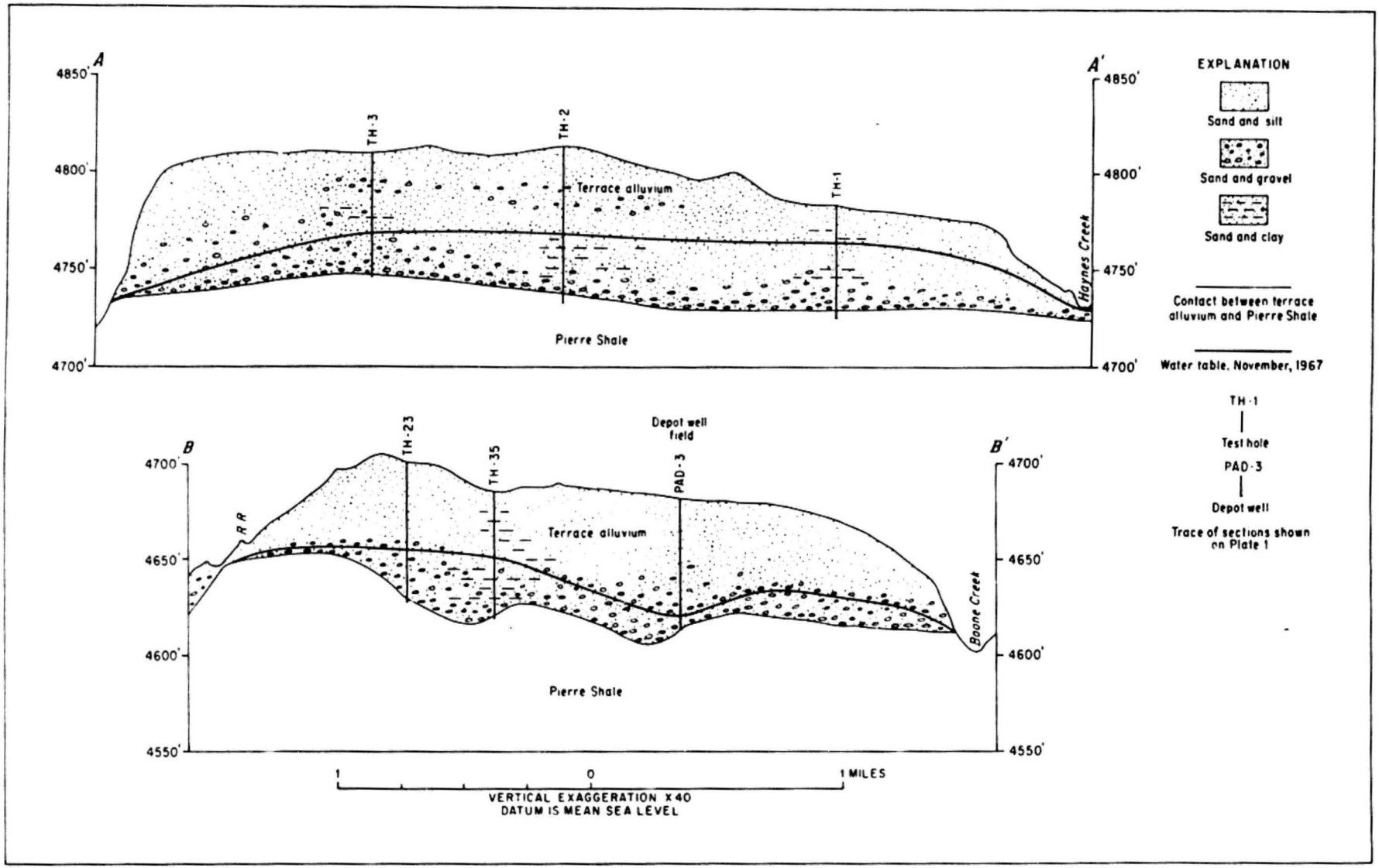


Figure 2. -- Hydrogeologic sections showing terrace alluvium.

The terrace alluvium, including the aquifer, is composed of stratified, unconsolidated clayey or silty sand, fine to coarse sand, sand and fine gravel, and a few thin beds of gravel (see Logs of test holes). The sequence of lithologies is not constant throughout the area, although generally the top part of the terrace alluvium is fine grained and grades downward into coarser, cleaner material. This gradation is illustrated by the gamma logs of test holes 40a and 41 (fig. 3) which show that the gamma activity decreases with depth. Gamma activity is generally indicative of clay content.

Test drilling indicated that the degree of sorting, or uniformity of grain size, within major lithologic sequences was poor. However, core samples taken at selected intervals below the water table in test holes 40a and 41 showed that these lithologic sequences are made up of alternating beds, one-half to several inches thick, of finer and coarser grained material. The finer material includes various proportions of sandy clayey silt. The coarser material is moderately well-sorted medium sand to fine gravel. The alternations of the beds is also grossly indicated by the alternations in the gamma logs of test holes 40a and 41 (fig. 3), where the presence of clay in the finer grained material increases the gamma activity of these beds. The particle-size distribution of a sample of the coarser material in test hole 40a is shown in figure 4. The percentage distribution of the particle sizes in this sample was: silt- and clay-size particles, 20 percent; sand-size particles, 67 percent; and gravel-size particles, 13 percent.

Hydraulic Properties

The hydraulic conductivity, or permeability, of the aquifer depends on the particle size of the aquifer material and on the degree of sorting--better sorted material is more permeable. The transmissivity, in turn, depends on the hydraulic conductivity and the thickness of the aquifer or water-bearing zone. Aquifer tests of supply wells 11 and 12 indicate a hydraulic conductivity ranging from about 350 to nearly 600 gpd per sq ft (gallons per day per square foot). However, because the aquifer is stratified and because the fine-grained materials have a relatively low hydraulic conductivity, the transmissivity values obtained from the aquifer tests are representative only of the water-yielding zones opposite the screened interval of the well. The transmissivity for the full thickness of aquifer is probably in the range of 7,500 to 12,000 gpd per ft (gallons per day per foot).

The fine-grained beds in the vicinity of supply wells 11 and 12 act, at least locally, as confining layers, so that the water-yielding zones in these wells are under artesian pressure. The storage coefficient determined by the aquifer tests was 3.3×10^{-4} for well 11 and 1.6×10^{-4} for well 12. Long-term pumping, however, would cause dewatering of the aquifer. The volume of water drained from aquifer material of the type present is generally 15 to 20 percent of the total volume dewatered.

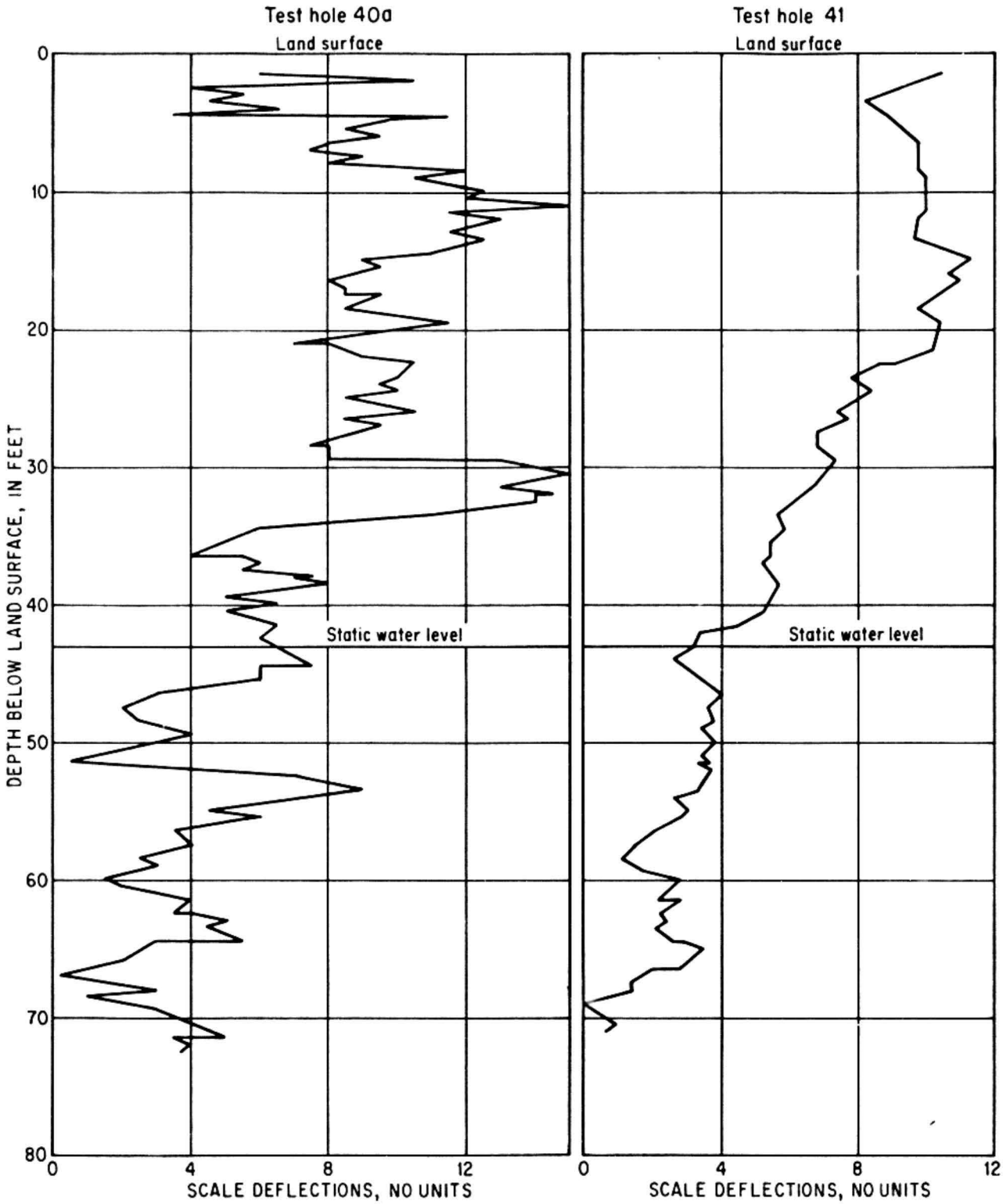


Figure 3. --Gamma logs of test holes 40a and 41, adjusted to same relative scale.

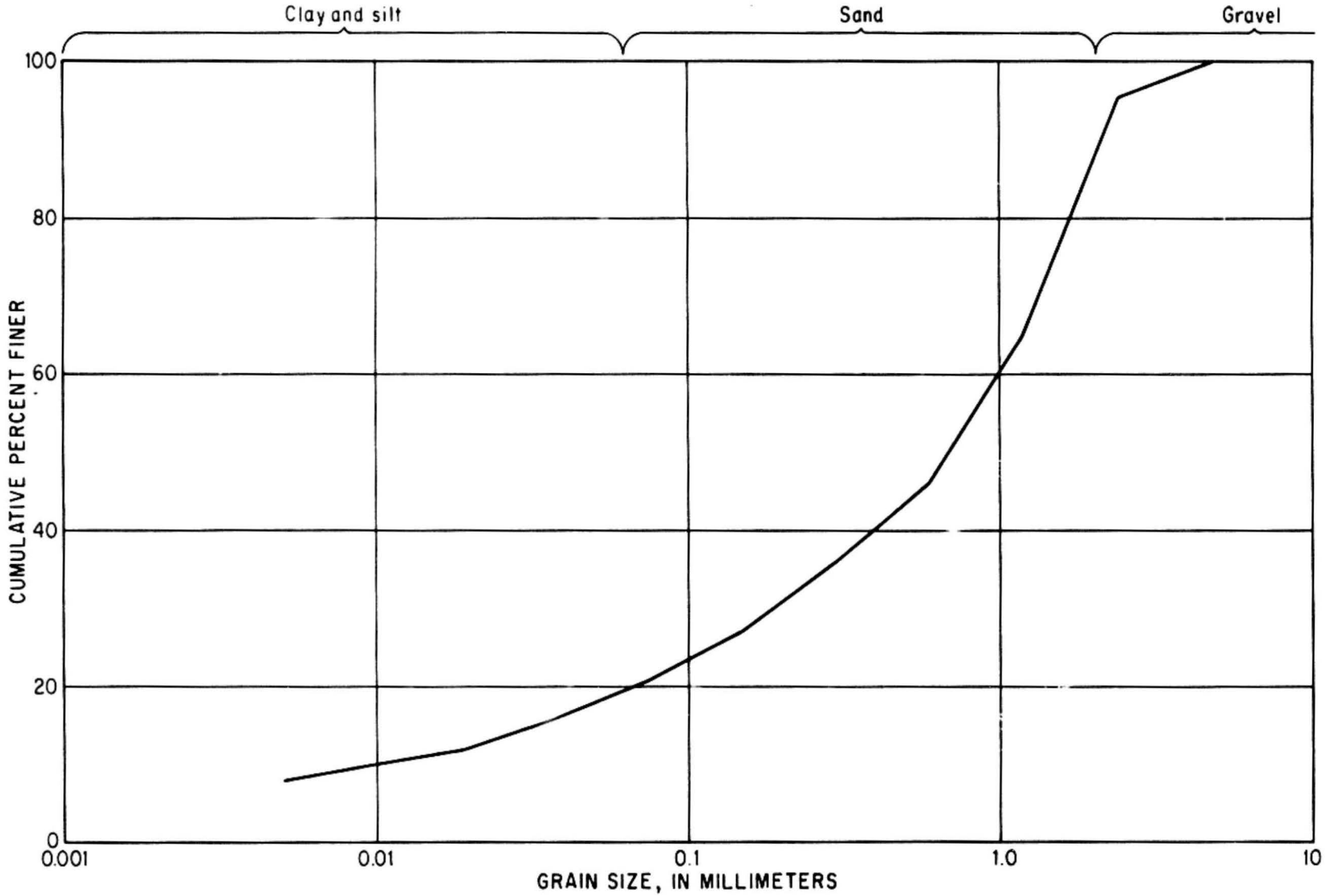


Figure 4. --Grain-size distribution of sample from test hole 40a.
(62-63 feet, sample 50N-4)

Well Performance

The results of aquifer tests on new supply wells are presented in table 2, and in figures 5 and 6; step drawdown tests are summarized in table 3. The lithologic log and well design of Depot supply wells 11 and 12 are shown in figures 7 and 8, respectively. Perhaps the most important factors affecting the specific capacity of wells tapping the aquifer (table 4) are well construction and length of test. For example, supply well 11 is equipped with 10 feet of screen and is, therefore, open to fewer water-yielding zones than is supply well 12, which has 20 feet of screen. The specific capacity of supply well 11 was 2.5 gpm (gallons per minute) per foot of drawdown, and the specific capacity of supply well 12 was 6.6 gpm per foot of drawdown (table 2). If all wells were of a similar design and all tests conducted for the same length of time, the specific capacity of wells penetrating equal thickness of aquifer composed of similar material would probably fall within a relatively narrow range of values.

Ground Water

Source

The source of ground water in the alluvial aquifer beneath the Pueblo Army Depot is predominantly underflow into the area from the north. This flow amounts to approximately 900 acre-feet per year. Recharge to the aquifer from precipitation falling within the boundaries of the Depot is negligible, even though the soil is sandy and apparently permeable. This lack of recharge is due to the small annual precipitation and the high evaporation potential. Moisture that does infiltrate the soil is quickly used by the native vegetation.

Discharge

Contact springs along the east, south, and west edges of the terrace are the main points of discharge from the aquifer. Many of these springs have been developed by private individuals for domestic and stock use.

Additional discharge from the aquifer is by the seven wells which have supplied the Depot since 1943. Six of the wells are grouped within an area about 1,000 feet in diameter, and the seventh is about 2,500 feet north of the center of the group (pl. 1). Peak withdrawal has increased from nearly 4 million gallons per month in 1943 to 13 million gallons per month in 1966. The average withdrawal from 1952 to 1964 was about 8 million gallons per month, or about 295 acre-feet per year, whereas from 1965 to 1968 the average withdrawal was a little less than 10 million gallons per month, or about 368 acre-feet per year (pl. 5).

Table 2.--Summary of aquifer test data from new supply wells, Pueblo Army Depot, Colo.

[All depths given below land surface]

Location	Supply well 11 SC20-62-28BAC2	Supply well 12 SC20-62-28ABB2
No. observation wells	5	4
Length of screen	10 feet	20 feet
Date tested	March 25-27, 1970	May 19-21, 1970
Depth to bedrock	72 feet	72.5 feet
Depth to water	43.7 feet	43.2 feet
Saturated interval	28 feet	29 feet
Pumping rate	40 gpm	84.5 gpm
Drawdown, end of test (adjusted for average yield)	16.1 feet	12.8 feet
Length of test	46 2/3 hours	47 1/2 hours
Specific capacity (yield/drawdown)	2.5 gpm per ft of drawdown	6.6 gpm per ft of drawdown
Residual saturated thickness	12 feet	16 feet

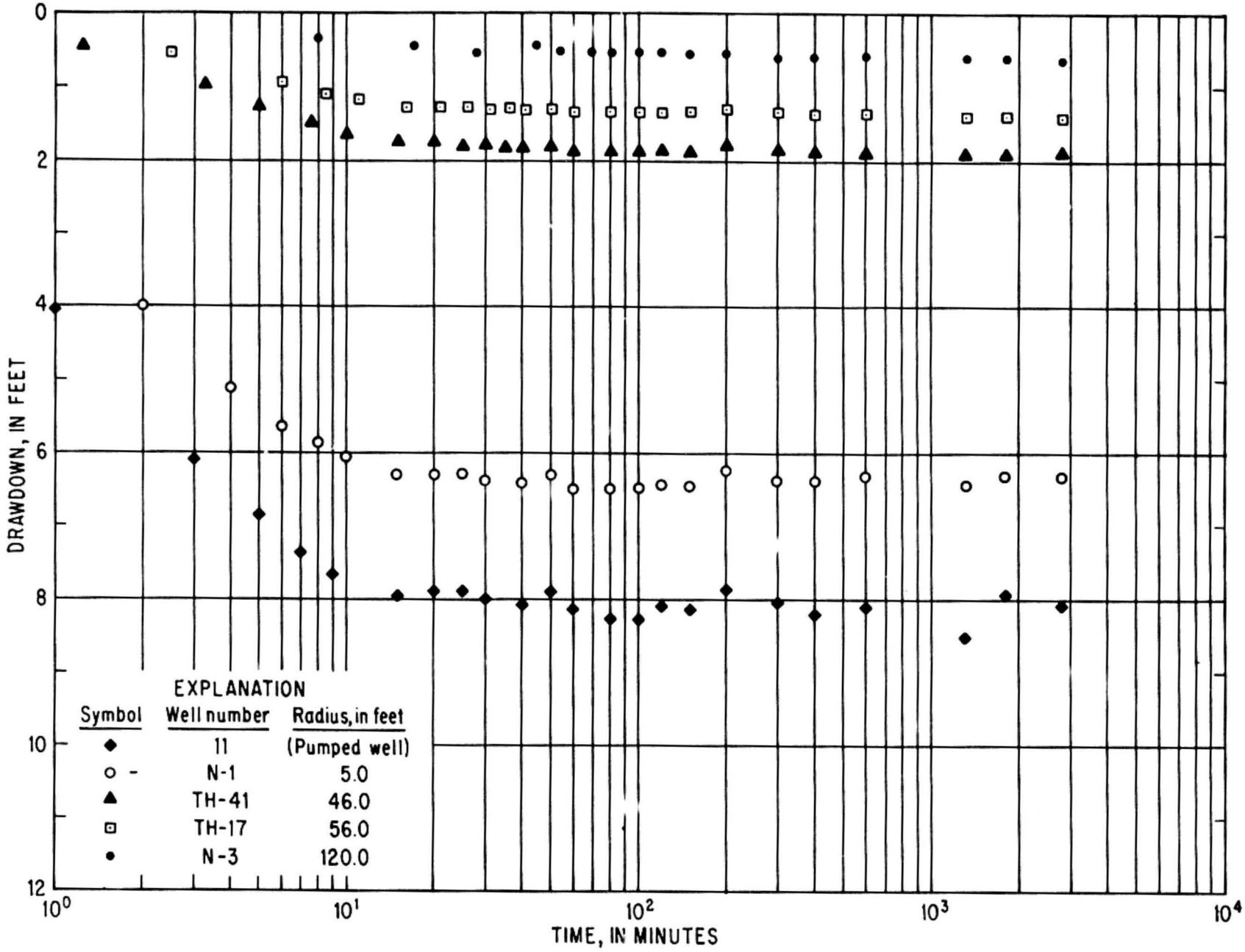


Figure 5. --Time-drawdown curves of test data adjusted to 20 gpm, Depot Supply Well 11, Pueblo Army Depot, Colo.

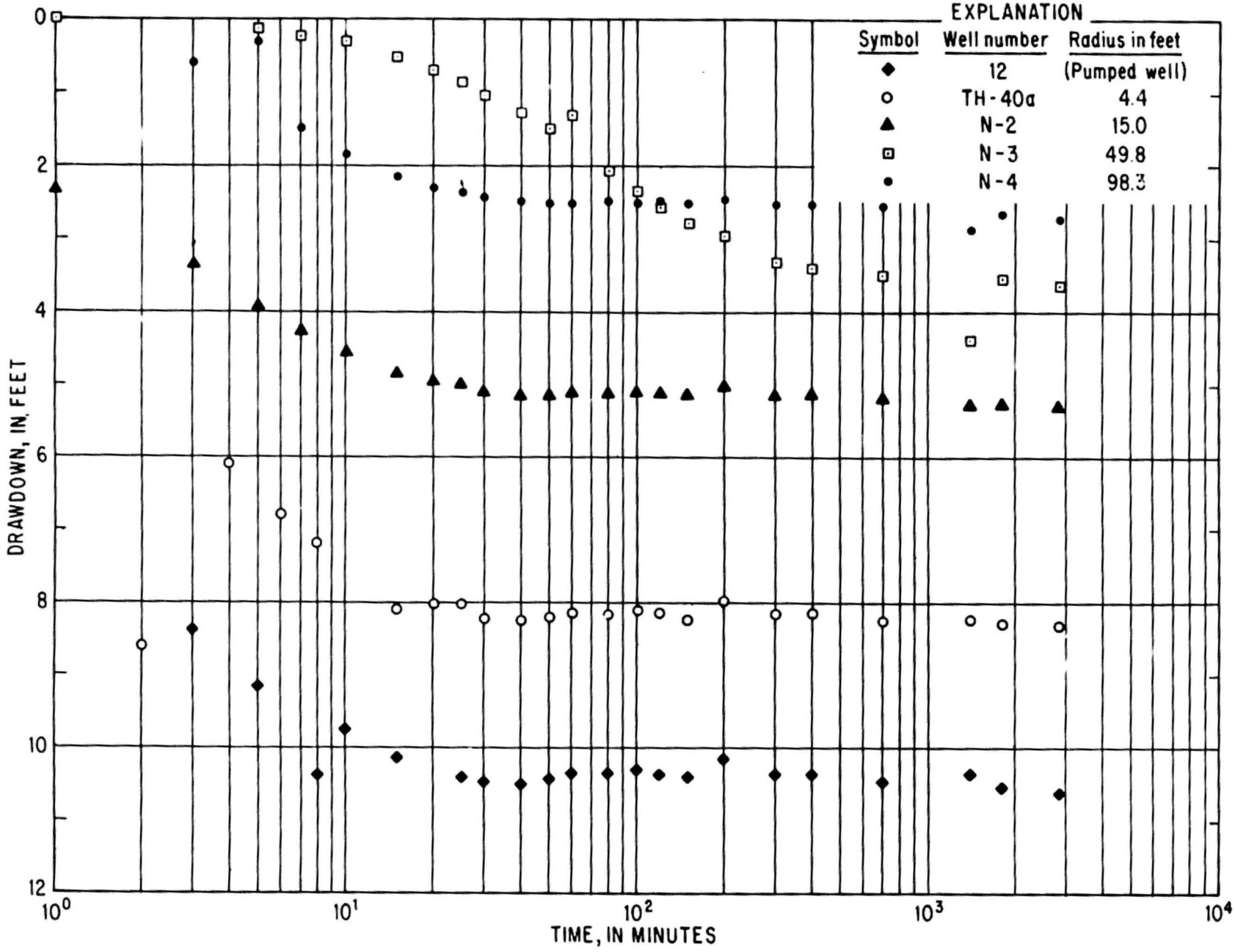


Figure 6. --Time-drawdown curves of test data adjusted to 70 gpm, Depot Supply Well 12, Pueblo Army Depot, Colo.

Table 3.--Summary of step-drawdown test data from new supply wells, Pueblo Army Depot, Colo.

Category	Supply well 11	Supply well 12
Step one		
Pumping rate, average, gpm	32	50
Drawdown, feet	14.35	7.35
Residual saturated thickness, feet	14	22
Time, minutes	50	50
Specific capacity, gpm per ft	2.30	6.80
Step two		
Pumping rate, average, gpm	42	73
Incremental rate, gpm	9	23
Incremental drawdown, feet	3.67	3.40
Residual saturated thickness, feet	10	18
Time, minutes	50	50
Incremental specific capacity, gpm per ft	2.45	6.85
Step three		
Pumping rate, average, gpm	58	101
Incremental rate, gpm	16	28
Incremental drawdown, feet	8.37	4.35
Residual saturated thickness, feet	2	14
Time, minutes	50	50
Incremental specific capacity, gpm per ft	2.03	6.37

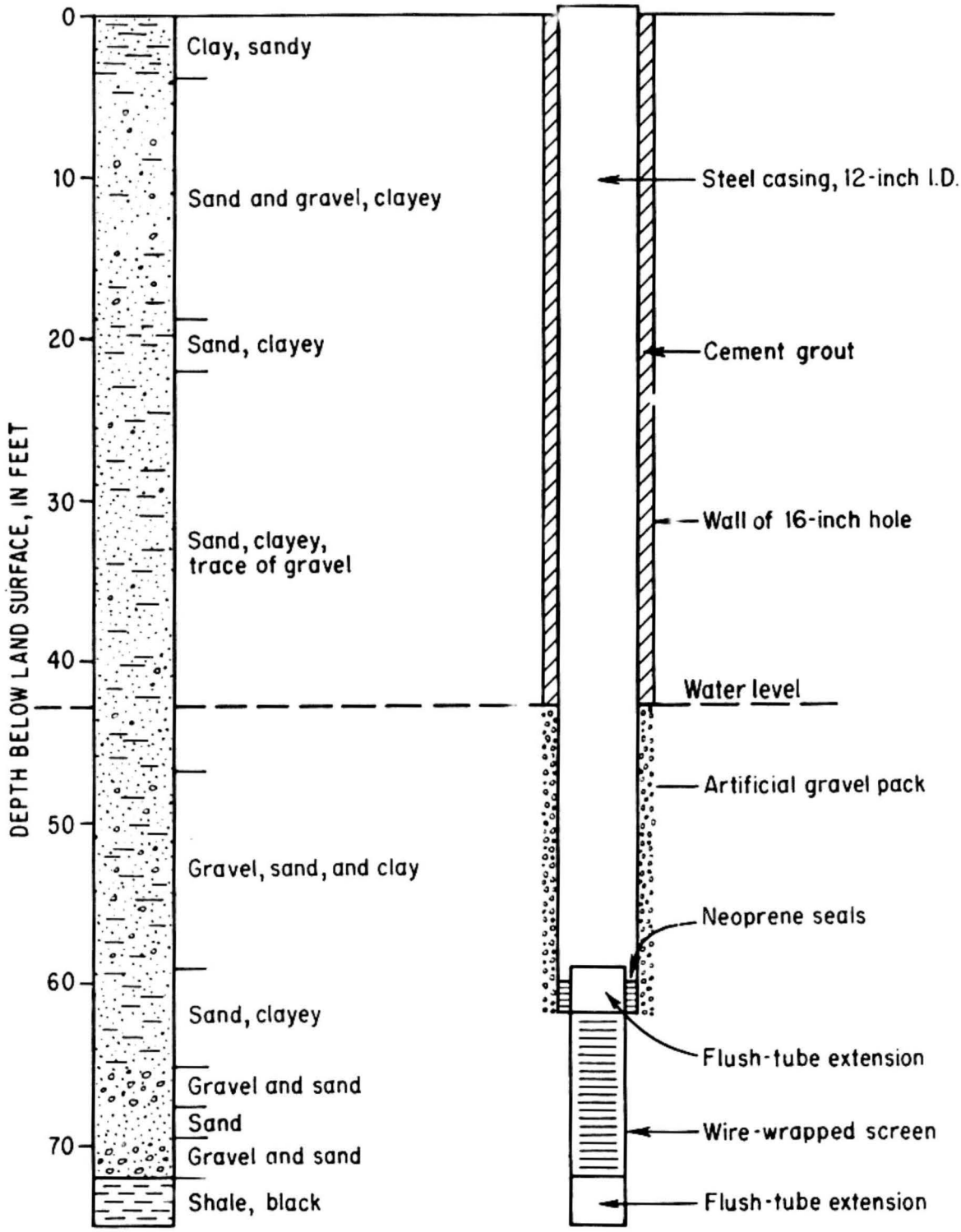


Figure 7. --Lithologic log and design of Depot Supply Well 11, Pueblo Army Depot, Colo.

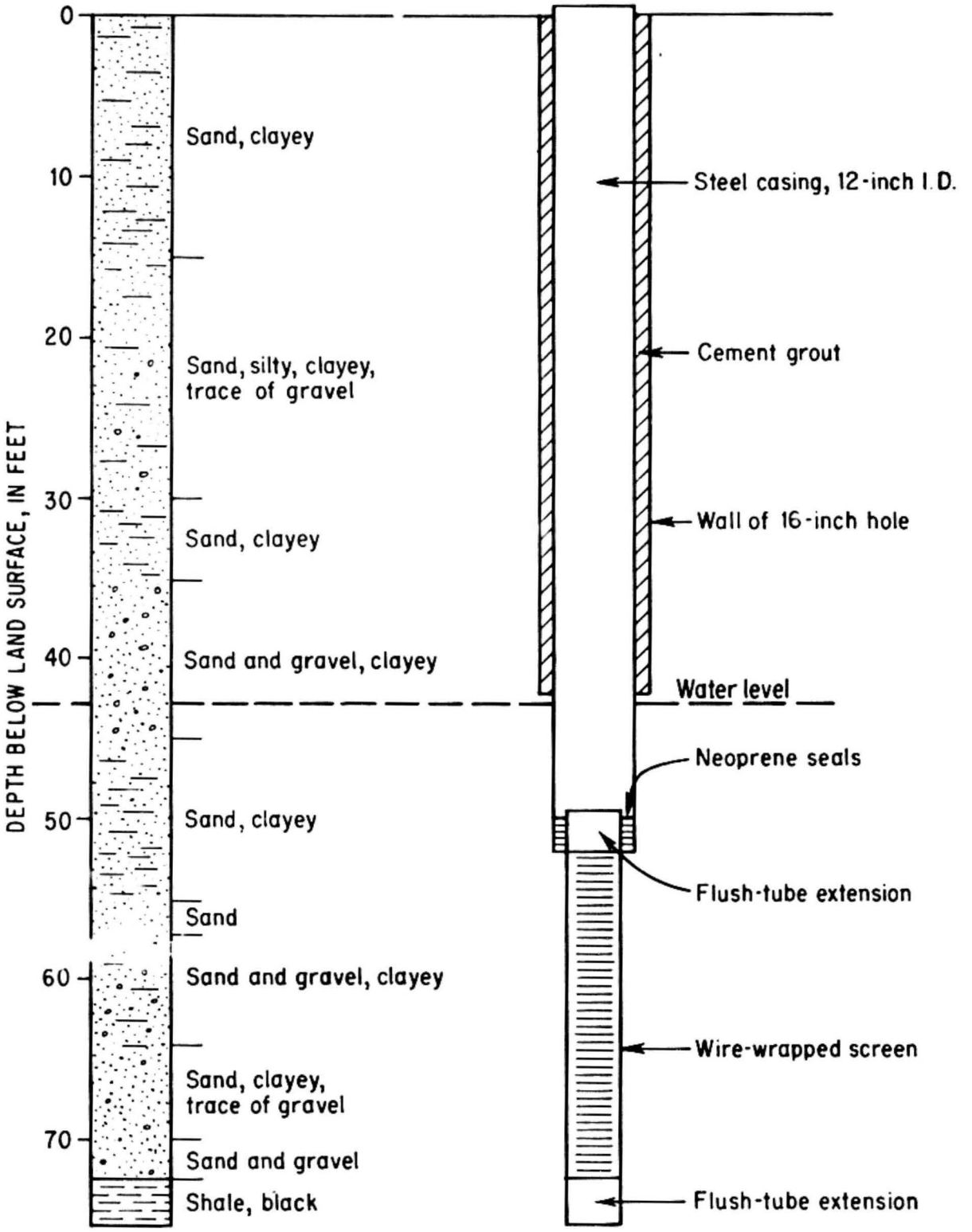


Figure 8. --Lithologic log and design of Depot Supply Well 12, Pueblo Army Depot, Colo.

Table 4.--Summary of well-performance tests

Well	Data	Static water level (feet)	Saturated thickness (feet)	Drawdown (feet)	Pumping rate (gpm)	Specific capacity (gpm per ft of drawdown)
1	2-19-43	42	35	7	60	8.6
	4-15-68	51.4	26	9.7	43	4.5
2	2-19-43	41.5	33	4	42	10.5
	4-15-68	52.5	22	16.4	51	3.1
3	2-19-43	30	39	6	80	13.3
	4-15-68	50	19	11.3	81	7.2
4	2-19-43	44	29	15	139	9.3
	4-15-68	55.5	18	6.8	74	10.9
5	2-19-43	44	24	24	120	5.0
	4-15-68	54.9	14	12	32	2.7
11	3-24-70	42	31	14.35	32	2.30
12	5-18-70	42	31	7.35	50	6.80

The effect of these withdrawals has been to dewater the aquifer in the vicinity of the well field. During 1943-70, water levels in the Lembke well, near the center of the well-field area, declined 27 feet. Seasonal fluctuations appear to be about 5 feet, with partial recovery each year (pl. 5). A decline of 27 feet is significant because the original saturated thickness of the aquifer in the well-field area was only about 35 feet, and because such a decrease in saturated thickness has reduced the rate at which the aquifer can yield water to the wells.

Water Quality

Ground water from the terrace alluvial aquifer is sodium bicarbonate type and is generally of good quality. The dissolved-solids content ranges from 254 to 415 mg/l (milligrams per liter), which is within standards for drinking water recommended by the U.S. Public Health Service (1962). Hardness ranges from 70 to 224 mg/l (table 5). Iron concentrations range from 0.00 to 0.23 mg/l, which is less than the amount that will cause severe staining of fixtures or laundry.

Water samples from wells in the existing well field (sec. 27, T. 20 S., R. 62 W.) have been analyzed periodically since 1952. Hardness has increased from 70 mg/l at that time, to 135 mg/l in 1967. The dissolved-solids concentration has increased from about 250 mg/l in 1952 to about 370 mg/l in 1967 (fig. 9). Water samples collected in 1970 from the two new supply wells in sec. 28, T. 20 S., R. 62 W., however, average about 95 mg/l hardness. If the trend in increasing dissolved solids continues (fig. 9), the water pumped from the existing well field will exceed the dissolved-solids limit of 500 mg/l recommended by the U.S. Public Health Service.

The tendency for water in an aquifer to incrust or corrode well casings and screens can be expressed by the Langelier index. This index is a representation of the degree of supersaturation or undersaturation of the water with respect to calcium carbonate (Langelier, 1936). For example, a value of + 1.0 represents supersaturation and a tendency for incrusting to occur, whereas, a value of -1.0 represents undersaturation and a tendency for corrosion to take place (Hem, 1970, p. 24). Based on the Langelier index, water in five of the wells sampled would tend to incrust the casings and screens slightly, and water in two of the wells would tend to corrode slightly (table 5).

Table 5.--Chemical analyses of water from wells

[Analytical results in milligrams per liter, unless otherwise indicated]

Well	Date of collection	Temperature (°C)	Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na + K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids (Residue at 180° C)	Hardness as $CaCO_3$ (Ca,Mg)	Noncarbonate hardness as ($CaCO_3$)	Percent sodium	Sodium adsorption ratio	Specific conductance (micromhos/cm at 25°C)	pH	Langelier index
SC20-62-22CDD (P.A.D. 3)	7-1-52	12	22	0.07	----	21	4.3	62	174	44	7.0	0.6	5.8	----	254	70	0	66	3.2	391	7.9	+0.2
SC20-62-22CDD (P.A.D. 3)	6-13-61	15	23	.00	----	27	4.0	64	177	53	11	.6	6.9	----	279	84	0	62	3.0	445	7.5	---
SC20-62-22DBD (P.A.D. 7)	7-1-63	21	23	.23	----	32	7.1	66	191	68	14	---	6	----	309	108	0	57	2.7	492	7.5	- .7
SC20-62-27ABC (P.A.D. 5)	2-28-65	17	24	.03	0.00	63	17	100	226	201	29	.5	5.9	----	343	224	39	49	2.9	824	7.7	+ .2
SC20-62-27BAA 1(P.A.D. 1)	7-1-52	12	23	.12	----	20	4.9	61	173	42	8.0	.6	6.0	----	258	70	0	66	3.2	388	8.2	+ .2
SC20-62-27BAA 1(P.A.D. 1)	5-18-66	15	21	.10	.00	33	7.1	72	188	83	16	.7	6.4	----	343	112	0	58	2.9	528	8.0	+ .3
SC20-62-27BAA 2(P.A.D. 2)	8-11-64	15	21	.03	----	28	6.1	68	181	72	10	.6	5.5	----	303	96	0	61	3.0	455	7.5	- .3
SC20-62-27BAA 3(P.A.D. 4)	7-1-52	12	22	.06	----	21	4.3	61	174	42	7.5	.6	5.7	----	252	70	0	65	3.2	8	8.1	+ .02
SC20-62-27BAA 3(P.A.D. 4)	5-29-59	17	24	.01	----	28	6.6	60	168	66	10	.6	4.7	----	301	97	0	57	2.7	467	7.8	----
SC20-62-27BAA 3(P.A.D. 4)	6-15-67	15	22	.00	.04	38	11	79	208	102	19	.6	5.8	----	381	138	0	55	2.9	600	7.5	----
SC20-62- 3BDD (P.A.D. 9)	9-14-67[1/]	17	--	<.1	----	--	----	---	---	---	---	---	---	----	---	170	--	--	---	400-590	7.6	----
SC20-62- 9BCA (P.A.D. 10)	9-12-67[1/]	16	--	<.1	----	--	----	---	---	---	---	---	---	----	---	103	--	--	---	440	7.6	----
SC20-62-28ABB2(P.A.D.12)	5-14-70[1/]	16	--	<.1	----	--	----	---	---	---	---	---	---	----	---	103	--	--	---	500	8.0	----
SC20-62-28BAC2(P.A.D.11)	3-5-70[1/]	16	--	.1	----	--	----	---	---	---	---	---	---	----	---	86	--	--	---	420	8.0	----
SC20-62-28 BDB(TH 17)	10-28-68	16	23	---	----	42	12	83[2/]	220	114	22	.7	14	.06	415	156	0	53	2.9	636	7.9	+ .1

1/ Field determination.

2/ Sodium only.

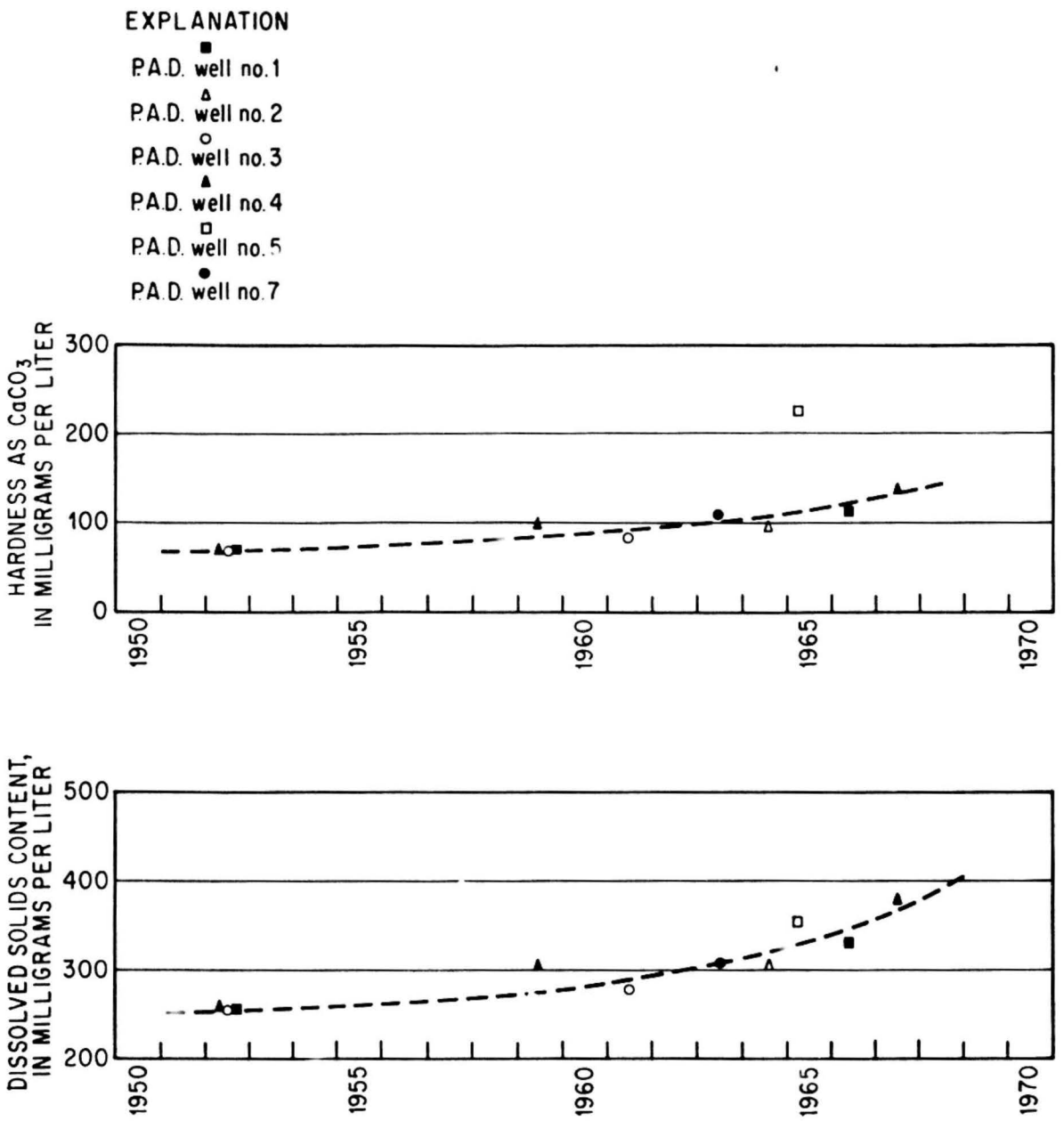


Figure 9. --Dissolved-solids concentration and hardness of water from supply wells, Pueblo Army Depot, Colo., 1952-67.

FUTURE WATER SUPPLIES

Within the Pueblo Army Depot, the areas of greatest saturated thickness offer the most promise for additional water supplies. In the broad trough trending southward through the southwest quarter of sec. 34, T. 19 S., R. 62 W. the saturated thickness exceeds 40 feet (pl. 4) and in the narrow trough trending generally westward through the northern part of sec. 28 and the southern part of secs. 21 and 22, T. 20 S., R. 62 W., the saturated thickness is about 30 feet (pl. 4). Supply wells 11 and 12, drilled in the southern area, should produce at a combined rate of about 140 gpm. A reduction of pumpage by this amount in the existing well field will allow some recovery of water level, and may slow or even reverse the trend of deteriorating water quality. If water from supply wells 11 and 12 follows the same pattern of quality deterioration or if the production declines as experienced at the well field, additional supplies can be obtained from the northern area.

A continuing program of data collection should be maintained to determine the effects of putting the new supply wells into operation and cutting back production in the well field. This program should include periodic measurements of water levels in observation wells, tabulation of pumpage records for the existing well field and the new supply wells, periodic performance tests on all supply wells, and the periodic collection and analysis of water samples to determine the quality of water produced from all supply wells.

SUMMARY AND CONCLUSIONS

Test drilling delineated two areas with a saturated thickness of at least 30 feet. Two new supply wells were drilled in the southern area and tested to determine the properties of the aquifer and the rate at which the wells could be pumped. The combined rate of pumping can be about 140 gpm. Reducing pumpage an equal amount in the existing well field will allow some recovery of water levels which have declined 27 feet during 1943-70 and may slow or even reverse a trend in water-quality deterioration that has been observed in samples taken over nearly 20 years.

SYSTEM OF NUMBERING WELLS AND TEST HOLES

The well numbers in the logs of test holes indicate their locations as shown on plates 1 through 4. The numbers are based on the U.S. Bureau of Land Management system of land subdivision and show the location of the site by quadrant, township, range, section, and position within the section. A graphic illustration of this method of location of a well is shown in figure 10. The first capital letter, "S" preceding the location number means that the site is located in the area governed by the sixth principal meridan. The second capital letter, "C" (also preceding the location number), indicates the quadrant in which the well

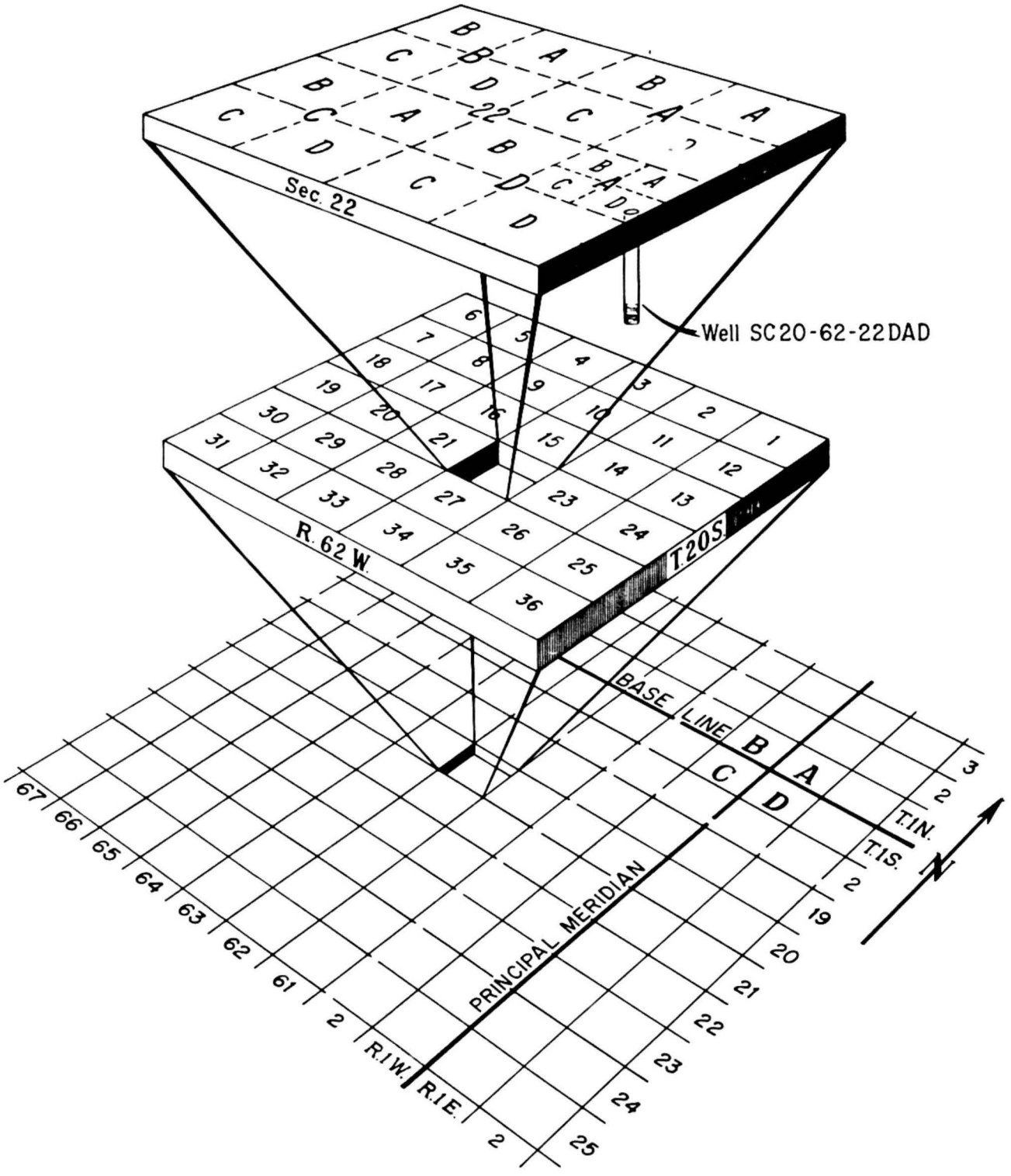


Figure 10. --System of numbering wells and test holes.

is located. Four quadrants are formed by the intersection of the base line and the principal meridan: A indicates the northeast quadrant; B, the northwest; C, the southwest; and D, the southeast. The first numeral indicates the township; the second, the range; and the third, the section in which the well is located. The letters following the section number indicate the location of the well within the section. The first letter denotes the quarter section; the second the quarter-quarter section; and the third, the quarter-quarter-quarter section. The letters are assigned within the section in a counter-clockwise direction, beginning with (A) in the northeast quarter. Letters are assigned within each quarter section and within each quarter-quarter section in the same manner. For example, SC20-62-22DAD indicates a well in the SE¼NE¼SE¼ sec. 22, T. 20 S., R. 62 W. Where two or more locations are within the smallest subdivision, consecutive numbers, beginning with 1, are added after the letter designation in the order in which the wells were inventoried.

SELECTED REFERENCES

Hem, J. D., 1970, Study and interpretation of the chemical characteristics of natural water: U.S. Geol. Survey Water-Supply Paper 1473, 2 ed., 363 p.

Langelier, W. F., 1936, The analytical control of anticorrosion water treatment: Am. Water Works Assoc. Jour., v. 28, p. 1500-1521.

Major, T. J., Hurr, R. T., and Moore, J. E., 1970, Hydrogeologic data of the valley-fill deposits in the lower Arkansas River valley, Colorado: Colorado Water Conserv. Board Basic-Data Release 21, 125 p.

McGovern, H. E., Gregg, D. O., and Brennan, Robert, 1964, Hydrogeologic data of the alluvial deposits in Pueblo and Fremont Counties, Colorado: Colorado Water Conserv. Board Basic-Data Release 18, 27 p. [1965].

U.S. Public Health Service, 1962, Drinking water standards: U.S. Public Health Service Pub. 956, 61 p.

Voegeli, P. T., Sr., and Hershey, L. A., 1965, Geology and ground-water resources of Prowers County, Colorado: U.S. Geol. Survey Water-Supply Paper 1772, 101 p.

Weist, G. W., 1963, Water in the Dakota and Purgatoire Formations in Otero County and the southern part of Crowley County, Colorado: U.S. Geol. Survey Water-Supply Paper 1669-P, 17 p.

LOGS OF TEST HOLES DRILLED BY U.S. GEOLOGICAL SURVEY

[Samples were described by the authors. Altitudes shown are land surface at test-hole sites. Thickness in feet. Depth in feet below land surface]

	Thickness	Depth
SC19-62-34AAB. Alt. 4,783.1 ft. Drilled October 1967.		
Test hole 1 - Observation well		
Terrace alluvium:		
Sand, fine to medium.	13	13
Sand, fine to medium, clayey.	5	18
Clay, sandy (water level at 18 feet).	2	20
Sand, medium to coarse.	4	24
Sand, medium to very coarse, and very fine gravel; contains silt and clay	16	40
Gravel, very fine to fine, and medium to very coarse sand, contains silt.	4	44
Gravel, very fine, and medium to very coarse sand; contains silty clay streaks . . .	10	54
Pierre Shale:		
Shale, black, sticky.	4	58
SC19-62-33AAB. Alt. 4,814.2 ft. Drilled October 1967.		
Test hole 2		
Terrace alluvium:		
Sand, fine to medium.	20	20
Gravel, very fine to fine, silty; contains coarse to very coarse sand	8	28
Gravel, very fine to medium, clayey; contains sand	5	33
Gravel, very fine to fine, and coarse to very coarse sand; contains silt.	4	37
Sand, medium to very coarse, and very fine to fine gravel; contains silt and clay	6	43
Sand, medium to coarse, and silt (water level about 46 feet)	11	54
Clay and silt	6	60
Sand, medium to coarse, silty, clayey	5	65
Sand, medium to coarse, silty; contains clay streaks	2	67
Sand, medium to very coarse, silty; contains very fine gravel	9	76
Pierre Shale:		
Shale, greenish-gray.	5	81

	Thickness	Depth
SC19-62-32AAA. Alt. 4,810.5 ft. Drilled October 1967.		
Test hole 3 - Observation well		
Terrace alluvium		
Sand, fine to medium.	8	8
Sand, fine to medium, clayey.	2	10
Sand, fine to very coarse, silty; contains very fine gravel	4	14
Sand, medium to very coarse	14	28
Sand, medium to very coarse, and very fine to medium gravel; contains clay.	5	33
Clay, sandy	1	34
Sand, medium to very coarse, silty, clayey; contains very fine gravel.	5	39
Clay, sandy; contains very fine to fine gravel (water level at 40 feet).	2	41
Sand, medium to very coarse, silty, clayey; contains very fine gravel.	11	52
Sand, coarse to very coarse, silty, clayey; contains very fine gravel.	5	57
Sand, medium to very coarse, and very fine gravel; contains silt.	6	63
Pierre Shale:		
Shale, yellow	1	64
SC20-62-4BBD. Alt. 4,774.6 ft. Drilled October 1967.		
Test hole 4 - Observation well		
Terrace alluvium		
Sand, fine, silty	4	4
Sand, medium to coarse; contains some gravel. . .	4	8
Sand, fine to coarse; contains some very coarse sand.	7	15
Sand, fine to very coarse; contains some very fine gravel	3	18
Sand, fine to very coarse; contains some very fine gravel, and clay streaks	5	23
Sand, medium to very coarse, and very fine gravel (water level at 32 feet).	12	35
Sand, medium to very coarse, and very fine to fine gravel; contains silt.	9	44
Gravel, very fine to medium, and medium to very coarse sand; contains clay.	1	45
Sand, medium to very coarse, and very fine to fine gravel; contains silt.	8	53
Pierre Shale:		
Shale, black.	1	54

	Thickness	Depth
SC20-62-3BDD. Alt 4,759.2 ft. Drilled October 1967.		
Test hole 5		
Terrace alluvium:		
Sand, fine to medium.	6	6
Sand, fine to medium, silty; contains some very coarse sand and very fine gravel	2	8
Sand, medium to very coarse, silty; contains very fine gravel	5	13
Clay, sandy, alternating with medium to very coarse sand and very fine gravel	7	20
Sand, medium to very coarse, and very fine silty gravel (water at 21 feet).	3	23
Clay, sandy	1	24
Sand, medium to very coarse, and very fine to fine gravel; contains silt.	8	32
Sand, medium to very coarse, and very fine to fine gravel; contains silt and clay.	13	45
Gravel, fine to medium, and medium to very coarse sand; contains silt	8	53
Clay, sandy	1	54
Sand, medium to very coarse, and very fine to fine gravel; contains silt	4	58
Pierre Shale:		
Shale, black.	1	59
SC20-62-9BCD. Alt. 4,759.5 ft. Drilled October 1967.		
Test hole 6		
Terrace alluvium:		
Sand, fine to medium.	2	2
Sand, fine to medium, silty; contains very coarse sand.	6	8
Sand, medium to very coarse, silty; contains some very fine gravel.	15	23
Sand, medium to very coarse, and very fine to medium gravel; contains silt and some coarse gravel.	4	27
Sand, medium to very coarse, and very fine to medium gravel; contains clay streaks	5	32
Sand, medium to very coarse, silty; contains very fine gravel	6	38
Clay, sandy	1	39
Gravel, fine to very coarse, and very coarse sand; contains silt (water level at 41 feet) . .	3	42
Sand, medium to very coarse, and very fine to fine gravel.	21	63
Pierre Shale:		
Shale, brown.	1	64

	Thick-ness	Depth
SC20-62-10BDD. Alt. 4,740.9 ft. Drilled November 1967.		
Test hole 7 - Observation well		
Terrace alluvium:		
Sand and silt.	5	5
Sand, fine to very coarse; contains very fine to medium gravel.	2	7
Sand, fine to very coarse; contains fine gravel. . .	5	12
Sand, medium to very coarse, and very fine gravel; contains silt	8	20
Gravel, fine to coarse, and medium to very coarse sand	1	21
Sand, medium to very coarse, and very fine gravel; contains silt	4	25
Clay, sandy; contains some clayey medium to coarse sand (water level at 29 feet).	5	30
Clay, sandy, alternating with silty clayey medium to very coarse sand.	18	48
Pierre Shale:		
Shale, black, soft	3	51
SC20-62-15ACA. Alt. 4,710.8 ft. Drilled November 1967.		
Test hole 8 - Observation well		
Terrace alluvium:		
Sand, fine to medium, silty.	3	3
Sand, fine to very coarse, silty; contains some very fine gravel	5	8
Clay, sandy, and medium to very coarse sand; contains silt, and very fine gravel	6	14
Sand, coarse to very coarse, clayey; contains medium sand and very fine gravel.	4	18
Sand, medium to very coarse, silty, clayey; contains very fine gravel	5	23
Sand, medium to very coarse, silty (water level at 27 feet)	17	40
Sand, medium to very coarse, silty; contains very fine gravel.	4	44
Sand, very fine, silty, clayey	3	47

	Thick-ness	Depth
SC20-62-15BCA. Alt. 4,720.4 ft. Drilled November 1967.		
Test hole 9 - Observation well		
Terrace alluvium:		
Silt, sandy; contains fine gravel.	7	7
Sand, fine to very coarse; contains fine to medium gravel.	5	12
Gravel, fine to medium, and fine to very coarse sand	10	22
Sand, very fine to very coarse, and very fine to medium gravel.	10	32
Gravel, very fine to medium; contains very fine to very coarse sand (water level at 33 feet). . .	3	35
Sand, very fine to very coarse, silty, clayey. . . .	12	47
Pierre Shale:		
Shale, black	2	49
SC20-62-16BDA. Alt. 4,734.2 ft. Drilled November 1967.		
Test hole 10 - Observation well		
Terrace alluvium:		
Sand, fine to medium, silty.	9	9
Sand, fine to medium, silty; contains very coarse sand and very fine gravel.	5	14
Sand, medium to very coarse, and very fine gravel; contains silt and some clay	4	18
Sand, medium to very coarse, and very fine gravel; contains silt, clay streaks, and sand streaks.	7	25
Sand, very coarse, and very fine gravel; contains silt, medium sand, and clay streaks	8	33
Sand, medium to very coarse, silty; contains very fine gravel.	7	40
Gravel, fine to coarse, silty; contains medium to very coarse sand and very fine gravel (water level at 41 feet).	2	42
Sand, medium to very coarse, and very fine gravel; contains silt	16	58
Pierre Shale:		
Shale, gray with yellow streaks.	1	59

	Thick-ness	Depth
SC20-62-17ADA. Alt. 4,723.9 ft. Drilled November 1967.		
Test hole 11 - Observation well		
Terrace alluvium:		
Sand, fine to medium, silty.	7	7
Sand, medium to coarse, and very fine gravel; contains silt and some very coarse sand	21	28
Sand, medium to very coarse, and very fine gravel; contains some fine to coarse gravel (water level at 31 feet)	5	33
Sand, medium to very coarse, and very fine gravel	5	38
Sand, medium to very coarse, and very fine gravel; contains clay streaks and silt.	6	44
Pierre Shale:		
Shale, grayish-brown	1	45
SC20-62-22DAD. Alt. 4,671.3 ft. Drilled November 1967.		
Test hole 12 - Observation well		
Terrace alluvium:		
Sand, fine to medium, silty.	1	1
Silt, sandy, and clay.	5	6
Sand, medium to coarse; contains some very coarse sand	2	8
Sand, medium to coarse; contains some very coarse sand	4	12
Sand, medium to coarse; contains some very coarse sand, silt, and clay	10	22
Sand, medium to coarse; contains clay, sandy clay streaks, and some very coarse sand (water level at 24 feet).	17	39
Sand, medium to coarse; contains some very coarse sand and very fine to medium gravel.	1	40
Sand, medium to coarse, and sandy clay; contains some very coarse sand.	3	43
Gravel, fine to coarse, medium to very coarse sand, and sandy clay streaks.	7	50
Pierre Shale:		
Shale, black, soft	2	52

	Thickness	Depth
SC20-62-22CAC. Alt. 4,691.2 ft. Drilled November 1967.		
Test hole 13 - Observation well		
Terrace alluvium:		
Sand, fine to medium, silty.	3	3
Sand, fine to medium, silty; contains some coarse to very coarse sand.	5	8
Sand, fine to medium; contains some coarse sand to very fine gravel.	27	35
Sand, fine to medium; contains some coarse to very coarse sand (water level at 40 feet)	5	40
Sand, medium to very coarse, and very fine gravel.	13	53
Pierre Shale:		
Clay, grayish-black.	10	63
Shale, greenish-gray to black.	1	64
SC20-62-22CBC. Alt. 4,695.1 ft. Drilled November 1967.		
Test hole 14		
Terrace alluvium:		
Sand, fine to medium, silty.	3	3
Sand, medium to coarse, silty.	9	12
Sand, medium to coarse	6	18
Sand, medium to very coarse, and very fine to fine gravel; contains some medium gravel.	5	23
Sand, medium to coarse; contains some very coarse sand and very fine gravel (water level at 41 feet)	25	48
Clay; contains medium to very coarse sand and very fine gravel.	1	49
Sand, medium to very coarse, and very fine gravel	4	53
Pierre Shale:		
Shale, black	1	54
SC20-62-21DBC. Alt. 4,696.8 ft. Drilled November 1967		
Test hole 15 - Observation well		
Terrace alluvium:		
Sand, fine to medium, silty; contains very fine to coarse gravel	1	1
Sand, fine to medium, silty.	1	2
Sand, medium to very coarse, and very fine gravel; contains clay	11	13
Sand, medium to coarse; contains some very coarse sand	5	18
Sand, medium to very coarse, clayey.	4	22

	Thick-ness	Depth
Clay, sandy, silty.	7	29
Sand, medium to coarse (water level at 31 feet)	4	33
Clay, sandy, silty; contains medium to very coarse sand streaks.	7	40
Pierre Shale:		
Shale, dark-gray.	1	41
SC20-62-21CBD. Alt. 4,699.5 ft. Drilled November 1967.		
Test hole 16		
Terrace alluvium:		
Sand, medium to coarse; contains some very coarse sand and very fine gravel	15	15
Sand, medium to very coarse, and very fine gravel	3	18
Sand, medium to coarse; contains some very coarse sand and very fine gravel (water level at 33 feet).	25	43
Pierre Shale:		
Shale	1	44
SC20-62-28BDB. Alt. 4,692.8 ft. Drilled November 1967.		
Test hole 17 - Observation well		
Terrace alluvium:		
Sand, fine to medium, silty	4	4
Clay, sandy; contains gravel.	4	8
Sand, medium to very coarse, and very fine to fine gravel; contains some clay	6	14
Sand, medium to coarse; contains some very coarse sand.	6	20
Gravel, fine to medium; contains some very coarse sand and very fine gravel.	3	23
Sand, medium to coarse; contains some very coarse sand.	7	30
Sand, medium to very coarse, and very fine gravel; contains some fine to medium gravel. . . .	8	38
Sand, medium to coarse; contains very coarse sand and very fine gravel (water level at 43 feet)	6	44
Sand, medium to very coarse, and very fine gravel; contains some fine gravel.	25	69
Sand and clay	1	70
Sand, medium to very coarse, and very fine to fine gravel	3	73
Pierre Shale:		
Shale, dark-gray.	1	74

	Thick-ness	Depth
SC20-62-33BAD. Alt. 4,678.7 ft. Drilled November 1967.		
Test hole 18		
Terrace alluvium:		
Sand, medium, silty; contains some coarse sand. . . .	8	8
Sand, medium to very coarse, and very fine to fine gravel; contains clay.	2	10
Sand, medium to very coarse; contains very fine gravel and some clay.	10	20
Sand, medium to coarse; contains some very coarse sand.	20	40
Sand, medium to coarse; contains some very coarse sand and very fine to fine gravel.	8	48
Gravel, fine to medium; contains medium to very coarse sand	2	50
Sand, medium to coarse; contains some very coarse sand and very fine gravel (water level at 53 feet).	6	56
Pierre Shale:		
Shale, greenish-gray.	2	58
SC20-62-34BAA. Alt. 4,661.0 ft. Drilled November 1967.		
Test hole 19		
Terrace alluvium:		
Sand, fine to medium, silty	9	9
Sand, medium to coarse, silty; contains coarse sand and very fine to fine gravel.	9	18
Sand, medium to very coarse, and very fine gravel; contains some fine gravel.	9	27
Sand, medium to coarse; contains some very coarse sand.	5	32
Sand, medium to very coarse, and very fine gravel; contains silt and some fine to coarse gravel.	15	47
Sand, very coarse, and very fine to to fine gravel; contains some medium to coarse sand (water level at 51 feet).	8	55
Pierre Shale:		
Shale, dark-gray to black	3	58
SC20-62-28BCA. Alt. 4,694.9 ft. Drilled November 1967.		
Test hole 20 - Observation well		
Terrace alluvium:		
Silt.	7	7
Gravel, medium, and fine to very coarse sand.	5	12
Sand, very coarse, and fine to medium gravel.	5	17
Sand, medium, and fine gravel	5	22
Sand, medium to very coarse, and fine to medium gravel.	5	27

	Thick-ness	Depth
Gravel, fine to medium, and fine to very coarse sand.	3	30
Sand, fine to very coarse; contains fine gravel	13	43
Gravel, medium to coarse; contains fine to very coarse sand (water level at 45 feet).	2	45
Sand, fine to very coarse; contains fine to medium gravel.	2	47
Gravel, fine to medium, and fine to very coarse sand.	5	52
Gravel, medium, and fine to very coarse sand.	23	75
Pierre Shale:		
Shale	2	77
SC20-62-28CAB. Alt. 4,688.7 ft. Drilled November 1967.		
Test hole 21 - Observation well		
Terrace alluvium:		
Sand, fine, and silt.	7	7
Gravel, fine to medium, and very fine to very coarse sand; contains clay	5	12
Sand, very fine to very coarse.	10	22
Sand, very fine to very coarse; contains fine to medium gravel	15	37
Sand, very fine to very coarse.	5	42
Sand, very fine to very coarse, and fine to medium gravel (water level at 43 feet)	5	47
Sand, very fine to very coarse.	6	53
Pierre Shale:		
Clay.	4	57
SC20-62-28BCB. Alt. 4,675.1 ft. Drilled November 1967.		
Test hole 22		
Terrace alluvium:		
Silt.	7	7
Sand, very fine to very coarse; contains fine gravel	2	9
Silt.	3	12
Sand, very fine to very coarse; contains fine gravel	10	22
Sand, very fine to very coarse, and fine to medium gravel (water level at 26 feet)	6	28
Pierre Shale:		
Shale	1	29

	Thick-ness	Depth
SC20-62-21CDC. Alt. 4,700.7 ft. Drilled November 1967.		
Test hole 23 - Observation well		
Terrace alluvium:		
Silt.	9	9
Clay; contains sand and fine gravel	1	10
Sand, very fine to very coarse.	25	35
Sand, very fine to very coarse; contains fine to medium gravel.	2	37
Gravel, fine to medium; contains sand (water level at 46 feet).	34	71
Pierre Shale:		
Clay.	1	72
SC20-62-28ACA. Alt. 4,679.1 ft. Drilled November 1967.		
Test hole 24 - Observation well		
Terrace alluvium:		
Silt and fine sand.	5	5
Clay, sandy	2	7
Sand, very fine to very coarse; contains fine gravel and clay.	5	12
Sand, very fine to very coarse, and fine to medium gravel.	5	17
Sand, medium (water level at 32 feet)	20	37
Gravel, fine to medium; contains sand and clay. . . .	1	38
Clay; contains sand	16	54
Pierre Shale:		
Clay.	1	55
SC19-62-34CCA. Alt. 4,776.7 ft. Drilled November 1967.		
Test hole 25		
Terrace alluvium:		
Sand, fine to medium.	5	5
Clay, sandy	3	8
Sand, medium to very coarse, and very fine to medium gravel.	7	15
Sand, medium to coarse; contains some very coarse sand and some clay streaks (water level at 25 feet)	12	27
Sand, medium to very coarse; contains clay and some very fine gravel.	26	53
Sand, medium to very coarse, and very fine gravel	6	59
Gravel, very fine to medium, and medium to very coarse sand.	3	62
Sand, medium to very coarse, and very fine gravel . .	8	70
Pierre Shale:		
Shale, dark-gray to greenish.	1	71

	Thickness	Depth
SC19-62-35CCA. Alt. 4,754.6 ft. Drilled November 1967.		
Test hole 26		
Terrace alluvium:		
Sand, fine, clayey, silty (water level at 7 feet). . .	7	7
Clay, silty, sandy	6	13
Clay	4	17
Sand, medium to coarse; contains silt and some very coarse sand.	6	23
Sand, medium to very coarse, and very fine gravel. . .	7	30
Clay	1	31
Sand, medium to very coarse, and very fine to medium gravel	9	40
Pierre Shale:		
Shale, dark-gray	1	41
SC20-62-3DDA. Alt. 4,733.6 ft. Drilled November 1967.		
Test hole 27		
Terrace alluvium:		
Silt, clayey	7	7
Clay, silty, sandy (water level at 12 feet).	7	14
Sand, medium to very coarse, and very fine gravel; contains clay	10	24
Sand, medium to very coarse; contains some very fine gravel	15	39
Pierre Shale:		
Shale, dark-gray	1	40
SC20-62-4DCD. Alt. 4,760.6 ft. Drilled November 1967.		
Test hole 28		
Terrace alluvium:		
Silt, sandy.	7	7
Sand, medium to very coarse, silty; contains some very fine to medium gravel.	6	13
Sand, fine to coarse, and very fine gravel; contains some very coarse sand.	4	17
Sand, fine to very coarse, and very fine gravel. . . .	6	23
Sand, fine to coarse, and very fine gravel; contains some very coarse sand (water level at 33 feet)	19	42
Sand, coarse to very coarse, and very fine gravel; contains some fine to medium sand	16	58
Sand, coarse to very coarse, and very fine to medium gravel; contains some fine to medium sand.	4	62
Sand, coarse to very coarse, and very fine gravel; contains some fine to medium sand	6	68
Pierre Shale:		
Shale, dark-gray to black.	1	69

	Thick-ness	Depth
SC20-62-9DDB. Alt. 4,746.7 ft. Drilled November 1967.		
Test hole 29		
Terrace alluvium:		
Sand, fine to medium, silty.	3	3
Sand, fine to medium, silty; contains some coarse sand	4	7
Sand, fine to coarse, silty; contains some very coarse sand.	6	13
Sand, fine to very coarse; contains some very fine to medium gravel	5	18
Sand, fine to very coarse; contains some very fine gravel	5	23
Sand, fine to very coarse; contains some very fine gravel and some clay	4	27
Sand, fine to very coarse, and very fine gravel; contains some clay (water level at 37 feet)	33	60
Sand, fine to very coarse, and very fine to medium gravel	3	63
Pierre Shale:		
Shale, dark-gray to black.	1	64
SC20-62-9CCD. Alt. 4,742.1 ft. Drilled November 1967.		
Test hole 30		
Terrace alluvium:		
Sand, fine to medium, silty.	2	2
Sand, fine to very coarse; contains very fine to medium gravel.	6	8
Sand, fine to coarse; contains some very coarse sand, fine gravel, and clay.	27	35
Sand, fine to very coarse, and very fine to medium gravel (water level at 40 feet).	10	45
Sand, fine to coarse; contains some very coarse sand and very fine gravel	2	47
Sand, fine to very coarse, and very fine gravel. . . .	3	50
Pierre Shale:		
Shale, dark-gray to black.	1	51
SC20-62-16CCD. Alt. 4,719.8 ft. Drilled November 1967.		
Test hole 31		
Terrace alluvium:		
Silt, sandy.	3	3
Sand, fine to very coarse; contains some very fine gravel and streaks of fine to medium gravel.	20	23
Sand, fine to coarse; contains some very coarse sand to fine gravel	2	25
Sand, fine to very coarse, and very fine gravel; contains some fine to medium gravel	11	36

	Thick-ness	Depth
Gravel, fine to coarse, and fine to very coarse sand.	1	37
Sand, fine to very coarse, and very fine to fine gravel (water level at 40 feet)	12	49
Pierre Shale:		
Shale, dark-gray.	1	50
SC20-62-16DCD. Alt. 4,715.5 ft. Drilled November 1967.		
Test hole 32 - Observation well		
Terrace alluvium:		
Sand, fine, silty	5	5
Sand, fine to medium, silty, clayey; contains some coarse sand	3	8
Sand, fine to coarse, silty; contains some very coarse sand.	5	13
Sand, fine to coarse; contains some very coarse sand and very fine gravel.	5	18
Sand, fine to coarse; contains some very coarse sand. .	3	21
Sand, fine to very coarse, and very fine gravel; contains some clay	8	29
Sand, fine to coarse; contains some very coarse sand, very fine gravel, and clay (water level at 36 feet).	9	38
Sand, fine to very coarse, and very fine gravel	16	54
Pierre Shale:		
Shale	1	55
SC20-62-15CCD. Alt. 4,711.5 ft. Drilled November 1967.		
Test hole 33		
Terrace alluvium:		
Silt, sandy	6	6
Sand, fine to medium; contains some coarse to very coarse sand	4	10
Sand, fine to very coarse, and very fine to medium gravel.	5	15
Sand, fine to very coarse; contains very fine gravel	4	19
Sand, fine to very coarse, and fine to medium gravel	10	29
Sand, fine to very coarse, and very fine gravel (water level at 36 feet).	11	40
Gravel, fine to medium, and fine to very coarse sand.	5	45
Pierre Shale:		
Shale	1	46

	Thickness	Depth
SC20-62-22ACA. Alt 4,689.8 ft. Drilled November 1967.		
Test hole 34		
Terrace alluvium:		
Sand, fine, silty.	5	5
Sand, fine to coarse; contains some very coarse sand and very fine gravel.	8	13
Sand, fine to coarse, clayey; contains some very coarse sand	8	21
Sand, fine to coarse, clayey (water level at 24 feet).	6	27
Sand, fine to very coarse, and very fine to medium gravel; contains silt and some clay	14	41
Sand, fine to coarse, clayey	1	42
Sand, fine to very coarse, and very fine gravel; contains silt and some clay.	8	50
Pierre Shale:		
Shale.	1	51
SC20-62-21DCD. Alt. 4,685.7 ft. Drilled November 1967		
Test hole 35		
Terrace alluvium:		
Sand, fine, silty.	5	5
Sand, fine to coarse, clayey; contains some very coarse sand.	18	23
Sand, fine to very coarse, and very fine gravel; contains clay.	2	25
Sand, fine to coarse, clayey; contains some very coarse sand	6	31
Sand, medium to very coarse, and very fine to fine gravel; contains clay (water level at 35 feet).	6	37
Sand, medium to very coarse, and very fine to fine gravel; contains some clay.	16	53
Sand, fine to coarse, clayey	2	55
Sand, fine to very coarse, and very fine gravel; contains some clay	3	58
Sand, fine to very coarse, and very fine gravel; contains clay, streaks of fine to medium gravel, and streaks of fine to coarse sand	7	65
Pierre Shale:		
Shale, black	1	66

	Thick-ness	Depth
SC20-62-27ACC. Alt. 4,670.2 ft. Drilled November 1967.		
Test hole 36 - Observation well		
Terrace alluvium:		
Sand, fine, silty.	3	3
Sand, fine to very coarse, silty, clayey	15	18
Sand, fine to medium	11	29
Sand, fine to coarse; contains some very coarse sand and very fine gravel.	8	37
Sand, fine to very coarse, and very fine to medium gravel; contains some clay (water level at 48 feet)	20	57
Sand, fine to very coarse, and very fine to fine gravel	11	68
Pierre Shale:		
Shale.	1	69
SC20-62-28DBA. Alt. 4,675.2 ft. Drilled November 1967.		
Test hole 37		
Terrace alluvium:		
Silt, sandy.	2	2
Sand, fine to coarse, silty.	8	10
Clay, sandy, silty	3	13
Sand, fine to coarse; contains some very coarse sand and very fine gravel.	5	18
Sand, fine to very coarse, and very fine to fine gravel	10	28
Gravel, fine to coarse, and medium to very coarse sand	2	30
Clay, fine to very coarse sand, and very fine to fine gravel (water level at 31 feet)	5	35
Sand, fine to very coarse, and very fine gravel. . . .	2	37
Pie		
Shale, black	15	52
SC20-62-28BDA1. Alt. 4,695 ft. Drilled October 1968.		
Test hole 38a		
Terrace alluvium:		
Silt, sandy.	5	5
Sand, very coarse, silty	3	8
Sand, medium, silty; contains fine to coarse sand. . .	10	18
Sand, medium to coarse; contains fine sand and silty very fine gravel.	4	22
Sand, medium to very coarse, and very fine to fine gravel; contains some silt	5	27
Sand, medium to very coarse; contains very fine to fine gravel and some silt.	10	37

	Thick-ness	Depth
Sand, medium to very coarse; contains silty clayey very fine gravel (water level about 43 feet).	8	45
Sand, medium to very coarse, and clayey very fine to fine gravel.	2	47
Sand, medium to very coarse, clayey; contains very fine to fine gravel	7	54
Sand	13	67
SC20-62-28BDA2. Alt. 4,695 ft. Drilled October 1968.		
Test hole 38b		
Terrace alluvium:		
Silt, sandy	2	2
Sand, very coarse, silty.	6	8
Sand, fine to medium; contains coarse to very coarse sand	5	13
Sand, medium; contains fine to very coarse sand . . .	7	20
Sand, medium to coarse; contains fine sand, very fine gravel, and silt	10	30
Sand, medium to very coarse, silty, clayey.	3	33
Sand, medium to very course, and clayey silty very fine to fine gravel.	2	35
Sand and clay	1	36
Sand, medium to very coarse, and clayey silty very fine to medium gravel (water level about 43 feet).	7	43
Sand and clayey gravel.	1	44
Sand, medium to very coarse, and very fine to medium gravel	29	73
Pierre Shale:		
Shale, gray-black	1	74
SC20-62-28BAA. Alt. 4,700 ft. Drilled October 1968.		
Test hole 39		
Terrace alluvium:		
Silt, sandy	2	2
Sand, fine to medium, silty	6	8
Sand, medium; contains silty fine to very coarse sand; lower part contains gravel.	20	28
Sand, medium to very coarse, clayey	5	33
Sand, medium to very coarse, and very fine gravel; contains some silt (water level about 45 feet). .	15	48
Sand, medium to very coarse, and very fine to medium gravel	1	49
Sand, medium to very coarse, silty, clayey; contains gravel	9	58
Clay, sandy, dark-gray.	5	63
Pierre Shale:		
Clay, dark-gray	1	64

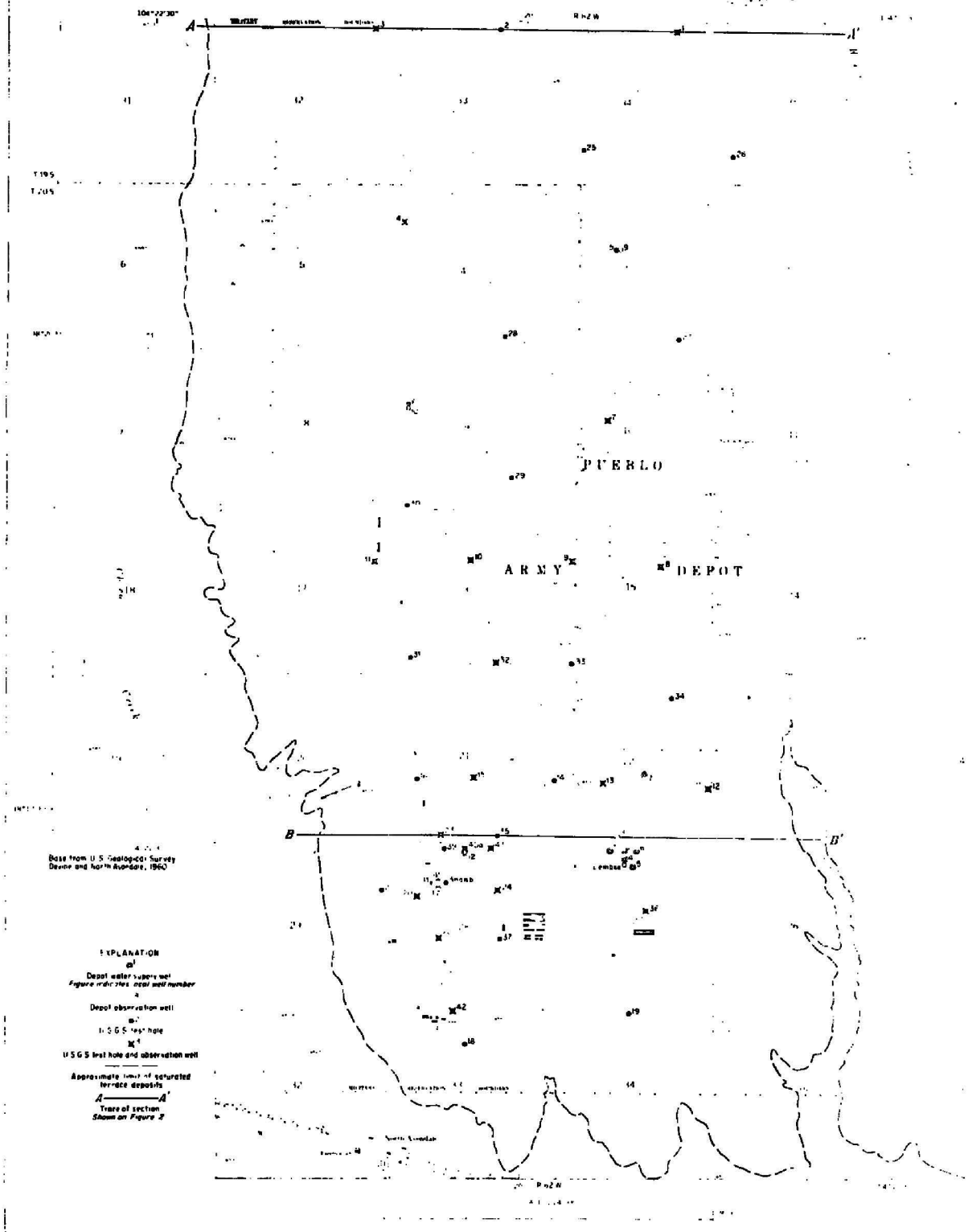
	Thick-ness	Depth
SC20-62-28ABB1. Alt. 4,698 ft. Drilled October 1968. Test hole 40a - Observation well. Gamma-ray log made in this test hole (fig. 3). Neutron moisture meter access pipe installed at this site.		
Terrace alluvium:		
Sand, silty.	2	2
Sand, fine to medium, silty.	3	5
Sand, medium to very coarse; contains silty very fine gravel.	3	8
Sand, medium to very coarse; contains very fine gravel.	6	14
Sand, medium to very coarse.	11	25
Sand, medium to very coarse; contains very fine gravel	8	33
Sand, medium to very coarse; contains sandy clay streaks.	5	38
Sand, medium to very coarse, silty	2	40
Sand, medium to very coarse, and clayey silty very fine to fine gravel (water level at 43 feet).	11	51
Sand, coarse to very coarse; contains some medium sand and very fine gravel (core sample)	1	52
Sand, medium to very coarse, and clayey silty very fine to fine gravel.	10	62
Sand, coarse to very coarse; contains some medium sand and very fine gravel (core sample). . .	1	63
Sand, fine to coarse; contains some very coarse sand, some very fine gravel, and two ½-1 inch streaks of gray silty clay (core sample).	1	64
Sand, medium to very coarse, and clayey silty very fine to fine gravel.	8	72
Sand, coarse to very coarse, and clayey very fine gravel; contains some medium sand (core sample)	1	73
Sand, medium to coarse; contains some very coarse sand and very fine gravel (core sample). . .	1	74
Gravel, very fine to fine; contains silty medium to very coarse sand	3	77
Pierre Shale:		
Shale, dark-gray	1	78

	Thickness	Depth
SC20-62-28BAC1. Alt. 4,693 ft. Drilled October 1968. Test hole 41 - Observation well. Gamma-ray log made in this test hole (fig. 3). Neutron moisture meter access pipe installed at this site.		
Terrace alluvium:		
Sand, very fine, silty.	7	7
Sand, fine to medium, silty, clayey	3	10
Sand, fine to very coarse, and clayey silty very fine gravel	3	13
Sand, medium to very coarse (water level at 43 feet)	40	53
Sand, coarse to very coarse; contains some medium sand, some very fine gravel, and three 2-4½ inch streaks of clayey sandy silt (core sample).	2	55
Sand, medium to very coarse; contains very fine gravel	8	63
Sand, coarse to very coarse, and very fine gravel; contains some medium sand (core sample).	1	64
Sand, medium to coarse; contains some very coarse sand and very fine gravel (core sample).	1	65
Sand, medium to very coarse, and very fine gravel	3	68
Sand, medium to coarse; contains some very coarse sand and very fine gravel (core sample).	1	69
Sand, fine to coarse, clayey; contains some very coarse sand and very fine gravel (core sample).	1	70
Sand, medium to very coarse, and very fine gravel	3	73
Pierre Shale:		
Shale, black.	1	74

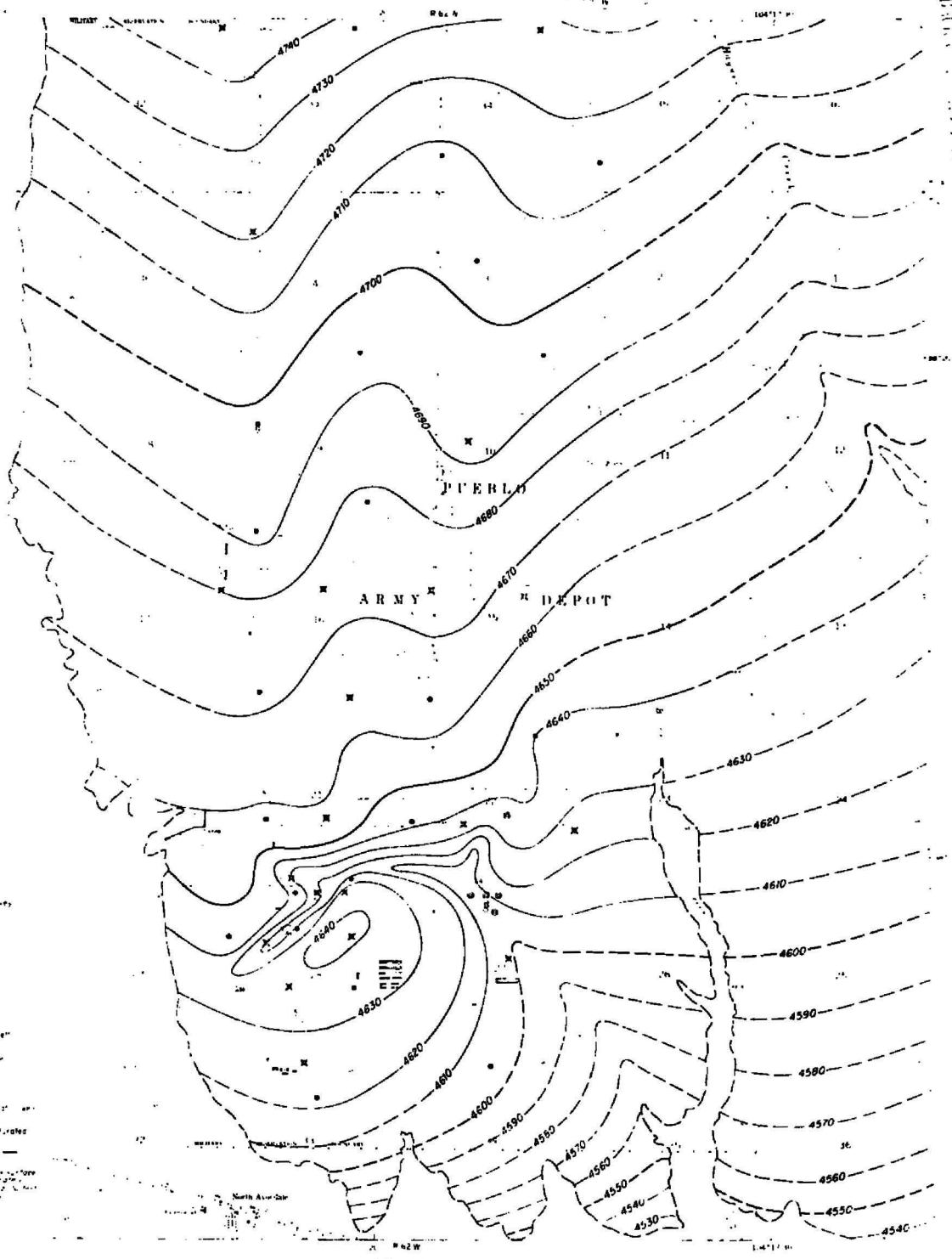
	Thickness	Depth
SC20-62-33BAA. Alt. 4,683 ft. Drilled October 1968.		
Test hole 42 - Observation well		
Terrace alluvium:		
Sand, medium to coarse.	8	8
Sand, fine to medium, silty; contains some clay . . .	5	13
Clay, sandy, silty.	3	16
Sand, coarse, to medium gravel.	1	17
Sand, medium, to very fine gravel	5	22
Sand, medium to very coarse	5	27
Sand, medium, to fine gravel, silty	3	30
Sand, medium to very coarse, and silty very fine to fine gravel.	13	43
Clay(?)	1	44
Sand, fine to very coarse, silty (water level at 46 feet).	2	46
Sand, medium to very coarse· contains silty very fine gravel.	12	58
Pierre Shale:		
Clay, yellow, brown and black	1	59
SC20-62-28ABA. Alt. 4,688 ft. Drilled October 1968.		
Test hole 43 - Observation well		
Terrace alluvium:		
Sand, fine, silty	2	2
Sand, fine to medium, silty	5	7
Sand, fine to very coarse; contains layers of silty sand and clay.	20	27
Sand, medium to very coarse	3	30
Sand, medium to very coarse; contains silt and very fine gravel (water level at 36 feet).	6	36
Sand, medium to very coarse, silty; contains clay	9	45
Clay; contains medium to very coarse sand and silty very fine gravel	9	54
Pierre Shale:		
Clay, gray.	3	57

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

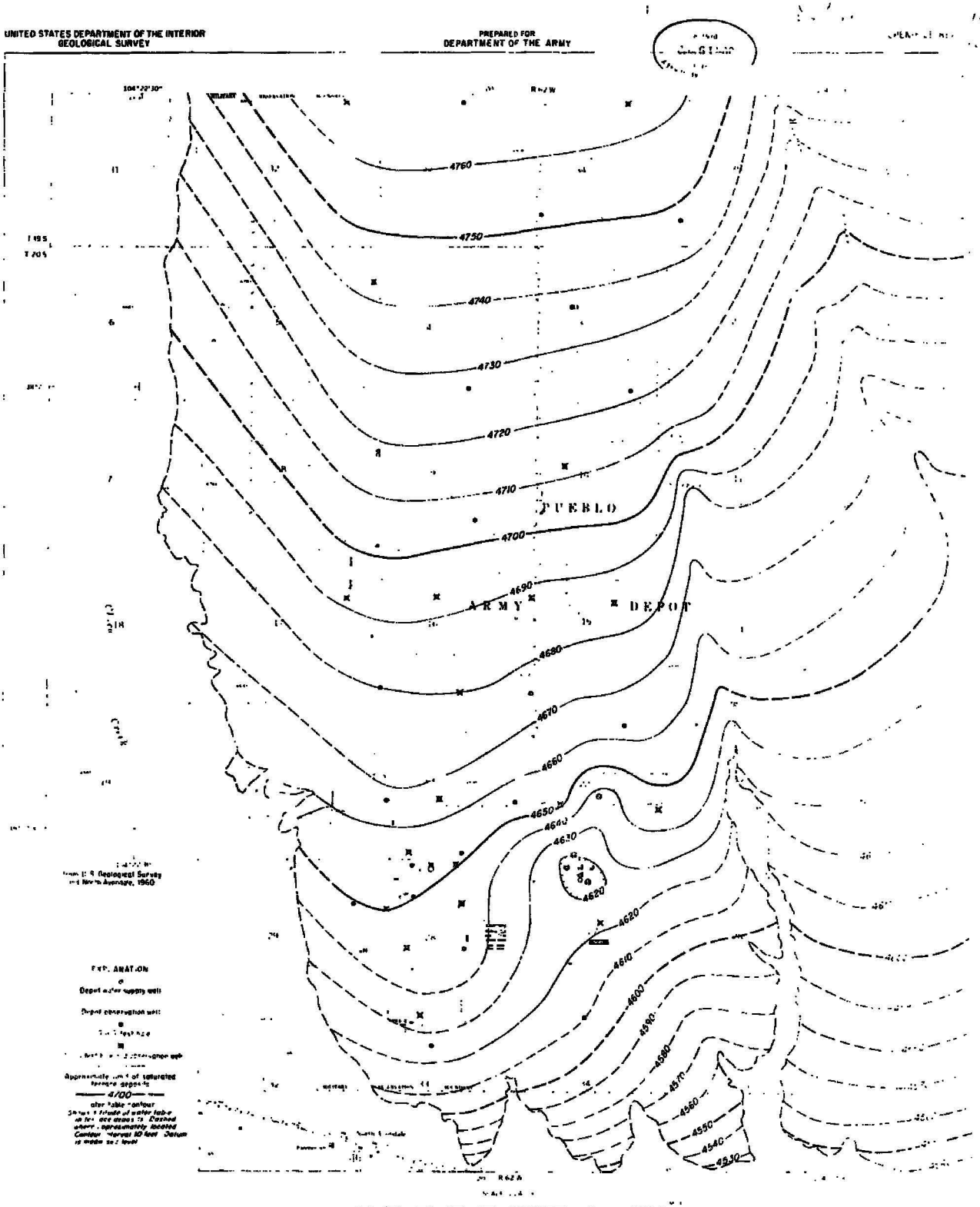
PREPARED FOR
DEPARTMENT OF THE ARMY



LOCATION OF WELLS, TEST HOLES, AND HYDROGEOLOGIC SECTIONS, PUEBLO ARMY DEPOT, COLORADO



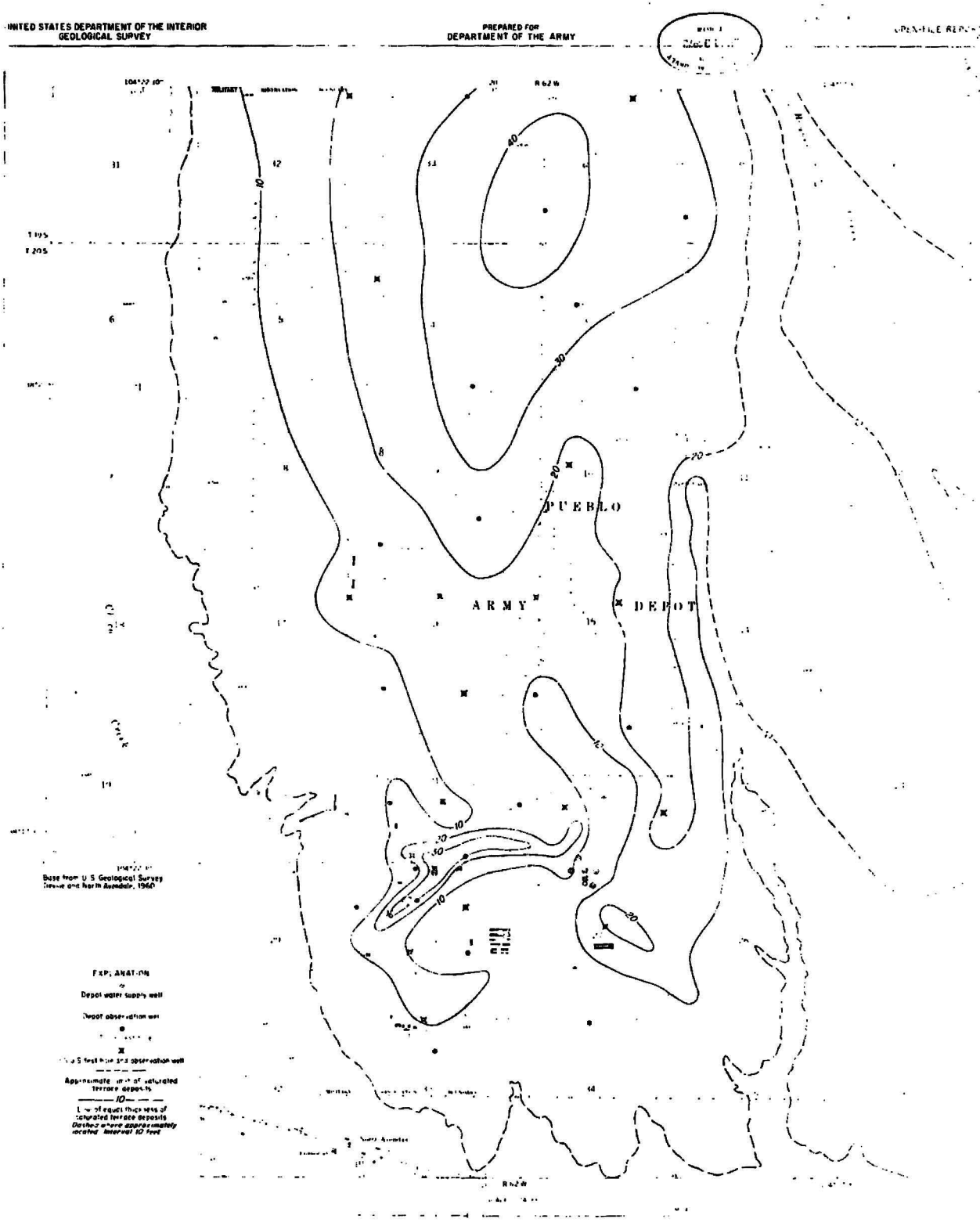
BEDROCK CONFIGURATION BENEATH THE TERRACE ALLUVIAL AQUIFER, PUEBLO ARMY DEPOT, COLORADO



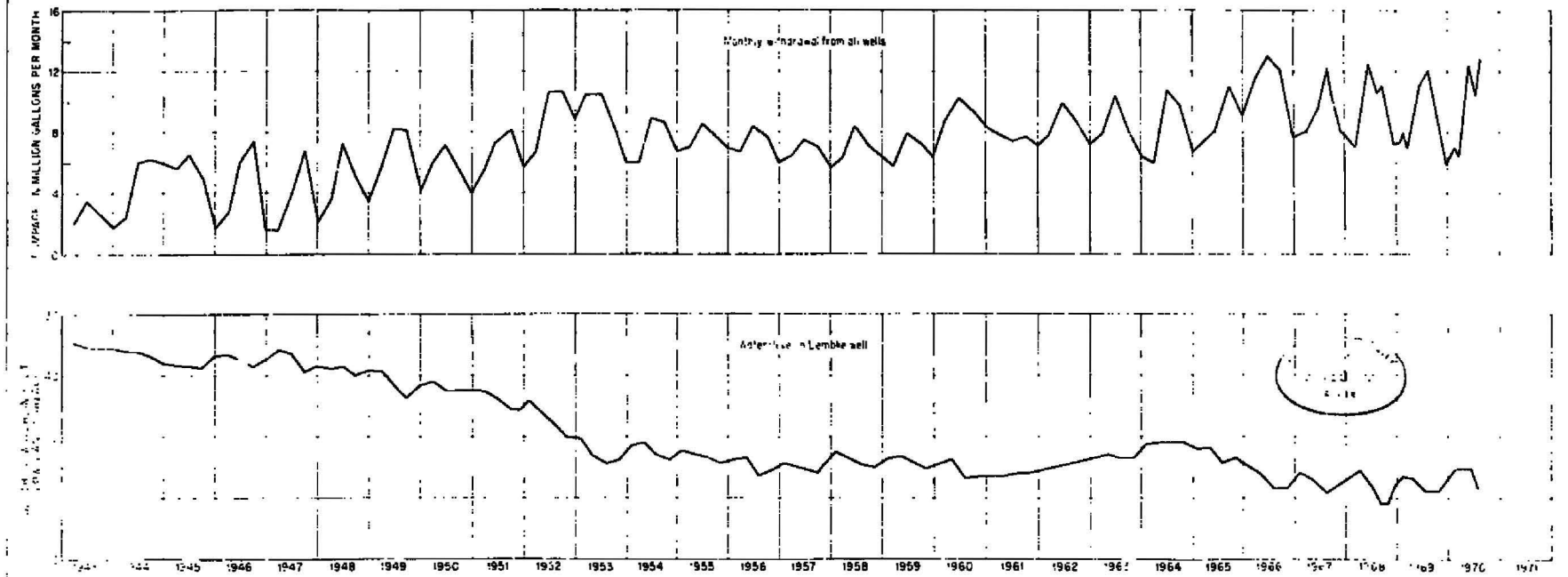
WATER—TABLE CONTOURS OF THE TERRACE ALLUVIAL AQUIFER (NOVEMBER 1967), PUEBLO ARMY DEPOT, COLORADO

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

PREPARED FOR
DEPARTMENT OF THE ARMY



SATURATED THICKNESS OF THE TERRACE ALLUVIAL AQUIFER (NOVEMBER 1967), PUEBLO ARMY DEPOT, COLORADO



MONTHLY WITHDRAWALS FROM WELL FIELD AND WATER LEVELS IN LEMBKE WELL, PUEBLO ARMY DEPOT, COLORADO