GROUND-WATER RESOURCES AND
RELATED GEOLOGY IN THE VICINITY OF
HOLLOMAN AIR FORCE BASE
OTERO COUNTY, NEW MEXICO

by

James W. Hood

U. S. ARMY ENGINEER DISTRICT, ALBUQUERQUE
CORPS OF ENGINEERS
ALBUQUERQUE, NEW MEXICO

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GROUND-WATER RESOURCES AND RELATED GEOLOGY IN THE VICINITY OF HOLLOMAN AIR FORCE BASE, OTERO COUNTY, NEW MEXICO

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ABSTRACT

This report describes the geology and ground-water resources in an area of about 320 square miles in the vicinity of Holloman Air Force Base in the northwest-central part of Otero County, N. Mex. A detailed study was made of the occurrence of ground water in the bolson fill, the principal aquifer in the area, in the vicinity of the Boles well field.

Holloman Air Force Base is near the east edge of the Tularosa Basin and near the west edge of the adjoining Sacramento Mountains which rise to a height of about 5,500 feet above the basin. The average annual precipitation amounts to about 10 inches in the vicinity of the airbase and increases with altitude to about 25 inches at Cloudcroft in the nearby mountains. The annual average temperature is about 61 degrees in the vicinity of the airbase.

Within the area studied, the unconsolidated bolson fill of Cenozoic age is of greater importance to the occurrence of water than the consolidated rocks of Paleozoic and Precambrian(?) age in the adjacent mountain escarpment. The bolson fill is the major aquifer in the area. Some of the consolidated rocks adjacent to the fill are important aquifers, but for the most part they are impermeable and serve only as sources of the erosional debris making up the bolson fill.

The total thickness of the bolson fill varies from place to place, depending on the configuration of the underlying bedrock surface. Although the thickness of the bolson fill probably exceeds 1,000 feet in the Boles well-field area, test drilling has revealed that only the first 200 to 300 feet of fill below the land surface is sufficiently permeable to yield water to wells. The fill in this interval is composed of grains ranging in size from clay to boulders, and the deeper fill is composed of much finer-grained deposits. The fill as a whole grades from a chaotic mixture of all grain sizes near the Sacramento Mountains through better-sorted deposits in the Boles well field to fine-grained deposits of clay, silt, and evaporites beneath the plain west of the well field.

Most of the surface water issuing from consolidated rocks in the mountains has been appropriated for municipal and agricultural use. Consolidated rocks underlying the bolson fill in the vicinity of Holloman Air Force Base possibly can yield water, but the water is too highly mineralized for any present use.

Beds of silt, sand, and gravel in the bolson fill yield water to wells in amounts ranging from a few gallons per minute to over 500 gpm. The water is stored in the fill under both artesian (confined) and water-table (unconfined) conditions. Depths to water range from more than 200 feet below land surface near the mountains to only a few feet below land surface in the area of the White Sands National Monument. The water table slopes in approximately the same direction as the land surface, toward the southwest.

Recharge to the fill occurs principally in a strip of permeable surface deposits along the Sacramento Mountain front. The principal source of the recharge is floodflow from the mountain canyons, and recharge to the potable-water body of the Boles field originates in canyons between Alamo and San Andres Canyons. The potable-water recharge is about 700 acre-feet or more per year. The indicated rate of recharge is 5 to 10 percent of the precipitation on the mountain watersheds.

The principal means of discharge of ground water in the area is by pumping. There is little transpiration or evaporation, and ground water not pumped moves down gradient, southwestward, and out of the area. About 130,000 acre-feet of fresh water, containing 300 ppm of sulfate or less, is available to pumps, but not all the water could be pumped out before saline water would enter the pumped area.

Both the per capita consumption and the total use of water at Holloman Air Force Base are increasing. As a result of increased use, the Boles well field is now the principal source of water supply and will have to be pumped at greater rates in the future until the Bonito Lake pipeline is put into use. From 1947 through 1955 the well field produced about 1,018 million gallons of which about 60 percent was produced during the past 3 years.

Water-level and pumpage records show that ground water is being removed from storage by pumping in the Boles well field, and that, as a result the water table is declining. The maximum declines are in the vicinity of the older part of the well field in secs. 18 and 19, T. 17 S., R. 10 E. Comparison of records shows that the maximum decline from 1947 to 1955 was probably in the order of 20 feet and that declines extend out to a distance of several miles.

Ground water in the vicinity of Holloman Air Force Base obtains most of its mineral content from the bolson fill through which it moves. The principal reason for the occurrence of potable water in the Boles area is that the fill beneath the area contains relatively small amounts of evaporites. The potability of the ground water in the Boles area can be judged by its sulfate content alone, because wherever the water is potable with respect to sulfate, the water is also potable with respect to chloride and dissolved solids. The mineral content of the water increases rather consistently westward across the well field and contains from 200 to about 650 ppm of sulfate.

About 10 square miles in the vicinity of the Boles well field contains water having a sulfate content of 300 ppm or less. Another potable water area, 12 miles south of the Boles well field, may extend over as much as 20 square miles.

Saline water in the well-field area is stored both on the north and west sides of the potable-water area and in a thin shallow zone which overlies the potable-water sands in part of the potable-water area. The latter source is affecting the quality of the water from Boles wells 10 and 14.

The bolson fill beneath the well field is not uniformly permeable. The permeability becomes greater westward from the mountains. The aquifer in the eastern part of the well field contains water under artesian pressure, whereas water-table conditions prevail in the western part. A hydraulic boundary probably representing a zone of low permeability trends northward through the middle of the well field. The specific yield of the bolson-fill aquifer in the well field is estimated to be about 8 percent.

Drawdown in the center of the well field may range from about 20 to 30 feet in 5 years to about 30 to 50 feet in 20 years, depending on the rate of pumpage from existing wells. The edge of the cone of depression could extend as far as 3 miles west of the well field in 5 years to as much as 7 miles in 20 years, and drawdowns of significant magnitude could occur from 1 mile or more west of the well field in 5 years to 3 miles or more in 20 years.

Pumping in the well field will eventually create a water-table slope toward the well field from the west and northwest. A slope from the north toward the well field already exists. The slope will create a movement of saline water toward the well field, and in time the saline water will penetrate into the well field. As pumping continues, downward movement of saline water from the shallow zone will continue.

In order to minimize the effects of pumping on the movement of saline water, it would be desirable to locate future wells southeast of the present well field. A spacing of 1,000 feet or more would prevent excessive mutual interference between wells.

Artificial recharge is one means of lessening the effect of pumping on the movement of saline water. Surplus water from Bonito Lake, if any, could be injected into the aquifer through the existing Boles well. Under present conditions, the wells probably could accept a total of about 1 million gallons per day for a period of 2 to 3 months before overflowing.

The chemical treatment of both old and new wells in the well field appears to aid in rehabilitation or development of wells.

Most wells in the Boles well field have been drilled by the cable-tool method and screened with torch-cut perforations of various sizes. Sand pumping is one of the principal problems in the well field. The sand probably can be controlled in cased wells by using adequate numbers of perforations of the proper size. A gravel-walled well, constructed carefully, with proper attention to perforations and gravel sizes, doubtless would be free of sand. Adequate development must be performed for either cable-tool or rotary-drilled wells. Electrical logging is desirable as an important aid in evaluating the probability of obtaining a producing well.

INTRODUCTION

Holloman Air Force Base is in the Tularosa Basin, in the northwest-central part of Otero County, N. Mex., about 7 miles southwest of Alamogordo. The base proper occupies about 9 square miles in the northeast quarter of T. 17 S., R. 8 E. Additional land extending northward from the base proper is occupied by testing facilities.

As shown in figure 1 , the base and the town of Alamogordo are served by U. S. Highways 54 and 70 and the Southern Pacific Railroad.

Holloman Air Force Base was originally established during World War II as an Army Air Corps training base, and the population was greatly reduced after the cessation of hostilities. When the base was reorganized and began to assume increasingly greater importance as a research center, the population began to increase more or less continuously. Exact figures for the population of the base were not obtained during the ground-water investigation of the area; however, it is known that the population was at least 3,500 in 1950 and was in excess of 4,500 at the beginning of 1955.

Alamogordo plays an important part in the operation of the base. The town is the county seat of Otero County and is the only town of appreciable size within 50 to 75 miles of the base. Alamogordo, together with the villages of La Luz, Tularosa, and a few smaller communities in the Sacramento Mountains, provides housing for personnel from both Holloman Air Force Base and White Sands Proving Ground, about 50 miles to the southwest. Owing mainly to the expansion of operations at these two research centers, the population of Alamogordo has grown rapidly since 1950. The population of Alamogordo was 3,950 in 1940 and 6,767 in 1950 according to the census. Estimates based on the annual school census and water consumption in the town show that the population was about 8,000 in 1952, 9,000 in 1953, and in excess of 12,000 in 1955. The town is a retail-trade center for the area and is a transportation terminal for rail and motor freight.

Purpose, Scope, and Area of the Investigation

Holloman Air Force Base presently is principally a research center under the Air Research and Development Command of the U. S. Air Force. During World War II it was used as a training base and used a relatively small amount of water which was obtained from Alamogordo. The town of Alamogordo obtained its principal supply of water from groups of springs arising along the west side of the Sacramento Mountains. In the several years immediately before Alamogordo agreed to supply water to the base, abnormally large amounts of precipitation caused the spring flow to increase, and the town had an excess of water which could be sold to the base. However, during the period 1943 to 1953, the discharge of the springs and supplies of surface water were declining. Conversely, population was increasing, owing mainly to the expansion of research facilities at the base since 1946, and water demands were increasing. For these reasons the town could not always supply maximum demands for water to the base in the summer months, and several water shortages occurred at the base after 1945.

After potable ground water was discovered in 1947 by Mr. L. C. Boles as the result of drilling an irrigation well, his property was leased by the U. S. Air Force, and the ground water was developed as a supplementary supply. As the population of both town and base grew rapidly after 1950, the base came to depend on the well field as the principal supply and on water from the town as a supplemental supply. By 1953 it had become readily apparent that the town could supply appreciable quantities of water to the base only during the winter months. The well field, located about 5 miles south of Alamogordo, has become known as the Boles well field.

In 1953, little was known concerning the extent of the potable ground water stored in the Boles area, although it was known that saline water was to be found a short distance west of the well field. Moreover, in view of the necessity of using the well field as a principal source of water, it was disturbing that so many of the wells had very low yields. Of 33 wells drilled by the end of 1953, only 12 had been used or could be used as production wells. Of the 12 wells 3 had been abandoned owing to casing failures, and the remaining wells were heavily pumped to meet water requirements in the summer months at the base. It was feared that the proximity of saline or brackish water to a center of heavy pumping might lead to chemical contamination of the supply wells.

Therefore, in the fall of 1953, the Geological Survey was requested by the Albuquerque District, U. S. Army, Corps of Engineers, to evaluate the ground-water resources of the Holloman area. Following a subsequent agreement between the Geological Survey and the Corps of Engineers, an investigation of the geology and ground-water resources in the vicinity of Holloman Air Force Base was started actively in March 1954.

The investigation had the following main objectives, not all of which could be met fully:

1. To determine the amount of potable ground water available to pumps at the Boles well field and the amount of ground water that can be pumped safely without danger of causing migration of poor-quality water from the west to the well field,
2. To determine the distribution of permeable sands in the bolson fill in order to locate additional well sites,
3. To determine the optimum spacing of wells in the area,
4. To determine the possibility of obtaining potable water at depth in the vicinity of the base itself, and
5. To determine if yields of some of the present wells could be increased by additional development with the help of chemicals or other means.

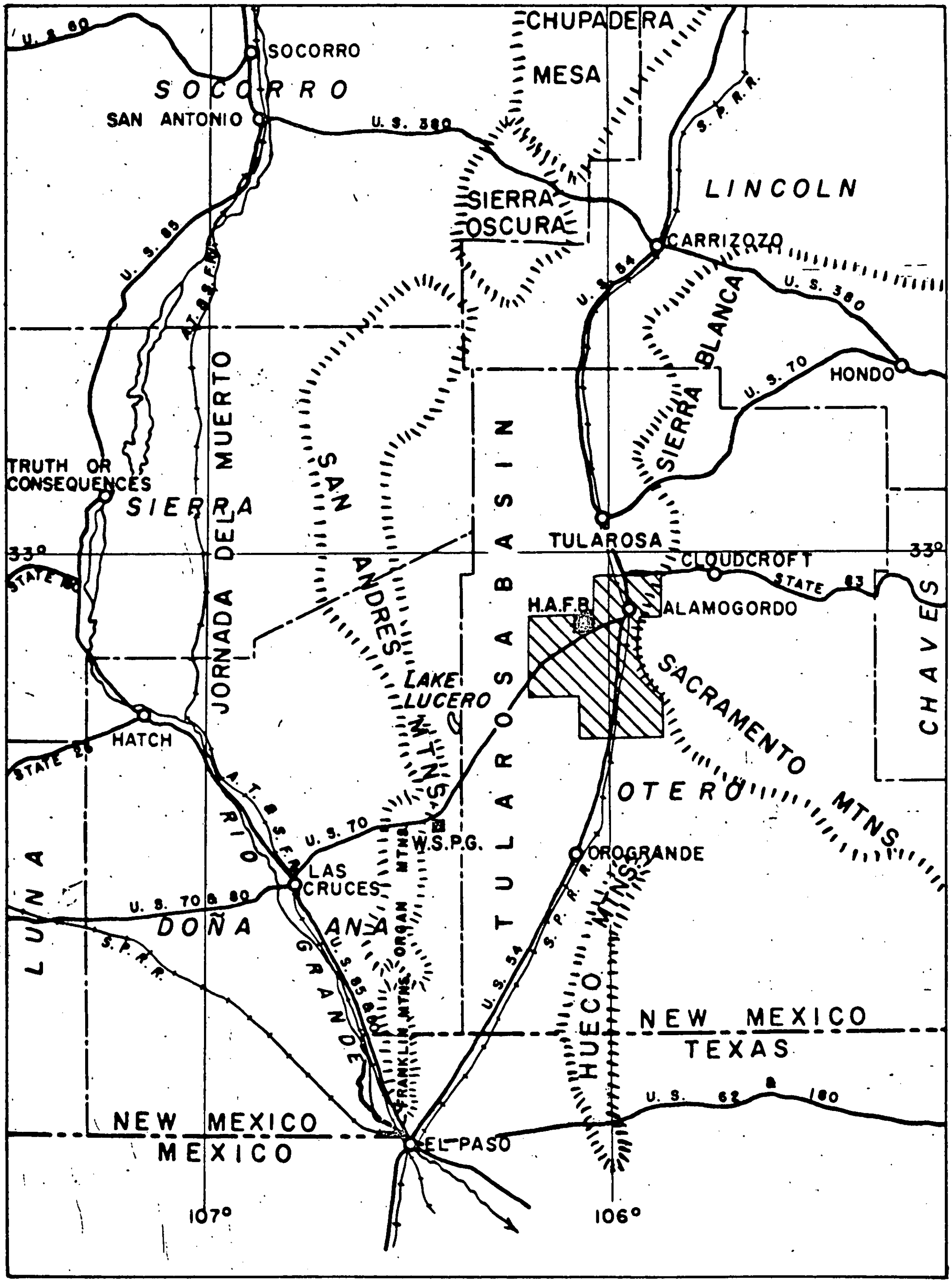


Figure 1. — — Map of south-central New Mexico showing the shaded area discussed in this report.

After field work had been completed and the writing of this report had commenced, it was learned that water from Bonito Lake would be made available to the town of Alamogordo and to Holloman Air Force Base. Inasmuch as such additional water supplies will have a direct effect on the operation of the Boles well field, some data pertaining to water from the lake are included herein, and a possible use for surplus water from the lake is suggested.

In order to meet the objectives of the investigation, the field work upon which this report is based covered an area of 320 square miles. Figure 1 and plate 1 delineate the area which was covered in reconnaissance. The area extends from the center of White Sands National Monument in R. 7 E. eastward to the west edge of the Sacramento Mountains in R. 10 E., and from the north edge of T. 16 S., north of Alamogordo, southward to the south edge of T. 19 S., south of Valmont siding on the Southern Pacific Railroad. The area of intensive study, about 44 square miles in the vicinity of the Boles well field, is shown in plate 2 and includes parts of T. 17 S., Rs. 9 and 10 E.

Previous Investigations

Although numerous scientific investigators have visited the Tularosa Basin, few have studied the occurrence of ground water. The principal source of information on the occurrence of ground water in the Tularosa Basin is the report by Meinzer and Hare (1915). Their areal coverage was relatively complete, and although subsequent studies have revealed minor local differences in ground-water conditions, their appraisal of ground-water conditions in the Tularosa Basin probably is essentially accurate.

Sayre and Livingston (1945), working in the Hueco Bolson to the south, provided information concerning the southern edge of the Tularosa Basin and the Tularosa-Hueco depression as a whole.

A continuing general investigation of a part of the Tularosa Basin by the Geological Survey in cooperation with the office of the State Engineer of New Mexico (State Engineer, 1926-32) has been carried on for a number of years and the investigation has provided some data of historical significance with regard to ground water in the Holloman area.

In the vicinity of Holloman Air Force Base, Theis (1942, 1945) and Murray (1947) studied the possibilities of ground-water development for the base and for the town of Alamogordo.

The occurrence of ground water in the Alamogordo-Tularosa area with reference to agricultural uses has been discussed by Meeks (1950).

Although many investigators have published geologic data concerning the Tularosa Basin and the adjacent mountainous areas, the most pertinent study with regard to the area discussed herein is that by Pray (1952, 1954) whose thorough work along the Sacramento Mountain escarpment has clarified the interpretation of the geology of much of the area.

Methods of Investigation

A brief reconnaissance was made of the area shown in plate 1 during the investigation of the Holloman area. Many of the wells in the area were inventoried and water samples were taken from some of the wells. Preliminary data from the reconnaissance indicated that within the 320 square miles shown on plate 1, potable ground water was confined principally to the vicinity of the Boles well field, a relatively narrow belt of land along the base of the mountains, and an area of undetermined extent about 12 miles south of the Boles well field in T. 19 S., R. 10 E. An area of about 44 square miles centering around the Boles well field (pl. 2) appeared to be the most promising in the vicinity of the airbase for the development of additional ground-water supplies. For that reason, and because it was desirable to gain additional information about the existing wells in the well field, detailed study was confined principally to this smaller area. All wells and springs in the smaller area were inventoried, and water samples for chemical analysis were taken wherever possible.

Geologic studies during the investigation were restricted mainly to the interpretation of subsurface conditions in the bolson-fill aquifer, as determined from the logs of wells and other data. The general geology of the Tularosa Basin and the adjoining Sacramento Mountains is described in several reports; therefore, in this report the discussion of the geology of those areas is taken largely from the work of others.

The depth to and altitude of the water table in the area were determined. Controlled pumping tests in the Boles well field to determine the hydraulic characteristics of the water-bearing formation throughout the well field were conducted in January, February, and March, 1955. A program of water-level measurements in observation wells was started in order to observe both the long-term and short-term effects of pumping. Records of pumpage and water levels were assembled in order to further the study of pumping effects. The climate of the area was studied in order to gain an understanding of the probable amount of recharge and the areas in which recharge water originated.

Preliminary consideration of required field work, before even the reconnaissance inventory was made, indicated that an evaluation of the ground-water conditions in the vicinity of the Boles well field would require a number of test holes. The test holes were necessary because, first, available data from the Boles wells were inadequate or lacking, and second, the wells from which information was available were concentrated in a relatively small area.

The number of test holes drilled was limited to 10 by the available funds. In order to obtain the maximum amount of information from the test holes, a flexible program was evolved wherein the 10 test holes might be drilled at any of 22 alternate locations. The alternate locations were chosen on the basis of, (1) indications that the individual location might be underlain by potable water, or (2) lack of data at the individual location, and (3) ease of access to the individual location for drilling purposes. The pattern of the alternate locations was a modified statistical envelopment of the existing well field. Provision was made in the program for drilling each test hole at a location to be determined by the results from the preceding test holes, thus giving an initial low and a final high accuracy of choice.

Samples of the bolson fill were obtained at intervals of 10 feet or less during the drilling of each of the 10 test holes. The samples were examined and described with regard to rock-type, mineral content, physical characteristics, and color. The samples were mechanically sieved in the hydrologic laboratory of the Geological Survey at Denver, Colo.

Each test hole was logged electrically. The electrical logs consisted of several curves showing the spontaneous potential and the resistivity of the strata encountered by the drill. The electrical logs in conjunction with other drilling data may be used to identify rock-types such as clays or shales, sands, limestones, etc., and to evaluate roughly the mineral content of water in the permeable zones. Charts showing electrical logs from each test hole are included in the appendix of this report.

During the drilling of each test hole a record was kept of the time required to drill each 5-foot interval of depth in the well. Drilling-time logs for the 10 test holes are individually plotted on the respective microlog charts in the appendix.

In order to obtain data pertaining to vertical variation in quality of water in the bolson fill, two water samples were obtained from each test hole. The shallower of the two samples was obtained by bailing the mud from the hole until clear water was obtained. The deeper sample, usually obtained first in order of sampling, was obtained by isolating the deeper sands from the upper part of the well by the use of a packer and pumping by the air-lift method. The water samples were analyzed by the Quality of Water laboratory of the Geological Survey at Albuquerque, N. Mex.

The drilling of the 10 test holes permitted the determination of the depth to water at locations where no existing well could be measured. This additional control contributed measurably to the accuracy of the water-table contour maps.

In the program of test drilling, provision was made for casing and test pumping of one test hole. The hole chosen, test hole 7 (17.9.25.324), was in the most promising area on the basis of high permeability and satisfactory chemical quality of water. The results of the test are given in the section on hydrologic characteristics of the bolson fill.

The basic data gathered during the investigations in the vicinity of Holloman Air Force Base are given in tables 11 through 24 and in the appendix of this report. Some of the data, particularly some of the chemical analyses of water from the Boles wells, were not used for interpreting ground-water conditions in the area but are included as a matter of record.

Topographic maps of the Holloman area, prepared by the Army Map Service (scale 1: 25,000), were utilized for the investigation and from them the various maps shown in this report were prepared.

Continuous field work was terminated in April 1955; however, additional data are being collected as they become available.

Well-Numbering System

The system of numbering wells used in this report is that used by the Geological Survey in New Mexico and is based on the common subdivisions in sectionized land. By means of it the well number, in addition to designating the well, locates its position to the nearest 10-acre tract in the land net. The number is divided by periods into four segments. The first segment denotes the township south of the New Mexico base line; the second denotes the range east of the New Mexico principal meridian; and the third denotes the section.

The fourth segment of the number, which consists of three digits, denotes the particular 10-acre tract in which the well is situated. For this purpose, the section is divided into four quarters, numbered 1, 2, 3, and 4, in the normal reading order, for the northwest, northeast, southwest, and southeast quarters, respectively. The first digit of the fourth segment gives the quarter section, which is a tract of 160 acres. Similarly, the quarter section is divided into four 40-acre tracts numbered in the same manner, and the second digit denotes the 40-acre tract. Finally, the 40-acre tract is divided into four 10-acre tracts, and the third digit denotes the 10-acre tract. Thus, well 17.9.24.342 at the Boles well field is in the NE$\frac{1}{4}$SE$\frac{1}{4}$SW$\frac{1}{4}$ sec. 24, T. 17 S., R. 9 E., as shown in figure 2. If a well cannot be located accurately within a 10-acre tract, a zero is used as the third digit, and if it cannot be located accurately within a 40-acre tract, zeros are used for both the second and third digits. If the well cannot be located more closely than the section, the fourth segment of the well number is omitted. When it becomes possible to locate more accurately a well in whose number zeros have been used, the proper digit or digits are substituted for the zeros. Letters a,b,c,...are added to the last segment to designate the second, third, fourth, and succeeding wells in the same 10-acre tract.

Approximately 35 wells and test holes were drilled in the Boles well field from 1947 through 1955. As drilling progressed, each well was assigned a number by Air Installations Office personnel at the well field. Through 1952, the wells were numbered in the order drilled. In 1953, however, the rate of exploratory drilling increased, and as a result the several agencies and persons involved assigned various numbers to the 15 wells and test holes drilled in 1953. In 1955 two additional production

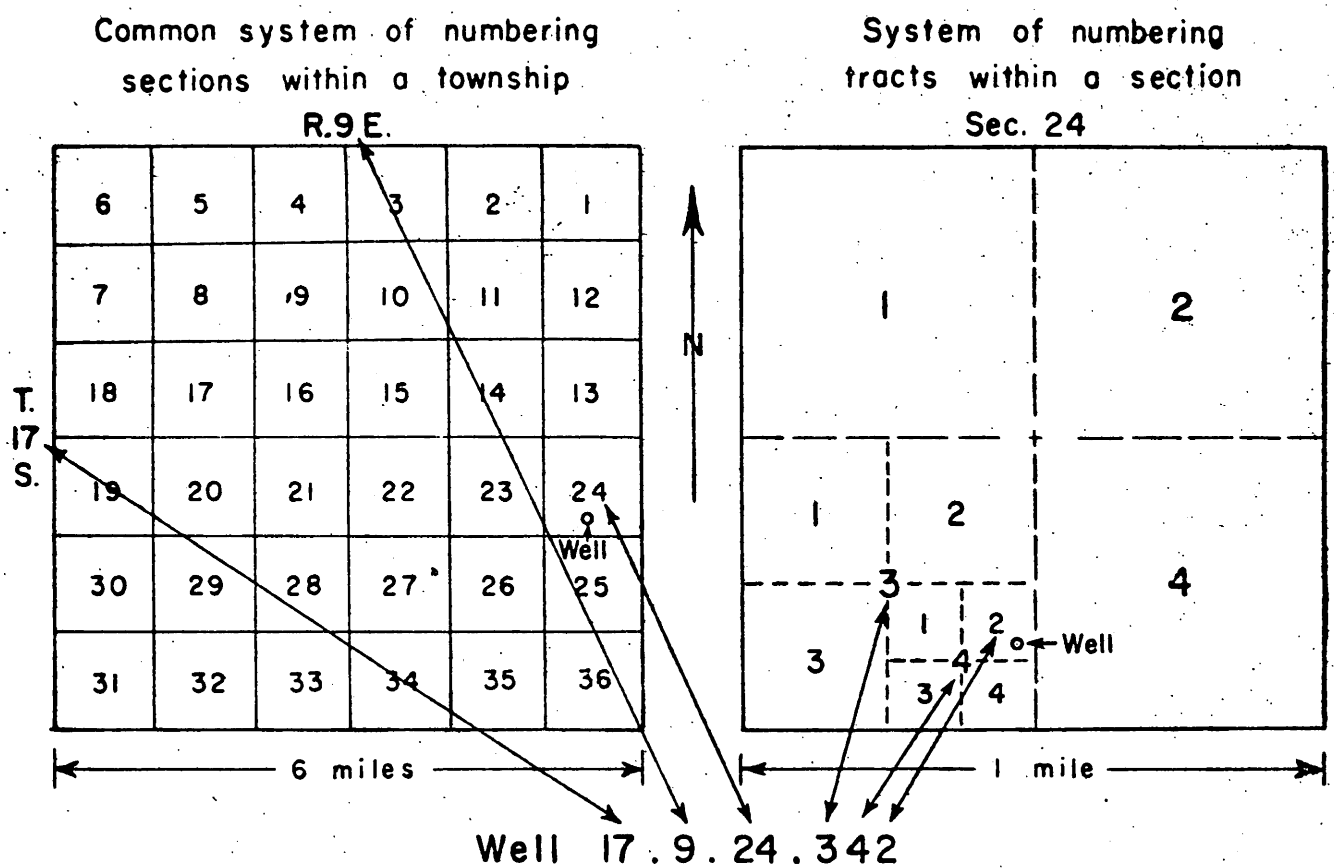


Figure 2. -- System of numbering wells in New Mexico

Table 1.--CROSS INDEX OF NUMBERS OF WELLS IN BOLES WELL FIELD
Holloman Air Force Base, Otero County, N. Mex.

Location	Date drilled	Well no. in order drilled	Boles no.	AIO Number Map 1/	AIO Number Notes 2/	Corps of Eng. No. 3/ Notes	Corps of Eng. No. 3/ Maps	Remarks
17.10.19.121	May 47	1	1	-	-	-	-	Abandoned
19.123	Aug 47	2	2	-	-	-	-	In use
18.424	Feb 48	3	3	-	-	-	-	Test well
19.214	Mar 48	4	4	-	-	-	-	Test well
19.144	May 48	5	5	-	-	-	-	In use
18.433	June 48 ?	6	6	-	-	-	-	Test well
19.132	July 48	7	7	-	-	-	-	Test well
18.343	Aug 48	8	8	-	-	-	-	Test well
18.424a	Oct 48	9	9	-	-	-	-	Test well
19.121a	Nov 48	10	10	-	-	-	-	In use
19.121b	Dec 48	11	11	-	-	-	-	Test well
19.122	Feb 50	12	12	-	-	-	-	Test well
19.112	Mar 50	13	13	-	-	-	-	Abandoned
19.142	May 50	14	14	-	-	-	-	In use
19.141	July 50	15	15	-	-	-	-	In use
17.9.25.222	May 52	16	16	-	-	-	-	In use
25.213	Aug 52	17	17	-	-	-	-	In use
17.10.18.424b	Feb 53	18	-	1	A No. 1	-	-	Test well
18.442	Mar 53	19	-	2	A No. 2	-	-	Test well (10 feet North of Well "A")
18.434	Apr 53	20	-	3	B No. 3	-	-	Test Well
19.234	Apr 53	21	-	4	C No. 4	-	-	Test well
19.241	Apr 53	22	-	5	D No. 5	-	-	Test well
17.10.18.443	May 53	23	-	6	E No. 6	-	-	Test well
18.432	May 53	24	-	7	F No. 7	-	-	Test well (10' N. of Well "B")
19.112a	June 53	25	New No. 13	-	Well to replace No.13	-	-	Unused
18.442a	July 53	26	1-A	-	-	2a	A	In use (10' S. of test well)
19.321	July 53	27	-	8	-	8	-	Test well (10' NW of Well "C")
18.432a	Aug 53	28	-	-	-	7f	B	Unused (10' S. of test well)
19.323	Aug 53	29	-	9	-	9	-	Test well (13' SW of Well "D")
19.321a	Sept 53	30	-	-	-	8a	C	Unused (10' SE of test well)
19.323a	Sept 53	31	-	-	-	9a	D	Unused (13' NE of test well)
19.113	Oct 53	32	1-C	-	-	E	"Pilot Hole"	Equipped for use
17.9.24.342	1951	33 4/	33	-	-	-	-	McCommon's well equipped for use.
24.343	Apr 55	34	34	-	-	-	-	-
25.212	May 55	35	35	-	-	-	-	-

1/ Air Installations office map, item J050, FY53, dated 16 June, 1953
2/ Notes by Mr. Genta, in charge of test drilling, Feb-June 1953
3/ From inspector's daily log and map pertaining to construction from July 1953 to July 1954
4/ Number assigned when well was integrated into Boles well-field system

wells were drilled and a privately owned well was added to the well-field system. The several numbers assigned to each of several wells led to considerable confusion both in reporting well and pumpage data and in making a thorough inventory of the area. A cross-index of well numbers assigned to wells and test holes in the well field was prepared during the investigation and is given in table 1. The cross-index gives the standardized location number of each well, the month and year in which the well was completed, the well number in the order of drilling, and the several other numbers used in reporting pumpage and well designation in various maps and reports. In order to prevent further confusion in the records it is desirable that the original practice of numbering wells in the order in which they were drilled be continued as long as the well field is used.

When the test-drilling program was planned, a map (District file AL-DJ-1/1) was prepared by the Corps of Engineers, which showed 22 alternative test-hole locations. The locations were numbered T-1, T-2, T-3... Test holes drilled at a specific location were given the number assigned to that location. Table 15 gives data from the test holes drilled in 1954, and columns one and two in the table relate the test-hole number to the statewide well-numbering system.

Acknowledgments

Field work and preparation of this report were performed under the direct supervision of C. S. Conover, District Engineer, and the general supervision of A. N. Sayre, Chief, Ground Water Branch, U.S. Geological Survey.

The investigation was made at the request of the U. S. Corps of Engineers acting as contracting agent for the Air Research and Development Command, U. S. Air Force.

The writer is indebted to the Corps of Engineers for providing space in the office of the Project Engineer at Holloman Air Force Base, for use as field headquarters during the investigation.

Mr. J. T. Foley, assistant Deputy Chief of Staff for Material, Mr. Edison Iles, and others in the Air Installations Office of Holloman Air Force Base were of great assistance in providing records pertaining to the Boles well-field and assistance of a general nature throughout the field investigation. Mr. L. C. Boles, land owner, and well-field operator for Holloman Air Force Base was of invaluable assistance in providing additional data pertaining to the well field, and in various phases of study in the well field.

Thanks are extended to the landowners and well drillers whose assistance made work possible in the outlying parts of the area.

The publications and other sources of information listed under References have been consulted and freely used in preparing this report, and their use is herewith acknowledged with thanks.

Plate 3A.--View of Alamo Canyon, looking west toward Tularosa Basin.

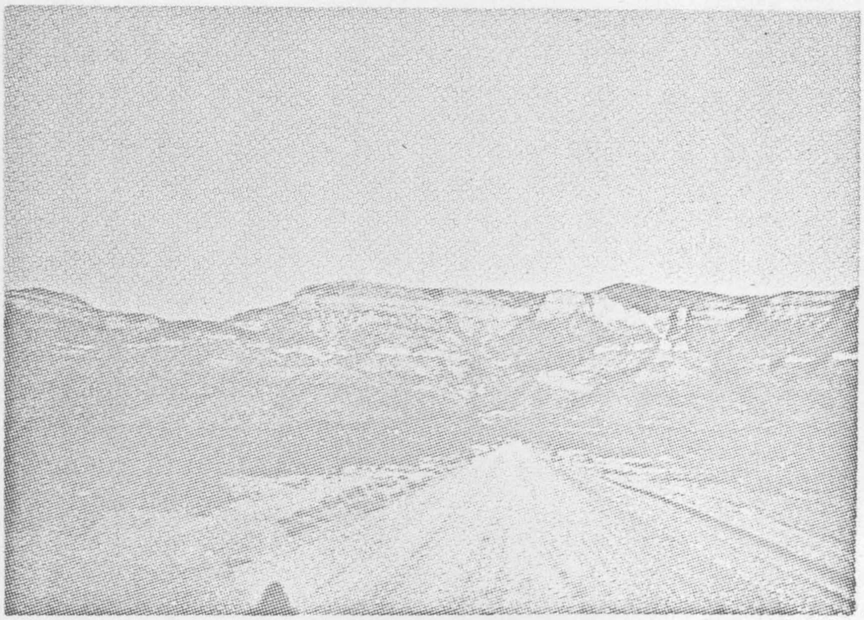


Plate 3B.--View of Sacramento Mountain escarpment and Arrow Canyon fan (center) from west side of Boles well field.

TOPOGRAPHY

Holloman Air Force Base is near the center of the east edge of the Tularosa Basin. The Tularosa Basin is a long, narrow intermontane basin and is part of a structural depression more than 200 miles in length extending southward from western Lincoln County, N. Mex., through western Texas and beyond the Rio Grande into the State of Chihuahua, Mexico. The larger depression was first called the Hueco Bolson by Hill (1900) and was subsequently divided on the basis of topography by Richardson (1909) into the Tularosa Basin, or Tularosa Desert, on the north and the Hueco Bolson on the south.

The Tularosa Basin is bounded on the south by a low topographic divide near the State line; on the west by the Organ, San Andres, and Oscura Mountains, and Chupadera Mesa; on the north by the Mesa Jumanes; and on the east by the Jicarilla, Sierra Blanca, and Sacramento Mountains. The interior plain has low relief (plates 3A and 5B), with altitudes ranging from about 4,000 feet on the south and west sides to about 4,400 feet on the north and east sides. The surrounding mountains rise abruptly to altitudes of 7,000 to 12,000 feet.

Within the area covered by this report the most striking topographic feature is the Sacramento Mountain escarpment, which rises abruptly to a height above the adjoining plain of over 2,000 feet in less than a mile and presents a nearly vertical wall to the plain (plate 3B). Beyond the top of the first range, the altitude increases by another 2,400 to 2,600 feet in about 6 miles. The escarpment is dissected by narrow, steep-walled canyons whose floors have steep gradients amounting to 500 to 1,000 feet per mile (plate 3A).

On the plain, topographic features are less striking. The entire plain in the vicinity of Holloman Air Force Base consists of sedimentary debris eroded from the mountains. The plain slopes west-southwestward at rates ranging from about 10 to more than 45 feet per mile. Locally the relatively smooth depositional surface of the plain has been modified by additional deposition and by erosion.

At the mouths of the several canyons in the area, surface runoff from the mountain area has deposited alluvial fans (plate 3B). The size of an individual fan is more or less proportional to the size of the watershed contributing alluvium to the fan. The fans project from the narrow mouths of the canyons in a semicircular pattern as illustrated by the contours in plate 4, hence the name "fan". Where the alluvial material in a fan interfingers with another fan, the deposits coalesce into an undulating steep slope (plate 5A). In the Holloman area, the heads, or upper parts, of the alluvial fans are currently being degraded and contain arroyos having vertical walls and relatively flat floors. According to reports of long-time residents of the area, the cutting of the arroyos began during the past 50 to 60 years.

As pointed out by Pray (1952), the heads of the fans have been displaced upward by recent faulting. The fault scarp at the mouths of the canyons has been largely eradicated by later erosion, but distinguishable remnants may still be seen, as in the mouth of Mule Canyon. The heads of the alluvial fans are important as recharge areas, owing to the large amount of coarse-grained debris found in them and to the relatively large amounts of water available to them.

Out from the fans the surface of the plain is considerably modified by the deposition of debris from the larger canyons (plate 5B). The plain has been further modified by structural movements which have tilted the surface downward to the west. Incised into the plain are a series of arroyos trending in a southwest direction. The arroyos are steep-walled, flat-bottomed, and usually quite broad.

A line of rocky buttes and knobs trends northward from the Jarilla Mountains (plate 6A). These outcrops of consolidated rocks are surface evidence of the uneven nature of the base upon which the bolson fill was deposited. The outcrops range in height above the plain from a slight swell in the surface of the plain, as illustrated by the outcrop in sec. 28, T. 17 S., R. 8 E., to about 500 feet in small steep hills, as illustrated in the Tres Hermanos, about 8 to 10 miles south of Holloman Air Force Base. From the longitude of Holloman Air Force Base westward, the plain is a gently undulating surface consisting of alternate small rises and flat-bottomed playas. The surface is broken only by the rocky outcrops described above and by the White Sands, derived from playas to the southwest and emplaced by the wind. The origin of the undulating surface of the central basin is not known, but may be related to deflation, subsidence from ground-water solution of evaporites in the bolson fill, subsurface structural activities as described by Sayre and Livingston (1945) in the Hueco Bolson, or perhaps all three processes.

Plate 5A.--View, looking southward, of Lead Canyon fan from Arrow Canyon, showing steep slope of fan, low inter-fan area, and coarse-grained fan deposits.

Plate 5B.--View of Tularosa Basin, looking westward, Boles well field in center on composite fan slope, and steep Arroyo Canyon fan in foreground. San Andres Mountains in background.

Plate 6A.--View, looking south, of flat surface of Tularosa Basin and Tres Hermanos, a group of consolidated rock outcrops which pierce the basin surface.

Plate 6B.--View of west face of Sacramento Mountains and surface of Tularosa Basin. Sparse vegetatio and gypsiferous soil are characteristic of t region.

CLIMATE

The Tularosa Basin has an arid to semiarid climate, a climate typical of the southwestern United States. Precipitation normally is 8 to 10 inches per year. Relative humidity is correspondingly low and usually does not rise above 20 to 30 percent. Temperatures are high on summer days but owing to the low relative humidity and generally clear skies, night-time temperatures are generally low. The diurnal range of temperatures in the summer may amount to as much as 60°F. though it is usually less. On the plain, potential evaporation is large owing to the prevailing low relative humidity and generally high temperatures. Although there are no Weather Bureau stations reporting evaporation rates in the basin, records from Alamogordo Dam on the Pecos River east of the basin, and at Elephant Butte Dam on the Rio Grande west of the basin indicate the potential evaporation as represented by a class A evaporation pan may be as much as 12 feet of water per year.

In the mountainous areas, precipitation is greater and temperatures are lower than in the interior plain. Along the west side of the Sacramento Mountains, the relation of precipitation and temperature to change in altitude is very nearly a straight-line function, as illustrated in figure 3. Averages of measured precipitation and temperature are given in tables 2 and 3 for the periods of record for five stations in the Holloman area. Annual precipitation and cumulative departures from average are given for Alamogordo, representative of the interior plain, and for Cloudcroft, representative of the mountainous area, in figure 4.

The cumulative departures of precipitation shown in figure 4 indicate that recharge to the bolson fill in the basin is not uniform but varies over a period of years in response to the accumulated deficiencies and surpluses in precipitation.

Table 2.--Average precipitation, in inches, at stations in vicinity of Holloman Air Force Base, Otero County, N. Mex. 1/

Location and Period of record	Altitude (feet)	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
White Sands National Monument	3,995	0.65	0.30	0.19	0.42	0.43	0.58	1.14	1.34	1.69	0.78	0.36	0.63	8.51
15 years														
Holloman Air Force Base	4,074	.53	.41	.10	.23	.46	.98	.90	.67	1.00	.70	.28	.51	6.77
Sept. 1942-Jan. 1946														
Aug.-Oct., Dec. 1946														
Nov. 1947-Sept. 1953														
Alamogordo	4,350	.62	.52	.44	.41	.57	.75	1.52	1.74	1.41	.91	.59	.68	10.16
39 years														
Mountain Park	6,720	1.18	1.05	.85	.70	.84	1.41	3.05	3.45	2.29	1.46	.85	1.15	18.28
31 years														
Cloudcroft 1	8,575	1.71	1.60	1.37	.86	1.14	1.71	5.01	4.64	2.90	1.58	1.16	1.51	25.19
47 years														

1/ All data from U. S. Weather Bureau (1954), except Holloman AFB which are from weather detachment, Holloman AFB.

Table 3.--Average temperatures, in degrees Fahrenheit, at stations in vicinity of Holloman Air Force Base, Otero County, N. Mex. 1/

Location and Period of record	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
White Sands National Monument	38.6	44.2	50.4	58.8	68.1	76.7	80.0	78.6	72.4	60.4	46.4	40.4	59.6
11 years													
Holloman Air Force Base	41.7	46.6	51.6	60.8	69.3	78.8	81.3	80.8	73.4	62.5	48.6	42.2	61.5
Sept. 1942-Jan. 1946													
Aug.-Oct., Dec. 1946													
Nov. 1947-Sept. 1953													
Alamogordo	41.8	47.1	49.0	60.4	69.0	77.8	79.5	77.9	72.5	62.5	49.9	43.3	61.2 (60.9)
31 years													
Mountain Park	35.7	38.7	43.7	51.1	58.7	67.2	68.4	67.0	62.4	54.1	43.6	38.0	52.4
21 years													
Cloudcroft 1	30.6	32.1	36.7	43.0	51.8	58.5	59.8	58.7	54.7	47.1	37.7	31.2	45.2
42 years													

1/ All data from U. S. Weather Bureau (1954), except Holloman AFB which are from weather detachment, Holloman AFB.

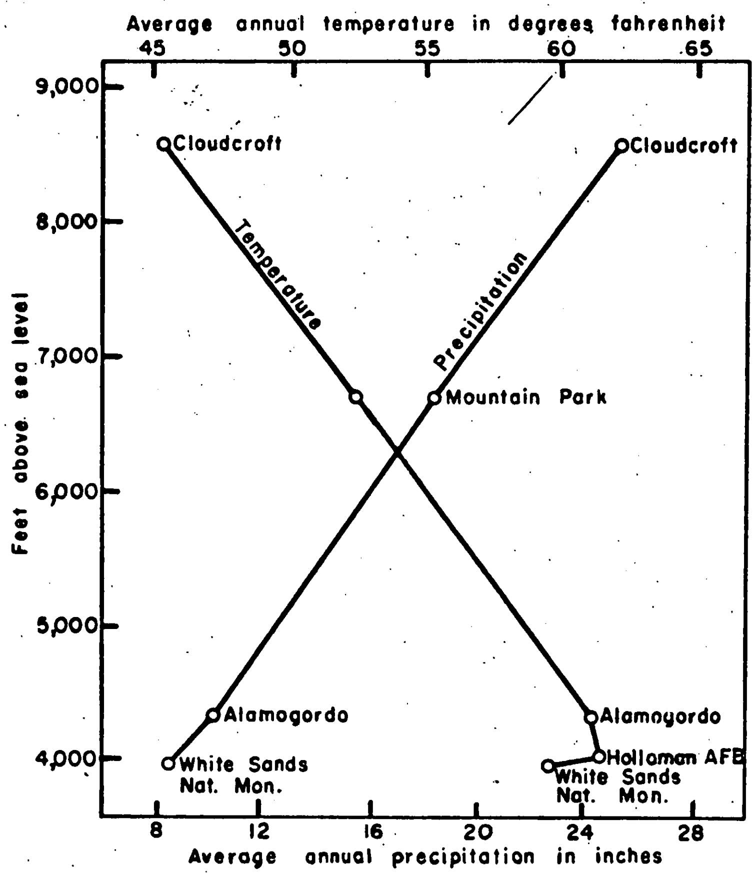


Figure 3.—— Relation of temperature and precipitation to altitude in vicinity of Holloman Air Force Base, Otero County, N. Mex.

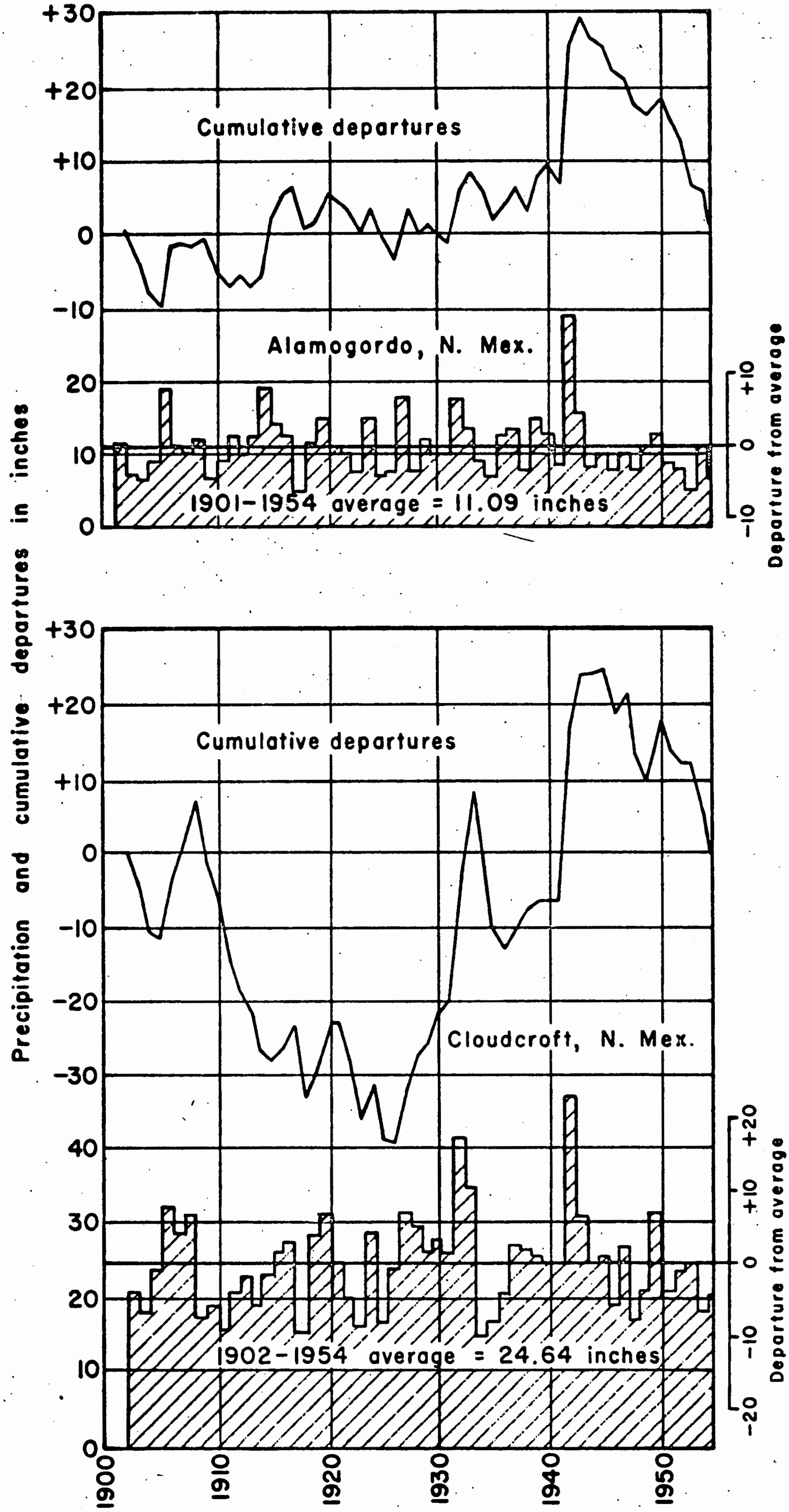


Figure 4.—-Annual precipitation and cumulative departures from average precipitation at Alamogordo and at Cloudcroft, Otero County, N. Mex.

GEOLOGY

Rocks exposed in the vicinity of Holloman Air Force Base range in age from Precambrian(?) to Recent. In the Sacramento Mountains, the Paleozoic geologic section is nearly complete and contains rocks ranging in age from Cambrian(?) to Permian. Mesozoic rocks are not present in the area investigated. The principal area of Cenozoic rocks in the vicinity of Holloman Air Force Base is the Tularosa Basin. There, thick deposits of Tertiary and Quaternary alluvial, lacustrine, and eolian sedimentary rocks fill a deep structural basin.

In the area investigated, rocks of different ages are of varying importance with respect to the ground-water hydrology. The unconsolidated bolson fill of Cenozoic age is of greater importance than the consolidated Paleozoic and Precambrian(?) rocks in the adjacent mountain escarpment. The bolson fill is the major aquifer in the area, whereas the consolidated rocks adjacent to and underlying the fill are comparatively impermeable and are important mainly as sources of the erosional debris making up the bolson fill and as sources of runoff. It is well known that large springs discharge from some of the formations high in the mountains; however, the springs do not enter to any great extent into the hydrology of the bolson fill in the Boles area and were not studied for this report.

Plate 7 shows the distribution of rocks in the Sacramento Mountain escarpment adjacent to the Boles well field, together with drainage-basin data discussed in other parts of this report. In the plate, the several formations that are shown in the composite columnar section (figure 5) are grouped in units based on their relative importance to the water in the bolson fill.

Stratigraphy

Precambrian(?) and Paleozoic Rocks

Consolidated rocks exposed in the vicinity of Holloman Air Force Base are principally sedimentary rocks and have a total stratigraphic thickness in excess of 7,000 feet. The geologic section includes a thin sequence of rocks of probable Precambrian age and a thick sequence of Paleozoic rocks containing formations which represent all seven periods of the Paleozoic era. The Precambrian(?) rocks consist of slightly metamorphosed sandstone, siltstone, and shale and some diabase sills. The Paleozoic rocks are mainly limestone, dolomite, shale and sandstone and lesser amounts of gypsum, chert, and conglomerate. The gypsum occurring in the Permian rocks of upper Paleozoic age is one of the main sources of the mineral content of ground water in the Tularosa Basin. Figure 5 shows a composite columnar section of the Sacramento Mountains in Otero County, N. Mex. The figure gives a graphic representation and description of the rocks in the mountains, together with age correlations, names, and thicknesses of the several formations described by Pray (1952).

The consolidated rocks are relatively impermeable for the most part, although some of the rocks are important aquifers in the higher parts of the mountains. The consolidated rocks are important to a study of the bolson-fill aquifer primarily because weathering products from these rocks provided material for the bolson fill in the Tularosa Basin. The chemical character of the weathering products, particularly those from the Yeso formation of Permian age, modify the quality of ground water occurring in the fill.

Cenozoic Rocks

Igneous rocks

The igneous rocks in the vicinity of Holloman Air Force Base are believed to be Tertiary in age and are probably related to igneous activity that occurred throughout the region during early and mid-Tertiary time. Known areas of occurrence of igneous rock near Holloman Air Force Base are relatively small. Exposures consist principally of dikes, sills, and small irregular bodies in the consolidated sedimentary rocks. One igneous plug pierces the surface of the basin in the Tres Hermanos, about 9 miles south of the air base.

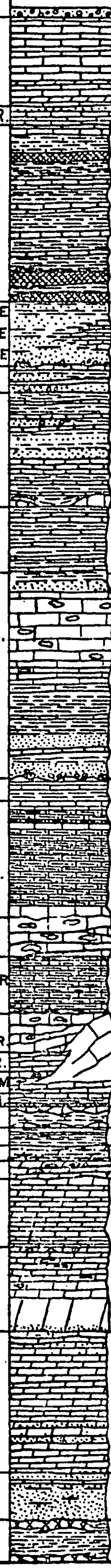
Bolson deposits

The sedimentary rocks making up the bolson deposits of the basin are of Cenozoic age and are the most important rocks with regard to the occurrence of ground water in the vicinity of Holloman Air Force Base. Beneath the surface of the Tularosa Basin along the west face of the mountains, Cenozoic rocks attain a maximum thickness known to be in excess of 1,800 feet. In the mountain area, the Cenozoic sedimentary rocks are terrace deposits, talus and landslide debris, and spring deposits.

In this report, no attempt is made to assign specific ages to different parts of the bolson deposits. Instead, reference is made to two general parts; the older fill, and the younger fill or the overlying alluvial fans which are important with respect to water supply in the Holloman area.

Character of the bolson deposits.--The bolson fill in the Tularosa Basin, in the vicinity of Holloman Air Force Base, is generally fine grained. The older fill in most of the area is virtually all clay, and generally contains little material coarser than very fine-grained sand. The logs of wells 18.9.14.200 and 16.9.26.210 show that nearly all the fill below 150 feet is clay to a depth of at least 1,800 feet. The fill penetrated in well 16.9.8.432 was nearly all clay from the land surface to a depth of 525 feet. The logs of the test holes drilled in the Boles area in 1954 show that the fill encountered at depth in the area is relatively fine grained. However, the logs of the test holes show also that the grain size of the older fill increases toward the mountains, which were the source of the fill. The older fill is

SYSTEM	SERIES	ROCK UNIT		DESCRIPTION	SCALE
QUATERNARY				ALLUVIUM, COLLUVIUM, SPRING DEPOSITS, ETC.	
PERMIAN	GUADALUPIAN	SAN ANDRES L.S.		700'+ LIMESTONE & MINOR INTERBEDDED DOLOMITE, EROSIONAL UPPER SURFACE.	
			HONDO MBR.	0-150' LIMESTONE & DOLOMITE; CLEAN QUARTZ SANDSTONE IN UPPER SURFACE.	
	LEONARDIAN	YESO FM.		1200-1800' LIMESTONE, RED AND YELLOW MUDSTONE, GYPSUM, AND MINOR FINE QUARTZ SANDSTONE.	7,000' 6,000'
	WOLFCAMPIAN	ABO FM.	UPPER TONGUE PENDEJO TONGUE LOWER TONGUE	200-550' ARKOSE, & RED MUDSTONE. THIN-BEDDED LIMESTONE & GRAY SHALE (PENDEJO TONGUE OF HUECO FM.) IN SOUTHERN PART OF AREA.	
		MAGDALENA GR.	BURSUM FM.	0-350' SHALE, GRAY & RED SANDSTONE; LIMESTONE AND LIMESTONE CONGLOMERATE.	5,000'
PENNSYLVANIAN	VIRGILIAN		HOLDER FM.*	0-850' LIMESTONE, GRAY AND RED CALCAREOUS SHALE, SANDSTONE, AND CONGLOMERATE. BIOHERMS AT BASE LOCALLY.	
	MISSOURIAN		BEEMAN FM*	0-500' SHALE, ARGILACEOUS LIMESTONE AND FELDSPATHIC SANDSTONE.	4,000'
	DES MOINESIAN ATOKAN MORROWAN (?)		GOBBLER FM.* BUG SCUFFLE LS. MBR. LOCALLY DIFFERENTIATED	0-1600' LIMESTONE, SANDSTONE, AND SHALE. COARSE QUARTZ SANDSTONE IN LOWER PART. MASSIVE, GRAY, CHERTY LIMESTONE (BUG SCUFFLE LIMESTONE MBR.) GRADES LATERALLY INTO SANDSTONE AND SHALE. SCALE CHANGE	3,000'
MISSISSIPPIAN	CHESTERIAN	HELMS FM.		0-60' LIMESTONE AND SHALE.	2,000'
	MERAMECIAN	RANCHERIA AND LAS CRUCES (?) FM.		0-300' LIMESTONE, SILTY, DARK GRAY, THIN-BEDDED.	
	OSAGIAN	LAKE VALLEY FM.	DOÑA ANA MBR.	0-150' LIMESTONE, GRAY, CHERTY, CRINOIDAL.	
			ARCENTE MBR	0-200' LIMESTONE, DARK GRAY, ARGILACEOUS, THIN-BEDDED, AND CALCAREOUS SHALE.	1,500'
			TIERRA BLANCA MBR.	0-140' LIMESTONE, GRAY, CHERTY, CRINOIDAL.	
			NUNN MBR.	0-120' LIMESTONE AND CRINOIDAL MARL.	
			ALAMOGORDO M.	0-400' LIMESTONE, CHERTY; LOCAL BIOHERM FACIES	
			ANDRECITO M.	0-35' LIMESTONE, SILTY, AND SHALE.	
	KINDERHOOKIAN	CABALLERO FM.		15-60' LIMESTONE, NODULAR & CALCAREOUS SHALE.	
DEVONIAN	UPPER	SLY GAP & PERCHA(?) FM.		0-45' SHALE & LIMESTONE. BLACK SHALE AT TOP MAY BE EQUAL. TO PERCHA SH	
	MIDDLE	ONATE FM.		0-60' SILTSTONE, DOLOMITIC	
SILURIAN	LOWER (?)	FUSSELMAN FM.		0-100' DOLOMITE, DARK, CHERTY, RESISTANT.	1,000'
ORDOVICIAN	CINCINNATIAN	VALMONT DOL.		150-225' DOLOMITE, LIGHT GRAY, SUBLITHOGRAPHIC THIN-BEDDED.	
		MONTOYA FM.		140-250' DOLOMITE, UPPER MEMBER CHERTY, LOWER MEMBER MASSIVE; 0-12' QUARTZ SANDSTONE AT THE BASE.	
	CANADIAN	EL PASO FM.		420' DOLOMITE, THIN-BEDDED, SOME QUARTZ SANDSTONE.	500' 400' 300'
CAMBRIAN (?)	UPPER (?)	BLISS SS.		110' QUARTZ SANDSTONE, GLAUCONITIC	200
PRE-CAMBRIAN (?)				80'+ SANDSTONE-SILTSTONE AND SHALE, SLIGHTLY METAMORPHOSED, DIABASE SILLS.	100'



*Manuscript name

From L. C. PRAY 1954

Figure 5.-- Composite columnar section, Sacramento Mountains, Otero County, N. Mex.

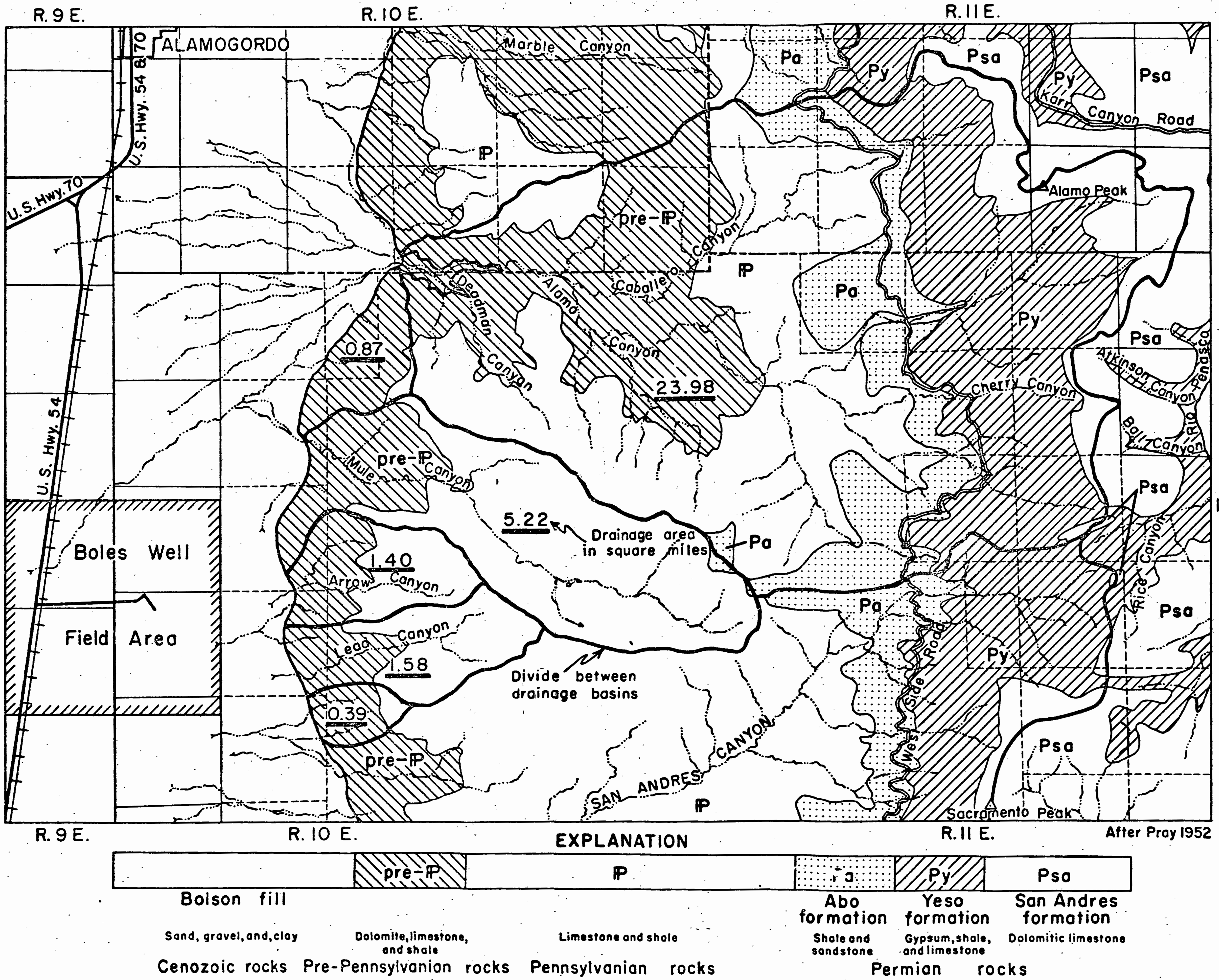


Plate 7.—— Geologic sketch map showing groups of related rocks and drainage basins in the Sacramento Mountains, east of the Boles well field area, Otero County, N. Mex.

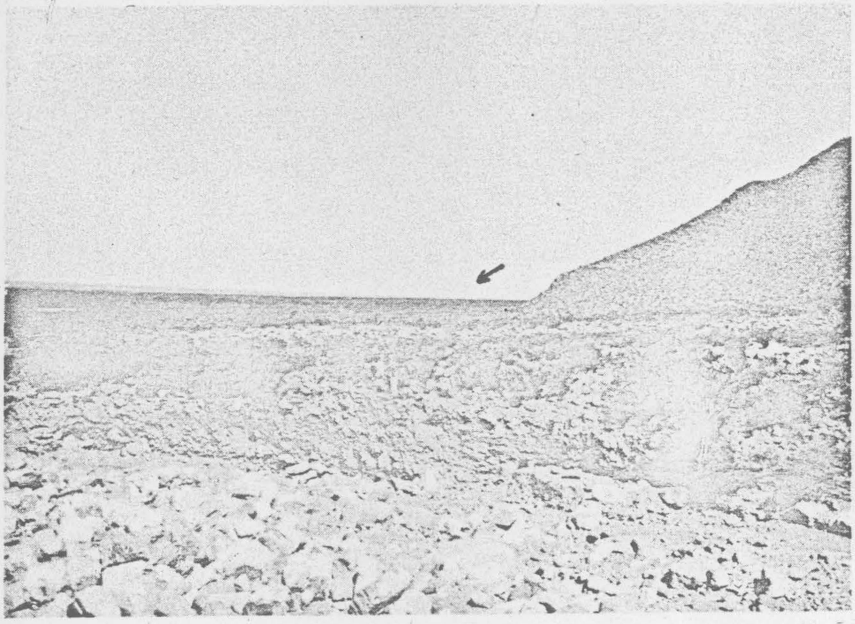


Plate 8A.--View northward from head of Arrow Canyon fan toward Alamogordo. Smoke on horizon is from smokestack at Alamogordo which is hidden by the high composite Alamo-Mule Canyons fan. Note coarse-grained fan deposits in foreground.

Plate 8B.--Mid-fan deposits exposed in Mule Canyon arroyo, north of Boles well field. Dense clay (adobe) overlies lenticular bed of gravel.

characterized not only by fine-grained sediments, but also by a considerable amount of caliche or calcium carbonate. The caliche occurs throughout the older fill both as disseminated flakes or nodules and as beds ranging from about an inch to several feet in thickness.

Owing to the common sources of erosional debris filling the Tularosa Basin near the Boles well field, the older bolson fill and the younger fill in the alluvial fans are similar in appearance and are difficult to separate. However, a rather arbitrary division may be made in the Boles area on the basis of relative grain sizes found in the deposits. The alluvial fans, like the older fill, are principally fine grained, but the grain size is noticeably coarser and locally may be very coarse. Along the base of the Sacramento Mountains, the younger fill consists of fanglomerates which have little or no sorting (plates 5A and 8A). This condition is illustrated in the log of well 16.10.33.340. The fan sediments become increasingly better sorted (plates 8B and 6B) with distance from the mouth of the canyon from which the fan sediments are transported. On the upper slopes of the fans even the clays are silty or sandy, and a number of strata are encountered which contain particles ranging from fine sand to small boulders. The logs of test hole 9 (17.9.24.222) and test hole 22 (17.9.13.244) illustrate this. Farther down the fans, the average grain size diminishes, and the sorting is better. In this zone, beds of sand and of clay are rather well defined. This is the general condition in much of the Boles well field and is illustrated by the logs of test hole 21 (17.9.25.123) and test hole 7 (17.9.25.324). Although some caliche is found in parts of the alluvial fans, the occurrence of caliche is not a general characteristic as it is of the older fill. The results of mechanical analyses of samples from the 10 test holes drilled in 1954 are shown graphically on the electrical logs which accompany this report as the appendix. A composite mechanical analysis of the bolson fill in the Boles area and data from test hole 7 (17.9.25.324) are given in table 4. These data illustrate the changes in grain size of the fill with increasing depth.

Table 4.--Mechanical-analysis data for test holes drilled in 1954 in vicinity of Boles well field, Otero County, N. Mex.

Source of data	Particle size, in mm, as percent of sample by weight								
	Silt - clay	Sand sizes					Gravel sizes		
	<0.004-0.0625	Very fine 0.0625-0.125	Fine 0.125-0.25	Medium 0.25-0.5	Coarse 0.5-1.0	Very coarse 1.0-2.0	Very fine 2-4	Fine 4-8	Med. 8-16
Composite of Boles area—average of 283 samples from 9 test holes ranging from 200 to 500 feet deep.	57.8	10.7	8.8	5.0	5.0	6.3	5.4	1.6	0.1
Test hole 7: From 0 to 255 feet—average of 26 samples	38.0	12.4	13.8	9.2	10.3	11.6	4.1	0.3	-
From 255 to 512 feet—average of 25 samples	49.6	12.5	10.3	8.8	8.3	6.9	3.3	0.4	-

Farther out in the basin, the younger fill is probably quite thin. The rocks at the surface and at shallow depths consist of silt, clay, and evaporites including principally caliche and gypsum (plate 6B). The thickest deposits of younger fill, other than the fan deposits, are in the low, west side of the basin in the vicinity of Lake Lucero. In that area, fine-grained rocks and deposits of evaporites consisting principally of gypsum are reported to extend to depths of more than 100 feet, on the basis of a well drilled in the White Sands Proving Ground. Meinzer and Hare (1915) postulated the existence of Pleistocene lakes in the area on the basis of the evaporites and some probable wave-cut terraces. They state that the evaporites probably resulted from the desiccation of the lakes, although they add that the deposits could have been formed from the continuous evaporation of shallow, mineral-laden ground water.

The wind, moving across Lake Lucero, has scoured out bits of the gypsum and, by abrasion, has reduced the particles to the size of sand. During the transportation by wind, silt included in the gypsum has been winnowed out and carried away. As a result of the wind erosion, the White Sands, west of Holloman Air Force Base, were emplaced. The average thickness of the White Sands is about 50 feet over an area of about 500 square miles. The area of the White Sands is significant because the sands absorb most of the water from intense local thundershowers, and the solubility of the gypsum results in the occurrence of highly mineralized ground water under a large area.

Thickness of the bolson deposits.--The bolson fill as a whole has a relatively smooth surface which slopes west-southwest. However, the base of the fill is far from smooth, and as a result the total thickness varies from place to place in the basin. The fill was washed into the basin and covered an uneven surface which was controlled by the structure of the consolidated rocks. Therefore, the fill is relatively thin where the consolidated rocks were high and thick where valleys were developed in the consolidated rocks. In the Plymouth Oil Co. No. 1 Federal Lands oil test (20.9.15.110), 2 miles south of Escondida, N. Mex., consolidated rocks were encountered at about 500 feet. Near Valmont, well 18.9.14.200, drilled prior to 1911, penetrated about 1,800 feet of fill without entering consolidated rocks. The fill did not cover all of the consolidated rocks in the basin, as attested by the line of outcrops with intervening valleys extending north from the Jarilla Mountains through the Tres Hermanos to Tularosa Peak. Near the Tres Hermanos, well 18.8.5.431 was drilled through 783 feet of fill before encountering consolidated rock. Near Alamogordo, well 16.9.26.210 was drilled through about 1,000 feet of bolson fill without piercing the base of the fill. To the north, near Tularosa, a test well drilled in 1930 for the State Engineer of New Mexico apparently encountered 1,100 feet of bolson fill. Northwest of Tularosa, an oil test, well 13.8.34.400, was drilled to a depth of 3,900 feet. Although interpretations of the driller's log and samples conflict, it appears that the fill may be as much as 1,300 feet thick at that place.

In the Boles well-field area, differentiation was made between the older fill and the alluvial-fan deposits in the logs of wells and test holes. Although the interpretations of the logs are somewhat arbitrary, it appears that from 100 to about 250 feet of fan material rests upon the eroded surface of somewhat finer grained older fill in the Boles area. The fan materials are thickest at the base of the Sacramento Mountains and become thinner with distance from the mountains. West of the Boles area it is believed that the younger fill of Quaternary age generally consists of a veneer of less than 50 feet of sediments and chemical evaporites. The young deposits, other than those of the alluvial fans, attain thicknesses greater than 50 feet in the White Sands, which are of Recent age, and in the vicinity of Lake Lucero where probable Pleistocene deposits exceed 100 feet.

Age of the bolson deposits.--The Cenozoic bolson deposits of the Tularosa Basin are believed to be largely Tertiary in age, with a relatively thin mantle of Quaternary rocks covering the Tertiary rocks. This conclusion is based on the work of Sayre and Livingston (1945) who described ground-water conditions in the vicinity of El Paso, Tex. They concluded that the sediments underlying the surface of La Mesa, west of the Franklin Mountains, consist principally of Tertiary deposits with no more than 100 feet of Pleistocene deposits and a thin veneer of Recent dune sand. They demonstrated the deformation of the Tertiary rocks in the Hueco Bolson, and concluded that the bulk of the Quaternary deposits there consists of uncemented and undeformed debris, containing Pleistocene fossils, at the bases of the mountains. Recent deposits in the Hueco Bolson consist of dune sand and a thin stratum of clay or other rock on the tilted surface of the basin.

If conditions in the Hueco Bolson and the Tularosa Basin are analogous, as they should be in a continuous structural depression, it is inferred that the Tertiary deposits comprise more than 90 percent of the Tularosa Basin fill and that the Quaternary deposits are of significant thickness only at the bases of the adjoining mountainous areas and in the depressed areas in the vicinity of Lake Lucero.

Structure

The Tularosa Basin is essentially a troughlike depression, or graben, bounded on the sides by faults of considerable throw. The San Andres and Sacramento Mountains are fault-block mountains, whose attitudes suggest that the graben is the result of downfaulting of the center of an immense anticline. The west face of the Sacramento Mountains has been formed by the relative uplift of the mountain block along the east side of a fault or fault system. Pray(1952) considers the escarpment to have been formed through normal, gravity faulting. He bases his opinion on several criteria, principal of which are (1) abrupt west dips at the mountain front and the existence of numerous sympathetic faults near the west edge of the mountain block, which increase in number and amount of throw toward the edge of the block, (2) truncation of internal features of the mountain block, (3) truncation of sculpture of the mountain front, (4) the presence of terraces above the present drainage in the mountains, and (5) the irregularity of the fault trace as evidence for gravity faulting with a dip-slip movement. The movement of the mountain block appears to be in a dip-slip direction on the basis of the faults near the west edge of the mountains and slickensides exposed at the base of the front by erosion of fan debris. The large thickness of fill known to exist near the mountain base, and the Jarilla-Tres Hermanos-Tularosa Peak chain of bedrock outcrops indicate that the base of the fill is far from even, and implies that either the bedrock outcrops represent the crest of a buried anticlinal block or the crest of a cuesta similar to the Sacramento Mountain block. In view of the amount of block-faulting in the region it would seem the latter hypothesis is the more probable.

Structurally, the bolson fill appears to be featureless. However, there are some gross features of the fill which the writer believes correspond to features of the fill in the Hueco Bolson, the southward extension of the Tularosa Basin.

Sayre and Livingston (1945) cite evidence for structural deformation of the fill near El Paso, Tex. In that area, the surface of the bolson appears to have been tilted downward to the west. Several remnants of a high-level terrace along the Franklin and Organ Mountains appear to represent the original bolson surface before faulting dropped the west edge of the bolson surface. On the bolson surface east of El Paso, there are a number of north-trending asymetrical troughs which appear to be the surface expression of faulting in the fill. Faulting of the fill is probably post-Tertiary and has continued intermittently into Recent time. Evidence for continuation of faulting lies in the fact that the probable faulting which created the asymetrical troughs involved all the fill up to and including the caliche beds near the surface of the fill. The caliche beds are possibly of Pleistocene age. Other evidence for the Recent age of some of the faulting of bolson fill in the El Paso area is the faulting and local tilting of Pleistocene rocks in a gravel pit at the south end of the Franklin Mountains.

Much of the evidence for deformation of the bolson fill can be extended northward into the Tularosa Basin. There, the basin surface has a pronounced slope from east to west, with the lowest parts of the basin along the west edge of the interior plain. The depressed areas at the east base of the Franklin Mountains can be traced more or less continuously northward into the vicinity of Lake Lucero. There are terraces along the east base of the San Andres Mountains (Meinzer and Hare, 1915, plate 9B). Elsewhere in the basin there is additional evidence of subsidence. Pray (1952) points out that the minor area of negative relief between Valmont and the Jarilla Mountains may be due to subsidence between the Sacramento Mountains and the bedrock high of the Jarilla-Tres Hermanos chain of limestone outcrops. Movement of the fill along the chain of outcrops may be analogous to the asymetrical trough cited by Sayre and Livingston (1945), although the surface expression is not the same.

The mound springs, briefly described by Meinzer and Hare (1915, p. 52-53) are believed to be evidence of faulting of the bolson fill along the chain of limestone outcrops. The mound springs occur in a narrow area extending from the Tres Hermanos northward along the west side of Holloman Air Force Base and past Tularosa Peak. The springs as a group are unique in the basin. The height of the individual mounds ranges from less than 10 to more than 20 feet. The mounds are composed of minerals from evaporated ground water, and vegetable matter and windblown material secured by the water. At the top of the mound is a small "crater" which may or may not contain a pool of water. Water flows from the tops of some of the mounds. The mounds are the result of waters flowing from the ground. As time passed, vegetation accumulated about the source of water, and windblown sand accumulated about the vegetation. Progressive growth in height apparently brought about the cessation of flow from most mounds.

It is apparent that the water is under appreciable hydrostatic head, because the water rises well above the general land surface. It is inferred that the water flowing from the mounds originates at a considerable depth. Compare the data from spring 18.8.17.412 and well 18.8.5.431 in tables 18 and 21. The well produces flowing warm water from rocks tentatively identified as the Yeso formation at a depth of about 890 feet. The spring also discharges warm water. Partial chemical analyses of water from the two sources show that the chemical character of the dissolved solids is virtually the same both in concentration and in distribution of constituents. Therefore, it is believed the spring water originates from the limestones in the Yeso formation beneath the bolson fill.

It is postulated herein that the bolson fill has moved differentially over a fault plane in the underlying bedrock along the trend of the mound springs and bedrock outcrops. This mode of explanation is necessary in order to account for the upward movement of the water along well-defined paths through consolidated beds of shale in the bedrock and through several hundred feet of clay and silt in the fill.

Evidence of recent faulting of the fill can be seen in the fan materials along the edge of the Sacramento Mountains. The recent faulting caused a relative uplift of the mountain block. The heads of alluvial fans which extended into the mouths of the mountain canyons were uplifted as much as 80 feet. Examples of the fault scarps in fan materials can be seen in the mouths of nearly every canyon, but are particularly prominent in Indian Wells Canyon east of Alamogordo, Mule Canyon, and Arrow Canyon (plate 9A).

The fan materials superimposed on the older bolson fill have a characteristic structure. The fans consist of interbedded clays and sands in the mid-fan and lower fan areas. The beds slope downward away from the heads of the fans. Ground water which enters these inclined strata is under artesian head downdip. The artesian conditions in part of the Boles well field are the result of such confinement of the ground water.

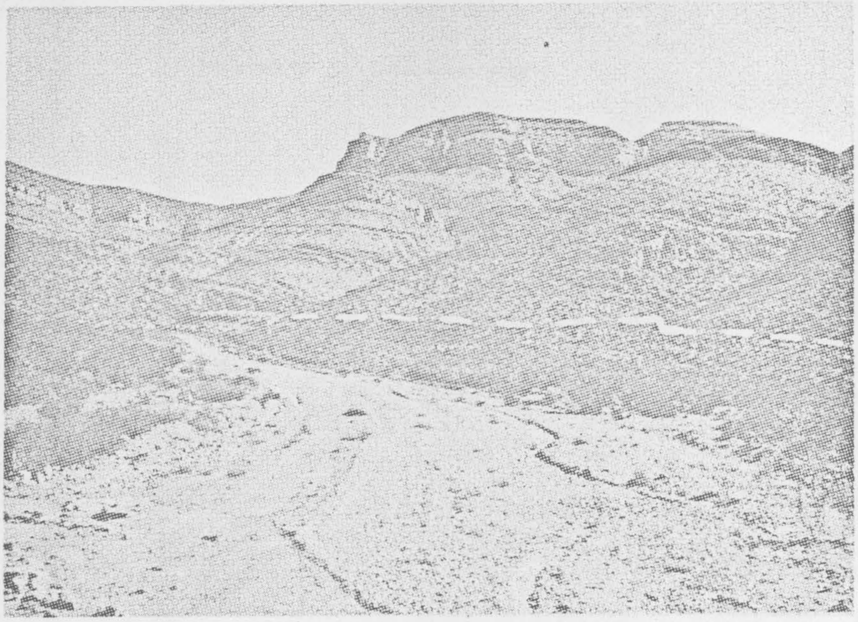


Plate 9A.--View of contact (white dashes) between fan deposits and consolidated rocks at head of Arrow Canyon. Note fault scarp in fan deposits between road and contact in center and at right.

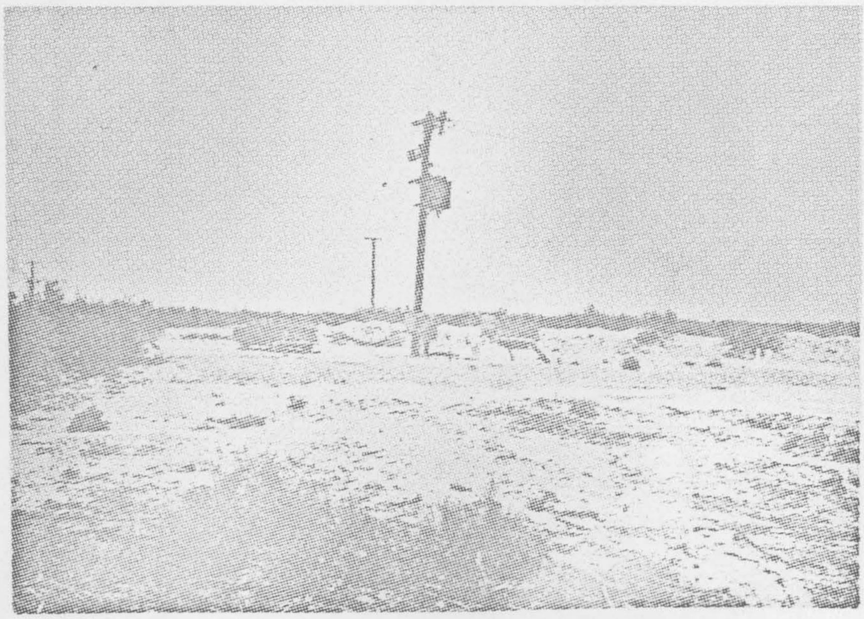


Plate 9B.--Boles well 17. One type of well installation in well field.

Geologic History

The geologic history of only Cenozoic time is of importance to the occurrence of ground water in the vicinity of Holloman Air Force Base. The thick accumulations of Cenozoic deposits in the Tularosa Basin may be attributed to a sequence of events which began no later than mid-Tertiary time, as demonstrated by the work of others in and adjacent to the Rio Grande depression. Dunham (1936) states that the Organ Mountains had been formed by the end of Oligocene time. It is inferred that erosion on a vast scale began with the beginning of the mountain-making processes and continued after the mountains were formed. Bryan (1938) concluded that present-day highland areas near the Rio Grande were formed about mid-Teritary time and were subsequently reduced by erosion. Both Dunham and Bryan indicate that rejuvenation of the eroded Tertiary mountain masses was effected by block-faulting at or after the close of the Tertiary. Pray (1952) concurs with the theory of late Tertiary or post-Tertiary rejuvenation, stating "the present Sacramento Mountains are the result of mountain-forming activity that occurred in late Cenozoic time". Therefore, most of the bolson fill in the Tularosa Basin is the result of deposition during Miocene-Pliocene time. During this time, the fill was deposited by canyon floodflows onto fans and into playas, by sheet floods, and by the wind--processes still active today. The existence of so much clay and silt in the older fill may indicate the existence of lakes during part of Miocene-Pliocene time, but it is more likely that the source rocks were limestones and shales and quickly weathered to clay.

After the Tertiary fill was deposited, the late or post-Tertiary rejuvenation of the mountains, cited above, occurred. During this period the Sacramento Mountains were lifted to approximately their present position, and the Tertiary section of the bolson fill was tilted and was slightly deformed by faulting in some areas. There is some evidence indicating that the structural movements did not stop, but continued into Recent times. As a result of the renewed uplift, previous grades were increased and the subsequent erosional debris was coarser grained than the material on which it was deposited. Most of the coarse-grained debris was deposited in alluvial fans at the edges of the mountains. During the humid periods of Pleistocene time, there probably were lakes in the low areas of the basin, which were created by the tilting of the basin surface. Fan building has continued into Recent time.

GROUND WATER

Occurrence

Ground Water in Consolidated Rocks

The role of consolidated rocks in supplying ground water in the vicinity of Holloman Air Force Base is as varied as the geology of the mountains. The rocks of the Paleozoic section, up to and including those of Pennsylvanian age, yield ground water in limited quantities locally. The dense limestones, shales, and well-cemented sandstones are essentially impervious for the most part and yield water only where faulting or folding has created fractures which provide permeability. Exposures of rocks older than Pennsylvanian are generally limited to the steep sides of the cuesta of the Sacramento Mountains, thereby limiting their intake areas to the floors of the canyons dissecting the mountain front. In the Sacramento Mountains, a few small springs, mostly seeps, issue from rocks ranging in age from Ordovician to Pennsylvanian. The water from these springs is usually hard but potable.

Of the consolidated rocks, those of the Permian system in the vicinity of Holloman Air Force Base are the most important aquifers. They are important as aquifers owing to the extensive exposure of the Permian in the Sacramento Mountains and to the large amounts of soluble minerals present, principally in the Yeso formation. The sandy parts of the Abo formation, and the limestones of the Yeso formation, are the principal sources of nearly all of the numerous springs high in the Sacramento Mountains. Most of these springs produce only small amounts of water. Nearly all of the flow from the larger springs has been appropriated for municipal or agricultural use.

It is known that Permian rocks underlying bolson fill in the vicinity of the airbase also can produce water, but the quality renders water from those buried rocks unfit for any present use.

Ground Water in the Bolson Fill

The principal source of ground water in the vicinity of Holloman Air Force Base is the unconsolidated bolson fill of Cenozoic age. Beds of silt, sand, and gravel in the bolson fill yield water to wells in varying amounts. Ground water occurs in the fill under both water-table and artesian conditions. In some wells in the area the water level remains at the level at which it was encountered by the drill. In other wells, thick sections of clay are encountered, and when a water-bearing sand is penetrated, the water level rises above the top of the sand. In the general vicinity of the Boles well field both conditions exist in the fill, frequently in the same well. The shallowest water-bearing sands contain water under water-table conditions.

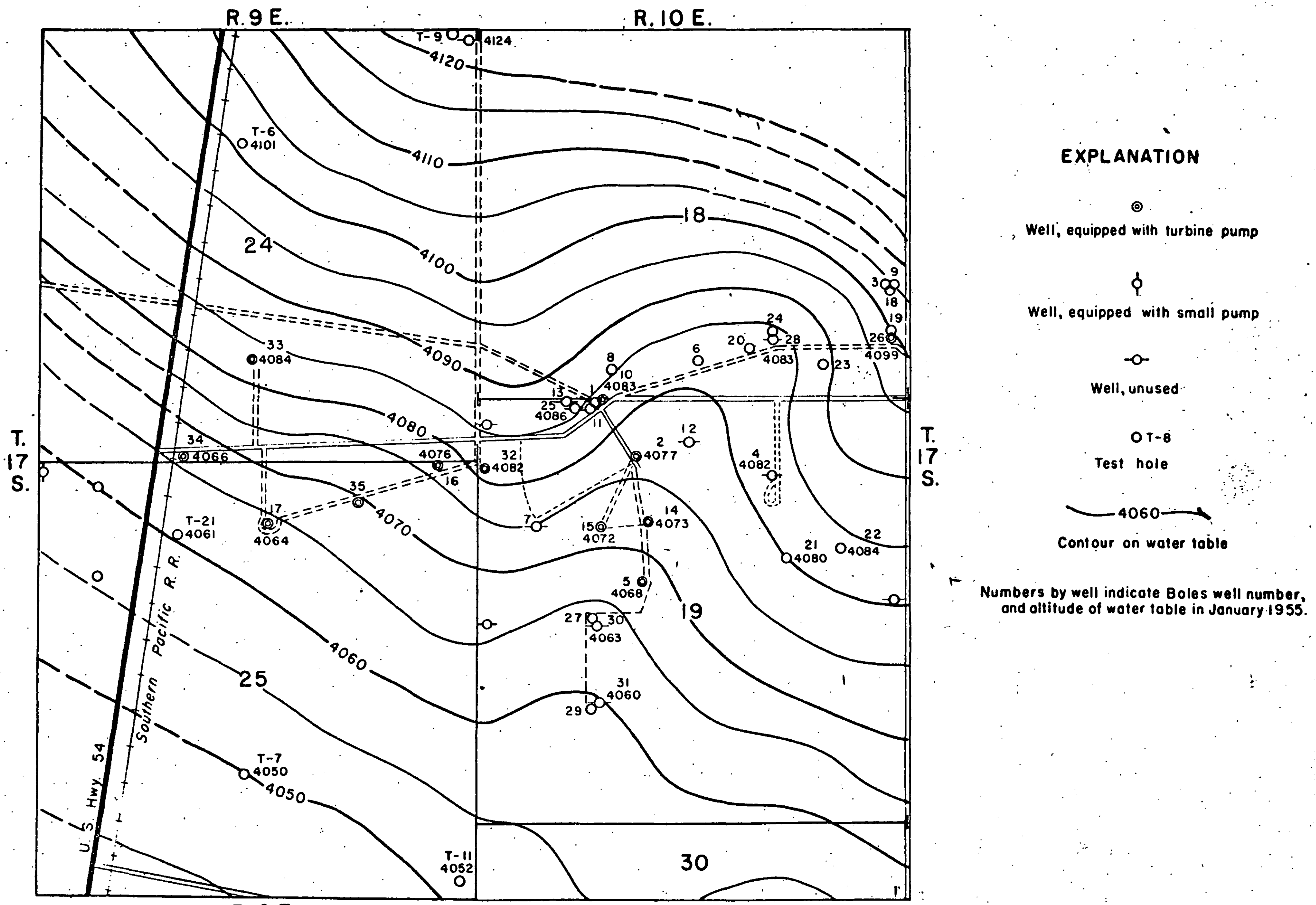


Figure 6.--Wells and test holes, and contours on the water table in the Boles well field area, Otero County, N. Mex.

Sands encountered deeper in the well contain water under artesian pressure. In some of the Boles wells the shallow sands are not present. However, owing to the erratic distribution of sands in the fill, artesian conditions generally are only local and temporary, and after long periods of ground-water withdrawal the aquifer acts essentially as a water-table aquifer.

Depths to water in wells in the area range from more than 200 feet below land surface near the mouth of Alamo Canyon to only a few feet below land surface in the vicinity of White Sands National Monument. The difference in depth to water is due to the difference in the slopes of the water table and the land surface. The water table slopes in approximately the same general direction as the land surface, toward the southwest, but not so steeply, with the result that the land surface and the water-table surface converge toward the west. Plate 1 shows by means of contours the general shape and slope of the water table in the vicinity of Holloman Air Force Base. Figure 6 is a more detailed map showing the slope of the water table in the immediate vicinity of the Boles well field in January 1955. The shape and direction of slope of the water-table contours shown in plate 1 indicate that the ground water in the fill moves toward areas south and west of the area covered by this study. The steep slope of the water table close to the mountains indicates that the permeability of the fill there is generally low.

The occurrence of potable water in the fill is related to the occurrence of soluble minerals in the fill and the source of the waters. Potable water occurs principally in fill derived from rocks containing only small amounts of easily dissolved minerals such as gypsum and salt, and from drainage areas wherein surface runoff over soluble minerals is at a minimum. Owing to the extensive distribution in the area of source rocks containing such easily dissolved minerals, the areal extent of potable-water-bearing fill is limited. The areal extent of the potable-water-bearing fill in the Boles area was determined by constructing "contours" on the sulfate content of water from wells, as determined by chemical analyses. The "contours" shown in plate 2 are lines along which the sulfate content of ground water in the fill is approximately equal to the value shown on the line. Between the edge of the Sacramento Mountains and the contour of 300 ppm sulfate the ground water generally contains less than 300 parts per million of sulfate. Using the sulfate content of the ground water as an indication of potability, the volume of potable water in storage has been computed and is discussed in the section on storage.

Recharge and Discharge

The water table in the vicinity of Holloman Air Force Base, as shown by plate 1, slopes away from the base of the Sacramento Mountains, indicating that recharge to the water-bearing bolson fill occurs along the mountain base. The surface of the bolson near the mountain front consists mostly of a dense adobe clay, except for a relatively narrow belt of coarser grained material in the upper parts of the alluvial fans. The streams in the mountain canyons are intermittent, flowing only after rains fall in the mountain area. Floodwaters from the canyons flow over the zone of coarse-grained fan material, and a part of the water sinks downward into the fan material. The water not absorbed flows over the zone of adobe clay, and most is returned to the atmosphere by evaporation and transpiration. A small amount of recharge to the ground-water reservoir results from precipitation directly on the fans. The amount of recharge to the upper part of the alluvial fans depends in part upon the rate at which the floodwaters pass over the intake area. Passage of flood flows into the basin is an indication that recharge is rejected in the intake area, either because the water table has risen to the land surface or because the soil cannot absorb the water fast enough to prevent a part of the water from running off. As water levels in the intake area are more than 100 feet below the land surface and the surface material is not continuously saturated, the second explanation is the correct one, and the alluvial fans are capable of storing additional water.

The amount of recharge to the fresh-water sands is difficult to estimate, partly because the fresh-water sands are only a part of a larger hydrologic system. However, the minimum amount of recharge can be estimated roughly. It may be seen by the contours in plate 2 that the fresh-water body is lobe-shaped and has subparallel sides trending in a southwest direction. The subparallel sides of the body trend in the same direction as the slope of the water table, indicating that the potable water has moved as a unit from the recharge area to its present position. By projecting the subparallel sides of the fresh-water body to the mountain front, it is indicated that the recharge area extends along the mountain front between Alamo Canyon and San Andres Canyon. The southernmost canyon contributing to the fresh-water body is the small canyon south of Lead Canyon. Water from Alamo Canyon probably does not contribute to the fresh-water body.

The amount of water moving through the fresh-water area may be estimated by a variation of Darcy's law:

$$Q = 0.0011\ TLI$$

in which Q is the quantity of water moving through the section, in acre-feet per year; 0.0011 is a conversion factor; T is the coefficient of transmissibility of the formation, in gallons per day through a section of the aquifer 1 mile wide at a gradient of 1 foot per mile; L is the width of the section, in miles; and I is the slope of the water table, in feet per mile. The coefficient of transmissibility is discussed later under hydrologic charateristics of the bolson fill.

In the Boles area, L was measured along the 4,100-foot contour on the water table, inside the "300 ppm sulfate" line, and amounted to about 2.8 miles (plate 2 and figure 6). The slope (I) of the water table across the

4,100-foot contour was about 45 feet per mile. The coefficient of transmissibility (T) was estimated to be about 5,000 gpd per foot on the basis of aquifer tests made in the Boles well field. The result (Q) was an estimate of about 700 acre-feet per year moving through that part of the aquifer containing potable water.

The amount of runoff which results in the recharge of 700 acre-feet per year was estimated, using the total area of all drainage basins contributing to the recharge area, and an estimate of the annual rainfall on the drainage basins. Plate 7 shows a part of the mountain area adjacent to the Holloman area. The underlined figures in the plate give the area of the drainage basins in square miles. It was assumed that water from Alamo Canyon does not contribute recharge to the fresh-water body. The total area of the drainage basins contributing to recharge of the Boles well-field area is about 9.5 square miles, or about 6,000 acres.

Figure 3 shows that there is nearly a straight-line increase in precipitation with increase in altitude in the western part of the mountain area. The tributary area was divided into strips bounded by 1,000-foot contours of altitude, and the average precipitation on each strip was multiplied by the area of the strip. Using this method it was estimated that the average precipitation is 16.6 inches; that is, a total of about 8,300 acre-feet per year of precipitation falls on the drainage basins that contribute recharge to the fresh-water body in the Boles area. Thus, only about 8 percent of the precipitation recharges the water body. Runoff contributing to recharge of the alluvial fans is thus equivalent to 1.4 inches over the drainage area. However, losses due to evaporation and infiltration in the mountain area account for a large part of the precipitation, and the amount of water discharged from the canyons across the recharge area of the fans is much less than the amount that fell. Therefore, the amount of water reaching the water table is greater than 8 percent of the water discharged from the canyons.

Natural discharge from a ground-water reservoir may take place in several ways. Water from the reservoir may discharge into an effluent stream and be carried away as surface flow; dissipate by evaporation from water-table lakes, or evaporate directly from the land surface where shallow ground water is brought to the surface by capillary action. Ground water can be discharged also by transpiration from vegetation whose roots reach the water table or the capillary fringe above the water table. In the long run, natural discharge from a formation must equal recharge from the formation unless significant changes in storage in the formation take place.

In the Holloman area natural discharge of ground water takes place only by movement out of the area. There are no perennial streams and no water-table lakes. The water table is shallow enough to permit evaporation from the land surface only in small parts of the west side of the area. Although there are areas in which the water table is shallow enough to allow transpiration of the water by plants, commonly where the water is shallow, the salinity of the water in those areas inhibits plant growth. Most of the ground water moves through the aquifer to discharge far from the area covered by this report (Conover and others, 1955).

Within the Boles well-field area the principal mode of discharge of ground water is by pumping from wells. By the end of 1954 approximately 757 million gallons of water, or 2,300 acre-feet, had been pumped from the Boles wells since pumping began. The rate of pumping has been increasing, though there is no uniform increase from year to year, because the amount of water pumped depends on the amount of water supplied to Holloman by Alamogordo. As a result of the pumping, water levels in the area have declined. As long as pumping continues, water levels will continue to decline as the pumped water is being taken from storage, and there is little prospect of increasing recharge or decreasing discharge.

Other points of artificial discharge from the bolson-fill aquifer are the several irrigation wells about 2 miles north of the Boles well field, the irrigation well at the Taylor ranch about 1½ miles southeast of the well field, and the two municipal wells about 1½ miles southwest of the well field. The amounts of water pumped annually from these wells have not been included in the pumpage given in the preceding paragraph. It is not expected that declines resulting from pumping of these wells will affect the Boles area significantly in the near future.

Ground-Water Storage

In determining the amount of water available to pumped wells in the Boles area it is necessary to consider the several factors that affect the aquifer when ground-water withdrawals are made. The permeability of the aquifer regulates the movement of water toward the pumped wells. The coefficient of storage of the aquifer together with the permeability regulates the amount of water that can be pumped from a well and the rate at which effects of pumping are transmitted. When water is pumped, the water is taken from storage in the aquifer with a consequent lowering of water levels. Continued pumping results in continued lowering of water levels until such time as the effects of pumping reach distant areas where discharge from the aquifer is decreased or where recharge to the aquifer is increased. Natural discharge from the aquifer of the Boles well-field area occurs many miles away and will not be affected by pumping from the Boles well field for years to come. In the area of recharge to the aquifer of the Boles well field, the water table is far below the surface, and when recharge occurs there is sufficient storage space available in the bolson fill to store all the water that the surface alluvium is capable of transmitting downward. Lowering of the water level in the area of intake to the aquifer thus will not induce additional recharge to the aquifer. Therefore, water pumped from the Boles well field comes from an aquifer which for all practical purposes has fixed rates of recharge and discharge, and any water removed from the aquifer must come from storage.

It is apparent, then, that the useful life of the well field is based primarily upon the amount of potable water that may be removed from storage without inducing the rapid migration of undesirable saline waters from the west. The total amount of potable water in storage can be estimated, but this total is not significant in itself, because not all the potable water can be recovered before adulteration occurs.

In the Boles area, potable water is known to occur at depths of almost 400 feet. Water containing 300 ppm or less of sulfate occurs under an area of approximately 8 square miles or about 5,000 acres (plate 2). The weighted mean depth to water is about 100 feet, indicating a saturated thickness of about 300 feet.

The specific yield of an aquifer is the amount of water the aquifer will yield, expressed as a percentage of the volume of the saturated aquifer. The specific yield differs substantially in value from the storage coefficient of the aquifer when determined from short periods of pumping. The storage coefficient approaches the specific yield as time increases, and, in fact, ultimately would exceed it slightly. The specific yield in the Boles well field is estimated to be about $8\frac{1}{2}$ percent, based on the decline in well 33 from April 1952 to February 1954, and on the pumpage from the well field during that period (see Summary of Hydrologic Characteristics of the Bolson Fill). The specific yield in the well-field area indicates that the saturated bolson fill contains about 130,000 acre-feet (about 42,000 million gallons) of potable water. However, not all this water can be feasibly extracted, in part because of problems of encroachment of mineralized water and because of physical problems of extraction of water as water levels are lowered. Consideration of these questions is covered in a succeeding section of the report.

HISTORY OF GROUND-WATER DEVELOPMENT IN THE AREA

Before Holloman Air Force Base began to use ground water from the Boles well field, ground water in the bolson fill in the vicinity of Alamogordo and the airbase was used only for domestic and stock supplies, and for scattered small-scale irrigation, some dating back to the turn of the century. Following World War II, an expansion of irrigation by wells began in the area principally north of Alamogordo. Expansion of development in the vicinity of the town has been slow but steady. The irrigation wells have yields ranging from less than 100 gpm to nearly 500 gpm. Most of the water pumped for irrigation is too highly mineralized to be used for domestic purposes. The irrigated farms of significant size nearest the Boles well field are 2½ to 3 miles to the north. In addition to the irrigation wells, a few large-capacity wells are used for industrial purposes and for supplementary municipal supplies. Most of these wells are in or near Alamogordo.

Development of the Boles Well Field

Holloman Air Force Base obtained all of its water supply from the Town of Alamogordo during the operation of the base as an Army Air Field during World War II and to the summer of 1947. In 1947, Mr. L. C. Boles drilled a proposed irrigation well on his property, part of the present well field, and found that the water was potable. Subsequently, the Air Force leased the property and much of the surrounding property in secs. 24 and 25, T. 17 S., R. 9 E., and secs. 18 and 19, T. 17 S., R. 10 E. (fig. 6). During the 8-year period 1947 to 1955 at least 35 wells and test holes were drilled in the well-field area. Of the 35 wells and test holes, only 14 wells have been used or equipped at one time or another to produce water. In 1955 there were 12 wells equipped for use, but only 10 wells were used to any extent. Wells 14 and 32 were not used because of the mineralization, and sand content of the water, respectively.

Although drilling in the well field generally continued from year to year, table 1 shows that the years of maximum activity were 1948, after the well field was first established; 1950, a period of general water shortage; and 1953, the beginning of the present period of large demands.

When it became generally known that the potable-water body in the Boles area was rather extensive, the town of Alamogordo began to develop ground water in the area on a small scale. In 1953 two test holes were drilled west of the Boles well field, and subsequently, in 1954 two production wells were drilled on leased property in sec. 35, T. 17 S., R. 9 E., southwest of the Boles well field.

Water Use at the Base

Water requirements at the base were essentially stable during World War II. The amount of water used (table 5) ranged from 0.4 to 0.5 mgd.

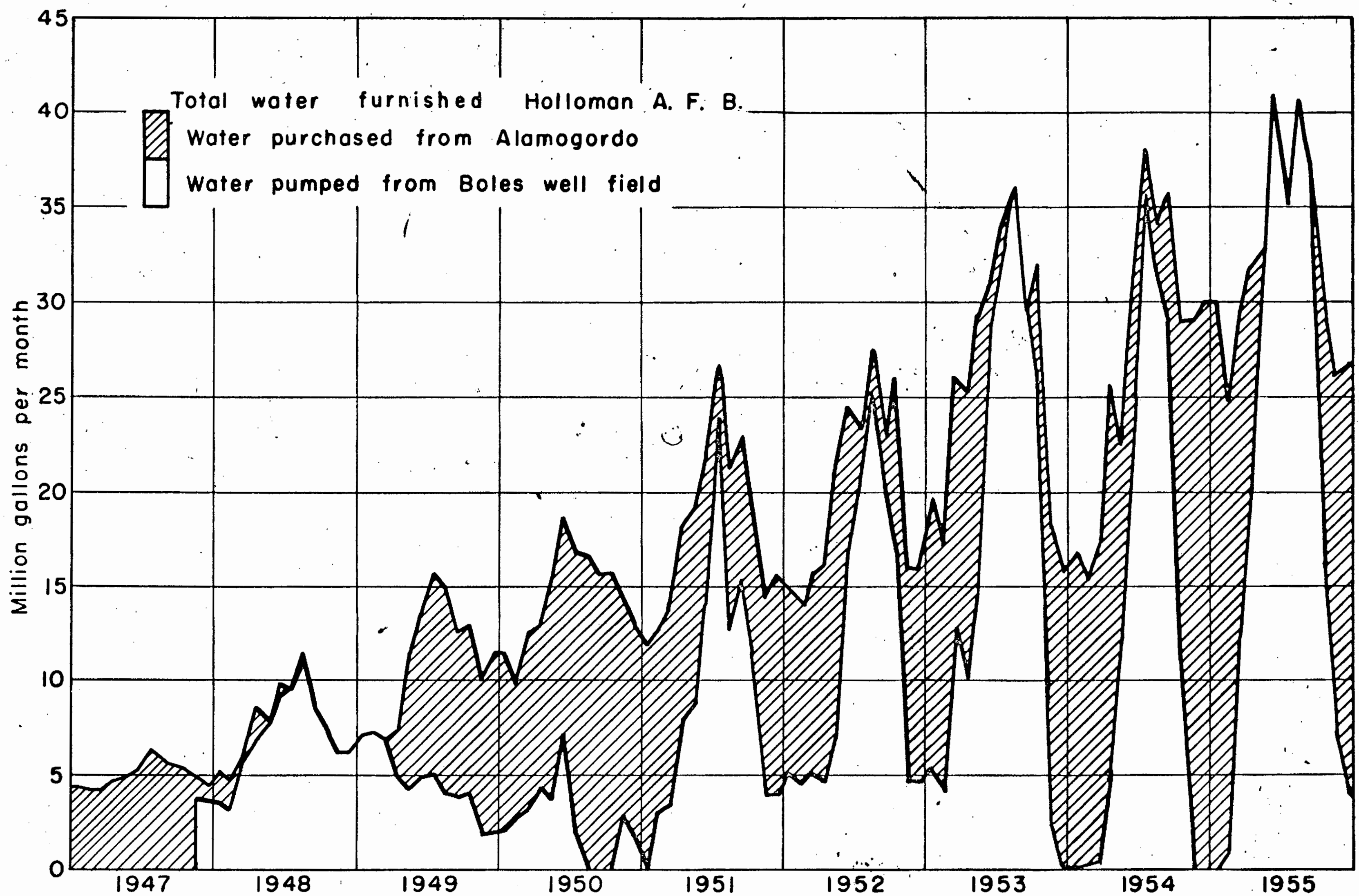


Figure 7. — — Monthly water consumption at Holloman Air Force Base, Otero County, N. Mex.

After the war, as activities at the base were curtailed, the use of water dwindled to about 0.1 mgd. When the base was reactivated as a research establishment, the demand for water began to increase again, reaching the wartime level in about 1950. Although the trend of water use has been generally a uniform increase, in 1953 there was an abrupt increase of nearly 0.2 mgd in the average daily demand. Water consumption at Holloman Air Force Base for the period 1943 through 1955 is shown in table 5 and for the period 1947 through 1955 is graphically illustrated in figure 7.

The continued increase in use of water at Holloman Air Force Base reflects the increase of the population of the base and the enlargement of the physical plant. The research facilities, on-base housing facilities, and landscaping have been expanded more or less continually. The abrupt increase of overall water use in 1953 probably is the result of opening the second group of Wherry Housing units for occupation during that year. The continued increase in research and landscaping has resulted in a rising average use of water per capita. The use of water per capita fluctuates seasonally and is related in part to the seasonal or monthly temperature. Generally, during cold weather individual consumption of water is reduced, and no water is used for air conditioning. During the colder weather, the amount of irrigation of lawns and trees is small. As the temperature rises, these uses of water increase rapidly. Figure 8 shows the average monthly temperature at Alamogordo, the use of water per capita at Holloman Air Force Base, and a partial record of the average population at the base for the period 1950 through 1955. The relation of temperature and per capita use is apparent.

The relation of average daily water use per capita to average monthly temperatures is shown by figure 9. The points for 8 months of record in 1950 and for 12 months in 1951 show relatively good relation, and the straight line shows the general relationship. Points plotted for 1952 and 1954 are too scattered to show a general relation. In 1953, however, the 7 months of available record show a general trend of increasing unit use of water which departs from the 1950 to 1951 conditions. Points plotted for 1955, though scattered, substantiate the trend indicated by the 1953 data. The scatter of points plotted for 1952, 1954, and 1955 is believed to be the result of using large amounts of water temporarily for construction purposes. Figure 9 shows that in general the amount of water used during cold weather has increased in the later years which reflects the increased basic or "industrial" use of water at the base. Moreover, the line for 1953 has a lower slope indicating that the per capita use of water per degree temperature was greater than in 1950-1951. This reflects the increase in use of water for irrigating lawns and other vegetation and for air conditioning.

Pumpage in the Boles Well Field

Prior to 1947, when the Air Base was obtaining all its water from the Town of Alamogordo, the water requirements for both the base and the town were relatively low, and the water supply for the town was relatively large.

Table 5.--Annual amounts of water supplied to Holloman Air Force Base, N. Mex., 1943 through 1955 1/ (1,000 gallons)

Year	Purchased from Alamogordo	Pumped from Boles well field		Total supply	
		Annual total	Daily average	Annual total	Daily average
1943 2/	162,237	-	-	162,237	444
1944	169,100	-	-	169,100	462
1945	156,991	-	-	156,991	430
1946	42,966	-	-	42,966	118
1947 3/	59,866	3,760	10	63,626	174
1948	5,630	86,049	235	91,679	250
1949	75,071	56,090	154	131,161	359
1950	143,097	29,455	81	172,552	472
1951	110,155	108,275	297	218,430	598
1952	101,309	135,606	371	236,915	647
1953	111,957	201,426	552	313,383	859
1954	173,175	149,464	409	322,839	884
1955	137,742	247,963	679	385,705	1,057
Total	1,449,296	1,018,088	-	2,467,584	-

1/ Data from records in Air Installations Office, Holloman Air Force Base

2/ Missing part of record estimated

3/ Month of September estimated

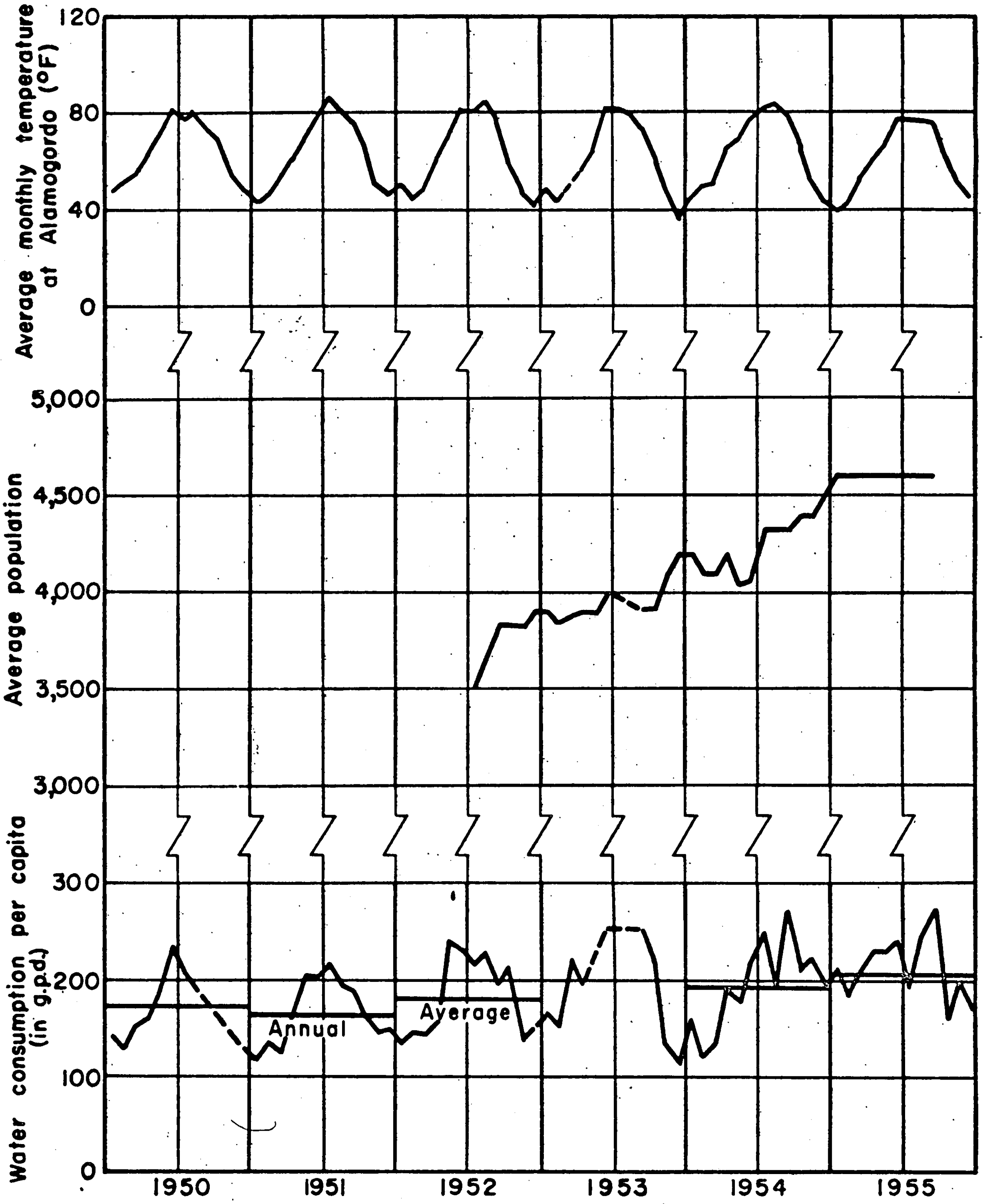


Figure 8.--Average monthly temperature at Alamogordo, average population and monthly water consumption per capita at Holloman Air Force Base, Otero County, N. Mex.

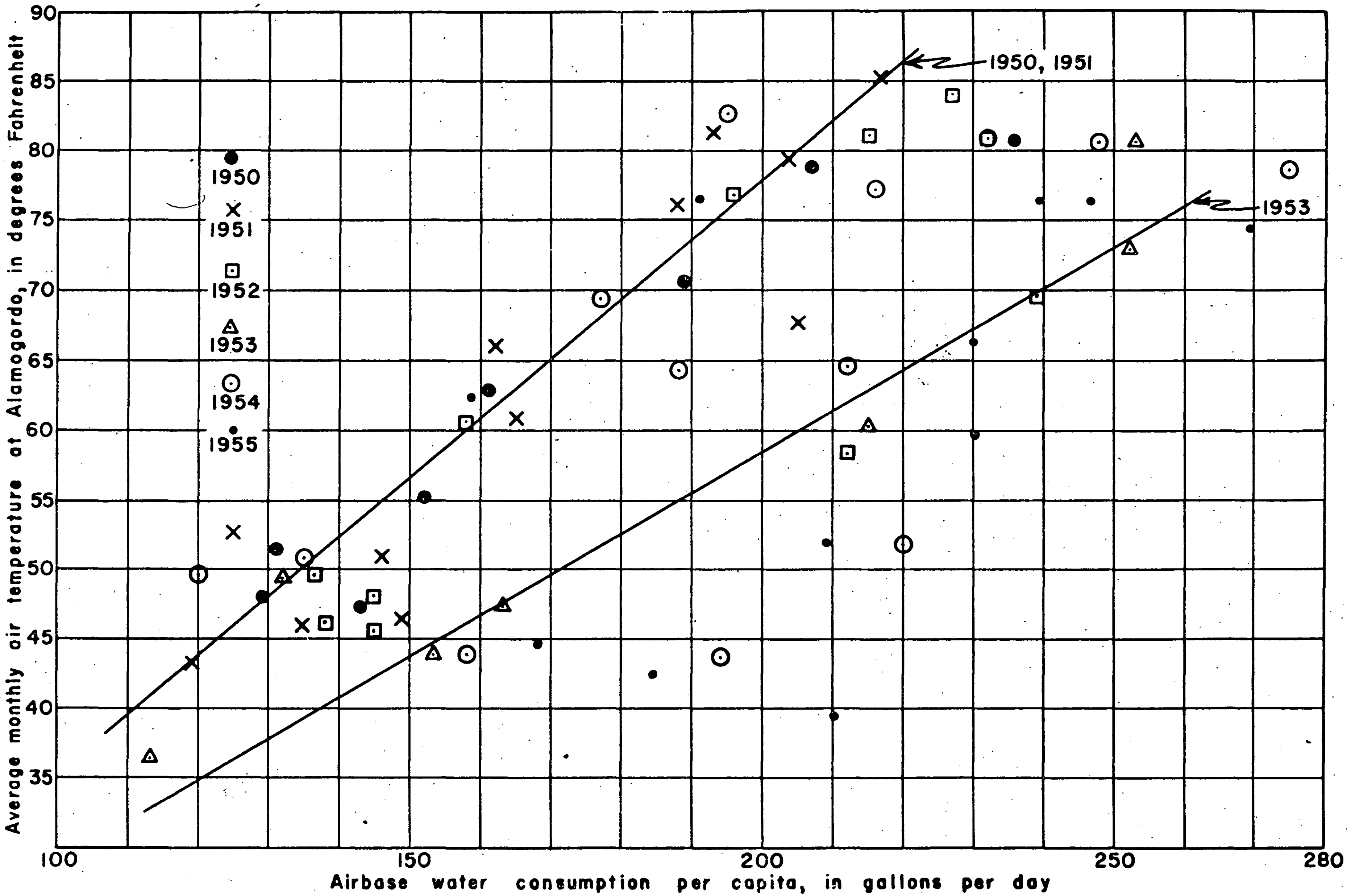


Figure 9.-- Relation of water consumption per capita to air temperature, Holloman Air Force Base, Otero County, N. Mex.

However, the decreasing annual precipitation in the area resulted in declining discharge from the springs which supplied water to the town, and by 1945 the supplies were generally deficient. The necessity of a solution to the water shortage was delayed when water requirements at the base were reduced following the end of World War II. However, the shortage became a problem again as the base began to expand in 1947. When first developed, the Boles well field was initially pumped at very high rates, relative to the number of producing wells then in existence. Since development of the Boles well field the population of both the town and the base have increased more or less continuously. As the town grew, its sources of water were increased. Pumpage at the Boles well field has fluctuated from year to year in response to the amount of water supplied to the base by Alamogordo. However, the water requirements of the town increased to such an extent that the town eventually could supply appreciable quantities of water only during the winter months, as illustrated in figure 7. Thus the well field has become the principal source, rather than a supplementary source, of water for the base.

During the period 1947 to 1950, more than 146 million gallons of ground water was pumped from Boles wells 1, 2, 5, and 10. Of the 4 wells, well 1 was abandoned during the period. In 1950, wells 13, 14, and 15 were added to the system, and the 6 wells produced nearly 138 million gallons during the 2-year period 1950 to 1952. In 1952 wells 16 and 17 were added to the well-field system, and well 13 was abandoned. The group of 7 or 8 wells produced about 337 million gallons of water during the period 1952 to 1954. With the addition of well 26 in 1954, the group of 8 remaining production wells yielded about 150 million gallons of ground water in 1954 alone. Wells 33, 34, and 35 were used in 1955, and during that year the well field produced nearly 248 million gallons of water. Table 5 shows the yearly well-field production. The total withdrawal of ground water from the well field through 1955 has amounted to about 1,018 million gallons, about 3,100 acre-feet, in less than 9 years. Of the total withdrawal, approximately 600 million gallons or about 60 percent was pumped during the last 3 years of the period.

GROUND-WATER LEVELS AND THEIR SIGNIFICANCE

The depth to water was measured in many wells in the vicinity of Holloman Air Force Base, during the course of this investigation. In the immediate vicinity of Boles well field, the depth to water was determined in all wells that could be measured. In most wells measurements were made with a steel tape from fixed measuring points. In a few wells measurements could not be made, and the depth to water was recorded as reported by the owner or driller. Measurements of water levels were reduced to depths below a datum approximating the general land surface at each well. In the Boles well field the altitudes of the measuring point and land-surface datum were determined by instrumental leveling for each of the Boles wells and older test holes and for each of the test holes drilled in 1954. The altitude of the land surface at wells near the Boles well field was determined by aneroid barometer. Elsewhere, the altitude of the land surface was estimated from topographic maps of the area. Measurements of the depths to water in several wells in the vicinity of Alamogordo have been made at bimonthly or greater intervals since 1952. Selected wells in the Boles well field have been measured at bimonthly or lesser intervals since the beginning of the investigation in 1954. Automatic water-level recorders were maintained on several wells in the Boles well field for periods of several months. The depths to water in wells in the Holloman area are given in tables 14, 15, 16, and 18, and fluctuations of water levels in several of the Boles wells are shown graphically in figures 10, 11, and 12.

The water-level data were used to prepare the water-table contour maps, plate 1 and figure 6, which show by means of contours the altitude of the water table in January 1955 in the entire area investigated and the Boles well-field area, respectively. The data provided in these maps are important to an understanding of the occurrence of ground water in the area. They provide information on the general direction to the intake area of the ground-water reservoir, the direction of ground-water movement, the probable areas of ground-water discharge, the effects of pumping on the reservoir, and the relative differences in permeability of the bolson fill in different areas. When studied in conjunction with data on the quality of the ground water, the maps show the area of recharge to the potable-water body in the Boles area and the possible direction of saline-water encroachment into the potable-water body.

Water Levels in January 1955

The contour maps of the water table are based on measurements of the depths to water in most of the wells which could be measured in January 1955. Some of the measurements in wells distant from the area of intensive study were made at different times during the investigation, or were reported by the well owner or driller. The fluctuation of the water levels in these wells over a period of months or even years is small, and so the measurements could be used in constructing the maps. The water-level measurements in the area were made in the winter season when few if any wells had been pumped during a period of several weeks or months.

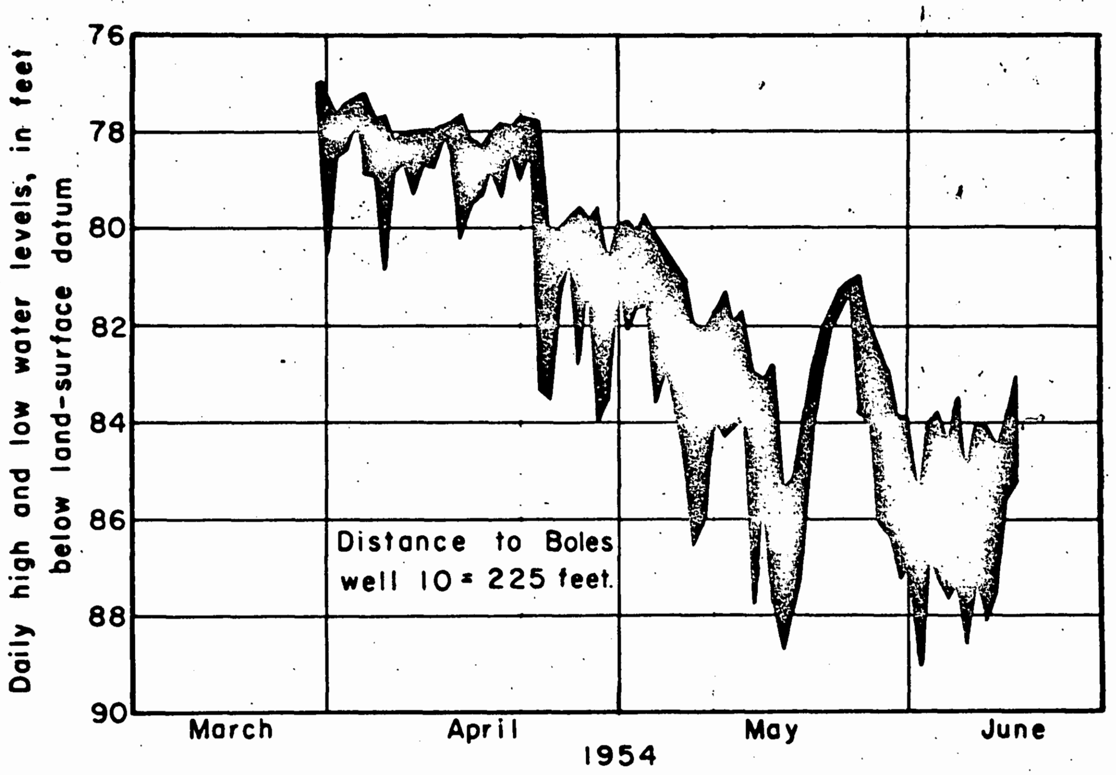


Figure 10 —-Daily high and low water levels in unused well 25, Boles well field, Otero County, N. Mex.

The areal water-table map (plate 1) shows that the water table slopes westward from the Sacramento Mountains. One to two miles west of the mountains the slope changes to a southwestward direction and continues in that direction beyond the area of the map. The steep slope of the water table near the mountains indicates that the fill in that area is thin or has a relatively low permeability, or both. However, the relatively gentle slopes of the water table in the western part of the map area do not indicate greater permeability. Most of the fill there has a low permeability, and the small slope is the reflection of an increase in thickness of the aquifer which outweighs the reduction in permeability.

The pronounced west-trending trough in the southern part of the map area represents a natural condition which does not exist to the north, in the vicinity of Alamogordo. The trough as represented by the contours may be related to the occurrence of deep water levels east of Orogrande, N. Mex., which were noted by Meinzer (1915, p. 104); however, the trough may not be as pronounced as shown because the water level in well 19.10.17.231, the principal well making the trough as sharp as shown, is reported.

The detailed water-table contour map of the Boles area (figure 6) shows that in the immediate area of the Boles wells, the water table slopes southwestward at rates ranging from 20 to 80 feet per mile. In the southern part of section 18 and the northern part of section 19, shown on the map, there is a south-trending trough in the water table. This trough is the result of pumping ground water from storage in the older part of the well field during the 7 years of well-field operation prior to January 1955. A second, incipient trough is shown in the southeast corner of sec. 24. This trough is the result of pumping of wells 16 and 17, because wells 33, 34, and 35 were not in operation in January 1955. The small nose between the two troughs is believed to be related to a hydraulic boundary, a zone of low permeability, which was detected by means of aquifer tests made in 1955.

Water-Level Fluctuations

In most ground-water reservoirs the water available to wells is a transient resource, because the water is in constant though slow movement in the aquifer from the area of recharge to the area of discharge. The amount of ground-water storage in a reservoir from which there is only natural discharge is essentially constant, over a long period of time because the amount of water discharged is equal to the amount of recharge. In such a ground-water reservoir the water table is in a state of dynamic equilibrium. The position of the water table is governed by the mutual relationship of recharge and discharge and the shape and permeability of the aquifer. The water table, however, is nearly always rising or falling though the amount of change may be minute. An excess of recharge over discharge will cause a water-table rise and a deficiency will cause a decline. Similarly, increased discharge causes a decline and decreased discharge will cause a rise.

Fluctuations of the water level that are due to natural changes in storage are largely seasonal, annual, or long-term effects. Changes in barometric pressure, and diurnal earth tides, cause minor daily fluctuations of water level which are noticeable in artesian reservoirs but do not represent changes in storage. During the analyses of pumping tests performed in the Boles area in 1955 it was found that changes in barometric pressure caused water-level fluctuations of a few hundredths of a foot in some of the wells. The diurnal fluctuations caused by earth tides amounted only to a few hundredths of a foot.

If a well is drilled into the reservoir and is pumped, a new discharge is introduced into a system that was previously in equilibrium. Such withdrawals must result in increased rates of recharge, reduced rates of natural discharge, a reduction in ground-water storage, or a combination of these. As discussed previously, pumping in the Boles well field does not increase recharge to the aquifer and does not reduce natural discharge from the aquifer. Therefore, the water must be extracted from storage with a consequent continuing lowering of water levels.

In 1952 the Geological Survey in cooperation with the State Engineer of New Mexico made a ground-water reconnaissance of the area in the vicinity of Tularosa and Alamogordo, and a number of water wells were selected as observation wells. Some of the wells are in the area described in this report. These wells have been measured at bimonthly or greater intervals since 1952; the measurements are given in table 14. In addition to these observation wells, the depths to water in many of the wells in the area were measured several times during the period March 1954 to February 1956. Most of these measurements are given in tables 16 and 18. The measurements show that the water table has been essentially stable in most of the western part of the area shown in plate 1. This area is some distance from areas of ground-water pumping. In the vicinity of Alamogordo, where a number of large-capacity irrigation and industrial wells are pumped, the water level is generally declining slowly at rates of less than a foot to 1 or 2 feet per year as a result of the pumping. The annual declines are small, principally because the large-capacity wells are not closely spaced, but are taking place over a relatively wide area.

Water-Level Fluctuations in the Boles Area

Records of water level from the Boles well field prior to March 1954 are fragmentary, and most levels are reported. The earliest accurate measurements made by the Geological Survey were at wells 10 and 33 in April 1952. After ground-water studies were started in the area, five wells were used as observation wells during part or all of the investigation, and four of the wells have been measured at bimonthly or lesser intervals since 1954. Water-level measurements have been made at least annually in all the Boles production and unused wells and in a number of wells adjacent to the well field. Depths to water were measured in all the test holes drilled in 1954. A steel tape was used for accurate measurements in all the existing wells and test holes.

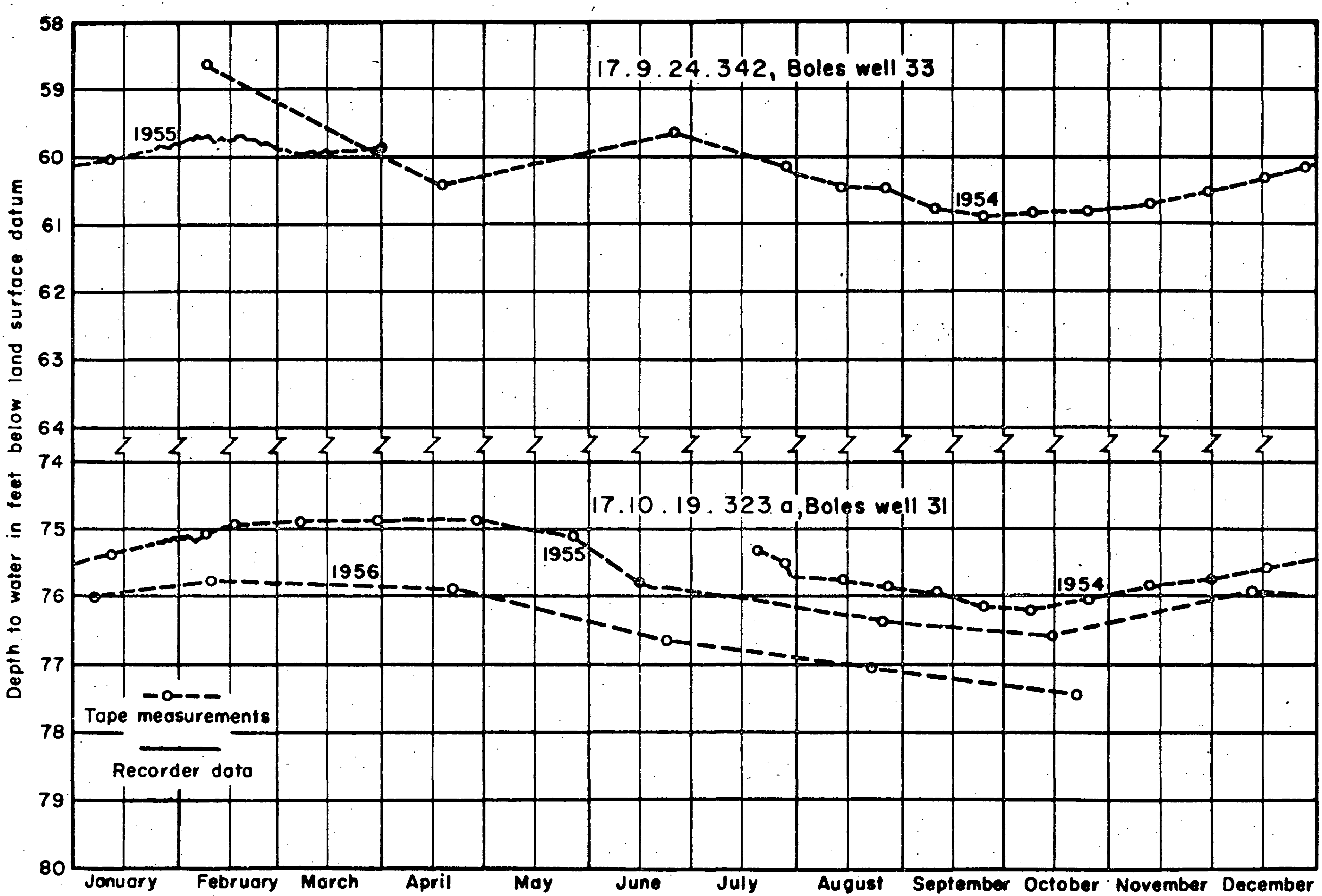


Figure 11.—— Changes in water levels in observation wells near edge of Boles well field, Otero County, N. Mex.

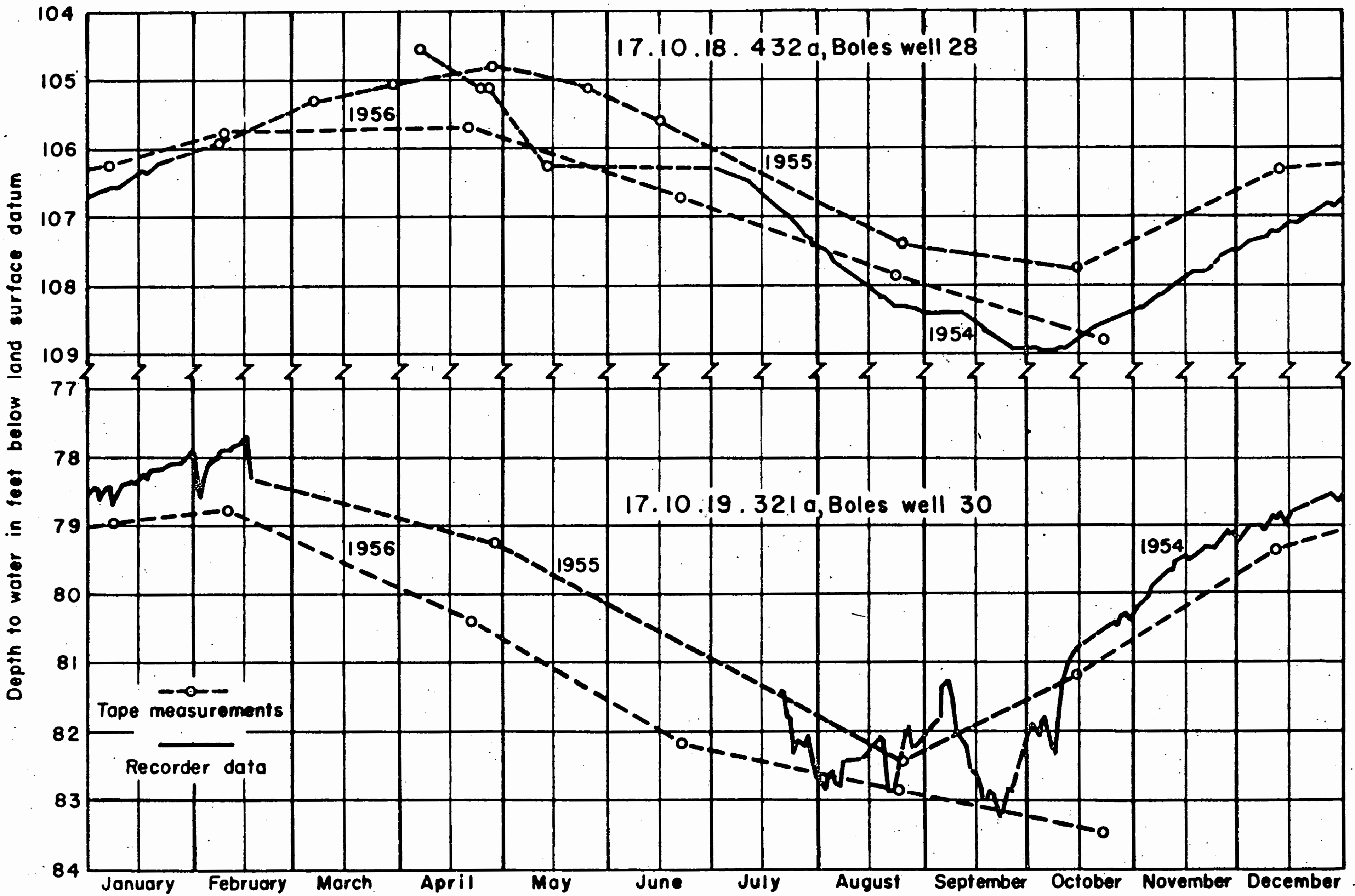


Figure 12--Changes in water levels in observation wells near center of Boles well field, Otero County, N. Mex.

Observation wells

Water-level measurements for the five wells used as observation wells are plotted as hydrographs shown in figures 10, 11, and 12. Figure 10 shows fluctuations in well 17.10.19.112a (Boles well 25) for the period March to June 1954, as taken from automatic recorder charts. This period spans the time when summertime pumping began in the well field. The hydrograph shows that the daily fluctuation of the water level in the well is as much as 5 feet. The daily fluctuations are superimposed on a general decline of water levels, which continued from March into June. The well is in the old part of the Boles well field, where artesian conditions generally exist. Nearly all the daily fluctuations are the result of pumping Boles well 10 which is 225 feet to the east; however, the general decline of the water level is apparently the net effect of pumping all the wells in the field.

The four hydrographs shown in figures 11 and 12 are the combined results of both individual tape measurements and automatic recorder operation during parts of 1954, 1955, and 1956 on wells 17.9.24.342 (Boles well 33), 17.10.18.432a (Boles well 28), 17.10.19.321a (Boles well 30), and 17.10.19.323a (Boles well 31). All of these wells are shown on the map of the well field (figure 6) and are at different locations with respect to direction and distance from production wells. All of the hydrographs show that each year the water levels in the well field recover from the lowest levels of the previous season to the highest annual levels during the period from February to April, which is immediately before the beginning of the heavy summertime pumpage. The water levels then decline again through the summer pumping season to the lowest seasonal levels at the beginning of October, at which time pumping is reduced. The long-term trend in water levels is one of continuous decline from year to year and is indicated by successively lower annual high water levels. For an example, see the hydrograph of well 17.10.18.432a in figure 12. The hydrograph shows that the annual high water level was 104.6 feet below land surface in 1954, 104.8 feet in 1955, and 105.7 feet in 1956. Records from each of the other three wells, shown in figures 11 and 12, indicate the same downward trend, although the water-level records for these wells represent a shorter period of time. It should be noted that the hydrographs show that the water levels in well 17.10.18.432a were higher in the summer and fall of 1955 than for the same period in 1954. The higher water levels in 1955 in this well may be the result of reduced pumping in the eastern part of the well field or of recharge. Precipitation in 1955 was about normal and recharge may have been greater than in the preceding years of drought; however, it would be very difficult, if not impossible, to distinguish effects of recharge from those of reduced pumping.

The year-to-year decline of water levels is indicated also by the 4-year record of water-level measurements in well 17.9.24.342 (table 14). Declines of the water level in the well amounted to about a foot per year until 1955 when Boles wells 34 and 35 were put into operation. Additional withdrawals during 1955 in the vicinity of well 17.9.24.342 (Boles well 33) caused a decline of about 4 feet in that area.

Production wells

All of the Boles production wells were measured several times during the investigation, and most of the measurements are given in table 16. In all cases, the year-to-year measurements in the early spring show the prevalent trend of declines. Measurements in January 1956 show that the largest decline in 1955 in the well field was 6.8 feet at Boles well 17, where only small declines occurred from year to year previously. The larger declines are attributed to heavier pumping in that part of the well field as a result of the completion of Boles wells 34 and 35 and the acquisition of Boles well 33. In addition to the Boles production wells, several wells on adjoining properties have been measured annually, and the measurements show that the declines resulting from pumping in the well field extend to 2 miles or more from the well field, although the magnitude of the effects of pumping diminish markedly with distance from the wells.

Original water levels and subsequent declines in the Boles well field

Records of water levels prior to pumping in the Boles area are either very old or reported. There are few records of accurate measurements prior to March 1954. However, the original depths to water and the amount of subsequent declines can be estimated on the basis of several sources of data. Meinzer and Hare (1915) published water-level measurements made during the period 1911 to 1912 for several wells in the area. Most of these wells no longer exist, but the locations are known, and the water levels can be compared either to existing wells at the same locations or to the water-table contour map in figure 6. The records of depths to water given by Meinzer and Hare can be used in a general comparison, because it can be assumed that the water table under natural conditions did not change appreciably from 1912 to 1947. The record of water levels in Boles well 33 is of sufficient length that it can be extrapolated backward in time to 1947 and thus provide a basis for general comparison at that point. The water table at some distance from the well field should be relatively undisturbed by pumping in the well field. A general comparison of water levels can be made by extrapolating the contours on the undisturbed water table into the well field. Comparisons of water levels can be made for shorter periods of time in many of the Boles wells by using either measurements reported from the time of well completion or measurements made by the Geological Survey in two wells since 1952.

Comparison of the various data shows that the maximum water-level decline from 1947 to 1955 is in the center of the older part of the well field in sec. 19 and is on the order of 20 feet. The amount of decline at other specific points is less and generally diminishes away from the well field. From 1911 to 1955, the water level apparently declined about 12 feet at location 17.9.24.222 (test hole 9). Extrapolation of the record from well 17.9.24.342 (Boles well 33) indicates that the depth to water was about 52 feet below land surface in 1947 and that by 1955 the water level had declined about 8 feet at that point. Records from Meinzer and Hare show that the depth to water was 42 feet at location 17.9.25.111. The net change from 1911 to 1955 was about 5 feet at that location. The earliest recorded water level in a Boles production well is that reported for well 17.10.19.121a (Boles well 1). When the well was completed in 1947, the water level was about 65 feet below land surface; in January 1955 the depth to water was about 80 feet in well 10, at the same location, which indicates a net decline of about 15 feet at the location. Meinzer and Hare state that in 1911 the depth to water was 55 feet at location 17.10.19.311. Interpolation from figure 6 shows that the altitude of the water table at the location is about 4,067 feet. The altitude of the land surface is about 4,130 feet, indicating a depth to water of about 63 feet in January 1955. The indicated decline from 1911 to 1955 is 8 feet and it may be inferred that the decline of water level at the location from 1947 to 1955 was between 5 and 8 feet.

In summary, a knowledge of the water levels in the Holloman area is important because it aids in determining the areas of recharge and discharge, and the direction of movement. Fluctuations of water levels also indicate changes in storage due to changes in rates of recharge and of natural and artificial discharge. The depths to water in nearly all of the wells in the Holloman area were measured during the investigation. Eight wells in the general area, including five in the Boles field, were measured at bimonthly or lesser intervals. The results of the measurements show that the water table is essentially stable in the western part of the Holloman area where there are no large-capacity wells. In the vicinity of Alamogordo and the Boles well field there are seasonal fluctuations due to the effects of pumping during the summer. In the vicinity of Alamogordo, the pumping of widely spaced irrigation and industrial wells is causing continuing declines of about 1 foot per year.

In the Boles well field, seasonal water-level fluctuations may amount to 10 feet or more near the center of the well field. Water levels in the well field are declining from year to year. The rate of decline has accelerated as annual pumpage has increased. The water-level declines at single wells have ranged from less than 1 foot per year to 6.8 feet. Although the amounts of decline for the 7-year period 1947 to 1955 are not precisely known, on the basis of the foregoing data it appears that the decline in water level beneath the Boles well field has ranged from about 20 feet in the older part of the well field to about 5 feet or less at the edges of the 4-square-mile well-field area. Smaller declines doubtless extend over a larger area. This general and continuing decline is the result of withdrawal by pumping of about 2,300 acre-feet of water during the 7-year period.

CHEMICAL QUALITY

All natural waters contain varying amounts of mineral matter that have been dissolved from the material through which the waters have moved. Chemical analyses not only indicate whether the water is chemically suitable for various uses but may also provide valuable information regarding the source, movement, and discharge of the water, character of the containing rocks, and effects of development.

The mineral matter in solution in water is referred to as dissolved solids. The most important such solids in most waters are the cations calcium, magnesium, and sodium and the anions bicarbonate, sulfate, and chloride. In a chemical analysis the concentration of each important dissolved constituent may be expressed in parts per million, equivalents per million, or tons per acre-foot.

In an analysis in which the concentration of dissolved solids is given in parts per million (ppm), 1 ppm equals 1 part, by weight, of the constituent per 1 million parts, by weight, of the water. The unit "equivalent per million" (epm) is defined as 1 equivalent weight of an element, ion, or a salt in 1 million weights of solution. The equivalent or combining weight in grams is the weight of an element or compound that will react with 8 grams of oxygen or its equivalent. In other words, the equivalent weight of a constituent is its molecular weight divided by its valence. In any solution the sum of the anions must equal the sum of the cations in terms of equivalents.

To change an analysis reported in ppm to epm, the concentration in ppm of each constituent is divided by its equivalent weight. To change an analysis reported in epm to ppm, the concentration in epm of each constituent is multiplied by its equivalent weight.

Analyses of water for irrigation are sometimes reported in tons per acre-foot. Such analyses indicate the amount, by weight in tons, of dissolved salts in 1 acre-foot (about 326,000 gallons) of water.

Principal Mineral Constituents of Water

A standard chemical analysis of water generally gives the following constituents or characteristics of the water.

Silica (SiO_2)

Silica, which is considered to be un-ionized and thus is not reckoned in the balance between cations and anions, is dissolved from practically all rocks and usually is present in both surface and ground waters in concentrations below 60 ppm. It is essentially inert as far as soils and plants are concerned but contributes to the formation of boiler scale.

Iron (Fe)

Iron is a common constituent of many ground waters as it is dissolved from many rocks and soils. Small quantities, more than a few tenths of a parts per million, may cause yellow stains on utensils, fixtures, and clothing but usually can be removed from the water by simple treatment, or prevented from precipitating by adding stabilizing compounds to the water.

Calcium (Ca) and Magnesium (Mg)

Calcium is dissolved from practically all rocks and magnesium from many rocks. Hence, both are usually present in ground waters. They cause practically all hardness of ordinary waters and are largely responsible for the formation of boiler scale.

Sodium (Na) and Potassium (K)

Sodium and potassium also are dissolved from practically all rocks. As the total quantity of the two constituents increases, the proportion of sodium to potassium generally becomes greater, and the sodium is often the predominant cation in highly mineralized waters of the western United States. Concentrations of less than 50 ppm of sodium and potassium generally do not affect the usefulness of water for most purposes. Waters that contain a large proportion of sodium salts (see "percent sodium") may be unsatisfactory for irrigation.

Bicarbonate (HCO_3) and Carbonate (CO_3)

The presence of carbon dioxide in water enables it to dissolve carbonates of calcium and magnesium, producing bicarbonates. Bicarbonates of those two metals are responsible for so-called "temporary" hardness, which is eliminated by boiling. Carbonate is not present in appreciable quantities in most waters; bicarbonate is present in almost all waters.

Sulfate (SO_4)

Sulfate is dissolved in large quantities from deposits of gypsum and sodium sulfate. It is formed also by the oxidation of sulfides and, therefore, is sometimes present in considerable quantities in mine waters. According to the standards of the U. S. Public Health Service (1946), sulfate should not exceed 250 ppm in waters used on interstate carriers. Sulfate in waters that contain much calcium or magnesium contributes to so-called permanent hardness, which cannot be eliminated by boiling.

Chloride (Cl)

Chloride is dissolved in small quantities from many rocks and may be present in large quantities in waters that have moved through sediments of marine origin. Waters containing more than 250 or 300 ppm of chloride tend to have a salty taste and generally are considered undesirable for domentic use.

Chloride, like sulfate, contributes to "permanent" hardness of waters that contain large amounts of calcium or magnesium.

Fluoride (F)

Fluoride occurs naturally in small quantities in many ground waters. Although fluoride much in excess of approximately 1.5 ppm may cause staining or mottling of the enamel of children's teeth, several recent studies have indicated that smaller concentrations of fluoride in drinking water tend to inhibit tooth decay (U. S. Public Health Service, 1946).

Nitrate (NO_3)

High nitrate concentrations in water usually indicate contamination by sewage, other organic matter, or fertilizer, although there are instances of natural origin by solution of nitrate-bearing rocks. Studies indicate that waters containing more than a certain amount of nitrate may contribute to cyanosis of infants ("blue babies"), and such waters should not be used for mixing baby formulas. The amount considered dangerous for that purpose has not been firmly established, however, water containing less than 10 ppm of nitrate is generally considered safe (California Institute of Technology, 1942, p. 301).

Dissolved Solids

The residue left after a filtered sample of water has been evaporated and dried at 180°C is weighed and reported as dissolved solids, in ppm or tons per acre-foot. The dissolved solids may be expressed also as the arithmetical sum of the determined constituents, the bicarbonate being computed as carbonate because bicarbonate decomposes to carbonate and carbonic acid upon evaporation. According to standards adopted by the U. S. Public Health Service, drinking water for use on interstate carriers should contain not more than 1,000 ppm and preferably not more than 500 ppm of dissolved solids. Water containing several thousand ppm of dissolved solids is used for irrigation and for watering stock in some areas.

Hardness as $CaCO_3$

Hardness of water is easily recognized by the difficulty with which a lather is produced with ordinary soap and by the precipitate or scale that forms in vessels in which the water is heated or evaporated.

Hardness is caused principally by compounds of calcium and magnesium and is expressed as the calcium carbonate equivalent of all the hardness-forming cations except sodium and potassium. Carbonate hardness, caused by calcium and magnesium bicarbonate, can be almost entirely eliminated by boiling and is often called "temporary" hardness. Noncarbonate hardness, caused mainly by sulfates and chlorides of calcium and magnesium, cannot be eliminated by boiling and is often called "permanent" hardness. Both types of hardness produce the same effect with respect to use of soap in water. Hardness can be reduced by zeolite softening and other processes for domestic or industrial use. Hard water is preferable to soft water for irrigation.

Water having a total hardness of less than 60 ppm is considered soft; water having a hardness of 60 to 120 ppm is considered moderately hard and is suitable for most uses except in high-pressure steam boilers and some industrial uses; water having a hardness of more than 200 ppm usually requires treatment to be satisfactory for most uses.

Specific Conductance

The specific conductance of water is a measure of its ability to conduct an electric current measured under definite conditions. It varies with the concentration and degree of ionization of the different minerals in solution. The specific conductance is useful in estimating the total concentration of dissolved solids in a water when only the specific conductance is known. However, the conductance determination does not indicate the chemical nature of the dissolved solids. Generally for water in the Boles well field, the specific conductance of water in micromhos at 25°C. multiplied by 0.65 is approximately equal to the dissolved solids in ppm. Elsewhere in the area the dissolved solids range from approximately 0.5 of the specific conductance where the principal anion is bicarbonate to 0.8 of the specific conductance where the water is very saline and chloride is present in large quantities.

Percent Sodium

The percentage of soluble sodium in a water, or percent sodium as it is commonly known, is determined by dividing the quantity of sodium, expressed in equivalents per million times 100, by the sum of the quantities of calcium, magnesium, sodium, and potassium in the water, also expressed in equivalents per million as follows:

$$100 \cdot \frac{Na}{Ca+Mg+K+Na} \quad \text{all in epm}$$

The percent sodium is particularly important in classifying water for irrigation. A percent sodium of less than 60 in irrigation water usually will not cause a deterioration of soil structure. Waters having a higher percent sodium may so react with the soil that the soil becomes increasingly less permeable, particularly if other salts are present in large quantities and drainage is poor.

Sodium-Adsorption Ratio (SAR)

The sodium-adsorption ratio, or SAR, has been developed as a useful index for designating the sodium or alkali hazard of waters used for irrigation.

The sodium-adsorption ratio is the ratio of Na^+ to $\sqrt{\frac{Ca^{++} + Mg^{++}}{2}}$, where Na^+, Ca^{++}, and Mg^{++} represent the concentration in milliequivalents per liter of the respective ions. Water having a sodium-adsorption ratio of less than 10 can be used for irrigation on almost all soils with little chance of soil deterioration. Water having a sodium-adsorption ratio of 10 to 18 will present an appreciable sodium hazard in fine-textured soils having high cation-exchange capacity, especially under conditions of relatively little leaching by fresh water, unless gypsum is present in the soil. Such waters may be used on coarse-textured or organic soils of good permeability. Water having a sodium-adsorption ratio between 18 and 26 may produce harmful levels of exchangeable sodium in most soils and will require special soil management, except in gypsiferous soils. Water having a sodium-adsorption ratio greater than 26 generally is unsatisfactory for irrigation except at low and perhaps medium salinity. The addition of gypsum may make the use of these waters feasible. (U. S. Dept. Agr., Feb. 1954).

Hydrogen-Ion Concentration (pH)

The hydrogen-ion concentration, expressed as the pH, or negative logarithm of the hydrogen-ion concentration, of a water indicates its degree of acidity or alkalinity. A pH of 7.0 indicates a neutral water, whereas values lower than 7.0 denote increasing acidity, and values higher than 7.0 denote increasing alkalinity. The pH of a water indicates in a general way its corrosive activity toward metal surfaces, and should be known so that proper treatment, if necessary, may be made. Acid waters are very corrosive and often contain excessive amounts of other objectionable constituents, such as iron.

Source of Mineralization of Ground Water in the Vicinity of Holloman Air Force Base

There are two principal sources of the mineral content of ground water in the area. The first and less important source is spring flow. Springs issuing along the base of the Sacramento Mountain escarpment from south of Alamo Canyon south to San Andres Canyon contribute only a negligible quantity of water to the bolson fill. Recharge water from the springs is already about as mineralized as ground water occurring in the Boles well field.

The second source of mineralization is the bolson fill through which the ground water moves. The fill was originally derived from the section of Paleozoic rocks exposed in the Sacramento Mountain escarpment. The mineral content of the fill near the escarpment depends to a large extent upon the source beds from which it originated. In the large fans radiating from the mouths of Alamo and San Andres Canyons, the bolson fill contains a greater amount of gypsiferous debris than does that of the small fans at the mouths of canyons between the two larger fans. The rocks exposed in Alamo and San Andres Canyons include the Yeso formation, which contains large amounts of gypsum and smaller amounts of other evaporites, whereas the rocks exposed in the smaller canyons, such as Mule and Arrow Canyons, include only rocks of Pennsylvanian age or older, which contain limestone or dolomite as the most soluble constituent.

When the most important source of recharge, flood flow from thunderstorms, is discharged from the mountain canyons and is taken into the ground-water reservoir, the mineral content of the water is low. However, from the time water enters the recharge area to the time it is eventually discharged from the Tularosa Basin, the ground water acquires an increasingly greater concentration of dissolved mineral matter.

The type of dissolved minerals in the water and the mode of accumulation vary from place to place within the aquifer. In areas where large amounts of gypsum are available the ground water is predominantly a calcium sulfate water. Where limestone debris is the principal constituent of the fill, the water is usually of the calcium bicarbonate type. This difference in the Boles area is illustrated by plate 2. As shown in the plate, water entering the bolson fill in the section between Alamo and San Andres Canyons acquires relatively little sulfate and remains low in sulfate until it reaches a part of the aquifer where gypsiferous sediments occur in greater concentrations. The principal reason for the existence of potable water in the Boles area is that the permeable bolson fill in the area was derived from rocks containing relatively few evaporites. In view of the large clay content of the ground-water reservoir, base exchange probably plays a part in determining the quality of the ground water in the Boles area.

Near the mountains, water levels are deep and the processes of evaporation and transpiration play little or no part in determining the ground-water quality. However, as the water moves southwestward out into the basin, the depth to water decreases, and a small amount of transpiration may occur at a distance of $2\frac{1}{2}$ to $3\frac{1}{2}$ miles from the mountains, where there is some mesquite growth and the depth to water is 40 feet or less.

In the same zone, about $3\frac{1}{2}$ miles west of the mountains, the quality of ground water in the bolson fill is modified by playa deposits, both ancient and modern. The quality of the ground water deteriorates rapidly, particularly in the shallower parts of the aquifer. The surficial deposits as well as those in the shallow part of the aquifer are abundant in calcareous and gypsiferous materials, as shown in the log of test hole T-3 (17.9.23.333, table 11), and the resulting highly mineralized water is illustrated by the analyses of water from the test hole (table 19). The rapid accumulation of mineral matter in the water is due to the slow movement of ground water through the fine-grained bolson fill and to downward percolation of mineral matter as a result of occasional heavy precipitation falling directly on the surficial playa deposits and arroyo floods which occasionally reach the lower slopes of the fans.

Westward from the zone in which some transpiration may occur, the ground water becomes increasingly more highly mineralized. The shallow ground water may be freshened slightly on occasion by the inflow from local precipitation where the ground water is very saline or locally increased in mineralization where old playa deposits lie below the water table. Thus, water from well 17.10.5.342, northeast of Alamogordo, has a specific conductance of 1,750 micromhos; water from well 17.9.5.122, west of Alamogordo, a specific conductance of 5,010 micromhos; and water from well 17.8.13.311, on Holloman Air Force Base, a specific conductance of 61,700 micromhos. In the vicinity of Holloman Air Force Base proper, ground water in its westward movement changes from a sulfate water to a chloride water, because the total mineral concentration rises to a point at which the solution of gypsum is inhibited, and the additional rise in mineral content represents addition of sodium chloride. An exception to this westward increase in the chloride content is the ground water under the White Sands, where direct infiltration of precipitation has dissolved gypsum from the sands, and water in the zone of saturation in the gypsum sands is a solution of calcium sulfate.

Although there are few data concerning ground water in the consolidated rocks beneath the bolson fill, it is known that well 18.8.5.431 yields water from limestone which probably belongs to the Yeso formation. The water is highly mineralized and has obtained its mineral content from the gypsum and other soluble rocks through which it moved.

Quality of Water in the Boles Well-Field Area

Within the overall area studied there are two smaller areas of appreciable size in which potable ground water occurs. One, the Boles area, was studied in detail, and the other (plate 1), the center of which is about 12 miles south-southeast of Boles pumping station, was not studied in detail owing to its distance from the air base and to the lack of sufficient well data.

In the Boles area the potability of ground water can be judged by the sulfate content alone because the concentrations of chloride (plate 10) and dissolved solids in the water are always within maximum recommended limits when the sulfate is below the limit (250 ppm) recommended by the U. S. Public Health Service (1946). Water for domestic purposes generally should not contain more than 250 ppm of sulfate, although water containing as much as 500 ppm may be used if nothing better is available. Water for most industrial uses, such as boiler water, should not exceed about 300 ppm in sulfate. Therefore 300 ppm was selected as the limit for "potable" water in this area. Within the Boles well field the sulfate content of ground water ranges from about 200 ppm in well 26 to about 655 ppm in well 14. Although the quality of water varies from place to place in the well-field area (figure 13A), the mineral content increases rather consistently westward, as illustrated by figure 13B which is "cross section A-A'" shown on plate 2. In the cross section it will be noted that the principal increase in anions from east to west is an increase in sulfate.

These general statements of the areal change in quality do not take into account vertical differences in quality in the well-field area. The data

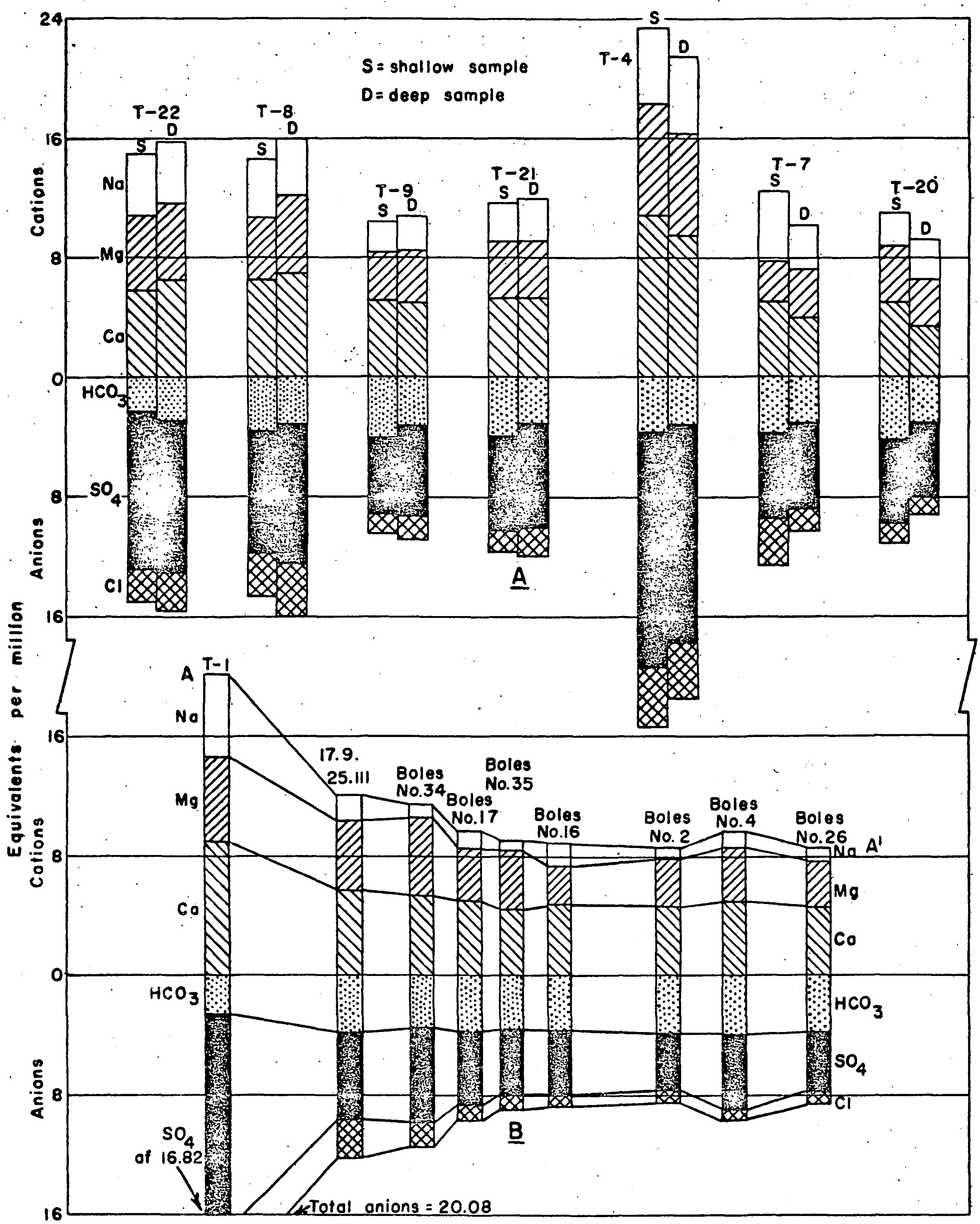


Figure 13.--A. Chemical analyses of water from the shallow zones and the deep zones in several test holes drilled in 1954 in vicinity of Boles well field, Otero County, N. Mex.
B. Mineral content of water from wells along line A—A' shown on Plate 2.

from the ten test holes drilled in the area in 1954 together with those from a few other wells for which data could be obtained indicate that the water-bearing sands in most parts of the Boles area may be divided vertically into at least two zones: a deep, thick zone containing water of good or fair quality; and a shallow, relatively thin zone containing water of fair to very poor quality. All production wells in the Boles well field except wells 10 and 14 produce a mixture of water from both zones which is of acceptable quality. Although the zone of shallow mineralized water is of appreciable thickness, its effect upon the quality of water from wells in the area is significantly large only locally. For this reason, estimates of the extent of potable water in the area are based upon the potable water in the deeper part of the aquifer.

In plate 2 it may be seen that the body of potable water stored in the Boles well-field area is lobe-shaped. The long axis of the body is perpendicular to the regional trend of the water-table contours shown in plate 1, that is, parallel to the direction of ground-water movement. As shown in the figure, the area underlain by water containing 300 ppm or less of sulfate is essentially between the edge of the Sacramento Mountains and the contour of 300 ppm sulfate. The area underlain by water containing 500 ppm or less of sulfate lies between the contour of 500 ppm sulfate and the edge of the mountains. From Alamo Canyon south to Dog Canyon, a distance of about 9 miles, about 10 square miles is underlain by ground water containing 300 ppm or less of sulfate. Of this area, about 8 square miles is in the immediate vicinity of the Boles well field. In the same 9-mile interval there is about 25 square miles beneath which the stored ground water contains 500 ppm or less of sulfate. On the basis of six water samples it appears that in the second area of potable ground water, 12 miles south-southeast of the Boles pumping station, there may be from 15 to 20 square miles of land underlain by water suitable for domestic consumption. However, data available in this area are few, and any proposed development of the area should be preceded by test drilling to determine the areal extent, thickness, and character of the fresh-water sands.

The effective boundary between fresh and brackish ground water may be taken at the 500-ppm sulfate contour shown in plate 2. However, it must be emphasized that the size and shape of the fresh-water body as shown in the plate are, in general, based on conditions existing in 1954. As pumping in the Boles well field continues, and the radius of influence from pumping spreads outward, the boundaries of the potable-water body will tend to contract. Although the size of the potable-water body will diminish slowly, it will continue to diminish as long as pumping continues. The rate of movement of brackish water into the well field will be slow and is related to the hydraulic characteristics of the aquifer, which are discussed in the section on pumping tests.

Of more immediate importance is the vertical relation of the ground waters of various qualities in the well field, because adulteration from the shallow mineralized zone is well advanced in wells 10 and 14. In the

Boles area the water-bearing sands south and west of the vicinity of test holes 9 and 22 may be divided into two zones: a relatively thin zone near the water table, which contains water of fair to very poor quality; and a deeper, thick zone containing water of good to fair quality. Northeastward from test holes 9, and 22, there is a tendency for the ground water to assume the normal order of mineralization, from lower to higher mineral content with depth.

Evidence for higher mineralization of water in the shallow zone is found in several wells both in the well field and in the adjacent areas. In older wells dug or drilled to the first water-bearing sand, the ground water is more highly mineralized than in deep wells in the same areas. For example, well 17.9.23.310 was 85 feet deep and produced water containing 2,140 ppm of dissolved solids. A companion well, 17.9.23.310a, was 50 feet deep and produced water containing 3,760 ppm of dissolved solids, or more than half again as much as in the water from 17.9.23.310. Boles well 16 (17.9.25.222) is 217 feet deep. Water from the well contains about 500 ppm of dissolved solids (table 20). Nearby well 17.10.19.111 was dug to the water table, prior to 1911. Water from this shallow well contained 1,369 ppm of dissolved solids, or nearly three times the amount of dissolved solids in water from well 16. Several water samples were bailed from Boles well 5 in 1948, during the drilling of the well. A water sample taken when the well was 75 feet deep (table 20) contained 1,340 ppm of dissolved solids. There were 1,410 ppm of dissolved solids in a water sample taken when the well was 100 feet deep. Well 5 is now approximately 205 feet deep, and since 1948 has produced water containing 520 to 570 ppm of dissolved solids. If the older wells could have been dug 10 to 30 feet deeper, the quality of water obtained from them would have been better.

The shallow-water samples taken from most of the ten test holes drilled in 1954 were more highly mineralized than the deep-water samples (fig. 13 A). Shallow-water samples from most of the test holes had a higher nitrate content than the deep-water samples. Samples from the holes also showed that the difference in mineralization between the two zones is pronounced where both zones are highly mineralized. For example, in test hole 3, water from the shallow zone at a depth of 46 feet contained 11,700 ppm of dissolved solids, whereas water from the deeper zone, between 107 and 208 feet, contained 3,970 ppm of dissolved solids. In test hole 1 the water was less mineralized. The shallow zone at a depth of 51 feet yielded water containing 2,210 ppm of dissolved solids, and the deeper zone yielded water containing 1,270 ppm of dissolved solids.

The reasons for the differentiation in quality where there are playa deposits at or near the surface of the plain is easily explained. Precipitation upon, or runoff flowing over, the surface of the ground percolates downward through the soluble playa deposits, dissolving and carrying to the water table a large amount of mineral matter. However, on the slopes of the fans in the Boles well field, playas do not and probably never did exist during the formation of the present alluvial fans, and the presence of shallow, mineralized water is less easily explained. In view of the generally higher mineral content and the higher nitrate content of the shallow water westward from the main intake area on the fans, it seems likely that the shallow ground water represents local recharge from runoff not absorbed at the edge of the mountains. The higher mineralization of the shallow water appears to have resulted from a smaller amount of recharge moving downward through less permeable material, than that in the intake area. The tendency towards a normal vertical order of mineralization of the ground water toward Alamo Canyon suggests that differentiation of quality of water into the two zones begins where the stream-laid fan deposits become differentiated into strata of clay, sand, and gravel, and the downward percolation of shallow water is halted by strata of silt and clay. The silt and clay apparently are not perfect aquicludes, and when the hydrostatic pressure beneath them declines, the shallow water eventually drains downward into the underlying sands. This seems to be taking place at Boles wells 10 and 14.

Wells 10 and 14 are in the eastern part of the Boles well field. They yield water which at times is from two to four times as mineralized as that from other wells in the same part of the well field. Well 10 was drilled about 40 feet from well 1, and the analyses of water from the two wells provide a record of changes in quality of water for the entire period of pumping at the location of the two wells (figure 14). The increase in mineral content of water from well 14 has been less consistent than that of well 10, but greater in proportion to the period of pumping.

In wells 10 and 14, the evidence for downward migration of the adulterating water is of dual nature. First, it is known from the analyses of shallow waters from wells 17.10.19.111 and 17.10.19.144 (Boles well 5) that highly mineralized water exists at shallow depths, and second, the chemical quality of the water from wells 10 and 14 fluctuates with pumpage in a way that precludes upward vertical migration. Parts of the chemical analyses of six water samples from well 10 have been extracted from table 20 and are given in table 6 along with parts of analyses of two samples from well 14. As illustrated by the series of analyses of water taken from well 10 during the period September 20-28, 1951, the water pumped from the well becomes less mineralized as pumping continues during any short-term pumping period. At well 10, a water sample was bailed from the water surface in the well on Sept. 20; the pump was then installed, and the well pumped continuously from Sept. 24 to Sept. 28, a water sample being taken each day. The progressive changes in the quality of the pumped water indicated that water from the well is a mixture from two sources, the shallow zone and the deeper zone. As pumping continued, an increasingly greater proportion of ground water was yielded by the deep zone containing the better quality of water. The consistent trend toward a decrease in nitrate content of the pumped water (table 6) is an added indication that the adulterating water is coming from the shallow zone, inasmuch as it is common to find the shallowest ground water high in nitrate in many areas where mineral sources of nitrate are absent but organic sources exist.

Table 6.--Partial results of chemical analyses of water from wells 10 and 14 Boles well field, Otero County, N. Mex., showing relation of quality to length of pumping period. 1/

Date	Time since pumping began (hours)	Sulfate (SO_4)	Chloride (Cl)	Nitrate (NO_3)	Dissolved solids
Well 10					
Sept. 20, 1951	0 2/	400	167	4.9	977
Sept. 24, 1951	8	360	135	2.3	873
Sept. 25, 1951	18	327	112	1.9	797
Sept. 26, 1951	50	322	104	1.8	774
Sept. 27, 1951	72	305	100	1.8	744
Sept. 28, 1951	100	293	97	2.0	723
Well 14					
May 23, 1955	7	321	605	5.4	1,400
Aug. 24, 1955	1 to 2	654	885	20	2,390

1/ Analyses by U. S. Geological Survey.

2/ Bailed from water surface in well before installing pump.

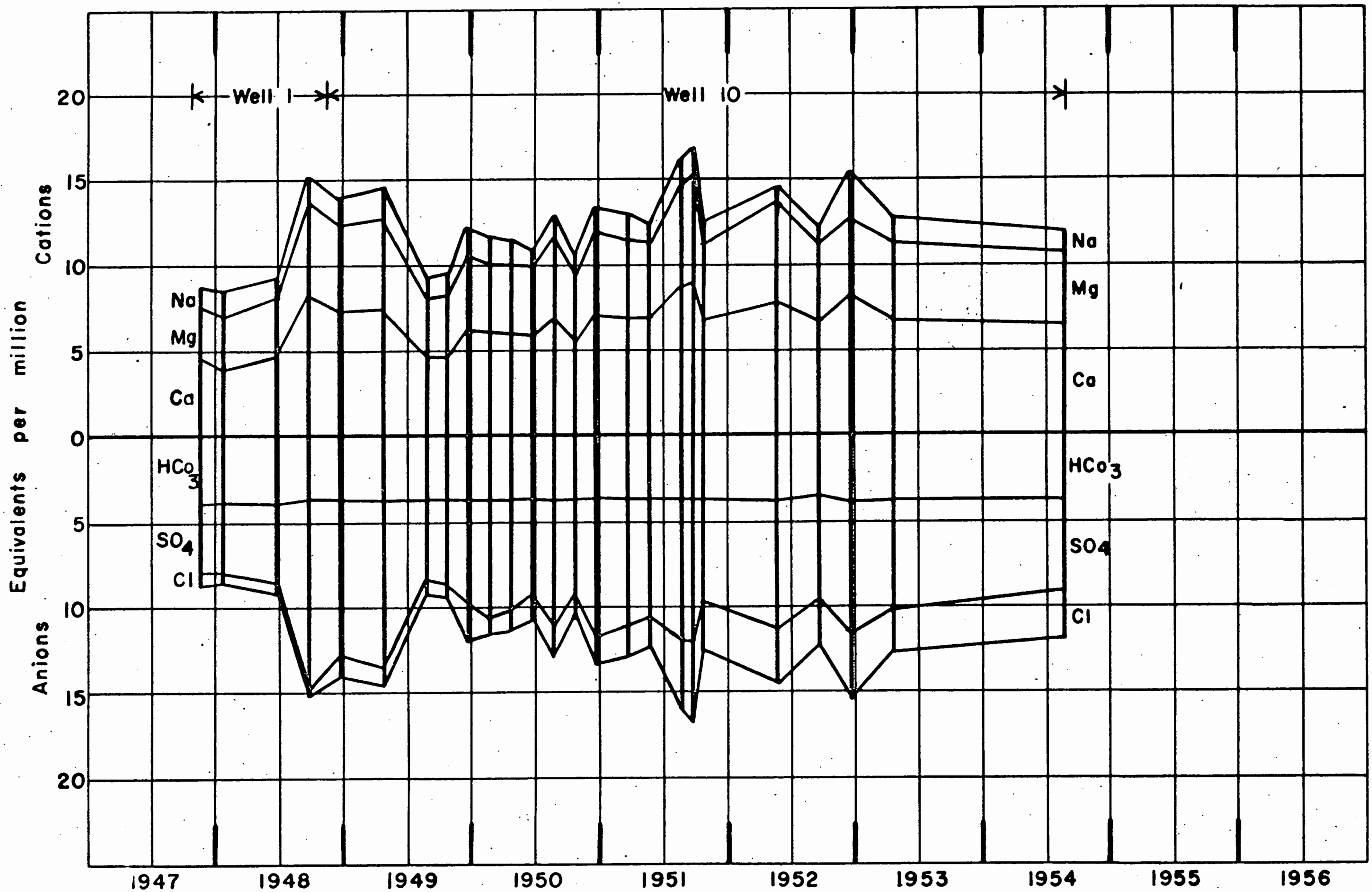


Figure 14.--Fluctuation of mineral content of water from wells 1 and 10, 1947 through 1954, Boles well field, Otero County, N. Mex.

These data suggest that, as pumping continued, the shallow zone containing highly mineralized water was being dewatered, and the adulterating water that had leaked into the deeper zone was being replaced by water of better quality. The data also suggest that the permeability of the deeper sands is many times that of the leaky confining bed.

The mechanism of adulteration of the deeper aquifer from above is probably leakage from the shallow to the deeper aquifer through a leaky confining bed, although it may be movement of water through the pumped well. Perhaps it is both. In either case the result is introduction of undesirable, highly mineralized water into the sands containing potable water. As the pumping from the deeper zone continues over a period of years, water levels will decline and the rate of adulteration probably will increase. If the mechanism is leakage through the confining bed, no correctional measures can be taken, because the leakage will continue as long as pumping continues to lower pressures in the deeper sands. However, if the contamination is due to movement through the pumped wells, it may be eliminated by plugging the contaminated wells with an impermeable medium such as very thick drilling mud, or cement slurry. In view of the present high mineral content of the water, Boles well 14 might best be plugged, and well 10 used only as a standby supply.

Only a few data are available concerning the quality of ground water in consolidated rocks underlying the bolson fill. Within the study area only well 18.8.5.431 passes through the fill and obtains water from consolidated rocks, which are probably part of the Yeso formation. A chemical analysis (table 21) shows that water from the well contains about 2,670 ppm of chloride and has a specific conductance of 11,700 micromhos. Nearby mound springs also are believed to yield water from the consolidated rocks. Samples of water from mound springs at locations 17.8.28.312 and 18.8.17.412 had 2,530 ppm and 2,670 ppm of chloride, respectively. Water from spring 18.8.17.412 had a specific conductance of 11,600 micromhos.

HYDROLOGIC CHARACTERISTICS OF THE BOLSON FILL

In order to provide a logical basis for effective future operation, development, and expansion of the Boles well field it is necessary to know the principal hydrologic characteristics of the bolson-fill aquifer. These characteristics are expressed by the coefficient of permeability and its practical extension, the coefficient of transmissibility, and by the coefficient of storage.

Owing to the unconsolidated nature of the bolson fill and to the manner in which samples of it are usually obtained from wells, laboratory determinations of the hydraulic coefficients of the aquifer usually do not accurately reflect the hydraulic characteristics of the fill. For this reason, the determinations of aquifer coefficients were made by observing the changes in water levels in wells as a result of pumping one or more wells in the well field. The following discussion of the coefficients and their determination is restricted to methods of determination that were used in the Boles area.

Coefficients of Permeability and Transmissibility

The rate at which water can be pumped from a well is partly dependent on the rate at which the aquifer can transmit water toward the well. The field coefficient of permeability (Pf) used by the Geological Survey expresses the rate of ground-water transmission through an aquifer in gallons per day per square foot (cross section) under a unit hydraulic gradient at the prevailing water temperature. A more practical extension of the field coefficient of permeability is the coefficient of transmissibility, which is the field coefficient of permeability multiplied by the thickness of the aquifer, in feet. The practicality of using the coefficient of transmissibility is that (1) the coefficient expresses flow through a section of dimensions practical for computation and easy to visualize, and (2) the coefficient, determined from field tests, gives an average rate of ground-water transmission even though the thickness of the aquifer is indeterminate. The coefficient of transmissibility as used by the Geological Survey expresses the amount of water in gallons per day moving through a vertical section of the aquifer 1 foot in width under a unit hydraulic gradient. Expressed in units more closely tied to natural dimensions, the coefficient of transmissibility is the amount of water in gallons per day that would move through a section of the aquifer 1 mile wide under a hydraulic gradient of 1 foot per mile.

The coefficient of transmissibility in the Boles well field was determined by the use of four methods. Three of the methods are based on the Theis nonequilibrium formula (Theis, 1935), which has been described also by Wenzel (1942) and Brown (1953), and one method utilizes Thiem's equilibrium formula (Wenzel, 1942, p. 81).

The nonequilibrium formula is based on the following assumptions: (1) the water-bearing formation is homogeneous and isotropic, (2) the formation is of infinite areal extent, (3) the discharge well penetrates the entire thickness of the formation, (4) the coefficient of transmissibility is constant at all places and at all times, (5) the discharge well has an infinitesimal diameter, and (6) water taken from storage is discharged instantaneously with the decline in head.

The first method uses the "type curve" solution derived directly from the nonequilibrium formula. In Geological Survey units the formula is

$$s = \frac{114.6\ Q}{T} \int_{\frac{1.87\ r^2\ S}{Tt}}^{\infty} \frac{e^{-u}}{u}\ du$$

in which: s = drawdown, in feet, at any point in the vicinity of a discharging well

Q = the rate of discharge of the well, in gallons per minute

T = coefficient of transmissibility, in gallons per day per foot

S = the storage coefficient

r = the distance from the discharging well, in feet

t = the time since pumping began, in days

e = the natural-logarithm base (2.71828)

$$u = \frac{1.87\ r^2\ S}{Tt}$$

It should be noted that T appears on both sides of the integral sign and, hence, a direct solution of the equation is not possible. However, the term under the integral sign is commonly represented by an abbreviation, "W(u)", so that:

$$s = \frac{114.6\ Q}{T}\ W(u) \qquad \text{or}$$

$$T = \frac{114.6\ Q}{s}\ W(u)$$

For every given numerical value of u there is a corresponding value for W(u). A table of values for the two variables has been published by Wenzel (1942). If the values are plotted on logarithmic graph paper, the resulting curve theoretically represents the drawdown in all wells under all hydrologic conditions for all lengths of pumping time, if the original assumptions of the theory are met. To use the type curve, the drawdown versus

1/t for an observation well or versus r^2/t for several observation wells is plotted on logarithmic graph paper to the same scale as the type curve. If one plot is superimposed upon the other so that the observed data track the type curve with coordinate axes parallel, any common point on the two graphs gives a value for u and W(u) for the observed values of s and 1/t or r^2/t at that point. A value for T can then be computed by substitution of values at a common point on the graphs into the formula for T given above. This method is valid only where the drawdown is measured outside the casing of the pumped well.

The method described above can also be used to compute T from the recovery of wells after pumping stops. Recovery is defined as the difference at any given time between the observed water level in the well and the pumping level in the well projected as if pumping had continued. All the methods of computation and plotting are the same as described above, s representing recovery in place of drawdown.

An abbreviated straight-line solution of the Theis nonequilibrium formula permits an approximation of the value of T in the vicinity of the pumped well by relating the length of time the well was pumped and the length of time since pumping stopped to the residual drawdown. Residual drawdown at any given time after pumping has stopped is the difference between the observed water level in the well and an extrapolation of the prepumping water level.

The formula for computing T from recovery of the pumped well by the straight-line solution is

$$T = \frac{264\ Q}{s} \log_{10} \frac{t}{t'},$$

where: s = residual drawdown

t = time since pumping began

t' = time since pumping stopped

Time may be in any unit, as the term t/t' becomes dimensionless by cancellation of units. The value of $\frac{\log_{10} t/t'}{s}$ is determined by plotting s versus t/t' on semilogarithmic graph paper, using the logarithmic scale for t/t' and the arithmetic scale for s. The resulting curve theoretically should be a straight line. The value for $\frac{\log_{10} t/t'}{s}$ is taken as the slope of the straight line. Over one log cycle, $\log_{10} t/t'$ becomes unity; s equals Δ s; and then $T = \frac{264\ Q}{\Delta s}$. If the line is not straight over at least a substantial part of the plot, the method cannot be used.

The coefficient of transmissibility can be computed also from observations of the rate of recovery of the water level after a well has been pumped at several different rates, as during a step-pumping test. For example, for a two-step test in which the well has been pumped for equal intervals at different rates, without shutting down:

$$T = \frac{264}{s} \left(q_1 \log \frac{t_1 + t'}{t_2 + t'} + q_2 \log \frac{t_2 + t'}{t'} \right)$$

where: s = residual drawdown at the pumped well
T = coefficient of transmissibility, in gallons per day per foot
q_1 = discharge of well, in gallons per minute, during the first step
q_2 = discharge of well, in gallons per minute, during the second step
t = time since pumping started of the step indicated by the subscript to the time that pumping stopped.
t' = time since pumping stopped

The values of s are plotted on linear graph paper against the values of the term in brackets for each particular time after pumping stopped. These points should theoretically fall along a straight line. By selecting two points on the line and dividing the difference in the two values of the term in brackets at those points by the difference in the two values of s at those two points and multiplying the quotient by 264, a value for the coefficient of transmissibility is obtained. The same procedure applies to a computation of the coefficient of transmissibility from the recovery after any number of pumping steps--an additional term in brackets being added for each additional pumping step. Thus:

$$T = \frac{264}{s} \left(q_1 \log \frac{t_1 + t'}{t_2 + t'} + q_2 \log \frac{t_2 + t'}{t_3 + t'} + \text{------} + q_n \log \frac{t_n + t'}{t'} \right)$$

It should be noted that conditions found in the aquifer rarely meet all the assumptions on which the Theis formula is based. Unconsolidated deposits of the type found in the Holloman area usually depart far from the assumptions, and the coefficient of transmissibility determined through the use of observation wells may be very erroneous, except for use in computing short-term pumping effects, as in locating nearby hydraulic boundaries. In general, the value for T is most easily determined from the recovery of water levels in the pumped well.

A fourth method of obtaining the coefficient of transmissibility is by means of the Thiem formula. This formula is an "equilibrium" formula and does not take time into account but assumes that the cone of depression resulting from pumping develops uniformly so that the rate of decline at all points on the cone is uniform. The formula modified to obtain T in Geological Survey units is

$$T = \frac{527.7 \, Q \log \frac{r_2}{r_1}}{s_1 - s_2}$$

where: T = the coefficient of transmissibility

Q = the rate of discharge of the pumped well, in gpm

r_1 = distance to the near observation well, in feet

r_2 = distance to the far observation well, in feet

s_1 = drawdown in the near observation well, in feet, at a given time

s_2 = drawdown in the far observation well, in feet, at the same time as for s_1

In applying the formula, it must be assumed that the cone of depression is developing uniformly in the vicinity of the two observation wells. Moreover, it is necessary that the pumping be continued long enough that water is no longer being yielded by compaction of the aquifer in the vicinity of the observation wells but is flowing through the aquifer from beyond the observation wells. It also appears desirable that the two observation wells be sufficiently far apart to establish a good value for the average slope of the water table.

Coefficient of Storage

A second important characteristic of an aquifer is expressed by the coefficient of storage. The present definition of the coefficient of storage, S, as used by the Geological Survey, is the volume of water an aquifer releases or takes into storage per unit surface area of the aquifer per unit change in the component of head normal to that surface. The volume of water cited in the definition is measured outside the aquifer under atmospheric pressure, not under pressure in the aquifer. The coefficient of storage is dimensionless, because it is the volume of water (in cubic feet, for example) released from or added to the aquifer divided by the product of the change in head (in feet) causing the change in storage and the cross-sectional area (in square feet) of the aquifer surface over which the change in head occurs.

In an artesian aquifer, the entire aquifer is filled with water. Any water released from or taken into storage can be attributed to the compression or expansion of the aquifer and, to a small extent, of the water. In the artesian or confined aquifer any change in pressure acts normal to the confining beds and the definition of the coefficient of storage is satisfied. In a well tapping the aquifer, changes in depth to water are a reflection of changes in pressure in the aquifer. Coefficients of storage of artesian aquifers generally range from about 0.00001 to about 0.001.

The definition of the coefficient of storage also applies to unconfined aquifers containing water under water-table conditions, although conditions in such aquifers are somewhat different. In a water-table aquifer a part of the water released from or taken into storage either drains from voids, or fills previously unfilled voids, in the aquifer. Usually, the amount of water released or stored by such draining or filling is so much greater than that attributed to the compressibility of the aquifer that in water-table aquifers the amount of water stored by compression is considered to be negligible. In true water-table aquifers the coefficient of storage is practically equal to the specific yield, differing from it only by being a little greater because of the compressibility effect, and generally ranges from about 0.01 to about 0.30.

The coefficient of storage of an aquifer may be determined by use of the type-curve solution of the Theis nonequilibrium formula. It was noted previously that:

$$u = \frac{1.87\ r^2 S}{Tt}$$

and, by transposition,

$$S = \frac{uTt}{1.87\ r^2}$$

In the method of determining the value of T by means of the type-curve solution, the means of determining u and W(u) are described. After the value of T has been computed, substitution of the field values for r and t and the computed values for T and u into the formula given above will give a value for S .

Values of the coefficient of storage determined from drawdowns in observation wells in a water-table aquifer should be used with caution, particularly if the length of the pumping period is short. Coefficients of storage obtained from such tests are generally valid for computing short-term pumping effects but cannot be applied to long periods of withdrawal. For computing long-term pumping effects the specific yield of the aquifer, if it differs from the coefficient of storage determined in short tests, should be used.

The specific yield of an aquifer is the volume of water that will drain by gravity from a given volume of the saturated aquifer, and generally is expressed as a percentage. It can be seen that the degree of sorting, which determines the porosity, and the size of openings govern the specific yield.

The porosity of an aquifer is the total pore space between the grains of the aquifer sediments, expressed as a percentage of the aquifer volume. In fine-grained sediments the porosity generally is high, but the pores are very small and the grains very close together. In coarse-grained sediments the porosity generally is lower, but the pores are larger. If an aquifer is drained, a certain amount of water is retained by molecular attraction against the force of gravity as a thin film around each grain and as a "ring" around the points of contact between adjacent grains. Therefore, the specific yield equals the porosity less the specific retention, each expressed as a percentage. Fine-grained aquifers have high specific retention and low specific yields. This is the general condition in the Boles well field.

Time is an important factor in determining the value of specific yield. Upon lowering the water level in a water-table aquifer, a given amount of water is released almost immediately. However, drainage from the partially dewatered part of the aquifer will continue at an ever diminishing rate. The length of time required for complete drainage depends on the grain size and degree of sorting of the aquifer sediments. Coarse-grained sediments will drain in a comparatively short time. Fine-grained sediments might continue to drain over a period of several years. Therefore, in an aquifer similar to that underlying the Boles area, an accurate value for the specific yield might not be obtained until the sediments had drained for perhaps years.

The most accurate method of determining the specific yield of an aquifer is by a comparison of the volume of water pumped from the aquifer to the amount of aquifer unwatered, but the method is accurate only if all the pumped water comes from storage. The volume of water pumped in the Boles area is easily determined, because records of annual pumpage are relatively complete. The amount of aquifer dewatered as a result of pumping cannot be estimated for the period prior to 1954, because a sufficient number of accurate water-level measurements in the well field are not available. However, this method can be applied in the future because a series of accurate water-level measurements was started during the field investigations in 1954.

A second, less accurate method of determining specific yield is based on the fact that the coefficient of storage of an aquifer approaches the specific yield, as the time of pumping from the aquifer increases. If it could be assumed that pumping of one or more wells continued over a very long period of time and the observation well was at a comparatively great distance from the pumped wells relative to their spacing, the pumped wells could be treated as a single point of discharge from the aquifer, and any effect of shutting down pumping for short periods of time would be negligible compared to the longer period of pumping. Boles well 33 is the one well in the Boles well field for which accurate water-level measurements are available for a period of several years. An estimate of the specific yield of the bolson-fill aquifer is based on the decline of water levels in well 33 as a result of pumping the well field from April 1952 to February 1954.

Aquifer Tests in the Boles Well Field

A series of pumping tests was run in the well field to determine the hydrologic characteristics of the bolson-fill aquifer. One test was run in May 1954 in connection with the chemical treatment of well 28 and two tests were run in the summer of 1954. One test was run in early January 1955 as a part of the 1954 test-drilling program; other tests were run consecutively during the period from January 24 to February 28, 1955, and in April and May 1955.

General conditions during each test are described in the following sections on the individual wells. However, several conditions common to the tests run from January to February 1955 are given here to avoid repetition.

To assure that the water levels in the well field were as near to "static" level as possible, all pumping was stopped on January 14, 12 days before testing began. During the 12-day period, measurements of depth to water were made intermittently at all wells in the area. The recovery period following pumping was at least as long as the pumping period, and water levels were measured by means of automatic recorders where possible. No two wells were pumped at the same time. During the tests at wells 10, 15, 17, and 26, the water was pumped into the storage tank at the Boles booster station. The water level in the storage tank was difficult to control and changes in head in the tank caused changes in the rate of discharge of the wells at times. The water levels measured in all observation wells cited in the following sections on individual tests were corrected as much as possible for barometric fluctuations. The basis of correction was records from a microbarograph operated at the booster station during the tests. Testing began in the eastern part of the well field and ended in the western part, and observations continued in the western part of the well field for 15 days after test pumping stopped. On February 16 and 17, wells in the eastern part of the well field were pumped to supply water to Holloman Air Force Base at the same time that well 17 was being test pumped. However, it is believed that this pumping had no effect on testing in the western part of the well field, owing to the distance between the two areas.

In the following discussions of individual wells, only the pumped wells are listed, and the effects of the pumping on water levels in observation wells used during the respective tests are discussed together with the effects at the pumped wells. The tests are arranged in chronological order.

Well 28

Test pumping of well 28 was a part of the procedure used to evaluate the results of chemical treatment of the well. On May 12, 1954, the well was pumped about 7 hours at an average rate of 52 gpm. The discharge was measured by means of an orifice plate in the discharge pipe, and the depth to water was measured with a steel tape. Water-level measurements were made in a cleanout pipe installed in the gravel envelope, outside the well casing. The water level was 186.6 feet below the measuring point at the end of the pumping period and recovered to 107.9 feet about $6\frac{1}{2}$ hours after pumping stopped. The coefficient of transmissibility indicated by a semilogarithmic plot of recovery data was about 1,350 gpd per foot. The low permeability of the bolson fill in the vicinity of well 28 illustrates the heterogeneity of the fill. Production wells have been developed both east and west of the well, indicating that there are areas of higher permeability on both sides of the area of low permeability. Figure 15 shows test data from well 28.

Well 26

One of the first aquifer tests in the Boles well field was made at well 26. The well was pumped for nearly 130 hours from July 26 to 31, 1954.

The average rate of discharge was 176 gpm, determined by means of a totalizing meter in the line between the well and the storage tank. All measurements of depth to water were made with a steel tape in a cleanout line in the gravel envelope outside the casing. The water level before pumping began was 108.9 feet below the measuring point. The water level declined to 167.0 feet by the end of the pumping period and recovered to about 109 feet 96 hours after pumping stopped.

Figure 16 shows the depth to water in well 26 during the pumping and recovery periods and the rate of discharge during the pumping period. Figure 17 shows the matching of observed data to the type curve for analysis by means of the Theis formula. Although the nonequilibrium formula generally cannot be applied to data from the pumped well to determine both T and S, it could be used at well 26 owing to the fact that the water levels were measured outside the casing, providing a measurable radius and eliminating the effects of screen losses.

The coefficient of transmissibility for the drawdown and recovery limbs of the curve are 4,480 and 4,690 gpd per foot, respectively. Estimates of the apparent coefficient of storage based on estimated effective radii of the well of 0.625 and 1 foot amount to 0.0031 and 0.0012, respectively, at the end of about 1 hour.

In figure 17 it will be noted that only the very earliest observed data track the type curve and that the observed data depart from the type curve in a manner indicating that more water is being made available to the well than would be the case if the T were consistent and other factors remained constant. Inspection of the data on a semilogarithmic plot shows that the departure is a continuous variation. The estimated value of the coefficient of storage shows that the aquifer contains water under artesian pressure under nonpumping conditions. However, the confining beds are imperfect seals, and when water is withdrawn from the aquifer the drop of pressure within the aquifer induces leakage through the confining beds. As the rate of leakage is related in part to the decrease in pressure within the aquifer, it can be seen that the continuous departure of the observed data from the type curve is a reflection of an increasing rate of leakage with an increasing drop in internal aquifer pressure.

Well 28, at a distance of 1,370 feet, was used as an observation well during the test at well 26. There was no measurable drawdown at well 28 as a result of pumping well 26. The absence of drawdown in well 28 is the result of the low permeability of the formation at well 28. However, if the pumping of well 26 had caused only 0.01 foot of drawdown at well 28 by the time pumping stopped, the coefficient of storage at well 28 would be in the order of 0.001, using a value of 1,350 gpd per foot for the coefficient of transmissibility.

Well 33

Well 33 was tested September 7, 1954, by pumping for about 5 hours and observing the rate of recovery of the water level. The equipment used

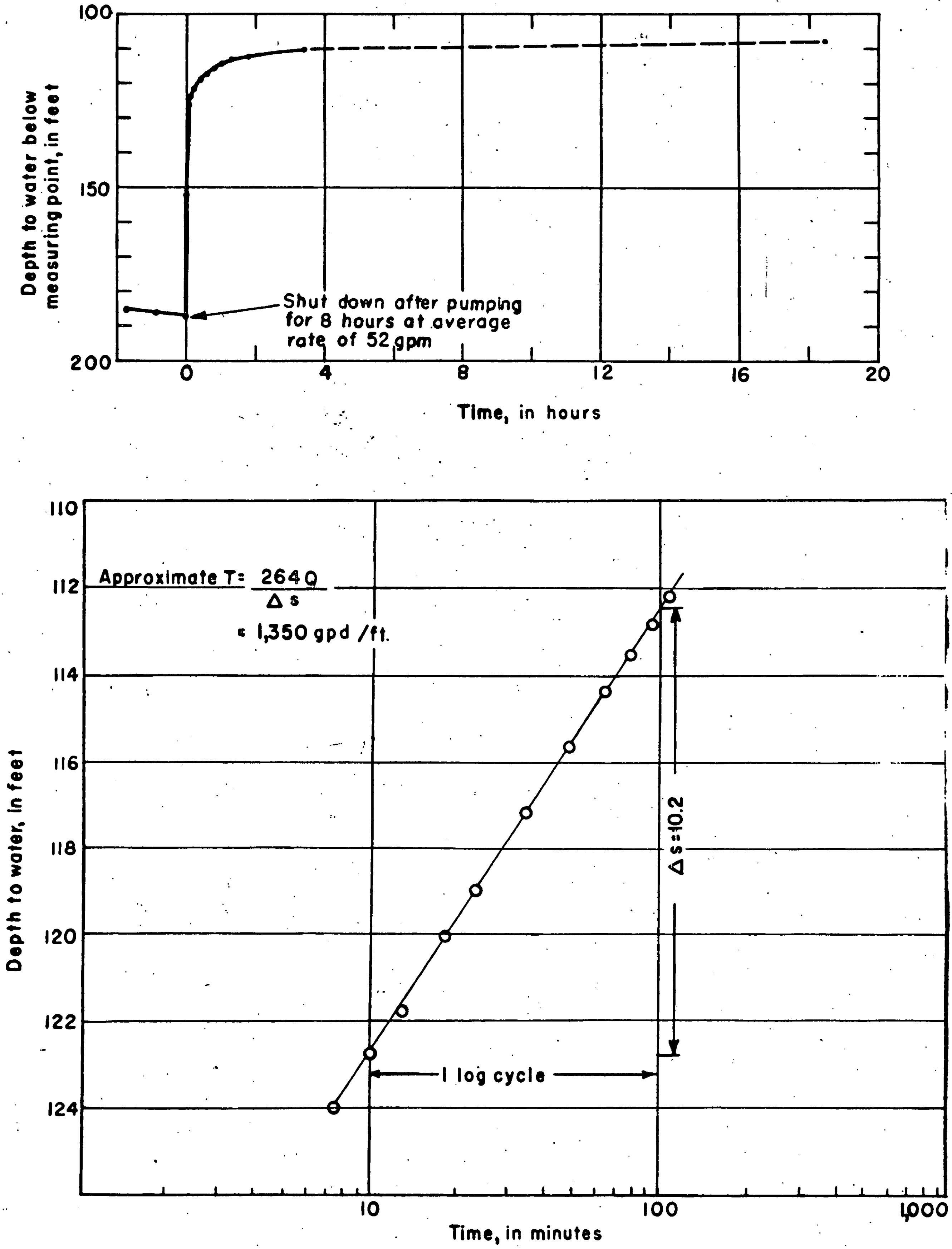


Figure 15.-- Recovery of water level during aquifer test at well 28, Boles well field, Otero County, N. Mex.

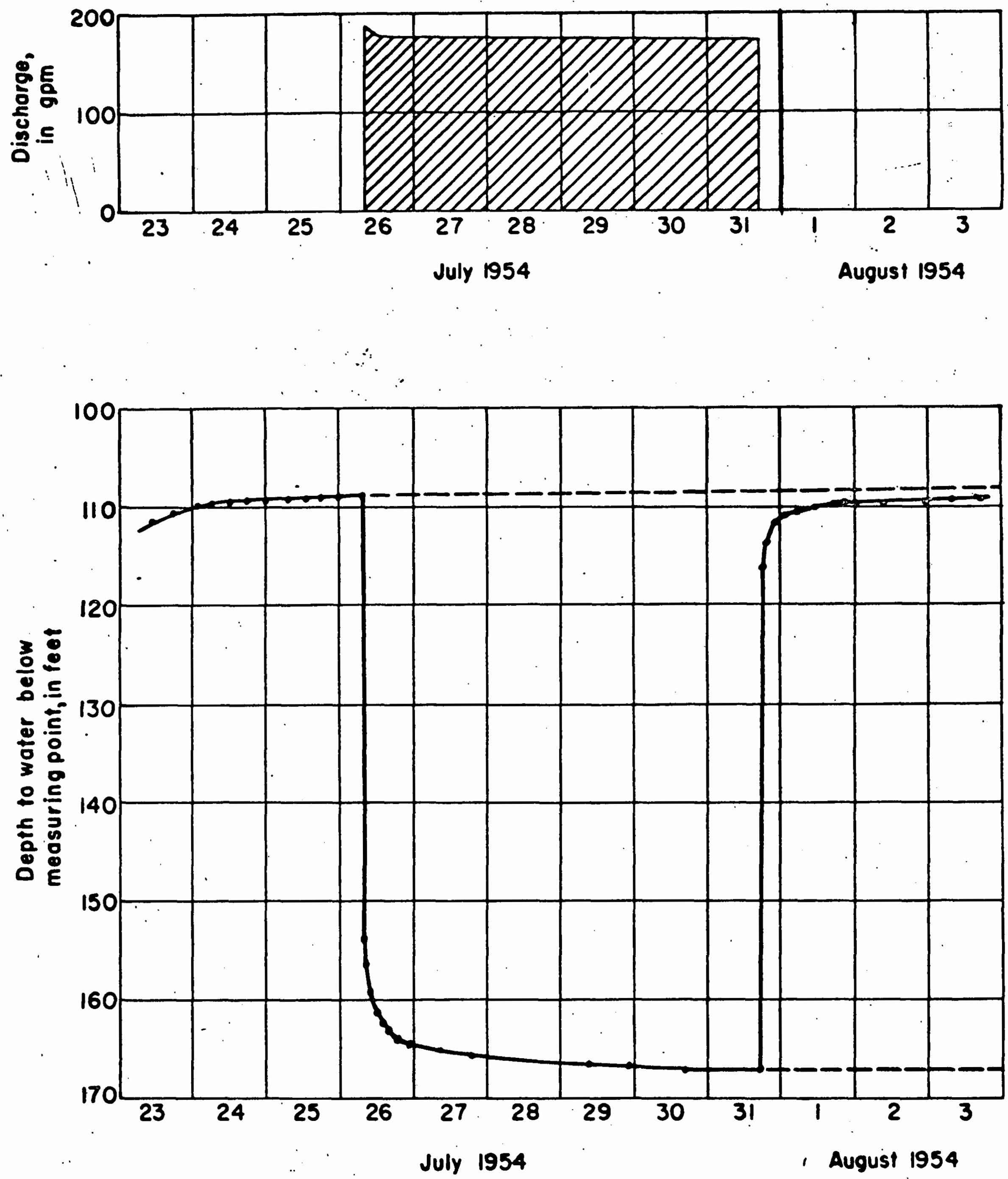


Figure 16.-- Changes in water level and rate of discharge during aquifer test at well 26, Boles well field, Otero County, N. Mex.

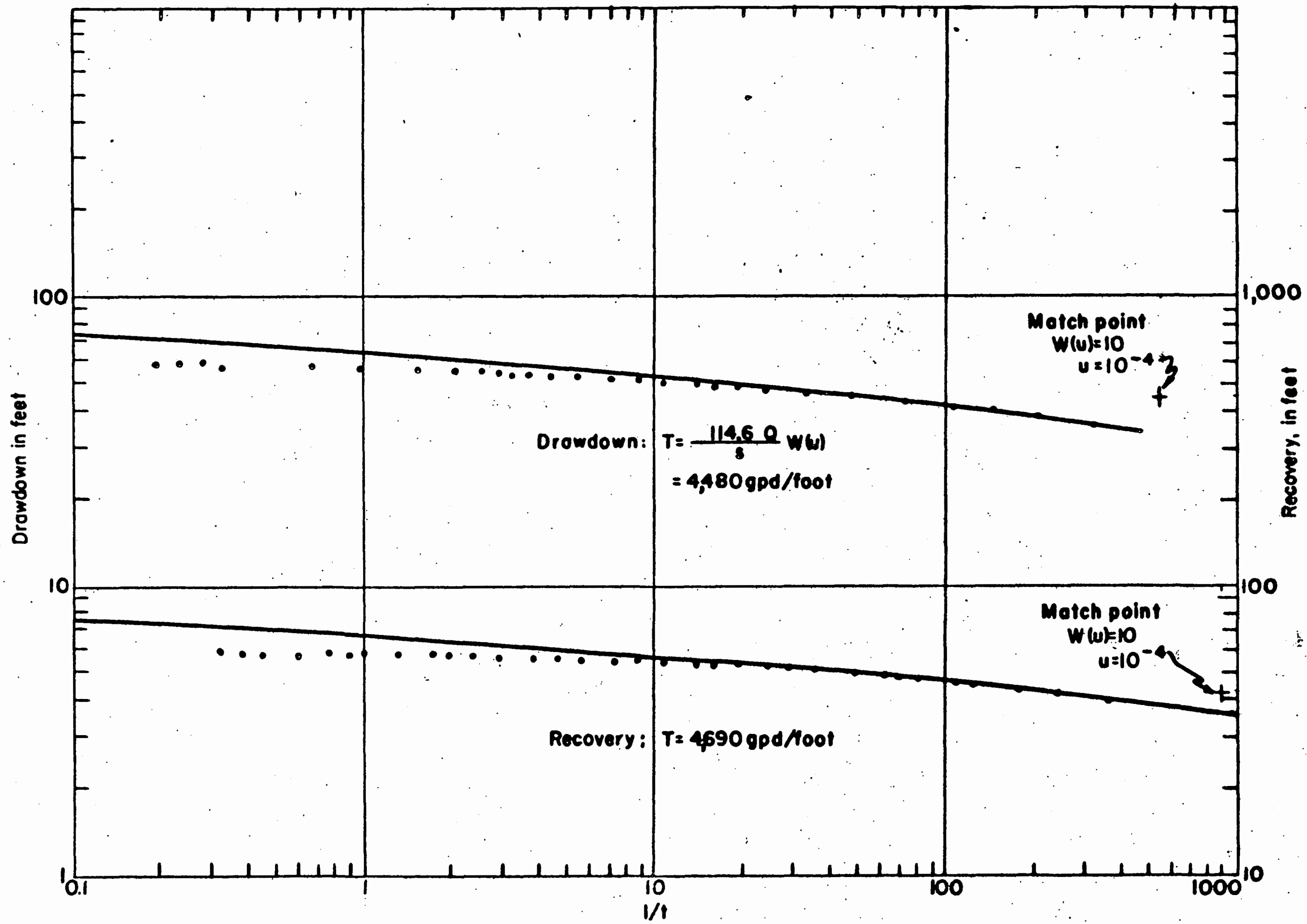


Figure 17.-- Logarithmic plot of drawdown and recovery of water level during aquifer test at well 26, Boles well field, Otero County, N. Mex.

for the test was a deep-well turbine equipped with an orifice, and a 20 hp, one-cylinder gasoline engine with a belt drive to the pump. Owing to poor carburetion the motor stopped after about half an hour of pumping, and could not be started again for about 20 minutes. The average rate of discharge during the test was 186 gpm. The depths to water were measured with a steel tape throughout the test. The water level prior to pumping was 63.6 feet below the measuring point. The water level had declined to 72.4 feet at the end of the test, and had recovered to about 64.7 feet 5 hours after pumping stopped.

Figure 18 shows water levels and the rate of pumping during the test at well 33 and a semilogarithmic plot of the recovery of the water level in the well. The term

$$\frac{t_1}{t'_1} \times \frac{t_2}{t'_2}$$

is an adjustment for the effect of the interruption in the pumping period when the motor stopped. Analysis of the curve by means of the Theis recovery formula indicates that the coefficient of transmissibility of the aquifer adjacent to well 33 is about 20,000 gpd per foot. This figure is comparable to that obtained from the pumping of well 17, and indicates the comparatively high permeability of the aquifer in the western part of the well field.

Test hole 7

In the test-drilling program in the Boles well field area in 1954, provisions were made for casing and test pumping one test hole. Test hole 7 was selected on the basis of sand content of the drill cuttings, location with reference to the well field, and the quality of water from the test hole. In January 1955, the test hole was cased to 302 feet below land surface, and the casing was perforated at selected zones with an aggregate of 50 feet of perforations. The well was developed by surging with a surge block and by bailing for a specific period of time. After the pump was set, a 6-hour step pumping test was run, in increments of 2 hours each at steps of approximately 75, 100, and 125 gpm consecutively. The prepumping water level was 59.3 feet below the measuring point. The water level declined to 77.5 feet at the end of the first step, 87.5 feet at the end of the second step, and to 110.5 feet at the end of the third step. Measurements of water levels below 80 feet were made with air line and gage, and the remainder were made with a steel tape. The rate of discharge was measured with an orifice.

An attempt was made to increase the pumping rate from 100 gpm to 150 gpm between the second and third steps; however, it was found that the amount of drawdown was excessive, and the rate of discharge was reduced to 125 gpm. The recovering water levels were analyzed in the same manner as the data from well 35, using the method of analysis of step-pumping tests. Water levels measured during the test, the rate of discharge during the pumping period, and the arithmetic plot of analytical data are shown in figure 19. The data indicate a coefficient of transmissibility of about 4,900 gpd per foot in the vicinity of test hole 7. This figure is about equal to that determined in the old part of the well field. It will be noted that the well could produce no more than about 125 gpm. It is believed that the low yield is the result in part of both an insufficient amount of perforated casing and an inadequate development period.

Well 10

Well 10 was pumped for 48 hours from January 26 to January 28, 1955. The average rate of discharge was 156 gpm, measured by means of a totalizing meter in the line from the well to the storage tank. Antecedent and most recovering water levels were measured with a steel tape, and pumping-level measurements were made with an air-line and direct-reading gage. The water level prior to pumping was 81.9 feet below the measuring point. At the end of the 48-hour pumping period the water level had declined to 131.5 feet. Forty-eight hours after pumping stopped, the water level had recovered to about 84 feet.

Figure 20 shows the depth to water during the pumping and recovery periods of the test at well 10 and the rate of discharge during the pumping period. Figure 21 shows a semilogarithmic plot of residual drawdown versus t/t' . By applying the straight-line solution of the Theis recovery method, values for T from the recovery of well 10 ranged from 4,300 to 5,600 gpd per foot; the average is estimated to be about 4,500 gpd per foot.

Pumping of well 10 resulted in measurable drawdowns at a distance of about 1,500 feet south of the well in 48 hours. Although water levels were measured in several observation wells, only two wells had drawdowns of sufficient magnitude for use in computing the aquifer coefficients. The pumping of well 10 for 48 hours caused a drawdown of 8.93 feet in well 25, which is 225 feet southwest of well 10. Figure 22 shows the drawdown and recovering water levels in well 25 during the test of well 10. Figure 22 also shows the Theis type-curve analysis of the drawdown limb of the curve. The departure of the measured drawdown from the type curve indicates a probable hydraulic boundary. The coefficient of transmissibility of the aquifer indicated by the type-curve solution of the drawdown curve is 11,900 gpd per foot. A similar analysis for the recovery limb of the curve gives a value of 10,800 gpd per foot. The values for the apparent coefficient of storage indicated by the type-curve analyses of the drawdown and recovery limbs of the curve are 0.00034 and 0.00043, respectively, at the end of about 4 hours.

The pumping of well 10 for 48 hours resulted in a drawdown of 1.15 feet in well 2, which is about 727 feet south of well 10. Figure 23 shows the drawdown and recovering water levels in well 2 during the test at well 10. Figure 23 also shows the Theis type-curve analysis of the drawdown limb of the curve. As in the case of well 25, there is a departure of the observed data from the type curve, indicating the presence of a hydraulic boundary in the aquifer. Values for T and S, determined from the type-curve solution, are 63,800 gpd per foot and 0.0079, respectively.

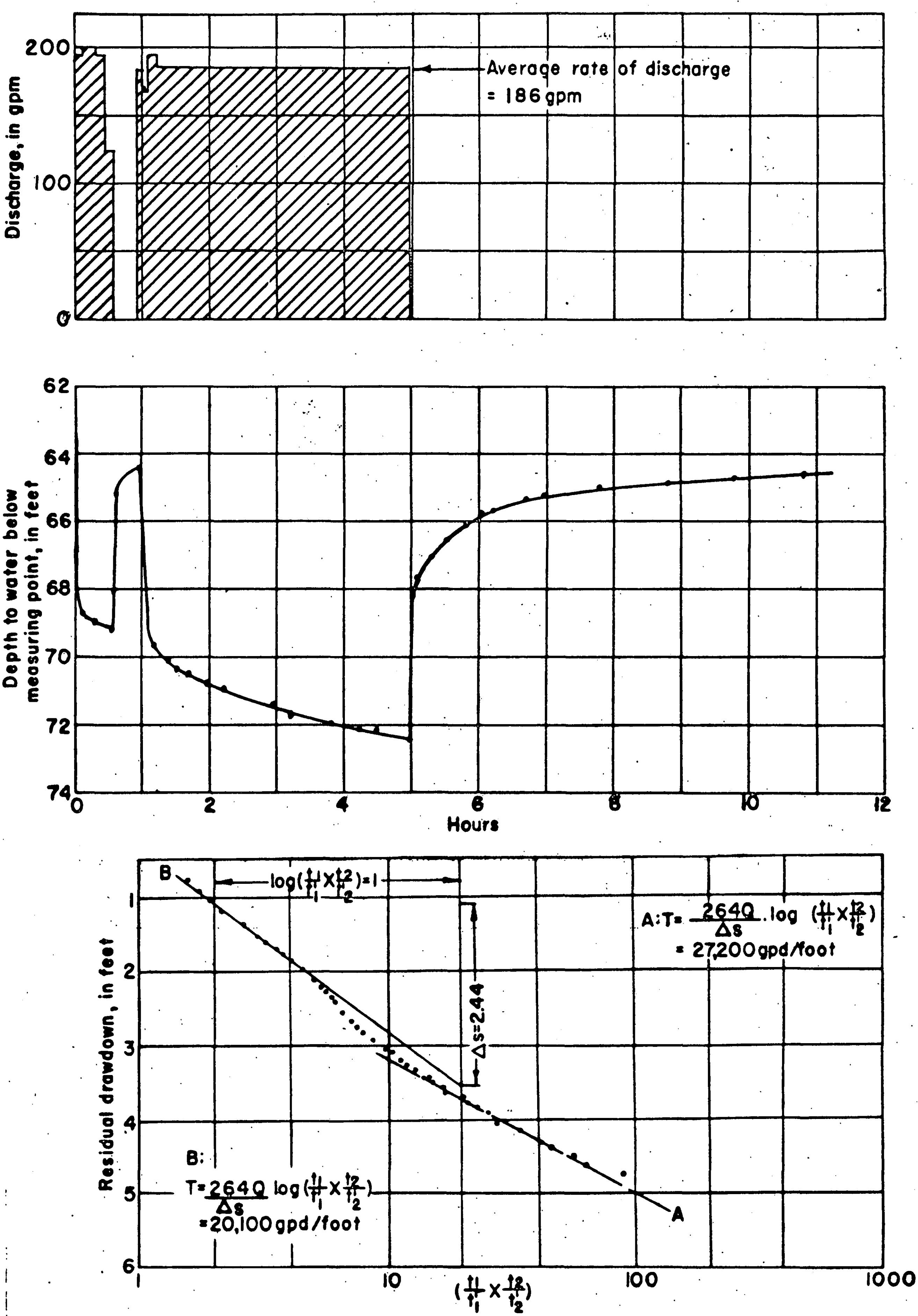


Figure 18.-- Rate of discharge and change in water level during aquifer test at well 33, Boles well field, Otero County, N. Mex.

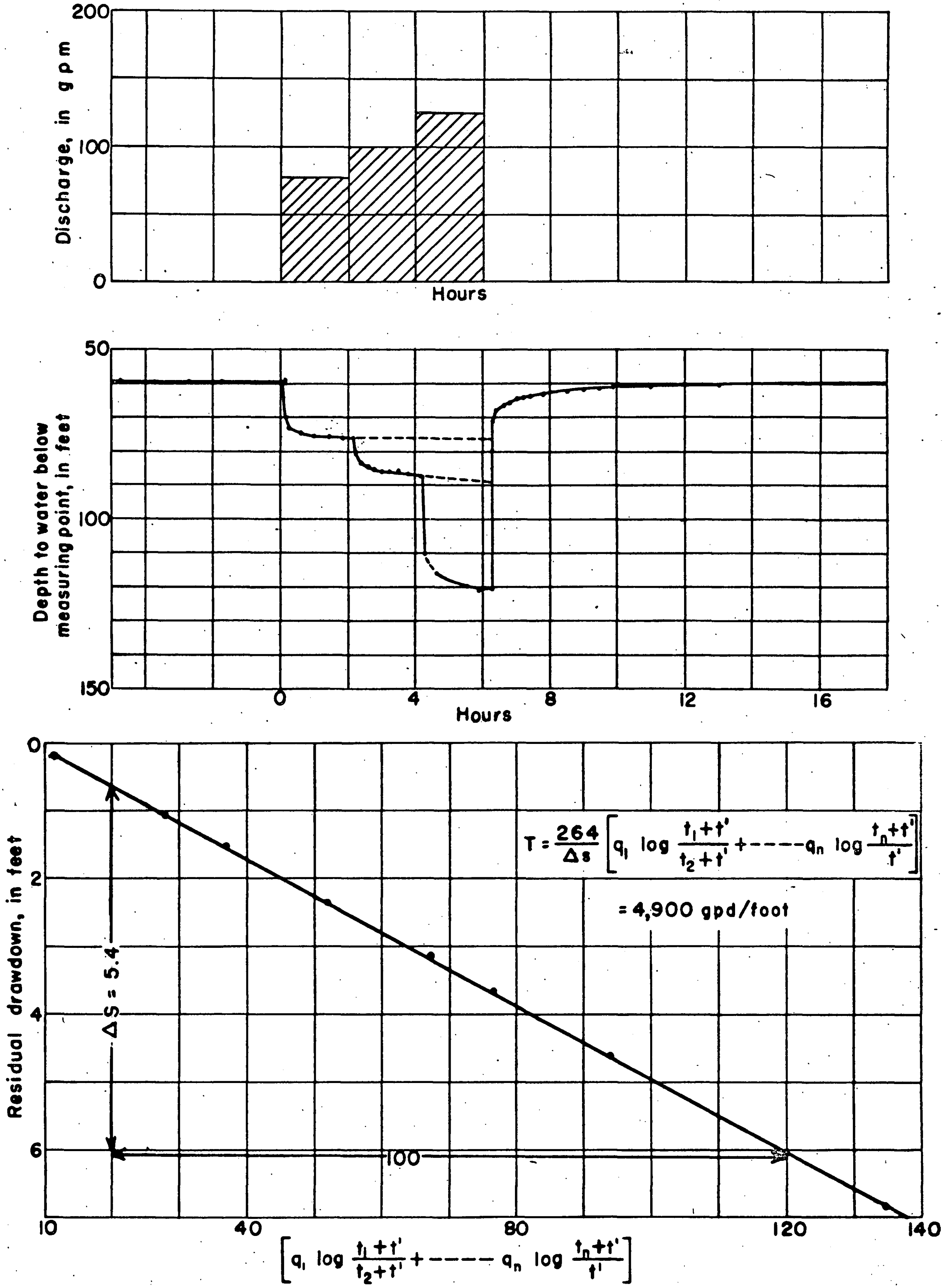


Figure 19.—— Rate of discharge and change in water level during aquifer test at test hole 7, (17.9.25.324), Otero County, N. Mex.

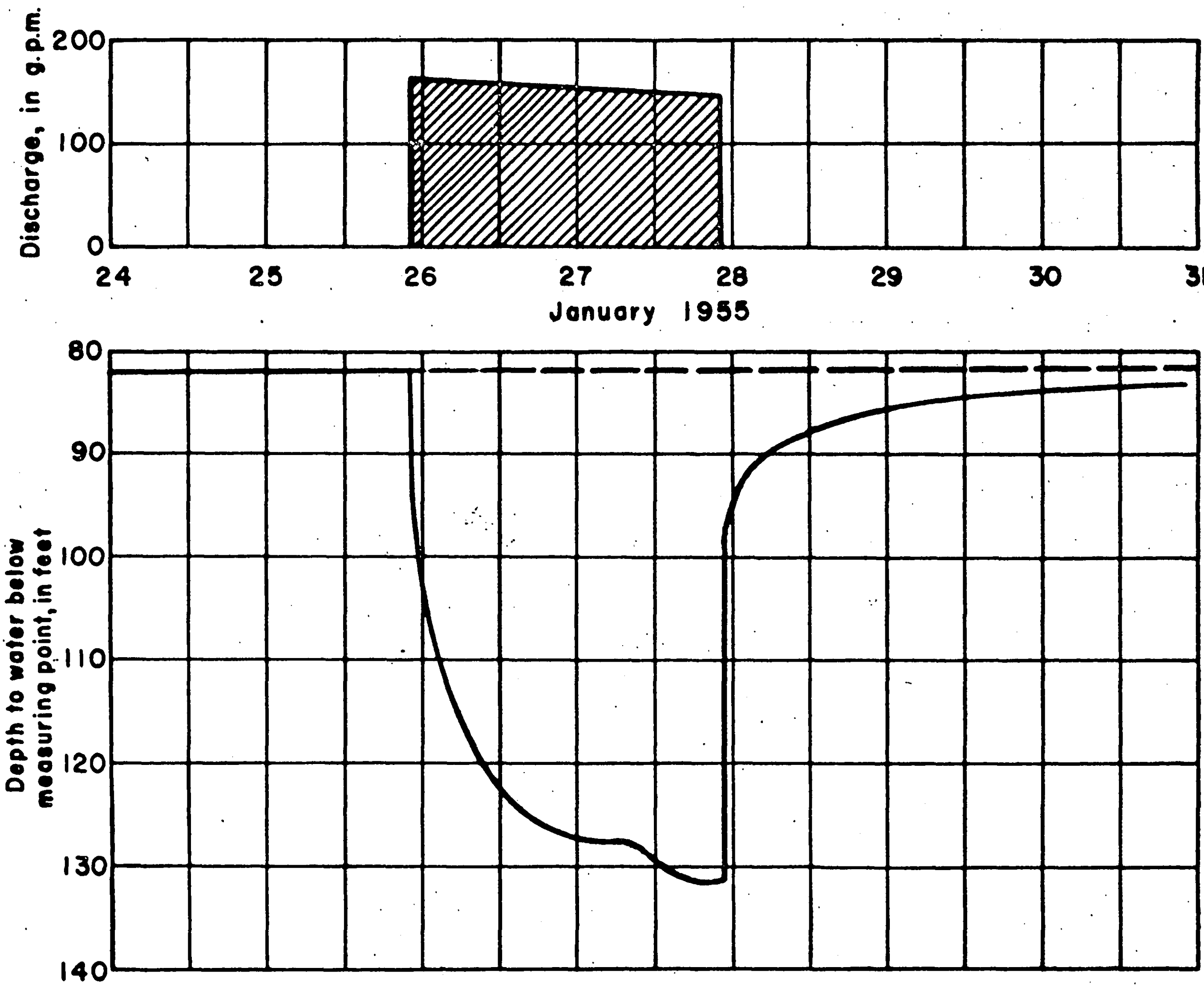


Figure 20.--Changes in water level and rate of discharge during aquifer test at well 10, Boles well field, Otero County, N. Mex.

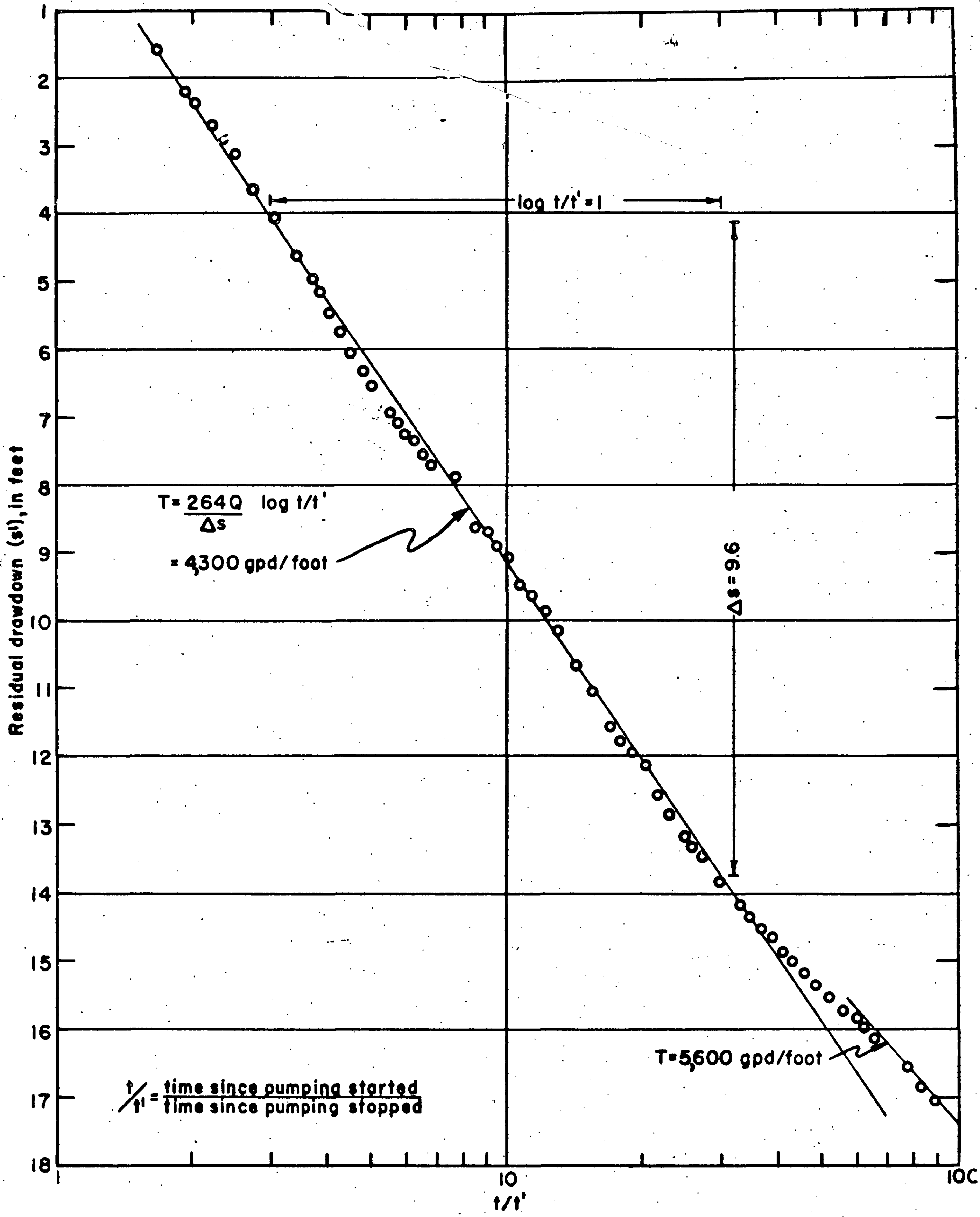


Figure 21.--Semilogarithmic plot of recovery of water level during aquifer test at well 10, Boles well field, Otero County, N. Mex.

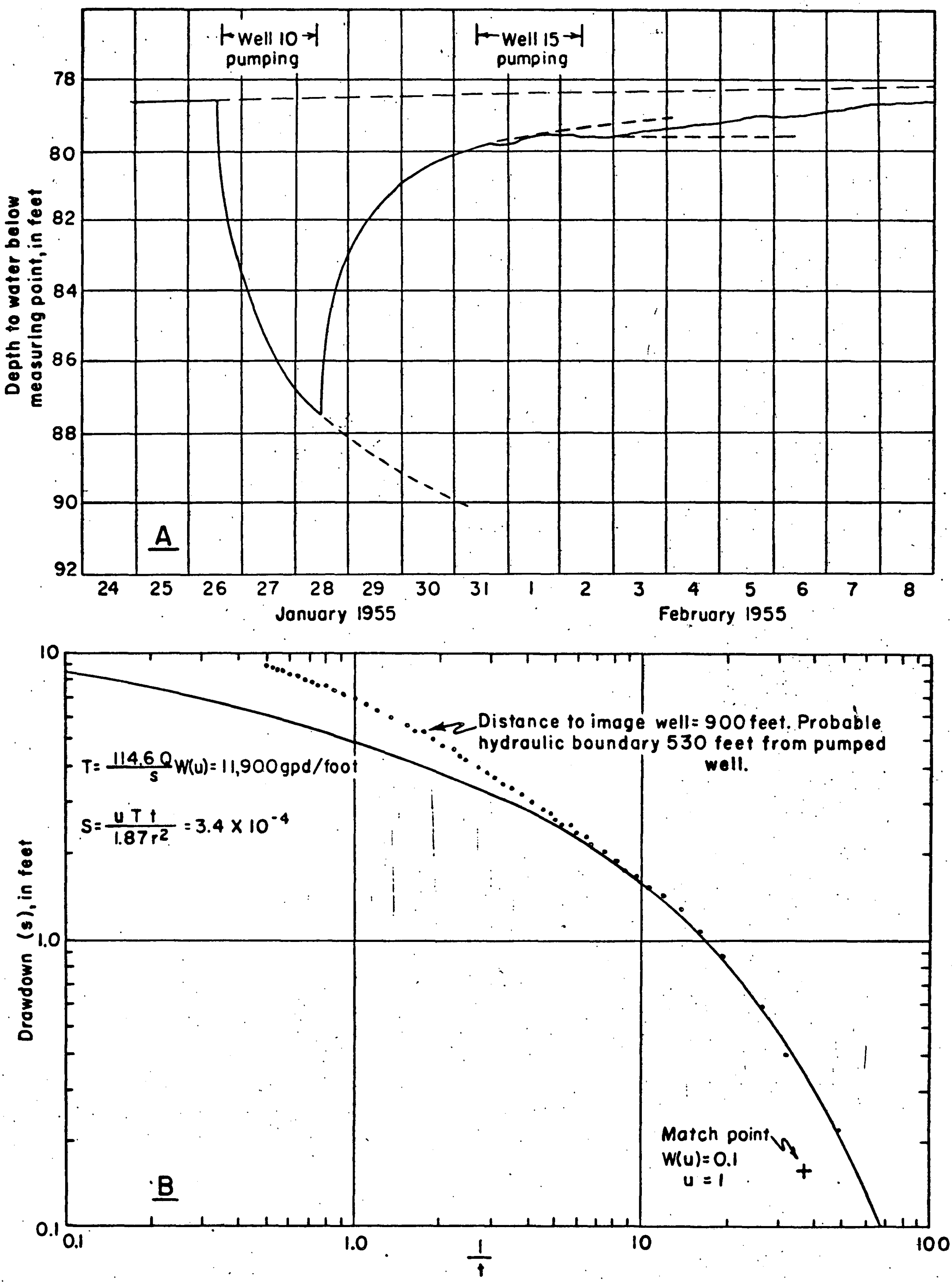


Figure 22.--A. Changes in water level in well 25 during aquifer tests at wells 10 and 15, Boles well field, Otero County, N. Mex.

B. Logarithmic plot of drawdown of water level in well 25, resulting from pumping well 10.

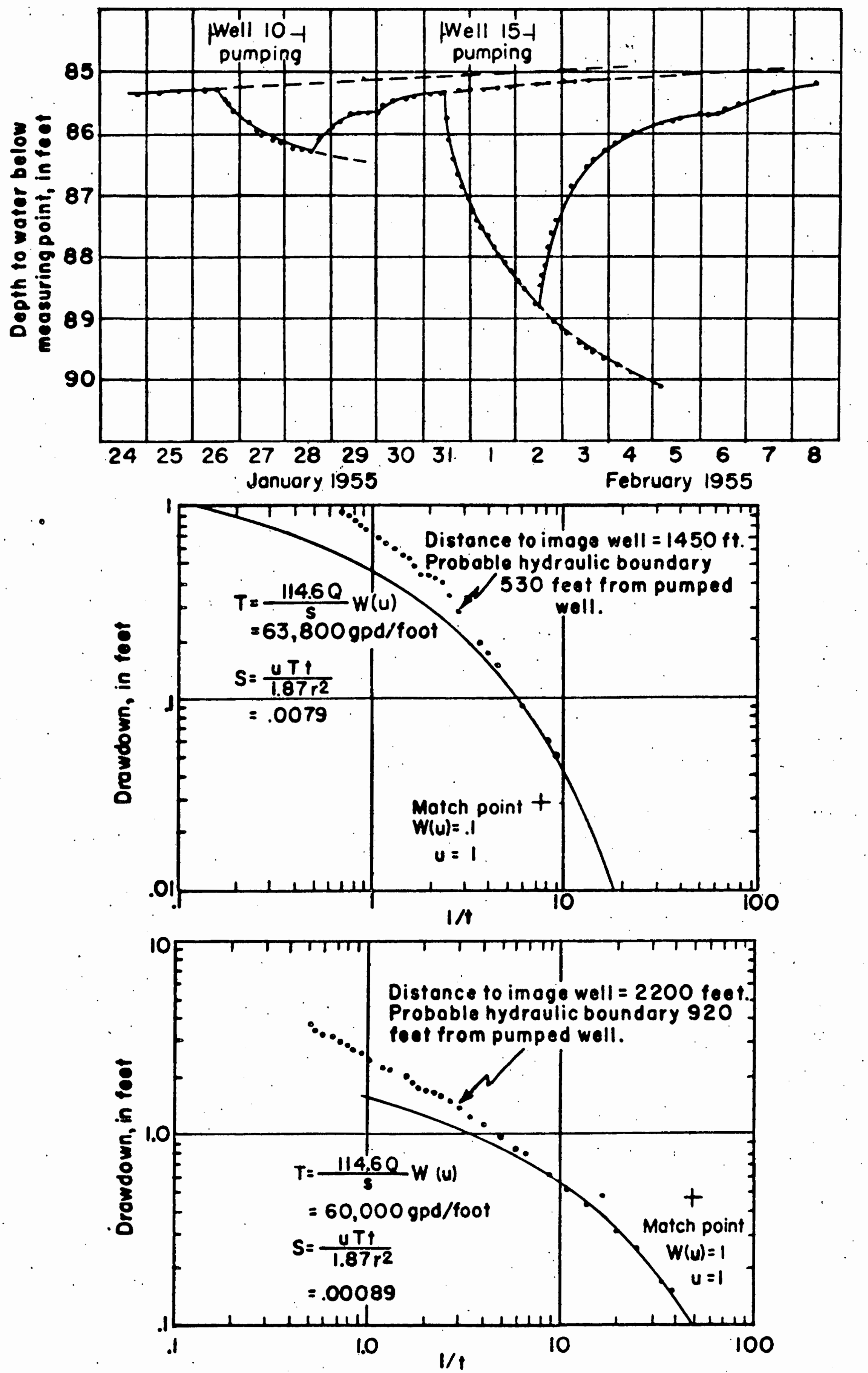


Figure 23.--Changes in water level in well 2 during aquifer tests at wells 10 and 15, and logarithmic plots of drawdowns in well 2 resulting from pumping wells 10 and 15, Boles well field, Otero County, N. Mex.

The values for the coefficient of storage obtained from the two observation wells indicate that the aquifer in the vicinity of well 10 contains water under artesian conditions. The values for the coefficient of transmissibility obtained from the observation wells are 2 to 15 times that obtained from the pumped well and should not be used for computation of long-term pumping effects.

Using Thiem's formula for the test at well 10 and using wells 2 and 25 as observation wells for a pumping time of about 48 hours, the computed value of T was 4,900 gpd per foot. In a similar computation for the test at well 10 and using wells 2 and 15 as observation wells, a coefficient of transmissibility of about 2,700 gpd per foot is obtained.

Well 15

Well 15 was pumped for 48 hours from January 31 to February 2, 1955. The average rate of discharge was 246 gpm, measured by means of a totalizing meter in the line between the well and the storage tank. Antecedent and most recovery water-level measurements were made with a steel tape. Pumping-level measurements were made with an air-line and direct-reading gage. The water level prior to pumping was 81.5 feet below the measuring point. At the end of the 48-hour pumping period the water level had declined to 195 feet. Forty-eight hours after pumping stopped, the water level had recovered to about 84 feet.

Figure 24 shows the depth to water in well 15 during the pumping and recovery periods and the rate of discharge of well 15 during the pumping period. Figure 25 shows the computation of the coefficient of transmissibility by means of the straight-line solution of the Theis nonequilibrium formula. The coefficient of transmissibility in the vicinity of well 15 ranges from about 2,700 gpd per foot to about 5,400 gpd per foot.

Drawdown in the aquifer as a result of pumping well 15 was determined by means of water-level measurements in wells 2, 5, 14, 25, and 30. All of these wells had drawdowns which, upon analysis, yielded coefficients of transmissibility 3 to 10 times greater than the values obtained at wells 10 and 15. Coefficients of storage obtained from the observation wells indicate artesian conditions in the vicinity of well 15 and the observation wells. Type-curve analyses of data from wells 2 (figure 23) and 30 indicate the existence of a hydraulic boundary.

By applying Thiem's formula to drawdowns in wells 2 and 25, and to drawdowns in wells 2 and 30, values for T amounting to 8,600 and 6,200 gpd per foot, respectively, were obtained.

Well 17

Well 17 was pumped for 72 hours from February 4 to February 7, 1955. The average rate of discharge was 395 gpm, measured by means of a totalizing meter in the line between the well and the storage tank. All water levels before, during, and after pumping were measured with a steel tape, with a minimum accuracy of 0.1 foot. The water level prior to pumping was 66.5 feet below the measuring point. At the end of 72 hours of pumping the water level had declined to 109.7 feet, and after about 72 hours of recovery the water level was about 71 feet.

Figure 26 shows the depth to water in well 17 during the pumping and recovery periods and the rate of discharge while pumping. Figure 27 is a semilogarithmic plot of recovery data using Theis' recovery formula. Although the line is not uniformly straight, it indicates a coefficient of transmissibility in the order 15,000 gpd per foot following initial recovery.

While well 17 was pumped, wells 16 and 33 were used for observation wells. There was no recognizable drawdown at either well as a result of pumping well 17. However, the approximate minimum value of the coefficient of storage could be estimated. If the pumping of well 17 for 3 days had caused 0.01 foot drawdown at well 33, 2,180 feet from the pumped well, and the coefficient of transmissibility at well 33 was in the order of 15,000 to 20,000 gpd per foot, then the apparent coefficient of storage would be approximately 0.025.

Well 17 subsequently was pumped for 12 days from February 15 to February 27, 1955. The average rate of discharge was 377 gpm. The resultant drawdown in well 33 amounted to 0.18 foot. For a coefficient of transmissibility of 15,000 gpd per foot, the indicated coefficient of storage is 0.04.

The test at well 17 indicates that a large part of the bolson fill in the vicinity of wells 17 and 33 contains water under water-table conditions at present, and the water-bearing fill in this area is considerably more permeable than that in the eastern part of the well field.

Well 32

The test at well 32 consisted of pumping the well for 24 hours from February 10 to 11, 1955. The average rate of discharge was 102 gpm, measured by means of an orifice. Antecedent and most recovery water levels were measured with a steel tape, and pumping levels were measured with an air-line and direct-reading gage. The depth to water prior to pumping was 69.8 feet below the measuring point. At the end of the pumping period the water level had declined to 121 feet; 24 hours after pumping stopped, the water level had recovered to about 70.5 feet.

Figure 28 shows water levels and rate of pumping during the test at well 32 and a plot of recovering water levels in the well. Analysis of figure 28 indicates that the coefficient of transmissibility of the formation in the vicinity of well 32 is about 1,500 gpd per foot.

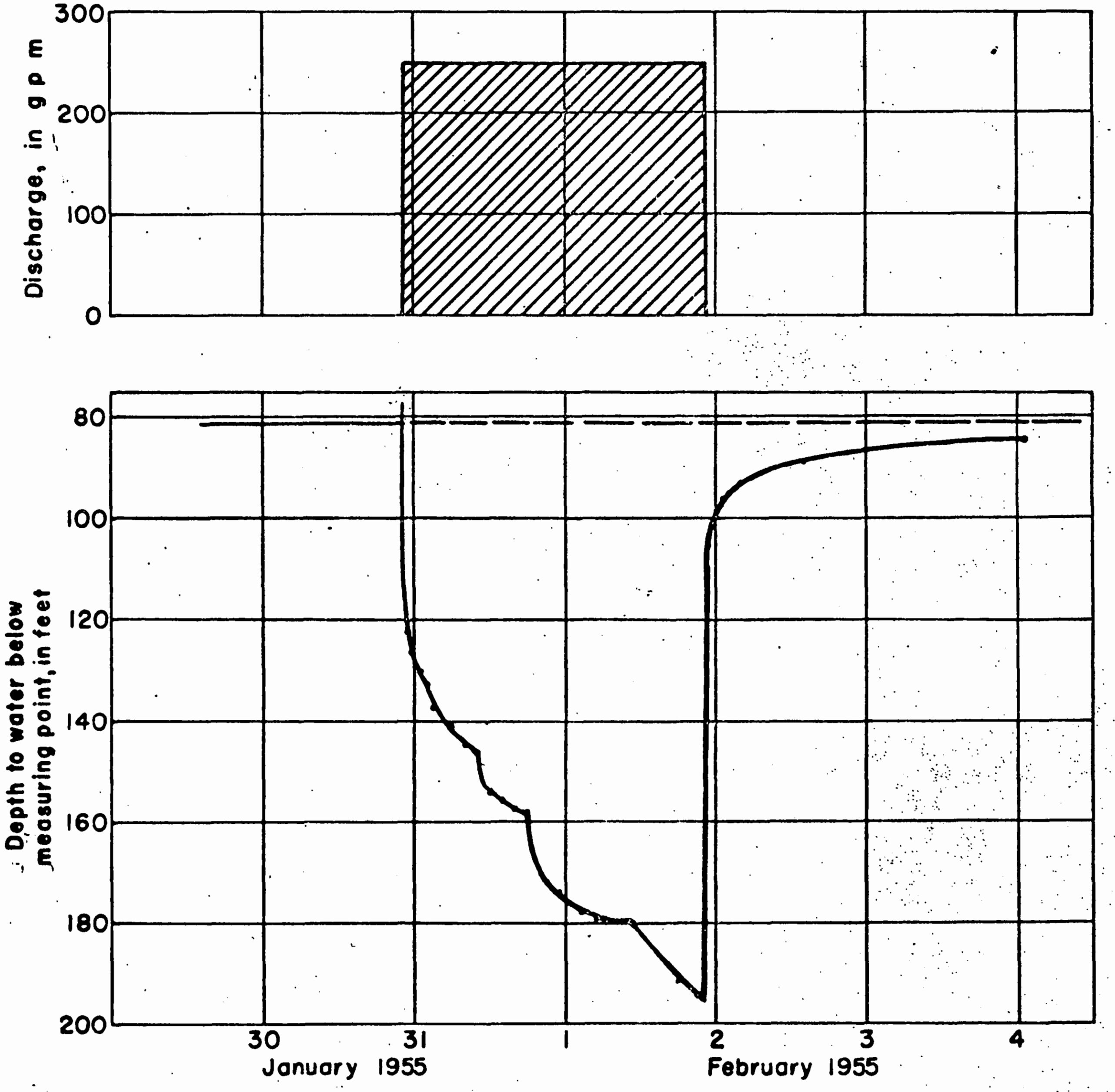


Figure 24.--Changes in water level and rate of discharge during aquifer test at well 15, Boles well field, Otero County, N. Mex.

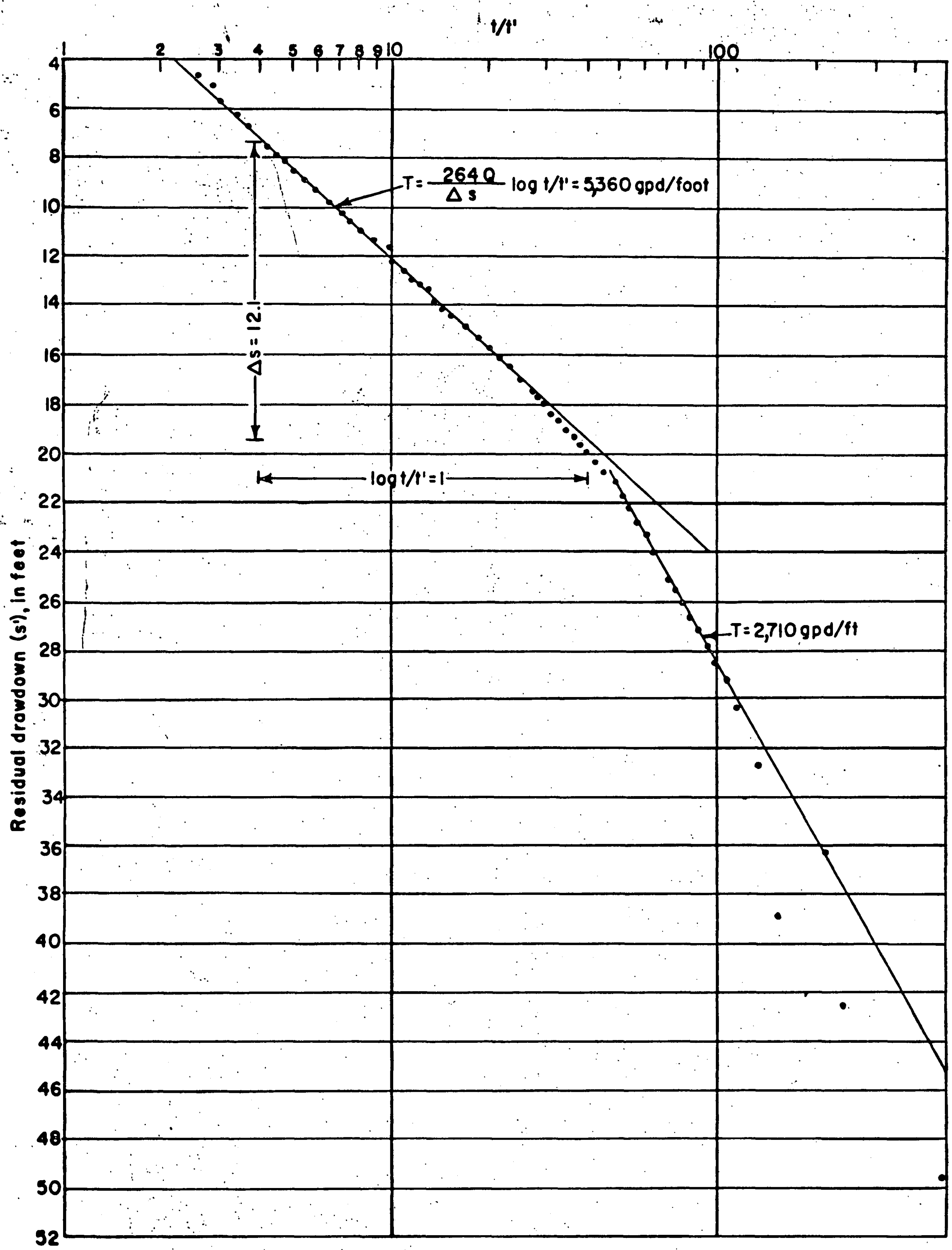


Figure 25.--Semilogarithmic plot of recovery of water level during aquifer test at well 15, Boles well field, Otero County, N. Mex.

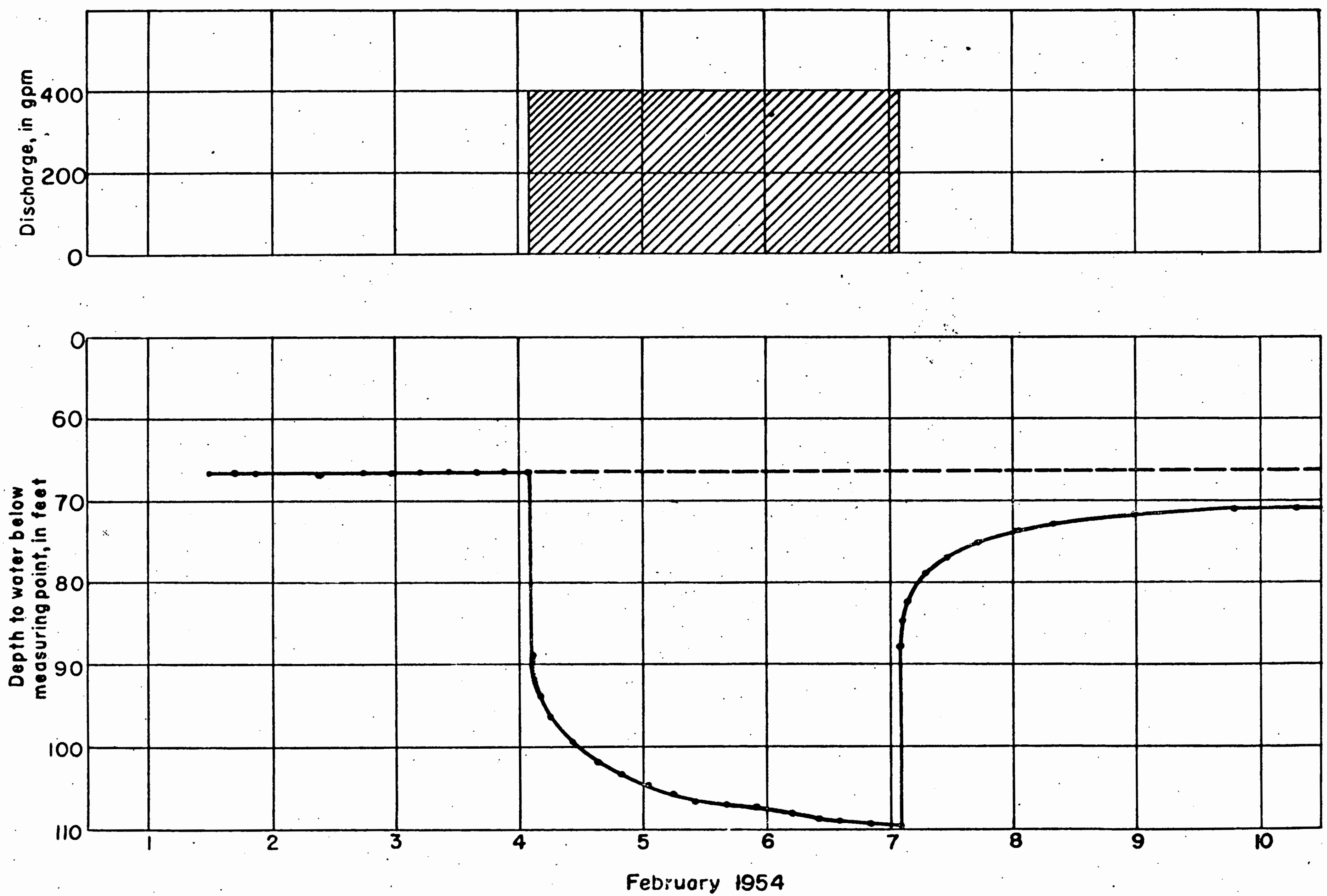


Figure 26.--Changes in water level and rate of discharge during aquifer test at well 17, Boles well field, Otero County, N. Mex.

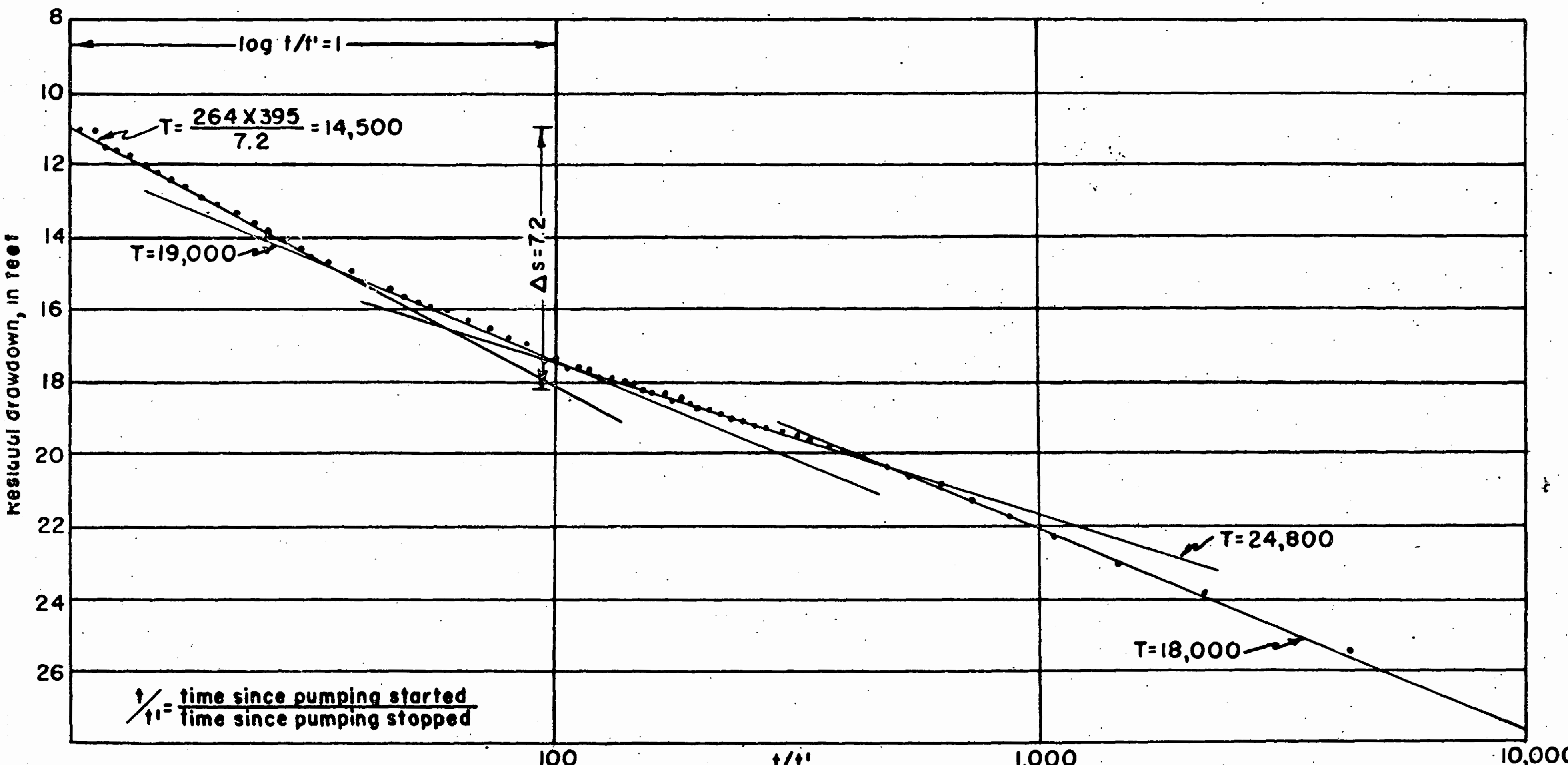


Figure 27.--Semilogarithmic plot of recovery of water level during aquifer test at well 17, Boles well field, Otero County, N. Mex.

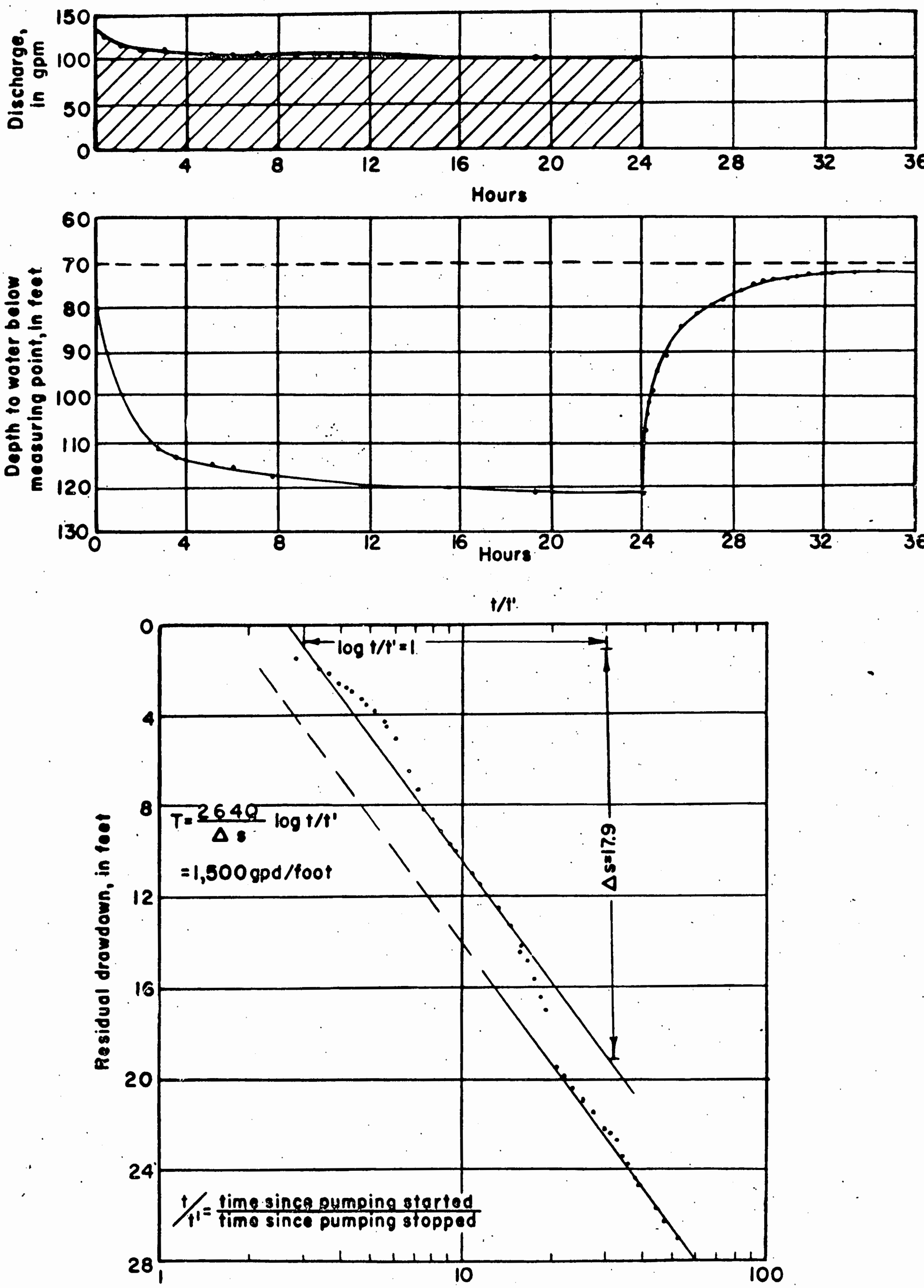


Figure 28.--Rate of discharge and change in water level, during aquifer test at well 32, Boles well field, Otero County, N. Mex.

Well 16, which is 585 feet west of well 32, was used as an observation well during the test. The water level in well 16 declined 0.9 foot as a result of pumping well 32 for 24 hours. The coefficients of transmissibility and storage obtained at well 16 were 24,300 and 0.0027, respectively. The value obtained for T at well 16 is abnormally high and is not considered to be accurate.

These data indicate that the permeability of the aquifer around wells 32 and 16 is low and that the ground water in the aquifer is under artesian pressure under nonpumping conditions.

Well 34

Well 34, the first of two new wells drilled in the spring of 1955, was completed in April. The well was cased to a depth of 255 feet below land surface with 10-inch casing which was perforated from 26 to 255 feet below land surface. The well was developed by surging and pumping for a period of 9 days. A great deal of fine sand was removed from the well during the development period.

On April 29, 1955, a step-pumping test of the well was made during a 14-hour period, which consisted of three steps of 4 hours each and a final step of 2 hours. During the test the pump was operated at rates of discharge of about 150, 200, 250, and 300 gpm. The prepumping water level was 64.5 feet below the measuring point. The water level while the well was being pumped declined to 97.1 feet at the end of the first step, 110.4 feet at the end of the second step, 128.3 feet at the end of the third step, and 144.8 feet at the end of the fourth step. The water level recovered to 70.6 feet about 2 hours after pumping stopped.

The data obtained during the test were not adequate for obtaining a value for the coefficient of transmissibility of the aquifer. However, the performance of the well indicates that the coefficient of transmissibility is at least as great as that measured in the old or eastern part of the well field.

Well 35

Well 35, the second of two wells drilled in the Boles well field in the spring of 1955, was completed early in May. The well was drilled to a depth of 280 feet, but was cased to only 236 feet below land surface. The 10-inch casing was perforated from 60 to 236 feet below land surface. Development of the well was accomplished by (1) 6 hours of surging with a close-fitting surge block and bailing, (2) treatment with 100 pounds of sodium hexametaphosphate mixed with water in the well while the pump was being set, and (3) intermittent pumping and surging for a period of 4 days.

A 30-hour step-pumping test of well 35 was started on May 23, 1955, and consisted of five successive steps, each of 6 hours' duration. During the test the pump was operated at rates of discharge of 250, 300, 350, 400, and 450 gpm, respectively. The deep pumping level during the last step caused the rate of discharge to decline to an average of 411 gpm for the step. The depth to water prior to pumping was 72.7 feet below the measuring point. During the pumping period the water level declined to 93.5 feet at the end of the first step, 99.1 feet at the end of the second step, 105.9 feet at the end of the third step, 114.6 feet at the end of the fourth step, and about 141 feet at the end of the fifth step. The water level recovered to about 74.7 feet 20½ hours after pumping stopped.

The data from the test at well 35 were analyzed by means of the extension of the Theis nonequilibrium formula for step-pumping tests. The water levels during the test, the discharge of the well during the pumping period, and the arithmetic plot of analytical data are shown in figure 29. The test data indicate a coefficient of transmissibility of about 11,700 gpd per foot for the aquifer around the pumped well. This figure is commensurate with the values obtained at wells 17 and 33 and is a further indication of the relatively high permeability of the aquifer in the vicinity of those wells.

Specific Capacities of Wells

A measure of the capacity of a well to yield water is expressed by the formula:

$$SC = \frac{Q}{s}$$

where SC is the specific capacity, in gpm per foot of drawdown, Q is the rate of discharge from the well, in gpm, and s is the drawdown of the water level in the well, in feet. With certain limitations, wells may be compared, one with another, by comparing their specific capacities. The specific capacities of most of the Boles wells and of the two Town of Alamogordo wells nearby are given in table 7.

Specific capacities should not be compared indiscriminately. It is necessary to take into account the length of time and the rate at which the well has been pumped when the specific capacity is determined. When pumping begins, the water level in the well declines very rapidly, and if the rate of discharge is held constant, the rate of decline generally will diminish as the pumping period lengthens. Therefore, the specific capacity of a well diminishes at a decreasing rate as the drawdown increases and should not be determined until the well has been pumped for a relatively long period of time and the rate of decline is slow. Owing to the change in specific capacity with time and drawdown, the specific capacities of two wells ideally should not be compared unless the pumping periods are of approximately equal length. To compare two wells, it is also desirable to have specific capacities for various pumping periods. For example, in table 7, it may be seen that wells 10 and 26 yield 3.3 and 3.1 gpm per foot of drawdown, respectively, at the end of 24 hours of pumping, but at the end of 48 hours the specific capacities were 2.9 and 3.1, respectively. The concept of specific capacity varying with time is illustrated in figure 30. Note in the figure that the short-time specific capacities may be as much as twice as great as the long-time values.

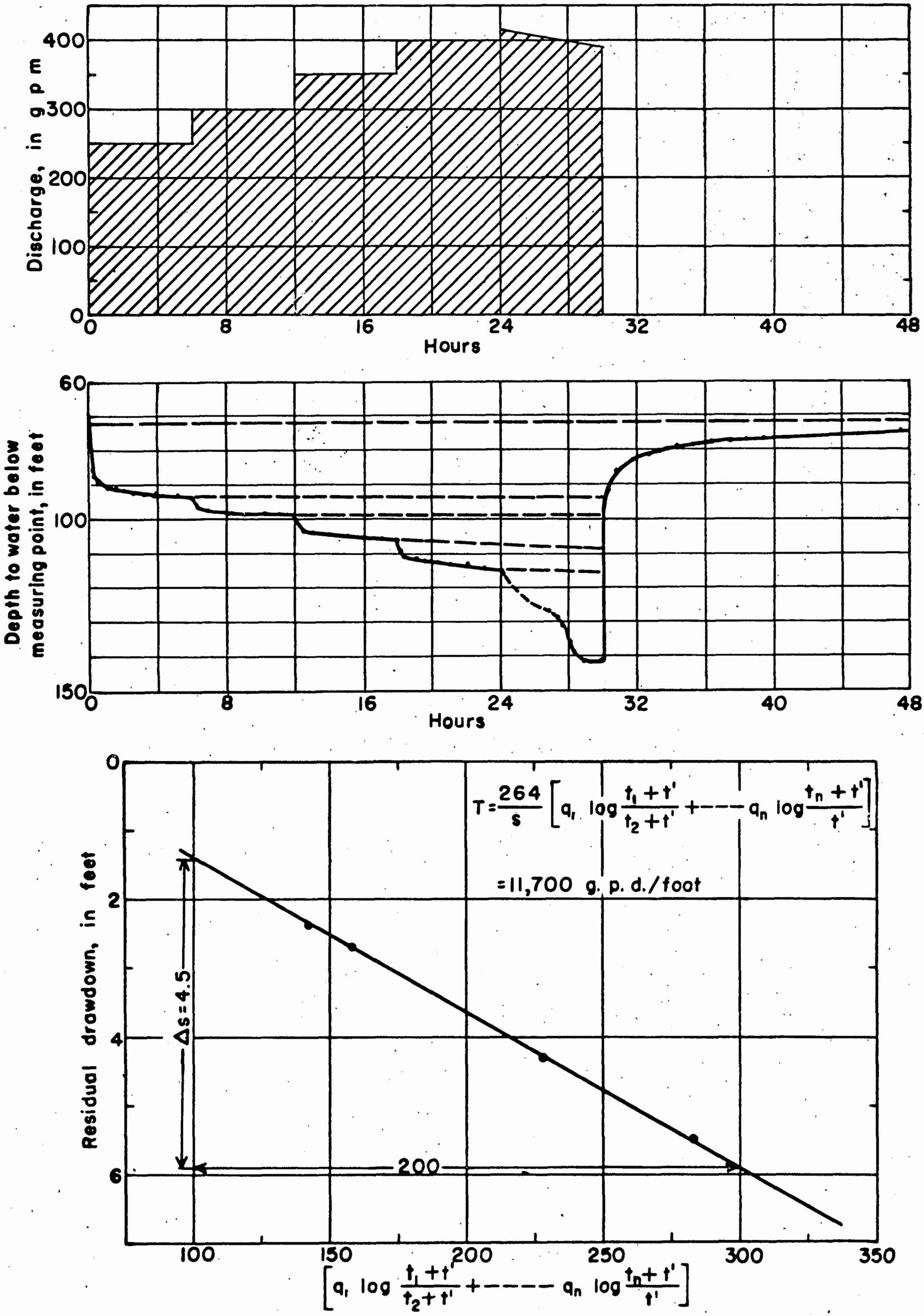


Figure 29.--Rate of discharge and change in water level during aquifer test at well 35, Boles well field, Otero County, N. Mex.

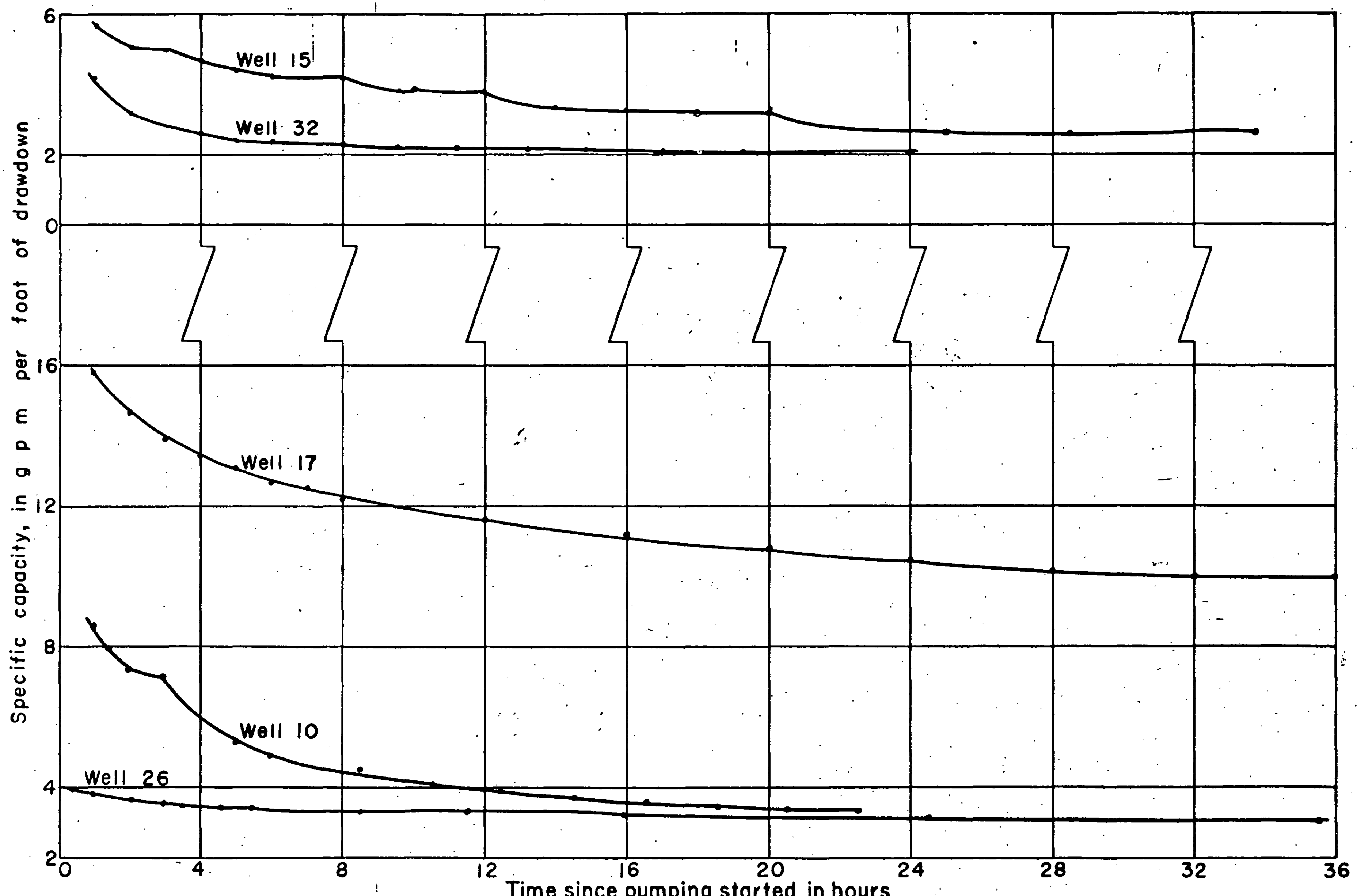


Figure 30.--Specific capacities of selected wells in Boles well field, Otero County, N. Mex.

Table 7.--Specific capacities of production wells in and near Boles well field, Otero County, N. Mex.

Well number	Date	Length of pumping period (hours)	Rate of discharge (gpm)	Specific capacity (gpm per foot of drawdown) 4 hours	8 hours	12 hours	24 hours	36 hours	48 hours	Aquifer coefficient of transmissibility (in gpd/ft)
2	1955	-	184	-	-	1.8 1/	-	-	-	-
5	1955	-	127	-	-	1.7 1/	-	-	-	-
10	Jan. 1955	48	156	5.7	4.6	3.9	3.3	3.1	2.9	4,300
10	1955	-	149	-	-	2.2 1/	-	-	-	-
15	Jan. 1955	48	246	4.7	4.2	3.8	2.7	2.5	2.2	5,360
15	1955	-	230	-	-	2.8 1/	-	-	-	-
16	1955	-	94	-	-	1.3 1/	-	-	-	-
17	Feb. 1955	72	395	13.4	12.2	11.6	10.5	10.0	9.6	15,000
17	1955	-	331	-	-	9.7 1/	-	-	-	-
26	July 1954	150	176	3.5	3.3	3.3	3.1	3.1	3.1	4,480
26	1955	-	174	-	-	3.3 1/	-	-	-	-
32	Feb. 1955	24	102	2.6	2.3	2.2	2.1	-	-	1,500
33	Sept. 1954	5	186	22	-	-	-	-	-	20,100
33	1955	-	357	-	-	12.2 1/	-	-	-	-
34	Apr. 1955	14	160	4.7	-	-	-	-	-	-
34	1955	-	220	-	-	4.3 1/	-	-	-	-
35	May 1955	30	265	12.9	-	-	-	-	-	11,700
35	1955	-	292	-	-	9.9 1/	-	-	-	-
17.9.35.242 (Town of Alamogordo no. 1)	Dec. 1954	14	1,076	16.2	15.8	15.8	-	-	-	-
17.9.35.444 (Town of Alamogordo no. 2)	Nov. 1954	54	720	-	-	-	8.6	6.9	-	-

1/ Average specific capacity computed from summertime well field operation records. Wells producing at operational rates. All other 12-hour values determined during aquifer tests in wintertime.

It is readily apparent that one of the main factors regulating the specific capacity of a well is the coefficient of transmissibility of the aquifer around the well. Conversely, the specific capacity of a well can be used to estimate the permeability of the aquifer, but there are sources of error which do not permit an exact correlation. In the eastern part of the Boles well field, where relatively low coefficients of transmissibility were indicated by aquifer tests, the specific capacities of wells range from 1.3 to about 3.3 gpm per foot of drawdown. In the western part of the well field, specific capacities range from about 4.3 to more than 12.2 gpm per foot of drawdown. In the latter area, the coefficients of transmissibility were found to be 1 to 4 times greater than in the eastern part of the well field.

Some of the other factors influencing specific capacity are usually grouped under the general term "well losses". These losses include friction loss from water passing through the screen into the well. Such loss may be caused by insufficient amounts of screen, screen plugging by encrustation, or improper screen installation. In addition to friction losses, there are well losses which may be attributed to turbulence at the well face, the entrainment of air in the discharged water caused by water falling from the screen to the water surface in the well, and the installation of oversized pumps. With reference to the size of pumps used, it might be pointed out that the specific capacity of a well is partly dependent on the rate of pumping. Specific capacities tend to be lower at high rates of pumping, principally because well losses are greater at higher rates of pumping.

The remaining factors influencing the specific capacity of a well are those relating to conditions in the aquifer. If an aquifer is pumped at a given rate the water level around the well declines at a predictable rate, and the specific capacity will assume a relatively stable value. However, if the rate of pumping or the length of pumping period is such that the water level declines to the extent that a large part of the aquifer is dewatered, the drawdown may increase again and the specific capacity continue to diminish, perhaps abruptly. Often the specific capacity of a well may vary with the season of the year, depending on how much pumping of nearby wells takes place seasonally. During the summer, increased draft on the aquifer may lower nonpumping levels, which in turn reduces yields by reducing the saturated thickness of the aquifer. In addition, mutual interference between pumping wells increases the drawdown and consequently lowers the value for specific capacity. Evidence of this difference in seasonal values for specific capacity may be found in table 7. In the table, the 12-hour values of specific capacity obtained during the wintertime aquifer tests are substantially higher than the 12-hour values computed from summertime pumping records.

In summary, the specific capacity of a well is a useful tool if used judiciously. It may be used as a general indication of the permeability of the aquifer, and as an indication of the comparative performances of two or more wells. However, the specific capacity should not be used without reference to the time at which the value was determined and the rate at which the well was pumped. It should be recognized that the value of specific capacity is influenced by many factors and therefore cannot be used as an absolute figure for any well. In table 7 the data given were obtained from aquifer tests in the well field and were computed from reported well-field operation records for the summer of 1955.

Summary of Hydrologic Characteristics of the Bolson Fill

In the Boles well field, the results of aquifer tests have revealed that the bolson fill in and around the well field does not have a uniform permeability. In general the aquifer becomes more permeable, and therefore has a higher coefficient of transmissibility, westward away from the mountains. It appears that there also may be a northward trend of increasing permeability in the western part of the well field.

Aquifer tests in the eastern part of the well field show that a hydraulic boundary exists west of wells 2, 10, and 15, and east of well 35, which trends northward and roughly parallels the range line between Rs. 9 and 10 E. The hydraulic boundary represents either a zone of low permeability or a thinning of the water-bearing formation. In view of the predominant clay content of the formation encountered by Boles well 7, it appears that low permeability probably causes the hydraulic-boundary effect. The presence of the boundary is substantiated by the nose or downslope bulge on contours in the detailed water-table contour map shown in figure 6. The contours also substantiate the conclusion that there are areas of higher permeability both east and west of the nose, because the contours show troughs in those areas.

Table 8 gives a summary of the values for the coefficients of transmissibility and storage obtained from aquifer tests in the Boles well field. It may be seen that the values for the coefficient of transmissibility of the aquifer vary considerably from well to well. Examples are wells 26 and 28, which are in an area where the average coefficient of transmissibility probably is about 4,000 to 4,500 gpd per foot. The variation of values is the result of the irregular nature of sedimentation in the bolson fill, both vertically and laterally. The trend toward higher coefficients of transmissibility in the western part of the well field is superimposed on the local variability, and reflects the increasing differentiation or sorting of the fill with distance from the mountains. It should be noted that wells 2 and 25 are observation wells, and the aquifer coefficients given for them are not believed to be accurate. They are included only as examples of the results obtained from water-level measurements at observation wells.

Values for the coefficient of transmissibility in the Boles well field range from about 4,000 gpd per foot in the eastern part of the well field through a low value of 1,000 to 2,000 gpd per foot in the area of the hydraulic boundary to about 20,000 gpd per foot in well 33 in the northwestern part of the well field.

The coefficient of storage and the specific yield of the aquifer in the area of the Boles well field were not obtained directly from the aquifer tests. Those values for the coefficient of storage obtained from the aquifer tests show that the ground water in the eastern part of the well field, as far west as well 16, is stored under artesian conditions. In that area the coefficient of storage was found to be in the order of 0.001 or less. In the area where S, the coefficient of storage, was estimated to be greater than 0.01, from the vicinity of well 35 westward to wells 34 and 33, ground water is stored under water-table conditions. However, the values for the coefficient of storage given in table 8 were determined from short tests and are not believed to be as reliable as values which could be obtained from long-term records of pumpage and water-level measurements.

In order to determine the coefficient of storage of the sediments over a long period of time, the trend of water levels in well 33 was related to to the pumpage from the Boles well field. Well 33 is the only well in the area having a long record of water-level measurements. Although well 33 is presently integrated into the water system, it was relatively unused prior to 1955. Owing to the relatively great distance of well 33 from the eastern part of the well field, the older group of wells was treated as a single well discharging at a constant rate of 253 gpm in 1952 and 246 gpm in 1953, for the period April 1952 to February 1954. The center of pumping was 4,200 feet east-southeastward from well 33. Well 17 was treated separately because it is only 2,180 feet from well 33 and is south of well 33. In 1953 the amount of water pumped from well 17 was equivalent to a constant rate of discharge of 139 gpm. In the period April 1952 to February 1954 the water level in well 33 declined 2.5 feet as an overall result of the pumping. The aquifer tests revealed that the coefficient of transmissibility (T) is about 20,000 gpd per foot at well 33, about 15,000 at well 17 and about 5,000 in the eastern part of the well field. By averaging the value of T at well 33 with each of the values of T at well 17 and at the center of pumping of the older wells, using a drawdown of 2.5 feet at well 33, and using various values for the storage coefficient, (S), it was found that S, in the well field, amounted to about 0.085. This value is assumed to approximate the specific yield of the bolson fill in the area. In view of the fact that the fill is predominantly fine-grained, an average specific yield of 0.085 appears to be the right order of magnitude and has been used for computing the effects of future pumping.

Table 8.--Summary of aquifer coefficients determined from tests in Boles well field, Otero County, N. Mex.

Well number	Coefficient of trans-missibility (gpd/ft)	Coefficient of storage	Limb of curve	Type of analysis	Pumped well
2	63,800	0.0079	Drawdown	Type curve	10
2	60,000	.00089	do.	do.	15
10	4,500	-	Recovery	Theis recovery	10
15	5,360	-	do.	do.	15
17	15,000	-	do.	do.	17
25	11,900	.0034	Drawdown	Type curve	10
25	10,800	.00043	Recovery	do.	10
26 a/	4,480	.0012 to .0031	Drawdown	do.	26
28	1,370	.001 b/	Recovery	Theis recovery	28, 26
32	1,500	-	do.	do.	32
33	20,100	.04 c/	do.	do.	33
35	11,700	-	do.	Extended Theis recovery	35
T-7	4,900	-	do.	do.	T-7

a/ Water levels measured outside casing. Coefficient of storage estimated.

b/ Estimated from test at well 26.

c/ Estimated from test at well 17.

EFFECTS OF PUMPING

Decline of Water Levels

Pumping in the Boles well field has resulted in water-level declines, and declines will continue as pumping continues. Comparison of the various data indicates that the maximum decline in the center of the older part of the well field is on the order of about 20 feet. Three-eighths of a mile south of well 16, the water level has declined between 5 and 8 feet. At well 33, the decline of the water level over the 8-year period of pumping may have been as much as 8 feet.

If the hydrologic characteristics of an aquifer are known and the aquifer substantially satisfies the assumptions of the Theis nonequilibrium formula, the effects of a well or wells discharging from that aquifer can be computed with a reasonable degree of accuracy. The heterogeneity of the aquifer in the Boles well field is such that the aquifer does not satisfy the assumptions of the Theis equation. However, to demonstrate the probable order of magnitude of future declines in the well field, a hypothetical observation well was located near the physical center of the well field at location 17.10.19.114, and the water-level decline was computed on the assumption that the aquifer conformed to the idealized conditions. In addition to the basic assumptions of the Theis theory, it was necessary to make several simplifying assumptions which are (1) only the 11 production wells existing in 1955 were considered as pumping, (2) each well was pumped continuously at a rate based on (a) the rated yield of the well, (b) the percentage of that yield in the total capacity of the well field, which amounted to about 2,275 gpm in 1955, and (c) the assumed daily rate of total well-field pumping, (3) the coefficient of transmissibility at the hypothetical observation well was 4,500 gpd per foot, (4) the coefficients at the observation well and at each pumped well were averaged, and (5) the coefficient of storage was a uniform 0.085 throughout the well field. Table 9 shows the declines that would theoretically occur in the observation well for periods of 5, 10, and 20 years for three rates of total well-field pumping.

It would be expected that under normal operating procedure the various wells would be pumped intermittently at greater rates. Continuous pumping at the lower rates would have much the same effect as intermittent pumping at the higher rates. More important, neither the local hydraulic boundary nor the boundary at the base of the adjacent mountains was taken into account in the computations because of the complexity of analysis.

The declines shown in table 9 are not intended to be used as absolute values. However, it is believed they do show the order of magnitude of declines that may be expected. The three assumed rates of well-field production were used to demonstrate the relative effects of (1) possible reduction of pumping through the use of water from Bonito Lake, (2) continuation of pumping at about the 1955 rate, and (3) a slight increase in production.

Table 9.--Maximum probable drawdowns in a theoretical observation well at location 17.10.19.114 in Boles well field, Otero County, N. Mex., under certain simplifying assumptions.

Years	Average rate of well field pumping (mgd)	Decline (feet)
5	0.60	19
5	.75	25
5	1.00	33
10	.60	25
10	.75	31
10	1.00	41
20	.60	30
20	.75	38
20	1.00	50

In order to demonstrate further the probable effects of future pumping, the theoretical radius of the cone of depression around the well field was computed for pumping periods of 5, 10, and 20 years. In order to make the computations it was necessary to assume that (1) the bolson fill has an average coefficient of transmissibility of 10,000 gpd per foot, (2) the coefficient of storage of the fill is 0.085, and (3) the 11 production wells are pumped continuously at the rates used in computing the drawdowns shown in table 9.

The results of the computations show that if the aquifer were uniform in permeability the gross effect of pumping in the Boles well field would produce a drawdown of 0.01 foot at a distance 3 miles west of U. S. Highway 54 in 5 years, 5 miles west of the highway in 10 years, and 7 miles in 20 years. The drawdown of 0.01 foot would extend northward to the intersection of U. S. Highways 70 and 54 in 5 years, to the south edge of Alamogordo in 10 years, and to the north edge of Alamogordo in 20 years.

Although a drawdown of 0.01 foot would indicate the measurable edge of the cone of depression, a decline of this magnitude would not create a significant change in the direction of slope of the water table. In order to show how the probable effects of pumping might affect the direction of slope of the water table, the distances to 1 foot of decline were computed for pumping periods of 5, 10, and 20 years. The computations involved the same assumptions used in computing the theoretical radius of the cone of depression. The results of computation show that 5 years of pumping of the well field could result in a drawdown of 1 foot at a distance of about a mile or more from the west edge of the well field. The pumping of well 17 alone could create in 5 years a decline of 1 foot at a distance of about one-half mile west of the well field. The decline would be increasingly greater toward the well field. At the end of 20 years of pumping of the well field, a decline of 1 foot could occur at a distance of 3 miles or more west and north of the well field. A decline of 1 foot would not create a significant hydraulic gradient toward the well field.

In summary, the future effects of pumping on water levels in and near the Boles well field can be forecast within limits using available data. Estimates of the effects have been made and are based on several assumptions. These estimates are not firm figures but are made only to demonstrate the order of magnitude of declines of the water table that may occur. Pumping of the well field may create a cone of depression with a depth in the center of the field ranging from about 20 to 30 feet in 5 years to about 30 to 50 feet in 20 years, depending on the rate of pumping. Measurable decline of the water table could occur at distances ranging from about 3 miles in 5 years to about 7 miles in 20 years. Declines of significant magnitude (1 foot or more) may develop 1 mile or more from the well field in 5 years, and 3 miles or more in 20 years.

Encroachment of Saline Waters

There are two sources from which saline water can migrate to the production wells as a consequence of heavy pumping in the Boles well field. The first and largest source is the saline-water body in the aquifer north, northwest, and west of the well field; the second is the shallow ground-water body in the well field itself.

Of the two sources, the shallow-water body in the well field poses the most immediate problem, since adulteration from that source is already evident in wells 10 and 14. Considering the changes in chemical character of ground water from the two wells, it is believed that the adulteration is the result of downward migration of the shallow ground water through beds of slightly permeable silt and clay. The shallow ground water is of poor quality to begin with, and passage through the clays increases its mineral content and changes its chemical character. If downward migration is the major cause of increasing salinity in the two wells, little can be done to remedy the condition other than to stop pumping the two wells. It is possible that wells 10 and 14 might be usable for the practice of artificial recharge.

Encroachment of saline water from the north, northwest, and west into the well field probably will occur eventually. The length of time for encroachment into the well field depends largely upon the extent to which measures are taken to retard the encroachment. Reducing the rate of pumping in secs. 24 and 25, T. 17 S., R. 9 E., locating new wells to the south-

southeast, rotating the pumping among the wells, and possibly artificially recharging the aquifer in the western part of the present well field would undoubtedly retard the rate of saline encroachment.

By January 1955, saline-water encroachment into the well field from the north and west had not been detected. Plate 2 shows that ground water containing 500 ppm or more of sulfate existed not more than half a mile west-northwest of well 33. Figure 6 shows that the slope of the water table in the vicinity of well 33 in January 1955 was toward the southwest, and that the slope of the water table throughout most of the well field is generally toward the south. The slope of the water table indicates that in January 1955 saline water was moving toward the well field only from the north. However, it is almost certain that encroachment will also occur from the northwest. In the foregoing section on water-level declines resulting from future pumping, it was estimated that a decline of 1 foot or more may extend 1 mile or more northwest of the well field in 5 years. Thus, declines may occur in a part of the bolson-fill aquifer which contains 500 to 1,000 ppm of sulfates, and the hydraulic gradient developed in that part of the aquifer would be sufficient to begin the process of encroachment. When the saline water begins to move toward the well field from the northwest, that is, when the water-table slope changes to a south eastward direction, and when saline water from the north reaches the well field, the encroachment into the well field will be indicated by an increase in mineralization that may occur rather abruptly.

It would be desirable to track the movement of saline water prior to encroachment into the well field. To achieve this end, at least three quality-of-water observation wells at locations between the saline-water body and the well field would be necessary. Of the three, one could be an existing privately owned stock well, 17.9.25.111. The other two wells possibly could be provided by rehabilitating test holes 8 and 9, which were plugged without casing. A schedule of semiannual water sampling should be established for these outpost wells. In addition to obtaining water samples regularly, it is advisable to maintain a program of accurate water-level measurements in the well-field area on at least an annual basis, in order to have a continuing record of the shape and direction of slope of the water table.

LOCATION AND SPACING OF FUTURE WELLS

In the Boles area the selection of future production-well sites involves not only locating the most productive areas with respect to quantity but also locating the areas where pumping of potable water will cause the least movement of saline-water toward the area of the wells. Unfortunately, the areas described are not coextensive. In the preceding section on hydrologic characteristics of the bolson fill, it was pointed out that the most permeable area in the Boles well field is the western part of the field in secs. 24 and 25, T. 17 S., R. 9 E. On the basis of the reports concerning the two Town of Alamogordo wells in sec. 35, the most permeable area extends westward and southwestward into that section. This most permeable area is immediately adjacent to and partly in areas known to be underlain by saline ground water. On the other hand, the eastern part of the well field in secs. 18 and 19, T. 17 S., R. 10 E., is an area of low to moderate permeability but is an area underlain by potable ground water.

The bolson fill appears to be most permeable in the first 100 to 250 feet below land surface. These more permeable deposits appear to thicken northward and eastward, toward the Alamo Canyon fan, and southward, toward the smaller fans between the Boles field and San Andres Canyon. It is believed that most of the water pumped from the Boles wells comes from the shallow fan deposits. If well-field development is to be extended away from the western part of the present well field, it will be desirable to develop those areas where the fan deposits are thickest. It will also be desirable to locate wells in areas in which the fan deposits are at least partly fairly well sorted and are not conglomeratic.

As a compromise between locating wells in areas of high yield and in areas where danger from saline-water encroachment would be at a minimum, future wells should be restricted to the eastern half of sec. 18, sec. 19, the northern half of sec. 30, and possibly the southwest corner of sec. 20, all in T. 17 S., R. 10 E. In addition, the eastern one-fourth of secs. 25 and 36, T. 17 S., R. 9 E., might be subject to development on a limited basis.

The reasons for extending future well development southward, rather than close to the mountains, are twofold. First, the relatively undisturbed water table west of U. S. Highway 54 slopes south-southwestward about 45 to 50 feet per mile (figure 6). Pumping has lowered the water table east of the highway, the maximum decline having occurred at the south edge of sec. 18, and as a result the gradient upslope from the area of decline has increased to nearly 80 feet per mile. The steeper slope of the water table induces an accelerated movement of ground water. In the area of decline the water table still slopes southwestward. An additional decline of about 20 feet would reverse the gradient and create ground-water movement from the southwest. It would appear desirable, therefore, to displace the center of pumping, and, therefore, the center of ground-water declines, southward closer to the south edge of the potable-water body. Second, figure 6 indicates that the northward development of the depression in the water table has tended to create a local eastward slope. With additional pumping in the future, the eastward slope will become better developed and create a movement of ground water from the west. To displace the center of pumping southward would place a larger section of potable water between the area of decline and the saline water to the west.

The spacing of wells is a matter of both hydrologic and economic consideration. Owing to the cost of laying pipeline, the distances from well to well and from pumping station to the most distant well should be as small as possible. However, when two adjacent wells are pumped, the pumping of each well lowers the water level in the other well. This effect of mutual interference increases the amount of lift at each well, and decreases the amount of water which each well can produce; that is, the total amount of water produced from both wells simultaneously is less than the total production from the two wells when pumping one at a time. In the Boles area, new wells should be not less than about 1,000 feet apart, in order to minimize the effects of mutual interference. The array of wells that would cause the least mutual interference would be a straight line of wells. However, a straight-line array may not be desirable because of pipeline cost and the inefficiency of pumping without a booster pump in the line. In any future development in the area southeast of the present well field, the wells should be arrayed along approximately a straight line, if possible.

ARTIFICIAL RECHARGE

Among the conservation practices that could be used in the Boles well field, one offers promise not only of inhibiting saline-water encroachment, but also of storing potable water in an evaporation-proof reservoir. This practice, artificial recharge, has been proved feasible in several areas in the United States. Of greatest interest to this area is the fact that experiments on recharging the Montana well field at El Paso were successful (Sundstrom and Hood, 1952).

The concept of artificial recharge is based upon the fact that formational and well coefficients should be independent of direction of flow. Therefore, the effect of artificial recharge by injecting water in wells should be the inverse of pumping—that is, the rate at which water can be injected into a well is governed by the specific capacity of the well and the coefficients of transmissibility and storage of the formation.

Water used for artificial recharge should be free of sediment, chlorinated, and stable chemically in relation to the water in the aquifer. The water must be free of sediment in order to prevent mechanical plugging of the wall of the well. Chlorination is necessary to prevent the growth of bacteria and algae, which could cause plugging of the screen and the formation. The chemical quality of the recharge water must be such that mixing with ground water in the well and in the formation will not lead to chemical reactions that would cause encrustation of the screens or plugging of the aquifer.

The idea of practicing artificial recharge in an area already short of water may not seem realistic. However, when the Bonito Lake pipeline is completed in 1957, additional water will be available. Possibly not all the water available from Bonito Lake will be required immediately. Moreover, during the winter months there may be a surplus of water which, if left in the lake, may cause the lake to overflow during the season of snowmelt or summer rains. Also, there may be wet periods when there is an excess of water in the lake. Any surplus water could be used to recharge the aquifer artificially in the Boles area, by injection through production wells.

Table 10 shows the rates at which the wells in the Boles well field probably could take water during short periods of artificial recharge. The table is based upon the specific yields of the wells under pumping conditions. Well 26 is not included in the table, owing to its high elevation relative to the pumping station.

Table 10.--Probable maximum rates of artificial recharge through existing wells in the Boles well field, Otero County, N. Mex.

Well number	Specific capacity (gpm/ft)	Computed rate of recharge (gpm)	Approximate terminal recharging water level: Below land surface datum (feet)	Approximate terminal recharging water level: End of period (days)
2	1.8	135	8	½
5	.7	128	5	½
10	2.2	218	5	2
15	2.8	165	5	2
16	1.3	85	5	½
17	9.7	576	5	2
32	6.9	137	5	1
33	12.2	732	5	½
34	4.3	258	5	½
35	9.9	644	5	½

From table 10 it can be seen that the well field probably could be recharged at a rate of about 3,100 gpm, or more than 2 million gallons in 12 hours. It is not likely that such amounts of water would be available; however, if one or more wells could be artificially recharged at lesser rates over a period of several weeks or more, a considerable amount of water could be put into storage, and water levels in the area of the recharge wells would be raised measureably. Under present conditions the wells probably could accept a total of about 1 million gallons per day for a period of 2 to 3 months before overflowing.

The advantages of practicing artificial recharge in the Boles well field are several. First, selected wells could be recharged to raise water levels in the western part of the well field. Raising the water levels would tend to create a water-table gradient away from the well field, which would tend to inhibit saline-water encroachment from the west. Wells 17, 33, and 34 could be used for this purpose. Second, artificial recharge of wells in the older part of the well field would repressure the artesian part of the aquifer, which would tend to halt downward migration of the shallow ground water. Third, the practice of artificial recharge would store surplus water for future use, which might otherwise be lost by overflow from Bonito Lake. Fourth, water stored in the aquifer in the Boles well field would not be subject to loss by evaporation. On the basis of data from evaporation stations in the Pecos River and Rio Grande valleys, the annual evaporation loss from Bonito Lake is estimated to be more than 6 acre-feet (about 2 million gallons) per acre of lake surface. The surface of Bonito Lake is approximately 45 acres when the lake is full. At this level the annual loss from evaporation may exceed 90 million gallons. Of course, some of the annual evaporation loss would continue even though artificial recharge were practiced, but the actual saving in water by preventing evaporation and by preventing overflow from Bonito Lake should amount to a considerable quantity.

It should be recognized that, prior to establishment of a standard procedure of artificial recharge in the well field, experiments should be made at the various wells to determine the practical long-term recharge rates for the wells. The general procedure at a well would be to remove the back-pressure valve, reverse the flow-meter position, and allow water from Bonito Lake to flow into the well at various rates for specific intervals of time. All the production wells are equipped with turbine pumps and electric motors (plate 9B). By allowing the recharge water to flow down through the pump column the dangers to the well inherent in roiling and entrapment of air would be eliminated. Before, during, and after the recharge period, water-level measurements should be made in the recharge well and nearby observation wells to determine the effect of recharge on the water table. During the recharge period and subsequent pumping periods, measurements of recharge and discharge rates should be made periodically, and water samples and temperatures should be taken at specific intervals to determine the amount of recharge water recovered.

Inspection of an analysis of water from the Bonito pipeline indicates that the minerals dissolved in water from Bonito Lake are similar in type and distribution to those in the water from the Boles well field, the principal differences being the amount of dissolved solids in waters from the two sources. Table 24 gives the chemical analyses of samples of water from Bonito Lake and other nearby sampling points related to the system.

CHEMICAL TREATMENT OF WELLS

A phase of study in the Boles well field was the investigation of the effect of chemical treatment of wells in the area with the objective of increasing yields. In general, two types of chemicals have been used in the treatment of water wells. One type is buffered hydrochloric acid, which is sometimes used to increase the yields of wells drilled into a limestone aquifer. Acid has been used with varying degrees of success on irrigation wells in the vicinity of Tularosa, where the bolson-fill aquifer contains a considerable amount of limestone particles. This type of treatment probably would not be effective in the Boles area because most of the fill consists of clay and sand. The second type of chemical used in water-well treatment is sodium hexametaphosphate, which is sold in several solid forms under various trade names. The chemical is ordinarily used in water-treatment plants to inhibit the deposition of calcium carbonate scale and iron oxide in water pipelines and to prevent corrosion. The phosphate in solution has the property of dispersing finely divided metallic oxides, salts, and clays. Two Boles wells were treated with phosphate solution. The results are described below.

The use of well-treatment chemicals obviously cannot remedy defects of a mechanical nature, such as a worn pump, nor can the chemicals remedy the effects of screen plugging by sand alone. However, chemical treatment of wells, using the phosphate solution, is apparently beneficial in the development of new wells, redevelopment of old wells, and the cleaning of old well screens that have become plugged with clay or chemical encrustation. Although none of the older wells in the Boles well field were treated experimentally, it was observed that the phosphate solution effectively cleaned rust from the barrels in which the solution was mixed for treatment of well 28, and the clay-dispersing properties of the solution were observed during the treatment of the well. It is inferred that the same action would take place at the screen in a well.

Wells 28 and 35 were treated with sodium hexametaphosphate solutions. Well 35 was treated with the solution as a part of developmental procedure. The well was completed in May 1955. Development consisted of surging and bailing, treatment with the phosphate solution, and pumping with a turbine pump. The well was surged with a close-fitting surge block, and then bailed, in cycles, for a period of 6 hours, after which a total of 130 pounds of the phosphate compound was mixed in the well with the surge block. After a 24-hour interval, during which the turbine pump was installed, the well was surged and pumped during parts of 4 successive days. When pumping began, the fluid pumped from the well consisted of a very thick suspension of clay, which was followed by water so heavily charged with sand that the pump was stopped several times by the sand. The water from the well contained very little sand at the end of the development period. The well produced more than 450 gpm during short pumping periods and about 350 gpm during relatively long pumping periods. Of course, the phosphate solution was not entirely responsible for the successful completion of the well. However, it is believed that the solution was instrumental in removing clays which were plastered or smeared over the walls of the well and the screen by the action of the drilling bit and by the installation of the casing and screen.

Well 28 was treated with phosphate solution in an effort to increase its yield. Well 28 was drilled in 1953, by the hydraulic-rotary method, and was gravel walled. After development, the well yielded only 30 to 40 gpm. Nearby well 26 was drilled during the same period as well 28 and is structurally identical with well 28. Well 26, however, produced about 180 gpm. Therefore, it was believed that well 28 might have been partly plugged with drilling mud which was not removed by development. A preliminary performance test of well 28 showed that at the end of $7\frac{1}{2}$ hours of pumping, the well had a yield of 44 gpm with a drawdown of 104 feet, an indicated specific capacity of about 0.4 gpm per foot of drawdown. The coefficient of transmissibility was computed from the rate of recovery of water level and amounted to about 1,000 gpd per foot. Although the pumped water carried some sand, it contained little clay.

After the performance test, the well was treated four times, with a total of 700 pounds of the phosphate compound. The chemical was dissolved in a small amount of water, and the solution was poured into the well. During each of the four treatments the solution remained in the well from two to three days during which time the well was surged about 10 times. After each treatment the well was pumped from 3 to 6 hours to flush out the chemical and the material loosened by the chemical. The water pumped out of the well following the first treatment carried so much clay and sand that it resembled thin drilling mud. The water cleared somewhat during the latter part of the subsequent pumping period. During each of the subsequent treatments, additional clay and sand were pumped from the well, but in diminishing quantities as treatment was continued.

Following the series of chemical treatments well 28 was tested again by pumping for a period of 8 hours. The maximum rate of production was 54 gpm; however, the specific capacity at the end of 8 hours amounted to about 0.6 gpm per foot of drawdown. The rate of recovery of the water level after the 8 hours of pumping indicated a coefficient of transmissibility of about 1,350 gpd per foot.

Samples of water for chemical analysis were taken at the end of each performance test. The analyses of the water samples indicated that no significant changes in the chemical quality of the ground water from well 28 resulted from the chemical treatment of the well.

The gravel pack in the well did not subside as a result of the chemical treatment.

The results of treating well 28 contain the following pertinent points:

(1) The well produced sand-laden water for about $1\frac{1}{2}$ hours during the test before treatment. The water did not contain clay or mud.

(2) During treatment the pumped water contained not only large amounts of sand, but also clay or mud. The amounts of sand and clay diminished toward the end of the treatment period.

(3) The water pumped during the second performance test was essentially free of sand after the first 15 minutes of pumping.

(4) The measurements of depth to water during the first performance test showed that screen losses were small at the rate the well was pumped. Therefore, the screen probably was not plugged.

(5) Measurements in the gravel-feed lines indicated that the gravel envelope did not subside, but gravel may have been bridged above the zone producing the sand. The sand pumped from the well probably came from the interstices of the gravel pack, or passed directly through the pack.

(6) Performance tests run before and after the treatment period show that the yield of the well at the end of approximately 8 hours was increased from 44 gpm to about 54 gpm. The specific capacity of the well increased from about 0.4 to about 0.6 gpm per foot of drawdown.

(7) The apparent coefficient of transmissibility of the aquifer was increased from 1,000 to about 1,350 gpd per foot.

It was concluded that the chemical treatment resulted in a measurable increase in the productive capacity of well 28, although the amount of water was not sufficient for practical production in the Boles well-field system. The increase in both the specific capacity and the apparent coefficient of transmissibility indicate either that sands producing before treatment were cleaned more thoroughly, or that additional sands, previously sealed off, were opened by the chemical treatment.

Attention is called to the apparent coefficients of transmissibility determined during the two performances tests. Although a substantial increase was noted from one test to the next, the values are low and indicate that the permeability of the water-bearing sands penetrated by the well is low or that the total effective thickness of the sands is small. Therefore, it is not expected that further treatments or manipulation of the well will result in a productive capacity much higher than that already obtained. Assuming that similar conditions of partial plugging may exist in other wells in the Boles well field, it appears that treatment with solutions of sodium hexametaphosphate might be profitably used in wells that had an initially high productive capacity.

WELL CONSTRUCTION

Appreciable difficulty has been experienced in the Boles well field in developing satisfactory wells because of the generally fine texture and heterogeneous mixture of the formation particles. It seems pertinent, therefore, to discuss general well-drilling and construction methods and how they can be applied to the specific problems of constructing wells in the Boles well field area.

Methods of Drilling

The two methods of drilling water wells most commonly used are the cable-tool (percussion) and hydraulic-rotary methods. While under certain conditions one method may be as satisfactory as the other, each method has advantages over the other in certain conditions. For example, the cable-tool method generally is unsatisfactory in very loose, caving sand, and the hydraulic-rotary method is unsatisfactory in cavernous formations where circulation cannot be maintained. In formations in which either method can be used, such as unconsolidated, or partly consolidated bolson deposits, the cable-tool method generally is employed for small-diameter, shallow wells and the hydraulic-rotary method for large-diameter, deep wells.

With the cable-tool method of drilling, a heavy cutting tool, or bit, at the end of a steel cable is alternately raised and dropped to break and loosen the formation material. The drill cuttings are removed from the bottom of the hole by means of a bailer. In unconsolidated material, casing must be lowered in the hole as drilling progresses in order to prevent caving. Normally, drilling mud is not used with this method.

With the hydraulic-rotary method, a bit attached to the lower end of a string of hollow drilling pipe is rotated while drilling fluid is pumped down through the drilling pipe, out through openings in the bit, and up to the surface through the annular space between the drilling pipe and the wall of the hole. The drilling fluid, generally consisting of a mixture of water, clay, and commercial admixtures, carries the drill cuttings to the surface, where they are deposited in a settling pit. The fluid forms a cake or seal against the wall of the hole, preventing caving. With this method of drilling, it generally is unnecessary to case the hole, except near the surface, during drilling operations.

Generally speaking, the drill cuttings obtained from a cable-tool rig are more representative of the formations than those obtained from a rotary drill, although they generally are finer grained than the latter. In order to obtain as much reliable data as possible from a rotary-drilled hole, it is necessary to keep the drilling procedures as uniform as possible. Even then, much clay and fine sand may be washed away or pass unnoticed in the drilling fluid. Another difficulty in this respect is that of distinguishing drilling mud from natural formation clay in the recovered samples.

If natural clay is used for the drilling mud, it may be impossible to distinguish the drilling mud from clay of the formation. Further, especially in fine grained clayey deposits, the drilling mud may plug the formation and considerable effort may have to be expended in developing the well to make sure that the drilling mud has been completely removed.

Casing Perforations and Screens

Many wells are completed with very little regard to choice of perforations or screens; anything that will act as a "strainer" to pass water is considered suitable. Actually, the choice of a suitable screen is one of the most important steps in the construction of a high-capacity well in unconsolidated deposits.

When screens were first developed, they were designed to exclude most or all of the formation. It now is generally considered that a screen should pass about the finer grained two-thirds of the formation material, unless the aquifer is a homogeneous sand having a low uniformity coefficient (high degree of uniformity). By allowing the finer grained 60 to 70 percent of the materials near the screen to pass through the openings during development, a natural gravel pack with particles increasing in size toward the screen is formed, which results in more efficient well performance.

Not only is the size of screen openings important, the shape and distribution of the openings also is important. Obviously, the ideal screen should contain as many openings as possible without sacrificing strength, and the shape of the openings should be such as to minimize plugging of the opening. A wide choice of manufactured screens is available today; some are designed with the above considerations in mind, whereas others probably are comparable to slotted casing. The required characteristics of screens or perforated casing for gravel-packed wells are slightly different than for plain cased wells and are discussed under gravel-packed wells.

Well Development

The purpose of well development is to finish the well in such a manner that the greatest possible amount of clean water can be pumped safely from the well with a minimum drawdown and that the well can be expected to remain in good condition for a reasonable number of years. This very important phase of well construction often is lightly regarded or completely neglected. Actually, proper development can mean the difference between a successful well or a complete failure.

Many methods of developing wells have been devised and are in common use. The most common method of developing wells in unconsolidated deposits is by a surging process, which is designed to remove the fine sand, silt and clay from the water-bearing strata near the well to form a natural gravel pack. Within the natural gravel pack the formation materials become more uniform and more permeable as the screen is approached. Thus, entrance losses are greatly reduced, and, as long as a reasonable pumping rate is maintained, there is much less likelihood that the well will yield sand.

Surging can be accomplished by agitating the water with some type of plunger which is alternately lowered and raised in the well, back-washing by intermittently starting and stopping the pump, or agitating the water with compressed air or dry ice. Development by a plunger is selective and concentrates the action in the immediate vicinity of the plunger. Over-pumping alone in such deposits may remove fine particles from the formation arount the well but is likely to result in bridging of sand particles, thus preventing full development. Also, development by overpumping is not selective and cannot be depended upon to affect all parts of the screens and adjacent formation. Under certain conditions, where the formation contains considerable admixed clay and or where drilling mud has penetrated the formation, sodium hexametaphosphate or similar chemical is satisfactorily used in development. The fine materials brought into the well during the development are removed with a bailer. Development normally must be accomplished by more than one method and is complete only when no more fine particles can be moved into the well, the water is clear, and the well has a specific capacity that is reasonable when considered in the light of examination of drill cuttings and well log and the transmissibility of the aquifer as determined from the pumping test.

Gravel-Packed Wells

In recent years the gravel-envelope or artificially gravel-packed well has become fairly common. In constructing an artificial gravel pack, the hole is reamed to a diameter several inches greater than that of the casing and screen to be used. The annular space between the screen and the wall of the well, or between an inner and an outer casing, is filled with sorted gravel of a uniform size.

In a rotary-drilled hole, the drilling fluid in the hole may be gradually thinned during the placement of the gravel. Also, a plunger may be surged inside the casing to help wash the plastered mud off the walls of the hole. Unless some effective washing procedure is followed while the gravel is being placed in a rotary-drilled hole, it is possible that drilling mud may remain mixed with the gravel, and cannot be removed by subsequent development.

There is considerable disagreement as to the relative advantages of artificial and natural gravel packs. Probably artificial gravel packs are most advantageous in formations of fine, uniform sands that contain an insufficient amount of coarse material to build up a natural gravel pack about the screen. An artificial gravel pack will permit the use of screens having larger slots than would otherwise be possible in such a formation. The size of the screen opening in a gravel-packed well depends not only upon the size of gravel used but also to some extent upon the shape of the slot openings. The slot size and shape should be such that the smaller gravel will pass into the well during well development, thus inducing a gradation in the gravel pack from the larger size at the screen to the smaller size at the well face.

Ideally, the size of the gravel to be used should be determined by a mechanical analysis of the sand in the formation; studies (Leatherwood and Peterson, 1954) indicate that the size of the gravel should be not more than four to six times the size of the finest materials in the formation that are to be excluded. If too coarse a gravel is used, fine sand may move from the formation into the gravel and may fill the voids in the pack, resulting in a reduced permeability. For maximum permeability, the gravel should be well-rounded and of a uniform size. It must be carefully placed, of course, to avoid bridging and to insure uniform placement.

When a well is drilled by the cable-tool method, the gravel envelope is inserted between an outer and inner casing. Generally the outer casing is withdrawn as the gravel is emplaced. The inner casing is slotted opposite the water-bearing strata; both are slotted if the outer casing is to be left in the well.

Basically the ability of a well to produce water is a function of the transmissibility of the aquifer, and the main effect of gravel packing is to enlarge the well diameter and thus reduce well-entrance losses. Such being the case, a screened well of diameter equal to the gravel pack might be more effective, but such a well having a large-diameter screen would be more expensive than a gravel-packed well. It is apparent also that the main function of the gravel pack is to support the walls of the hole rather than act as a filter. Wells constructed with large and ungraded gravel permit sand to move into the gravel pack and thus function more like filters and eventually become plugged. It is to be expected that the deterioration of such wells in time will be greater than those wherein the proper size gravel was installed.

Wells in the Boles Well Field

The cable-tool method of well drilling has been the principal one used in the Boles well field. All but 5 of the 35 wells drilled during the period 1947 through 1955 and all but two of the production wells in use in 1955 were drilled by this method.

Construction data for all the production wells in the well field and for some of the test wells are given in table 17. All the wells drilled prior to 1953 were drilled by the cable-tool method. In general, these wells were completed by installing a single size of casing down to or near the bottom of the hole. Perforations consisted of torch-cut slots and were generally cut in all the casing extending from above or near the water level to the bottom of the finished well. From the available records it appears that little consideration was given to the size or design of the casing perforations, and that well development consisted entirely of surging and pumping with a turbine pump. It is probable that some of the wells were drilled, tested, and abandoned as failures without adequate development or testing. However, records for some of the wells are missing, and little is known about wells 6 and 8. Some of the wells may have had inadequate amounts of screen, such as wells 11 and 25, which had low yields. Some of the wells produce a great amount of sand with the water when overpumped. Wells 1 and 13 were abandoned when they collapsed as a result of removing excessive amounts of sand from the water-bearing strata.

Well 13 is an example of the construction of most of the wells in the Boles well field. As shown in table 17, the well was drilled to a depth of 270 feet. Ten-inch casing was installed to a depth of 251 feet. Of the 251 feet of casing, 186 feet, from 65 to 251 feet, was perforated, with torch-cut slots $\frac{1}{4}$-inch wide and 14 inches long.

In 1953, five wells were drilled by the hydraulic-rotary method, under one contract. Four of the wells are identical in construction except for minor variations in depth. In each of the four wells, 50 feet of 20-inch blank surface pipe was cemented in place. A 19-inch hole was then drilled to about 250 feet, and about 250 feet of 10-inch casing and screen were centered in the hole. A total of 60 feet of the 10-inch casing was torch-perforated and placed at selected intervals in the string of casing. The annular space between the wall of the hole and the casing was filled with graded gravel of about 3/8-inch diameter. Each well was then developed by means of surging with a surge-block and bailing, overpumping, back-washing, and surging with air. Of the four, only the first (well 26) was a successful well. The lack of success at well 28 appears to be the result of drilling a section of fill that has a low permeability. However, on the basis of data from the aquifer tests in the well field, it appears that both wells 30 and 31 should have been successful. The water-table contours in figure 6 indicate that the aquifer is relatively permeable in the vicinity of the two wells. The coefficients of transmissibility of the aquifer in that area, though not uniform, are reasonably high. The coefficient of transmissibility computed by the Thiem method, using data from wells 30 and 2, was 6,200 gpd per foot, which is comparable to that obtained in the vicinity of the production wells north of well 30.

In view of the method of construction and size of gravel used, it is possible that the low yields of wells 30 and 31 may have resulted from sand and clay entering and bridging in the gravel, thus effectively reducing the permeability of the gravel envelope. Many of the water-bearing beds are composed principally of clay and very fine- to fine-grained sand with smaller amounts of material of larger grain size. It has been demonstrated by Leatherwood and Peterson (1954, p. 588) that the ratio of the mean diameters of grains in a filtering sand to those of the sand to be retained must not be greater than five. The difference in grain-size between the gravel and the formational sand at wells 30 and 31 is many times greater than 5, and the formational sand easily could have entered the gravel envelope.

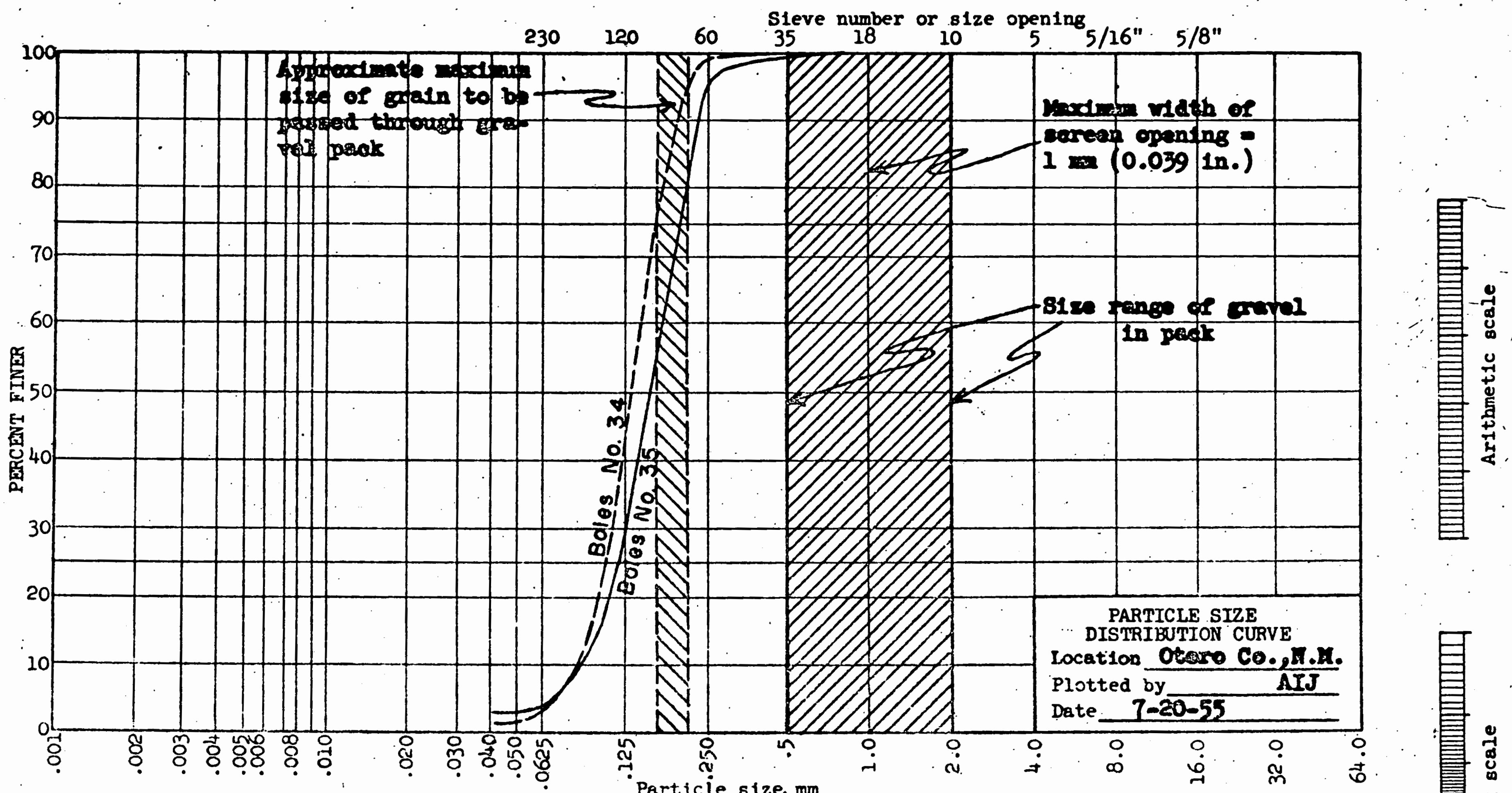
The fifth well drilled by the hydraulic-rotary method originally was intended to be only a "pilot hole," or test hole. However, the well was cased without gravel packing and eventually was put into operation in the well-field system. The history of the well, no. 32 (17.10.19.113), demonstrates the necessity for adequate development. When first drilled, the well produced only 50 gpm. After development over a period of several days, the well reportedly produced 175 gpm and was pumped regularly at about 100 gpm.

From 1953 through 1955 only two production wells were drilled in the well field. These wells, 34 and 35, were drilled by the cable-tool method and were cased and screened in the same manner as older wells in the field, but somewhat greater attention was given to the dimensions of the perforations. The wells were developed for periods of 4 to 9 days and were thoroughly tested to provide a basis for pump specifications. The wells were then put into production at rates of 250 and 350 gpm, respectively.

One of the principal problems with regard to well construction in the Boles well field is that of reducing the sand content of the pumped water. Owing to the fineness of the aquifer sediments, large quantities of sand have been pumped from the various wells. Such wholesale removal of sand led to the collapse and subsequent abandonment of wells 1 and 13. Production of sand from a well is related to the velocity of water entering the well. Reducing the velocity, therefore, will reduce the sand pumped. The velocity of water entering a well can be reduced in three ways: (1) reducing the pumping rate; (2) increasing the well diameter and; (3) increasing the number and decreasing the spacing of perforations. All three factors should be considered in reducing sand pumping from wells in the Boles well field.

Reduction in the amount of sand pumped can also be made by excluding the sand from the well. This normally can be accomplished by either reducing the size of perforations or by construction of gravel-walled wells. Because of the fineness of sand in the formation it is not practical to attempt exclusion of the sand by small screen openings. In view of the failure of three of the four gravel-walled wells drilled in 1953 in the Boles field it has been thought that such construction is not suitable there. However, in those wells, the gravel used was not small enough to retain sand from the aquifer. As an illustration, figure 31 shows the results of mechanical analyses of sand from wells 34 and 35. More than 90 percent of the sand was very fine- to fine-grained, and is believed to be representative of the aquifer at those wells. Analyses of drill-cuttings from nearby test hole T-21 showed that, other than clay and silt, the bolson fill there contained more than 80 percent very fine- to fine-grained sand. In order to retain the sand and allow proper development, it would be necessary to use well screen with a maximum opening of 1 millimeter (0.04 inch) with an envelope consisting of grains ranging from $\frac{1}{2}$ to 2 millimeters in diameter. Therefore, the envelope would have to consist of coarse to very coarse sand, rather than gravel. Assuming that proper and adequate development were performed, it would appear that a successful gravel-walled well could be completed in the well field, if the perforation and gravel sizes were carefully chosen.

With regard to the construction of future wells drilled in the Boles well field the following general conclusions appear to be true. In the eastermost part of the well field, from the centers of secs. 18 and 19 eastward to the base of the mountains, ordinary screened wells generally should be as successful as gravel-walled wells, owing to the normally coarse-grained fill encountered there. Elsewhere in the well field, it is believed that properly constructed gravel-walled wells would be more desirable than ordinary screened wells. In any part of the well-field area it would be desirable to obtain an electrical log in a test hole to aid in evaluation of the well site as a location for a permanent well. The screen and gravel sizes ideally should be selected after cuttings from a test hole have been examined. However, in general it would be desirable to have screen openings no greater than 1/8-inch wide. To help maintain screen strength, the openings preferably should be no greater than about 6 inches long. The number of openings should be as many as possible, consistent with screen strength. The entire length of the casing below the water table should be perforated or should consist of screen. To assure adequate development, it appears desirable (1) to surge the well with surge blocks, bailing out the sand washed into the well by the surging, (2) to treat the well, after surging, with mud-cutting chemicals, and (3) to surge and overpump the well. In steps one and three it would be desirable to continue operations until the amount of sand obtained from the well diminishes measurably. In no case, whether or not the well is gravel-walled, would it be desirable to carry on active developments for less than 72 hours, not including the period of chemical treatment. The development preferably should be followed by a performance test of not less than 24 hours. Finally, the capacity of the permanent pump should be appreciably less than the maximum capacity of the well.



Percent of size	CLAY SIZES less than .004 mm	SILT SIZES .004-.0625 mm	SAND SIZES V. fine .0625-.125	Fine .125-.25	Medium .25-.5	Coarse .5-1.0	V.coarse 1.0-2.0	GRAVEL SIZES V. fine 2-4	Fine 4-8	Medium 8-16	Coarse 16-32	V.coarse 32-64
Well 34	← 3.	2 →	39.1	57.0	0.7							
Well 35	← 3.	8 →	22.3	68.4	5.3	0.1	0.1					

Figure 31.-- Distribution of grain sizes in samples of sand from wells 34 & 35, Boles well field, Otero County, N. Mex.

COMPILATION AND DISPOSITION OF RECORDS

The value of complete and accurate records of exploratory drilling, well data, pump operation, water levels, and pumping-test data often is underestimated. Such records are particularly valuable in regions where usable ground-water supplies are limited to certain areas and where it is important to know the location and extent of those areas. Although, in general, operation records at Holloman Air Force Base are believed to be reasonably complete and accurate, during the course of this investigation attempts to find data relating to exploratory drilling, well construction, and water levels often were discouragingly unsuccessful. Many such data probably were not recorded because their possible value at a future time was not realized. Other data may have been recorded, but the records could not be located or were lost or destroyed.

Not only do such records aid in obtaining a more complete knowledge of ground-water conditions to guide future planning, but they should contribute to a more efficient utilization of existing wells. Periodic analysis of accurately kept records will indicate variations in well performance and the need for changes in operation or modification of equipment to meet changing conditions.

The following suggestions are included in this report in the hope that they may aid in utilizing more efficiently, and therefore more economically, the ground-water supplies of the area.

Exploratory Drilling

Many holes have been drilled in the Boles well field in an effort to obtain an adequate supply of potable water. In addition, several holes have been drilled on the air base in an effort to obtain water for construction purposes, such as roadbuilding.

It might appear that records of shallow holes drilled for temporary use in construction would be of little future value, particularly if very little water was obtained or if the water was known to be chemically unsuited for general use. However, almost all data relating to the occurrence of ground water are of value in estimating the extent and nature of the occurrence. Thus, even for shallow holes or holes drilled for purposes other than water supply, accurate formation logs aid in an interpretation of general geologic conditions; accurately measured water levels aid in determining the direction of slope and the gradient of the water table; data relating to the performance of wells contribute to a knowledge of the hydrologic characteristics of the aquifer; and chemical analyses of the water permit a more accurate estimate of the amount of potable ground water available in the area and may aid considerably in determining the source and direction of movement of the ground water.

It is suggested that as much as possible of the above information be collected and recorded whenever a test hole or well is drilled for any purpose, even by a contractor for temporary construction uses. It is suggested that recording of well data be a mandatory part of the contract. Such data should be collected for test holes and wells drilled even in remote or what may at the time seem to be relatively unimportant areas. At a future time, such data may be of considerable help in locating new installations, in planning expansions of existing installations, or in locating water supplies for construction and other purposes.

Well Data

The well data sheet described in Army Technical Manual 5-660 (Nov. 1952, p. 38-39) has been carefully planned to present much important well data in convenient form. It is suggested that similar records be kept for all of the Boles wells. It is realized that not all the information called for on this form is available for all wells. However, such information as can be obtained should be recorded, preferably at the time wells are drilled. The records should be retained in some accessible place even after the wells have been abandoned, as they may provide information that will be valuable in the development of future supplies or rehabilitation of existing supplies.

Operation Reports

Daily operation logs and monthly operating reports which give the hours pumped and pumpage are compiled for all wells supplying water for general use at the air base. Operation records of wells outside the main system, such as that at Tularosa Range Camp, apparently are not as carefully compiled, and such records as do exist are not readily accessible. If all such records could be filed together for ready and convenient reference, periodic general surveys of all the ground-water facilities would be considerably simplified.

Water Levels

Accurate records of changes in water levels, both pumping and nonpumping, are of great importance. Unfortunately, such records generally are the ones most often neglected or inaccurately kept. This is largely because it is almost physically impossible to obtain accurate measurements with existing equipment construction, and pumping schedules.

Generally, when a well is first drilled, the depth to water is determined by means of an airline gage and is recorded. It is apparent that some such determinations in the past must have been incorrect, because of inaccurate gages or other reasons. Therefore, it is suggested that, whenever possible, before the well is pumped the depth to water in a new well be accurately measured from a fixed measuring point by means of a steel tape. The measuring point used should be carefully described and its altitude determined with reference to a permanent reference point.

The depth to water in a used well, both while the well is pumping and after the water level has recovered, should be accurately determined at intervals of not more than 2 or 3 months. Such measurements should be made under similar circumstances each time. For example, the pumping level should be determined after the well has been pumped steadily for a definite length of time. The nonpumping level should be determined after the well has been off for a definite length of time, sufficient to allow water levels to recover as much as possible from pumping effects. Such measurements take only a small amount of time and could be fitted to the operation schedule.

It would be highly desirable, if possible, to have weekly recording water-level gages installed on all used wells. These generally are air-line gages actuated by small automatically operated air compressors. They are relatively inexpensive, require a minimum of maintenance, and provide an excellent record of fluctuations of the water levels in the wells.

Periodic analysis of water-level fluctuations in relation to data on such factors as yields of the wells will aid in determining the cause of a decline in yield, whether due to a deterioration of the well, a decline in water levels, or a decrease in pump efficiency. Such analyses may indicate approaching problems before they become serious. An accurate record of water-level fluctuations will permit appraisals of pumping effects and will aid in evaluating the hydrologic characteristics of the aquifer.

Pumping-Test Data

Soon after a well is completed, it generally is test pumped, principally in order to determine if the well has been adequately developed and to determine the size of the pump to be installed. Such a test may also have considerable value in determining aquifer characteristics.

In order for such data to be of greatest value, it is necessary that, during both the pumping and recovery periods of such a test, the depth to water and the time of measurement be frequently and accurately recorded. During the pumping period, the yield of the well should be frequently and accurately determined and should be recorded with other pertinent observations.

Oftentimes the specific capacity of a well is computed and recorded without indicating the duration of the pumping period; as noted in a previous section of this report, specific capacities are meaningful only when the yield of the pump, drawdown of the water level, and the duration of the test are known.

Disposition of Records

Good records are valuable, of course, only if they are available for reference and study. It is realized that the disposition of records is determined largely by existing regulations; however, it is assumed that the disposition of records is determined largely by local authorities. It is suggested that all records relating to wells and ground-water conditions be filed together in an accessible place. It is probable that many of the records could be periodically summarized and at the same time studied and analyzed. Then, many duplicate records could be disposed of in order to conserve space.

It is suggested that arrangements be considered whereby the Geological Survey will be able to study such records periodically with the purpose of learning more about the ground-water resources of the area. Such knowledge, it is hoped, will contribute much to the efficient utilization of the resources.

CONCLUSIONS

On the basis of the foregoing data and interpretations, the following conclusions have been reached concerning ground water in the vicinity of Holloman Air Force Base:

(1) In the area of 320 square miles shown in plate 1, the principal aquifer is the bolson fill of Cenozoic age. Consolidated rocks are important only as sources of the erosional debris making up the fill. Although the fill attains a known maximum thickness of more than 1,800 feet, the results of test drilling and drillers' logs of wells in the area show that down to a depth of 500 feet the most permeable zones in the fill are between 200 and 300 feet below the land surface. In the Boles well field area, any additional production wells need not be more than 300 feet in depth. Wells drilled very near the mountains possibly can be drilled to somewhat greater depths because the coarse-grained fill there is thicker, but it is not necessarily more productive.

(2) In the vicinity of Holloman Air Force Base (plate 1) there are only two areas in which appreciable quantities of potable water are stored, the Boles well field area and an apparently larger area in T. 19 S., R. 10 E.

(3) The ground water is saline in both the bolson fill and the consolidated rocks beneath Holloman Air Force Base proper. The quality of the water from both sources, the character of the fill beneath the base, and the depth to consolidated rocks make it clear that potable water cannot be obtained from wells on the base.

(4) The depth to water beneath the air base proper is small, and excess irrigation of lawns and trees might raise water levels to an extent that foundation and other maintenance problems may be experienced.

(5) The extent of potable ground-water supplies is shown in plate 2. The area of potable water of desirable quality lies between the contour of 300 ppm sulfate and the edge of the Sacramento Mountains, and amounted to about 10 square miles in 1954. Eight square miles of the area was in the immediate vicinity of the Boles well field. The area that contains potable, but less desirable, ground water lies between the contours of 300 and 500 ppm sulfate. The area underlain by ground water containing 500 ppm or less of sulfate was about 25 square miles in 1954. Of this area, about 20 square miles was in the vicinity of the well field. The potable ground-water area in T. 19 S., R. 10 E., south of the Boles well field, may extend over as much as 20 square miles.

(6) The principal source of recharge to the bolson fill is precipitation in the adjacent Sacramento Mountains and consequent floodflows that issue from the mountain canyons. The amount of recharge is estimated at 8 percent of the precipitation on the mountain escarpment. Recharge to the potable-water body in the Boles area comes from the several small canyons between Alamo and San Andres Canyons, and is estimated to amount to about 700 acre-feet per year.

(7) About 130,000 acre-feet (about 42,000 million gallons) of potable water containing 300 ppm or less of sulfate is present in the Boles area; however, not all the potable water can be recovered before saline water will enter the pumped area.

(8) There is little natural discharge of ground water in the area. The depth to water is too great near the mountains to permit transpiration and too great over nearly all of the area to permit evaporation. A small amount of transpiration may take place where the depth to water is less than 40 feet and where the quality of the ground water and the soil do not inhibit the growth of phreatophytes. Most of the water moves downslope through the aquifer and out of the area.

(9) The effects of pumping water from the bolson-fill aquifer cannot increase the rate of recharge, nor can they reduce natural discharge; therefore, all the pumped water comes from storage. The removal of water from storage is creating declines of water level in the pumped areas. The declines will continue as long as pumping continues. The declines extend or will extend into areas of saline water because the saline and potable ground waters are stored in the same aquifer.

(10) The permeability of the aquifer in the Boles well field, and consequently the yields of wells, increase from east to west as a result of the better sorting of the fill with increasing distances from the mountains. The most permeable area is in the vicinity of Boles wells 17 and 33 and extends from those wells southwestward to the area of the Alamogordo municipal-supply wells. A hydraulic boundary that trends northward through the middle of the well field probably represents an area of low permeability. Additional production wells probably would not be successful in the area of low permeability.

(11) The specific yield of the bolson fill in the area of the Boles wells is about 8 percent.

(12) At the 1955 rate of pumping from existing production wells in the Boles well field, it is estimated that the water level in the center of the well field will decline about 30 feet in 5 years, 40 feet in 10 years, and 50 feet in 20 years. Declines of significant magnitude (1 foot or more) could occur 1 mile, or more, west of the well field in 5 years and 3 miles, or more, in 20 years.

(13) Saline water is stored as close as one-half mile from the Boles well field. Thus far, saline water has not begun to move toward the well field from the west or northwest because a gradient has not been developed toward the well field from that direction. However, an increased gradient has been developed toward the well field from the north, and saline-water movement from that direction probably has begun.

(14) Saline-water contamination of the Boles wells is taking place as a result of downward vertical migration of small amounts of saline water stored in the shallow part of the aquifer. It is believed that the downward movement is through a leaky aquiclude. This form of contamination probably will increase as pumping continues to lower water levels in the well field. Thus far, only Boles wells 10 and 14 have been so affected.

(15) It appears that a well spacing of 1,000 feet or more is desirable in the well field.

(16) It is desirable that future wells be located southeast of the present well field. Although the aquifer in this area does not have a high permeability, location at new wells in that direction would lessen the effects of pumping on the movement of saline water.

(17) The chemical treatment of both old and new wells in the Boles area appears to be beneficial.

SUGGESTIONS

The life of the well field is finite, and saline-water encroachment will eventually occur as a result of continuing the 1955 rate of pumping. From the results of aquifer tests in the well field, it is believed that saline-water encroachment would occur even if pumping were continued at only half the 1955 rate. Inasmuch as it is anticipated that the rate of pumping in 1956 and subsequent years will be even larger than that in 1955, it seems desirable to begin certain conservation measures as soon as feasible. The procedures listed below are suggested so that future declines may be distributed over a larger area in the well field in order to minimize the effects of pumping on the movement of saline waters. The procedures, if followed, also should result in the interception of a larger part of the potable water moving through the aquifer.

Suggested short-term conservation measures consist of the following:
(1) Rotation of pumping of the Boles production wells, which is already practiced in the well field when possible. The procedure consists of pumping wells alternately so that no single well is pumped continuously 24 hours per day, or is pumped 2 days consecutively. Such interruptions of pumping of an individual well permit the recovery of the water level around the well and prevent to some extent the development of a deep cone of depression around the well. It is especially undesirable to develop such deep cones of depression in the western part of the well field. If the summertime water requirements are too large to permit rotation of pumping, it would be desirable to drill additional wells.

(2) Drilling additional wells. Consideration of the present total capacity of the well field and probable water requirements suggests that at least three new wells are needed, each capable of pumping 200 gpm. It is desirable that the new wells be drilled at locations that will shift the center of pumping away from the saline-water area.

(3) Reduction of pumping in the western part of the well field. This is desirable in order to lessen the amount of decline of water levels in that area.

Suggested long-term conservation measures are:
(1) Dispersing the draft on the aquifer and shifting the center of pumping southeastward. This may be effected by locating all new production wells in that direction. In general it appears that future wells should be restricted to the eastern three-fourths of section 19; the northern half of section 30, excepting the northwestern 40 acres; and possibly the southwestern corner of section 20; all in T. 17 S., R. 10 E. It should be emphasized that wells in these tracts probably will have smaller yields than some of the existing wells, and that a test hole should be drilled first at each desired location. The two unsuccessful wells (30 and 31) in the SW$\frac{1}{4}$ sec. 19 should not deter future exploration of that area because it appears that the lack of success of the two wells may be due in part to plugging of the gravel packs rather than low productivity of the aquifer.

(2) Artificial recharge of the Boles wells. When the Bonito Lake pipeline is completed, and if surplus lake water is available, the surplus supplies could be used to recharge the aquifer artificially in the Boles well field by injecting the water into the production wells. Experiments would first have to be made to determine the effects on both the wells and the aquifer. Prolonged artificial recharge in the well field would raise the water level measurably. In the western part of the well field artificial recharge would inhibit saline-water encroachment from the west and northwest. In the eastern part of the well field, artificial recharge would repressure the artesian part of the reservoir and inhibit local adulteration of the wells from the shallow part of the aquifer. Artificial recharge, using the lake water, would store surplus lake water that otherwise might be lost by overflow from Bonito Lake or by evaporation.

(3) Water-level-measurement program. In order to evaluate changes in the shape of the water table in the Boles well field area, it is suggested that the program of water-level measurements started in 1954 be continued.

(4) Water-sampling program. In order to evaluate the changes in ground-water quality that result from pumping, it is suggested that:

a) a firm schedule of semiannual water sampling be set up wherein each Boles well will be sampled in March and September, and

b) three quality-of-water observation wells be established between the Boles well field and the saline water body to the north and west. The existing privately owned well in the NW corner of sec. 25 and test holes T-8 and T-9 in sec. 24, T. 17 S., R. 9 E., which are presently uncased and plugged, are satisfactorily located for use as outpost wells. These observation wells, if established, should be sampled in March and September each year.

In addition to the conservation measures described above the following suggestions are made with respect to the Boles well field and expansion of the water supply of the Holloman Air Force Base.

(1) Well 10 should be used only on a standby basis; and if, after cleaning and testing, well 14 continues to produce saline water, it should be plugged. However, both wells 10 and 14 could be used for artificially recharging the aquifer.

(2) It does not appear necessary to mud or case off the shallow-water aquifer because most wells in the well field produce a mixture of water of acceptable quality from the deep and shallow zones. However, the quality of water from the several wells in the field should be determined semiannually in order to detect probably further adulteration of the deep zone from the shallow zone.

(3) Greater care should be exercised in perforating the casings of production wells drilled in the future. Perforations generally should not be longer than 6 inches and wider than one-eighth inch. However, the number of perforations should be as great as possible consistent with screen strength. Consideration should be given to the use of manufactured screen if gravel-walled wells are developed.

(4) Successful gravel-walled wells seemingly can be developed in the well field if sufficient care is exercised in choosing the screen and gravel sizes.

(5) Before drilling a production well at any desired location, a test hole should be drilled first and if possible an electric log of the strata obtained. Data from the test hole will indicate whether a production well will be successful and will form the basis for choosing the amount of screen to be used, the size of the screen opening, and the size of gravel, if any, to be used.

(6) The development of future production wells should be thorough. The wells should be (a) surged with close-fitting surge blocks, bailing out the sand washed into the well by surging, (b) treated after surging, with mud-cutting chemicals, and (c) surged and overpumped with the test pump. Operations (a) and (c) should be continued until the amount of sand obtained from the well diminishes measurably.

(7) The well should be test pumped after development both to determine the hydrologic characteristics of the aquifer around the well and to provide a basis for specifying the size of the production pump.

(8) No production well should be pumped at its maximum capacity. Generally the production pump should be capable of pumping not more than three quarters of the maximum yield of the well.

(9) In order to provide a basis for continuing re-evaluation of the status of ground-water supplies in the Boles well field, it is suggested that complete records of all phases of well-field operation be collected and filed together in an accessible place.

(10) In order to facilitate the orderly keeping of records it is desirable to continue the practice of numbering wells and test holes consecutively, in the order of drilling, throughout the life of the well field.

(11) The area of ground-water studies should be broadened. The investigation upon which this report is based was confined to the general vicinity of the airbase and dealt specifically with problems in the Boles well field. In view of the limitations of the Boles area and the anticipated growth of the airbase and Alamogordo, all possible sources of potable water within a reasonable distance from the airbase should be investigated. The area of potable water in T. 19 S., R. 10 E., south of the Boles well field, is one such source that merits further investigation.

REFERENCES

Brown, R. H., 1953, Selected procedures for analyzing aquifer test data: Am. Water Works Assoc. Jour., v. 45, no. 8, p. 844-866.

Bryan, Kirk, 1938, The geology and ground-water conditions of the Rio Grande depression in Colorado and New Mexico: Nat. Resources Comm., Regional Planning, pt. 6, v. 1, pt. 2, sec. 1., California Institute of Technology, 1942, Water Quality Criteria: Calif. State Water Pollution Control Board, Pub. no. 3.

Conover, C. S., Herrick, E. H., Hood, J. W., and Weir, J. E. Jr., November 1955, The occurrence of ground water in south-central New Mexico: N. Mex. Geol. Soc. Guidebook of south-central N. Mex., p. 109-120.

Dunham, K. C., 1935, The geology of the Organ Mountains: New Mexico Bureau Mines Bull. 11.

Hill, R. T., 1900, Physical geography of the Texas region: U. S. Geol. Survey Topog. Atlas, folio no. 3.

Leatherwood, F. N., and Peterson, D. F. Jr., 1954, Hydraulic head loss at the interface between uniform sands of different sizes: Am. Geophys. Union Trans., p. 588-594.

Meeks, T. O., 1950, The occurrence of ground water in the Alamogordo-Tularosa area of the Otero County Soil Conservation District, N. Mex.: U. S. Dept. Agr., S. C. S., S. W. Region, Regional Bull. III, Geol. series 2.

Meinzer, O. E., and Hare, R. F., 1915, Geology and water resources of Tularosa Basin, New Mexico: U. S. Geol. Survey Water-Supply Paper 343.

Murray, C. R., 1947, Memorandum on the possibilities of developing ground water for the Alamogordo Army Air Base: Manuscript report in open files of U. S. Geol. Survey, Albuquerque, N. Mex., 4 p.

New Mexico State Engineer, 1926-32: 8th, 9th, and 10th Biennial Reports.

Pray, L. C., 1952, Stratigraphy of the escarpment of the Sacramento Mountains, Otero County, N. Mex.: Manuscript report on file at New Mexico Bur. Mines, Socorro, N. Mex.

__________ 1954, Outline of the stratigraphy and structure of the Sacramento Mountain escarpment: New Mexico Geol. Soc. Guidebook of southeastern New Mexico, p. 92-107.

Public Health Service, 1946, Drinking water standards, 1946: Federal Security Agency, Public Health Reports, v. 61, no. 11, p. 371-384.

Richardson, G. B., 1909, U. S. Geol. Survey Geol. Atlas 166, El Paso folio.

Sayre, A. N., and Livingston, Penn, 1945, Ground-water resources of the El Paso area, Texas: U. S. Geol. Survey Water-Supply Paper 919.

Sundstrom, R. W., and Hood, J. W., July 1952, Results of artificial recharge of the ground-water reservoir at El Paso, Tex.: Tex. Bd. Water Eng., Bull. 5206.

Theis, C. V., 1935, The relation between the lowering of the piezometric surface and the rate and duration of discharge of a well using ground-water storage: Am. Geophys. Union Trans., p. 519-524.

__________ 1942, The availability of irrigation water at the Alamogordo Air Base: Manuscript report in internal files of U. S. Geol. Survey, Albuquerque, N. Mex., 3 p.

Theis, C. V., 1945, Memorandum on the water supply of Alamogordo, N. Mex.: Manuscript report in internal files of U. S. Geol. Survey, Albuquerque, N. Mex., 3 p.

U. S. Dept. Agr., Handbook No. 60, February 1954, Diagnosis and improvement of saline and alkali soils.

U. S. Dept. Commerce, Weather Bureau, 1930-54, Climatological data, New Mexico.

U. S. War Dept. TM 5-660, November 1952, Operation of water supply and treatment facilities at fixed Army installations.

Wenzel, L. K., 1942, Methods for determining permeability of water-bearing materials, with special reference to discharging-well methods: U. S. Geol. Survey Water-Supply Paper 887.

Table 11.--Description of drill cuttings from wells and test holes drilled in 1954 and 1955 in vicinity of Boles well field, Otero County, N. Mex.

17.9.13.244. U. S. Dept. of Interior

(Test hole 22)

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

17.9.23.333

(Test hole 3)

	Thickness (ft)	Depth (ft)
Caliche and a little clay	11	11
Sand and clay; sand appears to be mostly evaporites	5	16
Clay, red	4	20
Clay, red; crystalline gypsum; and some coarse-grained quartz sand	3	23
Clay, red, and crystalline gypsum	7	30
Sand, very fine- to medium-grained; caliche; crystalline gypsum; and a little red clay	5	35
Sand of caliche, very fine- to coarse-grained, and gypsum, with little clay	3	38
Missing	3	41
Caliche sand and flakes or grains	4	45

Table 11.--Description of drill cuttings - Continued

17.9.23.333 - Continued

(Test hole 3)

	Thickness (ft)	Depth (ft)
Clay, red	5	50
Clay, red and white, and caliche, becoming sandy toward bottom	5	55
Clay, white, and caliche	6	61
Clay, red	4	65
Clay, silty red	8	73
Caliche	3	76
Clay, sandy red, and caliche	6	82
Caliche, hard	1	83
Caliche, thin, strata of, intercalated with sandy, red clay. Minor amounts of red sand and crystalline gypsum	12	95
Caliche and red, sandy clay	10	105
Caliche, very fine-grained sand, and silty red clay	10	115
Clay, sandy, brown	6	121
Caliche, fine-grained sand and some white clay	4	125
Clay, white, and caliche, with minor amounts of sand and red clay	10	135
Clay, tan, with minor amounts of sand and caliche	10	145
Clay, brown, with minor amounts of sand and caliche	25	170
Clay, brown, with thin, intercalated strata of caliche	10	180
Clay, brown	20	200
Clay, brown, with minor amounts of sand and caliche	8	208

17.9.23.431. U. S. Dept. of Interior

(Test hole 1)

	Thickness (ft)	Depth (ft)
Soil, gypsiferous	10	10
Clay, brown, and caliche	10	20
Clay, silty, brown, and small gravel	20	40
Clay, silty, brown, very fine-grained sand, and small gravel	9	49
Sand, very fine- to fine-grained, and some brown clay	21	70
Clay, sandy, brown, and caliche	16	86
Clay, brown, and caliche	19	105
Clay, sandy, brown, and caliche	10	115
Clay, sandy, brown, and caliche with minor amount of gravel	10	125

Table 11.--Description of drill cuttings - Continued

17.9.23.431. U. S. Dept. of Interior
(Test hole 1) - Continued

	Thickness (ft)	Depth (ft)
Sand, fine- to very fine-grained; finely divided caliche; and minor amount of brown clay	20	145
Sand, very fine-grained; brown clay; and minor amount of caliche	11	156
Caliche, and very sandy, brown clay	10	166
Caliche, and very fine-grained sand	9	175
Caliche, and sandy, brown clay	8	183
Clay, sandy, brown, and caliche	17	200
Clay, brown; very fine-grained sand; and caliche	10	210
Clay, brown, and caliche	10	220
Clay, sandy, brown, with minor amounts of caliche and small gravel	10	230
Clay, brown, caliche and minor amount of small gravel	10	240
Clay, sandy, brown, with minor amount of caliche	10	250
Clay, brown, with minor amount of caliche	20	270
Caliche, and sandy, brown clay	10	280
Caliche, fine- to very fine-grained sand, and minor amount of brown clay	10	290
Clay, sandy, brown; caliche; and minor amount of gravel	10	300

17.9.24.142. A. Stafford and W. B. Blakemore
(Test hole 8)

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

Table 11.--Description of drill cuttings - Continued

17.9.24.142. A. Stafford and W. B. Blakemore

(Test hole 8) - Continued

	Thickness (ft)	Depth (ft)
Clay, soft, sandy, red-brown; becoming very sandy with medium-grained sand near bottom	10	130
Sand and small gravel, mostly of black limestone, and sandy, reddish clay	10	140
Clay, sandy, red, with a little sand and small gravel	40	180
Clay, sandy, red-brown; very sandy clay in thin strata below 200 feet	30	210
Clay, sandy to very sandy, red-brown, with minor amount of small gravel	50	260
Clay, sandy, brown	40	300
Clay, soft, brown, and very small gravel	12	312

17.9.24.222. Pearl F. Harrington, et al.

(Test hole 9)

	Thickness (ft)	Depth (ft)
Soil, sandy, chocolate-brown, with much sand and gravel and some reddish clay	10	10
Sand and gravel, and red clay in alternating beds about 2 feet thick	10	20
Clay, silty, red, with included gravel	9	29
Sand and small gravel	1	30
Gravel, mostly bit-cut	3	33
Clay, red, and bit-cut gravel	7	40
Clay, silty, brown, with some gravel	20	60
Clay, sandy, red-brown, with small amount of very coarse sand	10	70
Clay, sandy, brown, with very small gravel	20	90
Clay, sandy, red-brown, with small gravel	20	110
Clay, sandy, firm, red-brown, and bit-cut gravel	10	120
Clay, sandy, brown, with small gravel and minor amount of large gravel	10	130
Clay, sandy, brown, and minor amount of gravel	10	140
Clay, sandy, brown, and clayey sand	10	150
Clay, sandy, brown, and small gravel	20	170
Clay, red-brown to brown, and sandy clay, with minor amount of gravel and white clay	10	180
Sand and gravel, 75 percent; sandy clay, 25 percent	7	187
Sand, and small gravel, 50 percent; sandy clay, 50 percent. (Rocks drilled from 180 to 200 feet alternated in beds from 6 inches to 2 feet thick)	13	200

Table 11.--Description of drill cuttings - Continued

17.9.24.222. Pearl F. Harrington, et al.
(Test hole 9) - Continued

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

17.9.24.343. W. L. McCommon

(Boles well 34)

	Thickness (ft)	Depth (ft)
Soil, silty clay; and caliche	10	10
Clay, soft, silty yellow-tan	10	20
Clay, sandy, tan, and gravel	10	30
Sand, very fine- to fine-grained, with minor amount of clay and gravel	10	40
Clay, firm, slightly silty, red-brown, with minor amount of gravel	20	60
Clay, soft, very sandy, tan, with minor amount of gravel and caliche	10	70
Clay, silty, brown	10	80
Clay, sandy, brown, and some large, black limestone gravel	10	90
Clay, firm, brown, with minor amount of gravel	10	100
Clay, firm, brown, and nodular caliche	10	110

Table 11.--Description of drill cuttings - Continued

17.9.24.343. W. L. McCommon

(Boles well 34) - Continued

	Thickness (ft)	Depth (ft)
Clay, soft, tan, with minor amount of very small gravel	5	115
Clay, firm, silty, brown, and nodular caliche	15	130
Clay, silty, brown, with minor amounts of caliche and small gravel	10	140
Clay, silty, brown, and white calcareous clay	10	150
Clay, brown; caliche; and minor amount of gravel	10	160
Clay, plastic, red-brown	10	170
Clay, brown; white calcareous clay; and minor amount of small gravel	10	180
Clay, soft, very sandy, tan; very small gravel; and minor amount of caliche	10	190
Clay, firm, plastic; caliche; and minor amount of gravel	30	220
Caliche and gravel with some brown clay	3	223
Clay, tan	7	230
Clays, brown and white	10	240
Clay, soft, very sandy, tan, and caliche	10	250
Clay, firm, red-brown, and caliche	10	260
Clay, silty, brown, with minor amount of gravel	10	270
Clay, firm, red-brown, and caliche	10	280

17.9.25.123. Leah Henry

(Test hole 21)

	Thickness (ft)	Depth (ft)
Clay, silty, with minor amount of caliche	10	10
Clay, silty, brown, with minor amount of gravel	3	13
Clay, soft, gray to white	4	17
Clay, silty, brown, with inclusions having a limonitic appearance	3	20
Clay, firm, brown, with minor amount of caliche near bottom	10	30
Clay, brown, with several thin, hard strata of caliche	10	40
Clay, red-brown, with caliche, and with minor amount of sand at about 48 feet	10	50
Clay, red-brown, with some sand and gravel	10	60
Clay, sandy, red-brown; minor amount of gravel; and thin strata of very fine-grained sand	10	70
Clay, silty, red, intercalated with strata of caliche and fine-grained sand	20	90

Table 11.-Description of drill cuttings - Continued

17.9.25.123. Leah Henry

(Test hole 21) - Continued

	Thickness (ft)	Depth (ft)
Clay, silty, red	10	100
Clay, silty, red, and caliche	10	110
Clay, red, and sandy caliche	10	120
Clay, red; caliche; and a very compact red clay, called "shale" by driller; becoming much softer and sandier toward bottom	20	140
Clay, silty, red to brown; caliche; and minor amount of sand and gravel	10	150
Clay, red and white	6	156
Caliche	4	160
Clay, red; sand in very thin strata; and some very small gravel or very coarse sand	10	170
Sand, very fine- to medium-grained, and sandy clay	7	177
Clay, red, and gravel	3	180
Clay, sandy, and sand, grading into clay and caliche at bottom	10	190
Clay, red, and caliche	20	210
Clay, red-brown, and caliche; with thin strata of sand from 218 to 220 feet	20	230
Clay, sticky, silty, red, and caliche	20	250
Clay, red-brown, with minor amount of caliche	62	312

17.9.25.212. L. C. Boles

(Boles well 35)

	Thickness (ft)	Depth (ft)
Clay, brown	20	20
Clay, brown, with sand and gravel of black limestone	10	30
Clay, tan; very fine-grained sand; and gravel of tan limestone	10	40
Clay, brown; small gravel; and minor amount of caliche	10	50
Clay, silty to sandy, brown, with minor amount of gravel	20	70
Clay, firm, plastic, brown	10	80
Clay, firm, plastic, brown; gravel; and pebbles	20	100
Clay, sandy, brown; very fine-grained sand; and gravel	10	110
Clay, silty, brown, and gravel	10	120

Table 11.--Description of drill cuttings - Continued

17.9.25.212. L. C. Boles

(Boles well 35) - Continued

	Thickness (ft)	Depth (ft)
Clay, brown, with minor amount of gravel	10	130
Clay, tan, with minor amount of gravel	20	150
Clay, silty, tan, and caliche	10	160
Clays, silty, red-brown and tan, and caliche	10	170
Clay, slightly silty, brown	20	190
Clay, red-brown; caliche; and minor amount of gravel	10	200
Clay, red-brown, and caliche	10	210
Clay, firm, brown; a few pebbles; and a minor amount of caliche	30	240
Clay, firm, brown, and caliche	10	250
Clay, tan	10	260
Clay, tan, and minor amount of caliche	10	270

17.9.25.324. L. L. Pate, et ux.

(Test hole 7)

	Thickness (ft)	Depth (ft)
Soil, black-brown, clayey	6	6
Caliche	1	7
Clay, brittle, red and white	3	10
Clay, silty, brown, with grains of caliche and minor amount of very small gravel or very coarse-grained sand; becoming siltier toward bottom	10	20
Clay, sandy, yellow-brown, and sand	10	30
Sand, very fine- to medium-grained, limestone; and minor amount of tan clay	10	40
Sand and caliche with minor amount of clay	10	50
Clay, sandy, red, with included grains of caliche	10	60
Clay, sandy, red, becoming sandier toward bottom	10	70
Clay, sandy, tan, with thin stratum of caliche at 70 feet	10	80
Sand, very fine- to coarse-grained, with minor amount of caliche and clay	5	85
Sand, medium- to very coarse-grained	10	95
Clay, sandy, tan, with some caliche and very coarse-grained sand	7	102
Clay, silty, red	3	105
Silt, silty clay or clayey	10	115
Clay, and very coarse-grained sand or very small gravel, mostly of limestone. Clay is very silty from 125 to 135 feet	20	135

Table 11.--Description of drill cuttings - Continued

17.9.25.324. L. L. Pate, et ux.

(Test hole 7) - Continued

	Thickness (ft)	Depth (ft)
Clay, soft, silty, tan, with very small gravel	20	155
Clay, firm, tan, with much very small gravel in some zones	10	165
Clay, sandy, tan, and caliche	10	175
Clay, sandy to silty, red and tan; caliche; and some very small gravel	10	185
Clay, slightly sandy, with some gravel and caliche (Stratum of caliche from 190½ to 191 feet)	10	195
Clay, red to red-brown, and large amounts of caliche, either as granules or as thin strata 1 to 2 inches thick. Minor amount of gravel and little or no sand	75	265
Clay, red-brown, with less caliche than from 195 to 265 feet	30	295
Clay, light red-brown, with minor amount of caliche....	10	305
Clay, red, and caliche. Some of clay very compact and brittle	20	325
Clay, firm, red and brown	10	335
Clay, brown, with some sand and very small gravel; less gravel toward bottom	20	355
Clay, sandy or silty, red and gray	30	385
Clay, sandy or silty, red to brown and gray, with minor amount of gravel and caliche. Nearly all clays in last 40 to 50 feet appear partly to dissolve into the drilling mud	40	425
Clay, slightly sandy, tan, which appears to dissolve into the drilling mud	66	491
Clay, dense, hard, red, and sand	26	517

17.9.25.444. Virginia H. Leonard

(Test hole 11)

	Thickness (ft)	Depth (ft)
Clay, firm, tan, becoming softer toward bottom	20	20
Clay, soft, silty, tan, with minor amount of gravel ...	10	30
Clay, firm, tan, with some silt or sand near top	10	40
Clay, slightly sandy, tan	10	50
Clay, sandy, tan, intercalated with thin strata of very fine-grained sand. Partial loss of circulation when 60 feet reached.	10	60

Table 11.--Description of drill cuttings - Continued

17.9.25.444. Virginia H. Leonard

(Test hole 11) - Continued

	Thickness (ft)	Depth (ft)
Clay, slightly silty, tan, containing yellow-brown spots	20	80
Clay, slightly gritty, red-brown	35	115
Clay, red-brown, with some caliche	5	120
Clay, soft, tan to brown, with some caliche	10	130
Clay, soft, silty, brown, and caliche	22	152
Clay, silty and silt	8	160
Clay, silty, and caliche; clay became red at about 260 feet	147	307

17.9.26.431. U. S. Dept. of Interior

(Test hole 4)

	Thickness (ft)	Depth (ft)
Soil, tan	3	3
Clay with large amount of caliche	7	10
Clay, red; sandy near top and becoming full of caliche at about 15 feet	13	23
Caliche, gray clay, and crystalline gypsum	5	28
Clay, red and gray	2	30
Sand, very fine-grained	2	32
Clay, red, becoming very sandy at 39 feet	8	40
Clay and sand	1	41
Sand, very fine-grained, and minor amount of caliche	2	43
Sand, very fine- to fine-grained, becoming clayey toward bottom	7	50
Sand, with minor amount of clay	1	51
Clay, soft, red-brown and white; very sandy at top and grading downward to a gritty clay at bottom	9	60
Clay, sandy, with large amount of very fine-grained sand	5	65
Clay, gritty, red, containing grains of caliche or very small gravel, and becoming redder and more compact toward bottom	12	77
Clay, sandy, tan	4	81
Clay, red, intercalated with strata of very hard sandy caliche	5	86
Sand, clayey, and caliche, with a hard stratum at 89 feet	5	91
Clay, soft, sandy, and very small gravel	3	94

Table 11.--Description of drill cuttings - Continued

17.9.26.431. U. S. Dept. of Interior

(Test hole 4) - Continued

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

17.9.36.414. State of New Mexico

(Test hole 20)

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

Table 11.--Description of drill cuttings - Continued

17.9.36.414. State of New Mexico

(Test hole 20) - Continued

	Thickness (ft)	Depth (ft)
Sand, sandy white clay, very small, black gravel and minor amount of caliche	10	120
Clay, sandy, red, with some black gravel and minor amount of caliche	10	130
Clay, red; caliche; minor amount of gravel; and some thin strata of sand	20	150
Clay, sandy, red; some thin strata of sand; and minor amount of caliche	10	160
Clay, red, very sandy in some zones, with thin, hard strata of caliche at 166 and 168 feet	10	170
Clay, red, 50 percent; and caliche, 50 percent	10	180
Clay, silty, brown, and caliche, becoming somewhat sandy toward bottom	30	210
Clay, sandy, red, intercalated with thin strata of medium- to coarse-grained sand and caliche, with minor amount of gravel near bottom	20	230
Clay, red-brown, and caliche with thin stratum of caliche at 243 feet	60	290
Clay, red-brown	10	300
Clay, red-brown, with caliche and minor amount of black gravel	12	312

Table 12.--Drillers' logs of wells in vicinity of Holloman Air Force Base, Otero County, N. Mex.

16.9.8.432. State of New Mexico

(State Engineer's Alamogordo well, 1930)

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

16.9.23.240. J. I. Collins

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

16.9.26.210

(From Fig. 11, WSP 343)

	Thickness (ft)	Depth (ft)
Red clay	15	15
Gypsum	5	20
Stratified red clay and claystone	71	91
Red clay and gravel	35	126
Limerock	6	132
Yellow clay and claystone	80	212

Table 12.--Drillers' logs of wells - Continued

16.9.26.210

(From Fig. 11, WSP 343) - Continued

	Thickness (ft)	Depth (ft)
Red clay	25	237
Sticky red clay	69	306
Red clay	152	458
Yellow clay	10	468
Red clay	6	474
Blue clay	9	483
Yellow clay	20	503
"Clayey material"	501	1,004

16.10.18.241. New Mexico School for Visually Handicapped

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

16.10.33.340

(City of Alamogordo test hole No. 2, 1945)

	Thickness (ft)	Depth (ft)
Gravel and boulders	29	29
Boulders	11	40
Boulders and gravel	80	120
Boulders	20	140
Boulders and gravel	32	172
Boulders and layers of clay	38	210
Boulders and layers of clay and gravel	28	238
Boulders and layers of clay	32	270
Boulders and clay	6	276
Sand	5	281
Boulders, clay, and gravel	34	315
Sand	13	328
Rock	10	338

Table 12.--Drillers' logs of wells - Continued

16.10.33.340

(City of Alamogordo test hole No. 2, 1945) - Continued

	Thickness (ft)	Depth (ft)
Sand, boulders, and layers of clay and boulders	25	363
Boulders and layers of clay	29	392
Sand, gravel, boulders, and layers of clay	29	421
Hard boulders	16	437
Boulders and clay	41	478
Boulders and layers of clay	25	503
Boulders and clay, partly soft	24	527
Boulders and clay	31	558
Rock, boulders and layer of clay	15	573
Hard rock	10	583
Boulders	1	584
Rock, boulders, and layers of clay	8	592
Clay boulders	6	598
Clay	47	645
Boulders	3	648

16.10.33.440

(City of Alamogordo test hole No. 1, 1945)

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

Table 12.--Drillers' logs of wells - Continued

17.8.13.311. Holloman Air Force Base

(Swimming Pool well)

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

17.9.24.342. W. L. McCommon

(Boles well 33)

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

17.9.25.112. Dora Prather Cooley

(City of Alamogordo test hole 1, 1953)

	Thickness (ft)	Depth (ft)
Soil	10	10
Gray clay	40	50
Red clay	5	55
Brown clay	10	65
Brown clay, gravel, and water	15	80
Red clay	5	85

Table 12.--Drillers' logs of wells - Continued

17.9.25.112. Dora Prather Cooley

(City of Alamogordo test hole No. 1, 1953) - Continued

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

17.9.25.132. T. T. Mann

(City of Alamogordo test hole No. 2, 1953)

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

17.9.25.222. L. C. Boles

(Boles well 16)

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

Table 12.--Drillers' logs of wells - Continued

17.9.35.242. Dora Prather Cooley

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

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

17.9.35.444. Dora Prather Cooley

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

	Thickness (ft)	Depth (ft)
Caliche	4	4
Clay and chalk rock	14	18
Soft clay and some gravel	22	40
Clay and small boulders	4	44
Soft clay and strata of caliche	21	65
Boulders	2	67
Hard clay	19	86
Gravel	1	87
Clay	27	114
Gravel and boulders	6	120
Clay	9	129
Gravel	7	136

Table 12.--Drillers' logs of wells - Continued

17.9.35.444. Dora Prather Cooley

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

	Thickness (ft)	Depth (ft)
Clay	7	143
Sand	1	144
Clay	27	171
Coarse gravel and boulders	13	184
Clay	39	223
Gravel	7	230
Clay	44	274
Gravel	23	297

17.9.36.120. State of New Mexico

(State Engineers' Valmont test hole, 1930)

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

17.10.18.343. Harold Striker

(Boles well 8)

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

Table 12.--Drillers' logs of wells - Continued

17.10.18.424. R. G. Walker

(Boles well 3)

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

17.10.18.432a. Harold Striker

(Boles well 28)

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

17.10.18.433. Harold Striker

(Boles well 6)

	Thickness (ft)	Depth (ft)
Clay loam	6	6
Clay hardpan	6	12
Clay with trace of sand	10	22

Table 12.--Drillers' logs of wells - Continued

17.10.18.433. Harold Striker

(Boles well 6) - Continued

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

17.10.18.442a. Harold Striker

(Boles well 26)

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

Table 12.--Drillers' logs of wells - Continued

17.10.19.121a. L. C. Boles

(Boles well 10)

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

17.10.19.121b. L. C. Boles

(Boles well 11)

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

17.10.19.132. L. C. Boles

(Boles well 7)

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

Table 12.--Drillers' logs of wells - Continued

17.10.19.144. L. C. Boles

(Boles well 5)

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

17.10.19.214. R. N. Nolley

(Boles well 4)

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

17.10.19.321. W. E. Groom, et al.

(Boles well 27)

	Thickness (ft)	Depth (ft)
Soil	5	5
Brown clay	15	20
Brown clay with streak of embedded gravel	10	30
Brown clay	10	40
Brown clay with embedded gravel. Struck water at 90 feet	75	115
Very fine, silty sand. Water level at 80 feet	5	120
Silty clay with embedded gravel	10	130
Silty clay, clay lumps and embedded gravel	10	140
Not logged	10	150
Silty clay with embedded gravel and sand	10	160

Table 12.- Drillers' logs of wells - Continued

17.10.19.321. W. E. Groom, et al.

(Boles well 27) - Continued

	Thickness (ft)	Depth (ft)
Silty clay with embedded sand. Well caving	10	170
Clay with embedded gravel	10	180
Clay and fine sand. Water level at 78 feet	10	190
Clay with embedded gravel	10	200
Silty clay with sand and gravel	10	210
Silty clay with sand, gravel, and sandstone	10	220
Silty clay with streaks of sand	10	230
Silty clay with embedded sand and gravel. Water level at 81 feet	20	250

17.10.19.321a. W. E. Groom, et al.

(Boles well 30)

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

17.10.19.323. W. E. Groom, et al.

(Boles well 29)

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

Table 12.--Drillers' logs of wells - Continued

17.10.19.323a. W. E. Groom, et al.

(Boles well 31)

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

18.8.5.431. U. S. Government

(White Sands National Monument, Garton well)

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

Table 12.--Drillers' logs of wells - Continued

18.9.14.200

(From Fig. 12. WSP 343)

	Thickness (ft)	Depth (ft)
Gypsiferous adobe	10	10
Gypsum	11	21
Red clayey material	18	39
Sand and gravel	11	50
Red clayey material	25	75
Sand and gravel	10	85
Red clayey material	75	160
Sand and gravel	11	171
Red clayey material	118	289
Sand and gravel	20	309
Red clayey material	256	565
Sand and gravel	20	585
Red clayey material	305	890
Sand and gravel	20	910
Red clayey material	290	1200
Sand and gravel	17	1217
Red clayey material	18	1235

18.10.6.234. Mrs. B. D. Douglas

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

Table 13.--Mechanical analyses of drill cuttings from test holes drilled in 1954 in vicinity of Boles well field, Otero County, N. Mex.

All samples washed through sieves. Analyses in percent by weight.

Sand and gravel sizes: Estimated evaporite content;
A - 0 to 25 percent
B - 25 to 50 percent
C - 50 to 75 percent
D - 75 to 100 percent

Depth of sample (feet)	Particle size, mm								
	Clay and silt sizes	Sand sizes					Gravel sizes		
	.004-.0625	V. fine .0625-.125	Fine .125-.25	Medium .25-.5	Coarse .5-1.0	V. coarse 1.0-2.0	V. fine 2-4	Fine 4-8	Medium 8-16
			Well 17.9.13.244, Test hole T-22						
0- 10	15.9	2.7 A	4.4 B	9.7 B	16.1 B	27.8 B	22.7 A	0.7 A	
10- 20	40.4	3.5 A	2.9 B	2.1 B	2.5 B	7.2 B	40.5 B	0.9 A	
20- 30	62.4	5.4 A	3.3 B	2.4 B	2.5 B	3.8 B	9.8 B	9.2 A	1.2 C
30- 40	78.8	4.7 A	3.3 B	1.5 C	1.2 C	1.8 C	2.7 C	6.0 B	
40- 50	43.4	3.7 A	2.3 A	1.5 B	1.7 B	3.9 B	6.9 B	25.2 A	11.4 A
50- 60	71.2	7.2 A	6.2 B	1.9 C	1.9 B	3.5 B	4.0 B	3.3 B	0.8 A
60- 70	68.4	6.5 A	4.2 B	2.7 B	3.2 B	3.7 B	4.2 B	4.6 A	2.5 A
70- 80	64.9	4.1 A	3.7 B	2.8 B	3.2 B	4.2 B	7.1 B	10.0 A	
80- 90	27.0	3.4 A	3.1 A	4.1 B	6.4 B	10.2 B	25.5 B	20.1 A	0.2 A
90- 100	32.6	4.8 A	4.6 A	6.2 B	8.3 B	10.9 B	26.6 A	6.0 A	
100- 110	28.4	4.2 A	5.2 A	7.7 B	11.3 B	14.6 B	25.1 A	3.5 A	
110- 120	46.7	6.1 A	5.7 B	5.2 B	6.0 B	9.2 A	15.7 A	5.4 A	
120- 130	34.1	5.5 A	5.4 B	4.6 B	4.7 B	5.5 B	12.3 A	27.9 A	
130- 140	53.3	10.3 A	8.5 A	5.7 B	4.5 B	4.6 B	2.8 B	10.3 A	
140- 150	39.4	10.3 A	7.3 A	3.9 B	3.8 B	5.3 B	9.4 B	19.0 A	1.6 A
150- 160	26.6	0.9 A	2.8 A	2.7 B	6.3 B	8.2 B	12.0 B	37.9 A	2.6 A
160- 170	58.3	11.3 A	5.4 A	3.1 B	3.3 B	4.3 B	4.1 B	7.8 A	2.4 A
170- 180	65.3	6.9 A	4.2 B	3.5 B	4.0 B	4.2 B	3.1 B	6.0 A	2.8 A
180- 190	43.9	6.7 A	5.6 A	5.0 B	6.8 B	9.2 B	10.8 A	12.0 A	
190- 200	48.6	6.1 A	6.6 A	7.2 B	7.7 B	8.6 B	8.7 A	6.5 A	

See explanation at head of table.

Table 13.--Mechanical analyses of drill cuttings from test holes - Continued

Depth of sample (feet)	Particle size, mm								
	Clay and silt sizes	Sand sizes					Gravel sizes		
	.004-.0625	V. fine .0625-.125	Fine .125-.25	Medium .25-.5	Coarse .5-1.0	V. coarse 1.0-2.0	V. fine 2-4	Fine 4-8	Medium 8-16
		Well 17.9.13.244, Test hole T-22 - Continued							
200- 210	68.1	8.9 A	6.0 A	4.7 B	4.9 B	3.8 B	2.0 B	1.6 A	
210- 220	70.4	8.2 A	4.5 B	3.4 B	3.5 B	3.7 C	3.4 C	2.9 C	
220- 230	65.1	8.6 A	6.0 B	3.9 C	3.5 B	4.7 B	5.3 B	2.9 A	
230- 240	54.9	5.6 A	3.4 A	3.5 B	5.3 B	6.0 B	7.9 A	13.4 A	
240- 250	42.1	5.1 A	4.6 B	5.4 C	6.6 B	10.4 B	14.8 A	11.0 A	
250- 260	56.9	6.2 A	3.8 B	4.5 B	6.5 B	7.2 B	8.7 B	6.2 B	
260- 270	47.9	7.9 A	5.4 A	5.2 B	6.3 B	8.4 A	11.9 A	7.0 A	
270- 280	60.3	5.9 A	4.4 A	5.5 B	7.8 B	7.3 B	5.1 A	3.7 A	
280- 290	65.0	8.1 A	6.4 B	7.1 B	6.8 B	3.9 B	1.7 A	1.0 A	
290- 300	61.5	9.1 A	6.4 B	5.6 B	5.9 B	4.6 B	4.6 B	2.3 A	
300- 310	73.9	6.5 A	5.5 A	5.9 B	4.2 C	2.1 C	1.4 C	0.5 B	
		Well 17.9.23.333, Test hole T-3							
0- 10	61.4	7.5 D	6.2 D	4.7 D	8.0 D	7.6 D	3.4 D	1.2 D	
10- 20	33.8	9.3 C	18.8 C	10.6 D	14.4 D	12.0 D	0.8 D	0.3 D	
20-22.5	42.0	16.4 C	16.2 D	8.0 D	11.1 D	5.9 D	0.4 D		
22.5-30	34.0	9.1 B	13.1 C	7.4 C	11.5 D	14.6 D	8.3 D	2.0 D	
30- 35	17.6	15.5 A	35.1 A	11.8 B	10.4 B	7.5 D	2.1 D		
35- 38	18.2	7.4 C	35.9 B	15.7 B	10.9 D	10.4 D	1.1 D	0.4 D	
38- 45	6.6	6.0 A	24.0 A	32.8 A	11.0 B	19.2 D	0.4 C		
45- 55	21.6	19.6 A	40.0 A	10.6 A	2.7 C	5.3 D	0.2 D		
55- 60	30.2	16.3 A	32.2 A	10.0 A	4.1 C	6.0 D	1.1 D	0.1 D	
65- 75	24.6	13.3 A	33.7 A	8.8 B	7.3 D	9.9 D	1.8 D	0.6 D	
75- 85	23.3	13.8 A	15.1 A	4.7 C	8.8 D	20.3 D	13.8 D	0.2 D	

See explanation at head of table.

Table 13.--Mechanical analyses of drill cuttings from test holes - Continued

Depth of sample (feet)	Particle size, mm: Clay and silt sizes .004-.0625	Sand sizes: V. fine .0625-.125	Sand sizes: Fine .125-.25	Sand sizes: Medium .25-.5	Sand sizes: Coarse .5-1.0	Sand sizes: V. coarse 1.0-2.0	Gravel sizes: V. fine 2-4	Gravel sizes: Fine 4-8	Gravel sizes: Medium 8-16
		Well 17.9.23.333, Test hole T-3 - Continued							
85- 95	25.6	12.4 A	26.0 A	6.7 B	3.6 C	8.4 D	16.9 D	0.4 D	
95- 105	20.5	19.5 A	24.4 A	7.9 B	10.2 D	13.1 D	3.9 D	0.5 D	
105- 115	18.3	14.9 A	17.3 A	5.9 B	11.5 C	25.5 D	6.4 D	0.2 D	
115- 125	37.0	23.3 A	15.3 B	7.0 B	8.6 C	7.3 D	1.4 D	0.1 D	
125- 135	32.0	13.0 B	9.7 C	7.6 C	15.0 D	21.1 D	1.6 D		
135- 145	37.9	13.6 C	12.6 C	9.3 D	10.1 D	12.8 D	3.7 D		
145- 155	37.0	14.1 D	11.9 D	8.8 D	10.7 D	13.9 D	3.6 D		
155- 165	63.1	11.0 D	5.8 D	3.7 D	4.9 D	6.7 D	4.8 D		
165- 170	63.3	13.3 B	7.2 B	3.5 C	3.5 C	4.8 D	4.4 D		
170- 180	64.2	16.5 B	9.0 B	3.7 C	3.1 C	2.4 C	1.1 D		
180- 190	68.2	17.1 B	7.3 C	3.4 C	2.3 C	1.2 C	0.5 D		
190- 200	63.6	15.0 C	9.7 C	6.1 D	4.0 D	1.3 D	0.3 D		
200- 208	53.6	13.1 C	10.9 C	9.2 C	8.0 D	4.5 D	0.7 D		
Sand from mud pit	6.3	29.9	55.9	7.0	0.6	0.2	0.1		
		Well 17.9.24.142, Test hole T-8							
0- 10	89.7	4.8 A	2.5 A	1.1 B	0.6 B	0.6 B	0.3 A	0.4 A	
10- 20	87.0	6.6 A	3.5 B	1.0 C	0.6 D	0.5 D	0.6 D	0.2 D	
20- 30	73.0	9.7 A	8.4 B	3.3 C	2.0 C	2.0 D	1.3 D	0.3 C	
30- 40	51.4	12.0 A	16.7 A	7.9 B	5.1 C	3.8 C	2.5 C	0.6 D	
40- 50	71.7	9.3 A	9.7 A	3.0 B	2.3 C	2.8 C	1.0 C	0.2 D	
50- 60	59.6	14.3 A	15.4 A	4.6 B	1.6 C	2.4 D	1.9 D	0.2 D	
60- 70	69.3	13.8 A	8.8 A	2.1 C	1.5 D	2.2 D	1.6 D	0.7 D	
70- 80	66.0	17.9 A	10.9 A	2.2 C	1.0 D	1.0 D	0.9 D	0.1 D	

See explanation at head of table.

Table 13.--Mechanical analyses of drill cuttings from test holes - Continued

Depth of sample (feet)	Particle size, mm								
	Clay and silt sizes	Sand sizes					Gravel sizes		
	.004-.0625	V. fine .0625-.125	Fine .125-.25	Medium .25-.5	Coarse .5-1.0	V. coarse 1.0-2.0	V. fine 2-4	Fine 4-8	Medium 8-16
		Well 17.9.24.142, Test hole T-8 - Continued							
80- 90	65.4	12.4 A	11.7 A	5.3 B	3.0 C	1.7 C	0.5 D		
90- 100	60.7	8.2 A	7.9 B	4.2 B	3.6 C	9.3 C	6.0 C	0.1 A	
100- 110	71.0	11.5 A	9.6 A	2.0 B	1.1 C	1.7 C	2.8 D	0.3 D	
110- 120	71.9	11.0 A	8.1 B	2.7 C	2.0 D	3.0 D	1.3 D		
120- 130	49.6	14.6 A	10.3 A	6.4 B	6.1 C	6.5 D	6.4 D	0.1 A	
130- 140	55.1	9.7 A	11.4 A	5.4 B	4.5 C	7.1 C	6.8 D		
140- 150	53.6	17.2 A	15.3 A	3.8 B	2.5 C	3.0 D	3.9 D	0.3 D	0.4 D
150- 160	68.7	15.6 A	7.9 B	2.3 C	1.2 C	1.6 D	2.5 D	0.2 D	
160- 170	62.4	13.5 A	6.9 A	5.0 B	4.3 B	4.3 C	3.3 D	0.3 D	
170- 180	54.2	9.8 A	9.9 A	8.4 B	6.9 C	7.4 C	3.3 D	0.1 D	
180- 190	73.0	10.1 A	7.5 A	3.5 B	2.3 C	2.5 C	1.1 D		
190- 200	72.6	7.9 A	6.9 B	3.8 C	2.4 C	4.1 D	2.3 D		
200- 210	74.8	10.6 A	6.6 B	2.6 C	2.0 D	2.4 D	1.0 D		
210- 220	76.6	9.6 A	5.6 A	2.1 B	1.4 C	2.7 D	2.0 D		
220- 230	73.6	9.8 A	5.3 B	1.5 C	2.8 D	4.9 D	2.1 D		
230- 240	71.9	7.2 A	4.7 B	2.8 C	2.6 D	6.0 D	4.8 D		
240- 250	61.9	18.8 A	9.3 B	3.2 C	1.8 C	3.0 D	1.9 D	0.1 D	
250- 260	72.0	11.2 A	6.0 A	3.2 B	2.4 C	3.8 C	1.4 D		
260- 270	76.8	11.7 A	4.9 A	1.9 B	1.1 C	1.5 C	2.1 C		
270- 280	76.6	8.5 A	5.4 B	2.7 B	2.1 C	3.2 C	1.5 D		
280- 290	70.8	6.9 A	3.4 B	2.5 C	3.8 C	6.7 C	5.8 C	0.1 D	
290- 300	77.7	6.8 A	4.0 B	2.0 C	1.9 D	3.2 D	3.8 D	0.6 C	
300- 312	64.4	11.2 A	7.6 A	4.7 B	3.9 C	4.8 C	3.4 C		

See explanation at head of table.

Table 13.--Mechanical analyses of drill cuttings from test holes - Continued

Depth of sample (feet)	Particle size, mm								
	Clay and silt sizes	Sand sizes					Gravel sizes		
	.004-.0625	V. fine .0625-.125	Fine .125-.25	Medium .25-.5	Coarse .5-1.0	V. coarse 1.0-2.0	V. fine 2-4	Fine 4-8	Medium 8-16
	Well 17.9.24.222, Test hole T-9								
0- 10	45.1	6.6 A	7.5 A	6.7 A	7.0 A	9.2 A	10.9 A	4.7 A	2.3 A
10- 20	46.9	7.7 A	7.7 A	5.8 A	4.5 A	8.4 A	16.2 A	2.8 A	
20- 30	74.4	4.3 A	3.7 A	2.6 A	2.2 A	2.4 A	5.0 A	5.4 A	
30- 33	30.0	5.4 A	5.1 A	5.7 A	12.6 A	27.8 A	12.8 A	0.6 A	
33- 40	44.4	10.2 A	10.4 A	3.0 A	3.0 A	8.1 A	19.8 A	1.1 A	
40- 50	70.9	9.3 A	8.2 A	3.5 A	3.1 A	3.4 A	1.4 A	0.2 A	
50- 60	76.4	8.3 A	7.7 A	3.0 A	1.9 A	1.7 A	0.8 A	0.2 A	
60- 70	70.7	10.5 A	8.8 A	4.0 A	3.4 A	2.3 A	0.2 A	0.1 A	
70- 80	60.3	11.3 A	8.2 A	5.8 A	5.5 A	7.6 A	1.2 A	0.1 A	
80- 90	58.4	12.6 A	11.1 A	6.6 A	5.4 A	5.1 A	0.8 A		
90- 100	64.0	13.9 A	8.4 A	3.4 A	3.0 A	4.8 A	2.5 A		
100- 110	63.5	7.2 A	9.3 A	5.2 A	5.0 A	6.8 A	3.0 A		
110- 120	63.6	10.7 A	7.3 A	2.7 A	2.1 A	3.4 A	9.8 A	0.4 A	
120- 130	66.4	11.3 A	9.5 A	4.2 A	2.5 A	2.9 A	2.4 A	0.8 A	
130- 140	69.0	12.2 A	8.6 A	4.2 A	2.6 A	2.0 B	1.4 B		
140- 150	65.6	8.8 A	6.8 A	4.6 A	4.9 A	7.8 B	1.5 B		
150- 160	54.4	12.0 A	9.2 A	3.4 A	3.5 A	7.3 B	10.2 B		
160- 170	64.0	13.1 A	8.6 A	3.9 A	2.3 A	3.1 B	4.9 B	0.1 A	
170- 180	68.8	10.3 A	5.1 A	2.7 B	3.4 C	4.6 D	4.8 D	0.3 D	
180- 190	43.6	6.1 A	4.8 A	4.6 A	4.8 A	10.0 B	25.9 C	0.2 D	
190- 200	32.0	5.5 A	4.6 A	4.8 A	9.5 A	24.8 B	18.1 B	0.7 B	
200- 210	46.3	6.1 A	5.4 A	5.0 A	6.2 B	11.4 B	17.9 A	1.7 A	
210- 220	21.6	2.8 A	4.4 A	7.3 A	13.6 B	27.4 B	22.8 B	0.1 A	
220- 230	37.9	9.3 A	6.4 A	4.6 A	4.8 A	12.6 B	23.8 B	0.6 A	

See explanation at head of table.

Table 13.--Mechanical analyses of drill cuttings from test holes - Continued

Depth of sample (feet)	Particle size, mm								
	Clay and silt sizes	Sand sizes					Gravel sizes		
	.004-.0625	V. fine .0625-.125	Fine .125-.25	Medium .25-.5	Coarse .5-1.0	V. coarse 1.0-2.0	V. fine 2-4	Fine 4-8	Medium 8-16
		Well 17.9.24.222, Test hole T-9 - Continued							
230- 240	11.9	2.2 A	4.5 A	5.9 A	11.3 B	31.0 B	32.6 B	0.6 A	
240- 250	32.2	5.4 A	2.2 A	1.9 A	1.8 A	2.2 B	46.0 B	8.3 B	
250- 260	63.8	8.7 A	4.3 A	3.4 A	2.8 A	3.5 B	9.6 A	3.9 A	
260- 270	63.1	11.3 A	6.7 A	3.4 A	2.9 B	3.6 B	7.4 B	1.6 A	
270- 280	50.8	7.4 A	5.8 A	5.1 A	5.0 A	9.4 B	15.5 B	1.0 A	
280- 290	56.4	7.7 A	3.6 A	2.6 A	3.1 B	5.2 B	18.5 B	2.9 B	
290- 300	50.5	7.3 A	4.9 A	4.2 A	3.4 B	5.2 B	18.7 B	5.8 B	
300- 314	35.1	6.6 A	5.1 A	5.0 A	6.0 A	12.9 B	24.5 B	4.8 A	
		Well 17.9.25.123, Test hole T-21							
0- 10	82.8	6.7 A	6.2 A	1.2 B	0.8 C	1.0 D	0.6 D	0.7 B	
10- 20	70.0	11.0 A	6.7 B	1.8 C	1.6 D	3.1 D	5.8 D		
20- 30	75.3	7.4 A	4.2 B	1.6 C	1.4 D	3.0 D	5.2 D	1.9 D	
30- 40	35.4	8.2 A	11.3 A	3.3 C	3.9 D	9.3 D	19.0 D	9.6 D	
40- 50	70.6	10.3 A	9.0 A	1.8 C	0.9 D	2.2 D	3.6 D	1.6 D	
50- 60	75.3	9.8 A	8.1 A	1.8 A	1.1 C	1.6 D	1.8 D	0.5 D	
60- 70	70.0	10.2 A	12.2 A	2.4 B	1.1 C	1.8 D	2.2 D	0.1 D	
70- 80	64.5	17.1 A	15.5 A	1.6 B	0.5 C	0.5 D	0.3 D		
80- 90	72.8	10.2 A	13.4 A	1.7 B	0.6 D	0.9 D	0.4 D		
90- 100	81.8	7.0 A	4.5 A	1.2 C	0.9 D	2.0 D	2.5 D	0.1 D	
100- 110	77.9	8.6 A	7.9 A	1.4 C	1.2 D	1.6 D	1.4 D		
110- 120	69.5	10.3 A	8.6 B	2.2 C	1.9 D	3.9 D	3.4 D	0.2 D	
120- 130	66.8	6.8 A	5.4 B	1.8 C	2.4 D	5.8 D	10.9 D	0.1 D	
130- 140	71.2	8.0 A	5.1 B	1.7 C	2.4 D	4.4 D	6.5 D	0.7 D	

See explanation at head of table.

Table 13.--Mechanical analyses of drill cuttings from test holes - Continued

Depth of sample (feet)	Particle size, mm								
	Clay and silt sizes .004-.0625	Sand sizes V. fine .0625-.125	Sand sizes Fine .125-.25	Sand sizes Medium .25-.5	Sand sizes Coarse .5-1.0	Sand sizes V. coarse 1.0-2.0	Gravel sizes V. fine 2-4	Gravel sizes Fine 4-8	Gravel sizes Medium 8-16
		Well 17.9.25.123, Test hole T-21 - Continued							
140- 150	61.1	13.8 A	14.4 A	1.7 C	1.6 D	3.0 D	3.3 D	1.1 D	
150- 160	59.0	11.2 B	6.6 C	2.5 D	3.6 D	6.3 D	10.0 D	0.8 D	
160- 170	64.4	11.4 A	9.2 A	7.4 A	3.3 B	2.1 C	1.6 D	0.6 D	
170- 180	37.9	8.6 A	12.1 A	16.0 A	14.1 B	8.4 B	2.6 C	0.3 D	
180- 190	65.6	7.5 A	7.5 B	4.3 C	3.8 C	5.7 D	5.5 D	0.1 A	
190- 200	70.1	7.7 A	4.0 B	2.5 C	3.5 D	6.2 D	5.8 D	0.2 D	
200- 210	73.2	6.5 A	4.5 B	2.8 C	3.2 D	4.5 D	4.7 D	0.6 D	
210- 220	76.9	6.7 A	3.4 B	1.9 C	2.3 D	3.6 D	4.9 D	0.3 D	
220- 230	66.5	5.9 A	3.3 C	2.7 D	3.7 D	7.3 D	9.5 D	1.1 D	
230- 240	70.4	7.2 A	3.7 B	1.9 C	2.7 D	4.3 D	7.9 D	1.9 D	
240- 250	66.8	7.8 A	5.9 C	3.6 D	4.4 D	5.9 D	5.0 D	0.6 D	
250- 260	74.7	9.7 A	3.7 B	1.8 C	2.3 D	3.1 D	3.5 D	1.2 D	
260- 270	79.3	7.3 A	4.2 B	1.7 C	1.8 D	2.1 D	2.8 D	0.8 D	
270- 280	75.8	6.1 A	3.5 B	2.2 C	2.9 D	4.4 D	4.3 D	0.8 D	
280- 290	76.4	6.7 A	4.0 B	2.6 B	2.8 C	3.5 C	3.3 C	0.7 D	
290- 300	78.9	5.7 A	3.7 A	2.5 B	2.3 C	2.4 C	3.7 C	0.8 B	
300- 312	80.6	8.6 A	3.2 B	1.7 C	1.5 C	1.7 D	1.9 D	0.8 D	
		Well 17.9.25.324, Test hole T-7							
0- 10	55.0	9.5 C	12.9 C	10.0 D	6.5 D	5.1 D	1.0 D		
10- 20	43.2	13.3 C	11.3 C	7.1 B	8.6 C	11.2 C	5.1 D	0.2 D	
20- 30	54.1	11.9 C	13.2 B	9.6 B	8.0 B	2.9 C	0.3 D		
30- 40	30.0	9.9 B	22.0 B	16.9 B	18.9 C	2.0 C	0.1 D		
40- 50	15.7	13.5 A	40.0 A	14.7 B	11.7 C	4.3 D	0.1 A		

See explanation at head of table.

Table 13.--Mechanical analyses of drill cuttings from test holes - Continued

Depth of sample (feet)	Particle size, mm								
	Clay and silt sizes	Sand sizes					Gravel sizes		
	.004-.0625	V. fine .0625-.125	Fine .125-.25	Medium .25-.5	Coarse .5-1.0	V. coarse 1.0-2.0	V. fine 2-4	Fine 4-8	Medium 8-16
		Well 17.9.25.324, Test hole T-7 - Continued							
50- 60	31.7	11.4 A	20.6 A	10.6 A	11.0 B	14.6 C	0.1 D		
60- 70	42.0	14.0 B	17.7 A	9.6 B	8.0 C	8.7 D			
70- 80	39.2	10.2 A	13.1 A	10.2 B	19.6 D	7.7 D			
80- 85	7.6	4.8 A	13.5 A	31.8 A	27.4 A	14.8 B	0.1 D		
85- 95	32.9	10.2 A	10.7 A	6.0 A	10.9 A	28.7 B	0.6 C		
95- 105	45.6	13.3 A	15.0 A	7.3 A	7.3 B	11.1 B	0.4 D		
105- 115	45.6	16.4 A	17.9 A	7.8 A	6.4 B	5.7 B	0.2 D		
115- 125	35.4	12.0 A	14.0 A	6.9 B	9.5 C	19.1 C	3.1 D		
125- 135	30.8	12.5 B	14.1 C	9.8 C	13.0 C	17.1 C	2.7 C		
135- 145	42.4	17.4 B	15.3 C	4.3 C	5.1 C	12.2 C	3.3 C		
145- 155	40.4	20.0 B	12.7 B	5.4 C	6.9 C	12.8 C	1.8 D		
155- 165	31.2	19.6 B	13.0 C	5.5 D	7.4 D	15.3 C	8.0 C		
165- 175	34.8	14.4 B	13.7 C	10.2 C	12.0 D	10.5 C	4.2 D	0.2 D	
175- 185	39.4	18.2 B	11.8 C	6.2 C	6.0 C	13.3 C	5.1 C		
185- 195	43.3	13.3 C	11.6 C	9.1 D	10.1 D	10.4 C	2.2 C		
195- 205	31.3	9.3 C	7.4 C	6.8 D	14.8 D	28.1 D	2.3 D		
205- 215	30.5	9.5 C	9.0 D	7.1 D	8.7 D	15.8 D	18.9 D	0.5 D	
215- 225	34.9	10.1 C	10.9 D	10.1 D	8.7 D	9.3 D	14.3 D	1.7 D	
225- 235	54.1	8.2 C	7.1 C	6.1 D	6.1 D	9.6 D	8.0 D	0.8 D	
235- 245	42.2	7.0 D	4.9 D	4.5 D	8.0 D	13.7 D	17.3 D	2.4 D	
245- 255	54.4	12.7 B	4.9 C	4.6 D	6.1 D	7.9 D	7.1 D	2.3 D	
255- 265	59.2	14.9 B	7.2 C	3.8 D	4.3 D	5.9 D	4.3 D	0.4 D	
265- 275	54.0	12.0 C	7.6 D	5.9 D	5.6 D	7.3 D	6.4 D	1.2 D	
275- 285	54.6	10.3 B	7.5 C	5.9 D	6.0 D	7.9 D	6.5 D	1.3 D	
285- 295	50.7	11.8 B	9.2 C	6.9 D	7.1 D	6.8 D	6.0 D	1.5 D	

See explanation at head of table.

Table 13.--Mechanical analyses of drill cuttings from test holes - Continued

Depth of sample (feet)	Particle size, mm								
	Clay and silt sizes	Sand sizes					Gravel sizes		
	.004-.0625	V. fine .0625-.125	Fine .125-.25	Medium .25-.5	Coarse .5-1.0	V. coarse 1.0-2.0	V. fine 2-4	Fine 4-8	Medium 8-16
		Well 17.9.25.324, Test hole T-7 --Continued							
295- 305	57.5	8.8 B	7.6 C	6.7 D	6.6 D	6.8 D	5.0 D	1.0 D	
305- 315	48.2	11.9 C	10.9 C	7.8 D	7.1 D	6.9 D	6.8 D	0.4 D	
315- 325	42.8	13.1 B	13.7 C	12.4 D	9.5 D	5.8 D	2.5 D	0.2 D	
325- 335	46.6	12.9 B	12.8 C	9.9 D	8.1 D	6.0 D	3.4 D	0.3 D	
335- 345	50.8	14.4 B	14.1 C	13.4 D	3.6 D	2.9 D	0.8 D		
345- 355	59.4	11.6 B	9.4 C	7.0 D	6.1 D	4.5 D	1.8 D	0.2 D	
355- 365	40.6	13.2 C	13.2 D	12.8 D	11.1 D	6.8 D	1.9 D	0.4 D	
365- 375	47.2	15.0 B	11.9 C	8.7 C	8.8 C	6.0 D	2.2 D	0.2 D	
375- 385	50.8	11.5 B	9.3 C	7.8 C	8.8 D	7.6 D	3.6 D	0.6 D	
385- 395	49.2	13.8 C	11.3 D	8.8 D	8.4 D	5.8 D	2.5 D	0.2 D	
395- 405	53.1	10.7 C	8.4 D	7.4 D	8.3 D	8.4 D	3.5 D	0.2 D	
405- 415	51.0	11.4 B	8.7 B	7.2 C	7.4 D	7.0 D	6.3 D	1.0 D	
415- 425	51.9	11.7 B	10.2 C	8.7 D	8.2 D	7.3 D	1.7 D	0.3 D	
425- 435	45.0	12.9 C	11.8 D	10.6 D	9.4 D	7.1 D	3.2 D		
435- 445	47.2	12.9 B	12.0 C	11.4 C	9.3 D	4.9 D	2.3 D		
445- 455	43.4	13.4 B	12.3 C	11.2 C	10.5 D	7.3 D	1.8 D	0.1 D	
455- 465	57.1	11.0 B	8.9 C	7.4 C	9.2 D	5.9 D	0.5 D		
465- 475	46.0	18.7 B	4.0 C	10.8 D	12.4 D	7.4 D	0.7 D		
475- 485	45.5	11.0 C	11.6 D	10.0 D	12.4 D	9.1 D	0.4 D		
485- 495	45.2	4.8 B	13.9 C	9.9 D	11.2 D	12.1 D	2.9 D		
495- 512	42.0	18.8 B	10.2 C	6.9 D	7.9 D	8.1 D	5.5 D	0.6 D	

See explanation at head of table.

Table 13.--Mechanical analyses of drill cuttings from test holes - Continued

Depth of sample (feet)	Particle size, mm								
	Clay and silt sizes	Sand sizes					Gravel sizes		
	.004-.0625	V. fine .0625-.125	Fine .125-.25	Medium .25-.5	Coarse .5-1.0	V. coarse 1.0-2.0	V. fine 2-4	Fine 4-8	Medium 8-16
				Well 17.9.25.444, Test hole T-11					
0- 10	87.0	5.3 A	3.1 B	1.4 C	1.4 D	1.2 D	0.5 D	0.1 D	
10- 20	90.0	5.8 A	2.6 B	0.7 C	0.4 C	0.3 D	0.2 D		
20- 30	84.4	8.9 A	3.5 B	1.5 C	1.0 D	0.5 D	0.2 C		
30- 40	93.7	2.9 A	1.8 A	0.6 C	0.4 C	0.3 D	0.2 D	0.1 D	
40- 50	83.3	7.4 A	7.1 A	1.5 A	0.2 D	0.2 D	0.3 D		
50- 60	91.6	3.5 A	2.9 A	0.6 B	0.2 D	0.3 D	0.5 D	0.4 D	
60- 70	80.7	11.3 A	5.2 A	0.7 B	0.4 D	0.5 D	0.7 D	0.5 D	
70- 80	85.2	5.4 A	2.9 A	0.8 D	1.1 D	1.7 D	2.6 D	0.3 D	
80- 90	79.0	10.2 A	7.6 A	1.0 C	0.6 D	0.8 D	0.6 D	0.2 D	
90- 100	90.9	4.1 A	2.6 A	0.6 C	0.6 D	0.8 D	0.4 D		
100- 110	88.2	7.0 A	2.9 A	0.5 C	0.3 D	0.5 D	0.6 D		
110- 120	83.8	8.4 A	4.5 B	1.1 C	1.1 D	1.0 D	0.1 D		
120- 130	73.7	11.0 A	7.9 C	1.7 D	1.5 D	2.0 D	2.2 D		
130- 140	80.0	7.0 A	4.5 C	1.5 D	1.8 D	2.5 D	2.6 D	0.1 D	
140- 150	77.3	10.2 A	4.5 C	1.2 D	1.7 D	2.5 D	2.3 D	0.3 D	
150- 160	77.8	11.4 A	3.6 C	1.2 D	1.5 D	2.1 D	2.0 D	0.4 D	
160- 170	67.7	7.9 A	4.4 C	2.6 D	3.5 D	6.3 D	6.8 D	0.8 D	
170- 180	66.4	7.0 A	3.2 C	2.3 D	3.9 D	7.3 D	8.4 D	1.5 D	
180- 190	74.3	5.4 A	2.9 C	1.8 D	3.0 D	5.5 D	5.7 D	1.4 D	
190- 200	76.0	6.8 A	3.5 C	2.0 D	3.1 D	4.4 D	3.5 D	0.7 D	
200- 210	70.0	4.1 A	3.7 C	3.1 D	4.0 D	6.4 D	7.5 D	1.2 D	
210- 220	68.0	5.8 A	3.2 C	2.8 D	4.4 D	6.4 D	7.0 D	2.4 D	
220- 230	78.6	3.8 A	2.9 C	2.4 D	3.1 D	3.9 D	4.5 D	0.8 D	
230- 240	78.1	5.6 A	2.7 C	2.2 C	2.1 D	4.0 D	4.7 D	0.6 D	

See explanation at head of table.

Table 13.--Mechanical analyses of drill cuttings from test holes - Continued

Depth of sample (feet)	Particle size, mm								
	Clay and silt sizes	Sand sizes					Gravel sizes		
	.004-.0625	V. fine .0625-.125	Fine .125-.25	Medium .25-.5	Coarse .5-1.0	V. coarse 1.0-2.0	V. fine 2-4	Fine 4-8	Medium 8-16
		Well 17.9.25.444, Test hole T-11 - Continued							
240- 250	72.4	5.4 B	3.1 C	2.7 C	3.8 D	6.4 D	5.6 D	0.6 D	
250- 260	71.6	6.6 A	2.7 B	2.2 C	3.6 D	5.3 D	6.8 D	1.2 D	
260- 270	68.8	11.3 A	4.4 A	2.4 B	2.4 C	3.9 D	5.2 D	1.6 D	
270- 280	73.6	9.2 A	3.1 B	2.0 B	2.3 D	3.1 D	5.3 D	1.4 D	
280- 290	76.5	8.2 A	3.0 C	1.8 D	2.6 D	3.2 D	3.5 D	1.2 D	
290- 300	73.4	7.7 A	4.2 C	2.7 D	3.1 D	5.0 D	3.4 D	0.5 D	
300- 307	71.3	10.2 A	3.5 B	2.3 C	3.4 C	4.2 D	3.8 D	1.3 D	
		Well 17.9.26.431, Test hole T-4							
0- 10	70.1	8.6 A	8.3 A	5.8 B	5.4 C	1.4 D	0.4 D		
10- 20	50.2	10.6 A	9.3 A	5.7 A	7.0 B	8.5 C	8.0 D	0.7 D	
20- 30	42.3	6.5 A	6.9 B	8.3 C	9.7 D	12.6 D	10.0 D	3.7 D	
30- 40	16.6	8.5 A	35.2 A	18.7 A	7.2 B	4.6 D	4.8 D	4.4 D	
40- 50	10.5	11.9 A	53.9 A	18.9 B	2.7 C	1.3 C	0.2 C	0.6 C	
50- 60	47.1	14.0 A	12.7 B	8.0 D	8.6 D	8.4 D	1.2 D		
60- 70	32.0	11.2 A	40.9 A	9.4 B	3.2 D	2.8 D	0.5 D		
70- 80	42.4	14.5 A	24.7 A	6.4 C	4.5 D	5.4 D	2.1 D		
80- 90	24.3	16.5 A	36.1 A	12.1 B	6.6 D	4.0 D	0.4 D		
90- 100	39.3	18.6 A	17.9 A	11.6 C	3.4 D	9.0 D	0.2 D		
100- 110	50.8	13.0 A	12.4 B	5.1 C	7.9 D	10.5 D	0.3 D		
110- 120	29.5	18.9 A	29.8 A	8.1 B	3.8 D	5.3 D	4.6 D		
120- 130	35.5	24.3 A	10.1 B	10.1 D	8.6 D	9.9 D	1.5 D		
130- 140	51.6	28.1 A	10.3 B	3.2 C	1.9 D	3.0 D	1.9 D		
140- 150	58.6	19.1 A	9.3 B	3.6 B	4.4 C	3.7 D	1.3 D		

See explanation at head of table.

Table 13.--Mechanical analyses of drill cuttings from test holes - Continued

Depth of sample (feet)	Particle size, mm: Clay and silt sizes .004-.0625	Sand sizes: V. fine .0625-.125	Sand sizes: Fine .125-.25	Sand sizes: Medium .25-.5	Sand sizes: Coarse .5-1.0	Sand sizes: V. coarse 1.0-2.0	Gravel sizes: V. fine 2-4	Gravel sizes: Fine 4-8	Gravel sizes: Medium 8-16
		Well 17.9.26.431, Test hole T-4 - Continued							
150- 160	41.9	11.4 A	9.9 B	9.2 C	10.4 D	13.6 D	3.6 D		
160- 170	54.2	15.4 A	8.3 B	6.0 B	7.7 C	7.0 C	1.4 D		
170- 180	50.7	9.7 A	6.5 B	7.6 C	5.1 D	13.5 D	6.9 D		
180- 190	49.6	13.4 A	11.2 B	4.3 B	9.1 C	9.9 C	2.5 D		
190- 200	51.1	9.8 A	9.9 B	7.8 C	6.6 C	13.0 C	1.8 C		
200- 210	65.4	11.2 A	7.1 B	5.9 B	5.2 C	3.6 C	1.6 D		
		Well 17.9.36.414, Test hole T-20							
0- 10	73.1	5.2 C	4.2 D	2.8 D	3.3 D	5.4 D	4.8 D	1.2 D	
10- 20	91.0	4.9 D	2.0 D	0.4 D	0.4 D	0.2 D	0.3 D	0.8 D	
20- 30	86.8	6.4 B	3.1 C	0.9 D	0.6 D	0.9 D	0.8 D	0.5 D	
30- 40	79.6	7.1 B	2.5 C	0.8 D	1.3 D	3.0 D	4.2 D	1.5 D	
40- 50	57.3	1.9 D	3.4 D	2.2 D	3.3 D	8.5 D	16.5 D	6.9 D	
50- 60	78.0	9.8 A	7.0 A	2.1 B	0.4 C	0.6 D	1.0 D	1.1 D	
60- 70	73.6	13.8 A	6.7 B	0.8 C	0.8 D	1.5 D	2.6 D	0.2 D	
70- 80	75.1	9.3 A	6.6 A	2.4 B	1.8 B	1.8 C	2.3 D	0.7 D	
80- 90	76.6	10.9 A	5.9 A	1.4 B	1.0 C	1.5 C	2.1 D	0.6 D	
90- 100	73.2	10.2 A	10.4 A	2.0 B	1.0 C	1.0 C	1.8 D	0.4 D	
100- 110	73.8	11.9 A	5.5 B	1.6 B	1.2 C	1.8 D	2.2 D	2.0 D	
110- 120	68.6	12.0 A	8.4 A	3.5 B	2.3 C	2.6 C	2.6 C		
120- 130	72.4	10.2 A	5.6 B	2.1 B	1.8 C	2.0 C	4.3 D	1.6 D	
130- 140	82.1	6.2 A	4.2 B	1.5 C	1.4 C	1.8 D	2.3 D	0.5 D	
140- 150	70.5	11.1 A	4.4 B	1.4 C	1.9 D	2.9 D	6.1 D	1.7 D	
150- 160	77.4	7.8 A	3.6 B	1.2 C	1.3 D	1.8 D	4.0 D	2.9 D	

See explanation at head of table.

Table 13.--Mechanical analyses of drill cuttings from test holes - Continued

Depth of sample (feet)	Particle size, mm								
	Clay and silt sizes	Sand sizes					Gravel sizes		
	.004-.0625	V. fine .0625-.125	Fine .125-.25	Medium .25-.5	Coarse .5-1.0	V. coarse 1.0-2.0	V. fine 2-4	Fine 4-8	Medium 8-16
		Well 17.9.36.414, Test hole T-20 - Continued							
160- 170	57.6	9.0 B	4.5 B	2.5 C	3.9 D	7.2 D	11.3 D	4.0 D	
170- 180	54.9	5.9 C	3.3 D	2.7 D	4.7 D	7.7 D	13.7 D	7.1 D	
180- 190	77.1	7.9 A	2.4 B	1.5 C	2.4 D	2.6 D	3.7 D	2.4 D	
190- 200	65.1	6.4 B	3.1 C	2.7 D	4.4 D	7.1 D	8.4 D	2.8 D	
200- 210	67.6	5.5 B	2.6 C	2.1 D	3.2 D	5.8 D	9.1 D	4.1 D	
210- 220	69.1	7.0 A	3.1 A	2.9 B	5.0 B	8.3 C	4.2 D	0.4 D	
220- 230	75.7	4.6 A	2.1 B	1.6 C	2.3 C	5.1 C	8.3 C	0.3 D	
230- 240	78.2	5.7 A	1.9 B	1.5 C	2.6 D	3.9 D	5.9 D	0.3 D	
240- 250	69.6	6.2 B	2.7 C	2.3 C	3.8 D	6.2 D	8.2 D	1.0 D	
250- 260	73.1	6.3 B	2.1 B	1.9 C	2.7 D	4.1 D	8.1 D	1.7 D	
260- 270	77.4	10.1 A	3.2 A	2.0 B	2.0 C	2.1 D	2.6 D	0.6 D	
270- 280	75.4	11.1 A	3.7 B	2.2 C	1.8 C	2.8 D	2.7 D	0.3 D	
280- 290	83.4	9.5 A	2.5 B	1.3 C	1.2 C	1.0 D	0.8 D	0.3 D	
290- 300	73.2	9.5 A	4.2 B	3.1 B	2.4 C	3.2 C	3.6 C	0.8 D	
300- 312	77.9	7.7 A	3.4 B	2.3 B	2.4 C	3.0 C	2.6 D	0.7 D	

See explanation at head of table.

Table 14.--Depths to water, in feet below land surface, in observation wells in vicinity of Holloman Air Force Base, Otero County, N. Mex.

16.9.3.422. Wade Maupin

Date	Depth to water
April 12, 1952	124.38
March 26, 1953	153.10 a/
June 24, 1953	126.63
February 8, 1954	132.88 b/
April 17, 1954	134.75
August 26, 1954	128.80
October 26, 1954	127.53
December 27, 1954	118.43
April 30, 1955	122.30
December 12, 1955	124.23
February 9, 1956	119.35

16.9.5.244. Charlie Nichols

Date	Depth to water
April 7, 1952	55.40
March 26, 1953	55.93
February 8, 1954	55.43
February 21, 1955	57.22
February 9, 1956	57.48

See footnotes at end of table.

Table 14.--Depths to water in observation wells - Continued

16.9.13.320. E. A. Steinhoff

Date	Depth to water
April 14, 1952	90.85
March 26, 1953	92.60
February 8, 1954	91.63
February 21, 1955	95.29
February 9, 1956	95.92

16.9.26.341. R. J. Turner

Date	Depth to water
April 14, 1952	26.33
June 24, 1953	29.87
February 8, 1954	27.38
April 16, 1954	29.90
June 25, 1954	30.09
August 26, 1954	29.50
October 26, 1954	29.81
December 27, 1954	27.85
February 21, 1955	27.20
April 30, 1955	27.94
June 15, 1955	28.23
October 14, 1955	28.96
December 12, 1955	24.45
February 9, 1956	26.05

See footnotes at end of table.

Table 14.--Depths to water in observation wells - Continued

17.9.24.342. W. L. McCommon

Date	Depth to water
April 14, 1952	56.18
June 23, 1953	57.58
February 8, 1954	58.65
April 17, 1954	60.40
June 25, 1954	59.64
August 26, 1954	60.49
October 26, 1954	60.81
December 27, 1954	60.18
February 15, 1955	59.74
January 6, 1956	64.21

17.10.6.114. Walter Ray

Date	Depth to water
April 14, 1952	121.86
March 28, 1953	122.74
February 8, 1954	127.14
February 21, 1955	124.84 b, c/

a/ Pumping.

b/ Pumped recently.

c/ Nearby well pumping.

Table 15.--Records of test holes drilled in 1954 in vicinity of Boles well field, Otero County, N. Mex. a/

a/ Drilled for Corps of Engineers by Collins Motor Co. of Alamogordo, N. Mex. See table 11 for logs, table 20 for chemical analyses of water from sampling zones.

b/ Estimated from topographic map.

Location no.	Test hole no.	Land owner	Date completed (1954)	Altitude of land surface (feet)	Depth of hole (feet)	Diameter of drilled hole (inches)
17.9.13.244	T-22	Dept. of Interior	Dec. 24	4228 b/	310	8¾
.23.333	T-3	-	Oct. 18	4105.6	208	7 7/8
.23.431	T-1	Dept. of Interior	Oct. 9	4119.1	300	8¾
.24.142	T-8	A. Stafford and W. B. Blakemore	Nov. 29	4166.4	312	8¾
.24.222	T-9	Pearl F. Harrington, et al.	Dec. 2	4201.2	314	8¾
.25.123	T-21	Leah Henry	Dec. 9	4122.3	312	8¾
.25.324	T-7	L. L. Pate, et ux.	Nov. 2	4107.9	517	8¾
.25.444	T-11	Virginia H. Leonard	Nov. 22	4115.4	307	8¾
.26.431	T-4	Dept. of Interior	Oct. 23	4090.3	209	7 7/8
.36.414	T-20	State of New Mexico	Dec. 15	4096.6	312	8¾

Table 15.--Records of test holes drilled in vicinity of Boles well field, 1954 [a] - Continued

Location no.	Water level		Water sampling zones (Feet below land surface)		Remarks
	Below land-surface datum (feet)	Date of measurement	Shallow (bailed)	Deep (pumped)	
17.9.13.244	95.3	Dec. 27, 1954	95-120	168-310	Had trouble drilling beyond 21 feet, owing to caving of sand and gravel.
.23.333	37.7	Oct. 19, 1954	38-46	107-208	Lost circulation in evaporites at about 11 and 22 feet. Set 25 feet of $10\frac{3}{4}$" O. D. Surface casing.
.23.431	41.4 44.5	Oct. 9, 1954 Oct. 9, 1954	 45-51	147-300	Deep zone. Shallow zone.
.24.142	65.8	Dec. 2, 1954	66-80	143-312	
.24.222	76.9	Dec. 3, 1954	77-100	149-314	
.25.123	60.7	Dec. 10, 1954	61-80	149-312	
.25.324	58.8 57.9 57.9	Nov. 3, 1954 Jan. 17, 1955 Jan. 20, 1955	59-80	169-517	See results of test pumping p. 63. Temperature: 66°F.
.25.444	63.8	Nov. 23, 1954	64-80	251-307	Circulation partly lost from 50 to 60 feet. Added 100 lbs. NaCl to mud before electric logging.
.26.431	44.1	Oct. 25, 1954	44-60	100-209	
.36.414	58.7	Dec. 16, 1954	59-75	189-312	

Table 16.--Records of wells and test holes in and near the Boles well field, Otero County, N. Mex. 1/

Location	Well no. 2/	Landowner 3/	Driller 4/	Date completed	Depth of well (feet) 5/	Diameter of well (inches)	Altitude of land surface (feet) 6/
17.9.24.222	-	P. F. Harrington, et al.	-	Old	68	-	-
24.342	33	W. L. McCommon	J. I. Collins	1952	204	8	4,144 E
24.343	34	do.	U. S. A. F.	Apr. 1955	255	10	-
25.212	35	L. C. Boles	do.	May 1955	236	10	-
25.213	17	do.	do.	Aug. 1953	243	12, 10	4,129.3
25.222	16	do.	do.	May 1952	217	10	4,144.6
17.10.18.343	8	Harold Striker	do.	Aug. 1948	262	10	4,169.2
18.424	3	R. G. Walker	do.	Feb. 1948	128	10	4,211.8

See footnotes at end of table.

Table 16.--Records of wells and test holes in and near the Boles well field, Otero County, N. Mex. 1/ - Continued.

Location	Well no. 2/	Water level: Below land surface datum (feet) 7/	Water level: Date of measurement	Test Performance: Date	Test Performance: Yield (gpm) 7/	Test Performance: Draw down (feet) 7/	Test Performance: Duration of test (hours)	Chemical Analysis 8/	Remarks
17.9.24.222	-	65	Nov. 1911	-	-	-	-	-	Abandoned; Meinzer's well 1724.
24.342	33	56.2	4/14/52	9/ 7/54	185	8.8	5	x	Temperature: 68°F.; see log.
		59.7	2/15/55	Summer 1955	357R	-	-		
24.343	34	62.5	4/29/55	4/29/55	250	64	12	x	See sample log.
		63.6	6/15/55	Summer 1955	220R	-	-		
		65.6	1/ 6/56						
25.212	35	70.6	5/23/55	5/25/55	411	68	30	x	Temperature: 68°F.; see sample log.
		73.3	1/ 6/56	Summer 1955	292R	-	-		
25.213	17	62.9	2/ 8/54	11/24/52	865R	61R	--	x	Temperature: 70°F.; (R).
		72.5	5/13/54	2/28/55	353	62	288		
		65.2	1/20/55	Summer 1955	331R	-	-		
		72.0	1/ 6/56						
25.222	16	62R	5/ 1/52	May 1955	100R	-	-	x	Temperature: 70°F.; (R).
		67.1	1/21/55	Summer 1955	94R				
		70.5	1/ 6/56						
17.10.18.343	8	-	-	-	-	-	-	-	Well reported entirely dry; casing pulled and hole filled; see log.
18.424	3	-	-	-	-	-	-	x	Casing collapsed at 128 feet; casing pulled and hole filled; see log.

See footnotes at end of table.

Table 16.--Records of wells and test holes in and near the Boles well field, Otero County, N. Mex. 1/ - Continued.

Location	Well no. 2/	Landowner 3/	Driller 4/	Date completed	Depth of well (feet) 5/	Diameter of well (inches)	Altitude of land surface (feet) 6/
17.10.18.424a	9	R. G. Walker	U. S. A. F.	Oct. 1948	244	10	4,211.8
18.424b	18	do.	do.	Feb. 1953	-	-	-
18.432	24	Harold Striker	do.	May 1953	250	-	4,187.3
18.432a	28	do.	Harold Doty	Aug. 1953	260	20, 10	4,187.3
18.433	6	do.	U. S. A. F.	June 1948	228	10	4,175.7
18.434	20	do.	do.	Apr. 1953	250	-	4,181.5
18.442	19	do.	do.	Mar. 1953	250	-	4,206.3
18.442a	26	do.	Harold Doty	July 1953	250	20, 10	4,206.3
18.443	23	do.	U. S. A. F.	May 1953	250	-	4,190.6
19.111	-	L. C. Boles	-	Old	-	6	-
19.112	13	do.	U. S. A. F.	Mar. 1950	251	10	4,163.3

See footnotes at end of table.

Table 16.--Records of wells and test holes in and near the Boles well field, Otero County, N. Mex. 1/ - Continued

Location	Well no. 2/	Water level: Below land surface datum (feet) 7/	Water level: Date of measurement	Test Performance: Date	Test Performance: Yield (gpm) 7/	Test Performance: Draw down (feet) 7/	Test Performance: Duration of test (hours)	Chemical Analysis 8/	Remarks
17.10.18.424a	9	85R	Oct. 1948	Oct. 1948	120-180R	157R	-	x	Casing pulled and hole filled.
18.424b	18	-	-	-	-	-	-	-	Well drilled at wrong location and filled.
18.432	24	-	-	-	-	-	-	x	Uncased test hole.
18.432a	28	90R 105.9	8/26/53 2/ 8/55	8/27/53 5/12/54	30R 50	120 80	2 8	x	See description of Calgon treatment p. 83; see log.
18.433	6	90R	June 1948	June 1948	61R	80R	-	-	Casing pulled and hole filled; see log.
18.434	20	-	-	-	-	-	-	x	Uncased test hole.
18.442	19	90R	3/11/53	-	-	-	-	x	Uncased test hole
18.442a	26	93R 107.8 109.7	8/ 9/53 1/19/55 1/ 6/56	8/15/53 7/31/54 Summer 1955	205R 176 174R	63R 58	48 120	x	
18.443	23	110.7 109.8	8/30/54 1/ 6/56	-	-	-	-	x	Uncased test hole.
19.111	-	-	-	-	-	-	-	x	Meinzer's well 1725.
19.112	13	74R	3/ 7/50	1950	190R	106R	-	x	Casing collapsed; well filled and abandoned.

See footnotes at end of table.

Table 16.--Records of wells and test holes in and near the Boles well field, Otero County, N. Mex. 1/ - Continued.

Location	Well no. 2/	Landowner 3/	Driller 4/	Date completed	Depth of well (feet) 5/	Diameter of well (inches)	Altitude of land surface (feet) 6/
17.10.19.112a	25	L. C. Boles	U. S. A. F.	June 1953	243	12	4,162.1
19.113	32	do.	Harold Doty	Oct. 1953	175	6	4,148.7
19.121	1	do.	L. C. Boles	May 1947	140	8	4,163
19.121a	10	do.	U. S. A. F.	Nov. 1948	260	10	4,163.4
19.121b	11	do.	do.	Dec. 1948	570	10	4,160.9
19.122	12	do.	do.	Feb. 1950	215	8	-
19.123	2	do.	L. C. Boles	Aug. 1947	240	10	4,160.5
19.132	7	do.	U. S. A. F.	July 1948	253	10	4,147.0

See footnotes at end of table.

Table 16.--Records of wells and test holes in and near the Boles well field, Otero County, N. Mex. 1/ - Continued.

Location	Well no. 2/	Water level		Test Performance				Chemical Analysis 8/	Remarks
		Below land surface datum (feet) 7/	Date of measurement	Date	Yield (gpm) 7/	Draw down (feet) 7/	Duration of test (hours)		
17.10.19.112a	25	74.1 75.9 77.5	3/29/54 1/24/55 1/ 6/56	-	-	-	-	x	Unused
19.113	32	70.2 66.4 68.7	7/26/54 2/10/55 1/ 6/56	10/21/53 2/11/55	90R 102	65R 50	3 24	x	Temperature: 67°F.; see sample log.
19.121	1	65R	May 1947	May 1947	200R	55R	24	x	Temperature: 64, 71°F. (R); well collapsed and abandoned.
19.121a	10	72R 77.1 80.2 81.2	Nov. 1948 4/14/52 1/24/55 1/ 6/56	- 1/28/55 Summer 1955	250R 156 149R	32R 50	- 48	x	Temperature: 70°F. (R); see log.
19.121b	11	82R	2/15/49	-	58R	288R	-	-	Casing pulled and hole filled; see log.
19.122	12	74R	2/23/50	Feb. 1950	95	-	-	x	Casing pulled and hole filled; see log.
19.123	2	80R 83.5 84.1	- 1/24/55 1/ 6/56	- Apr. 1949 Summer 1955	340R - 184R	135R 61R	- -	x	Temperature: 68°F. (R).
19.132	7	70R	-	-	90R	150R	-	-	Casing pulled and hole filled; see log.

See footnotes at end of table.

Table 16.--Records of wells and test holes in and near the Boles well field, Otero County, N. Mex. 1/ - Continued.

Location	Well no. 2/	Landowner 3/	Driller 4/	Date completed	Depth of well (feet) 5/	Diameter of well (inches)	Altitude of land surface (feet) 6/
17.10.19.141	15	L. C. Boles	U. S. A. F.	July 1950	370	10	4,152.0
19.142	14	do.	do.	May 1950	253	8	4,155.5
19.144	5	do.	do.	May 1948	205	10	4,148.8
19.214	4	R. N. Nolley	do.	Mar. 1948	315	10	4,175.9
19.234	21	do.	do.	Apr. 1953	250	-	4,167.9
19.241	22	L. L. Pate, et ux.	do.	do.	250	-	4.174.0
19.244	-	do.	-	Old	75	-	-
19.311	-	W. E. Groom, et al.	-	Old	52	-	-
19.321	27	do.	U. S. A. F.	July 1953	250	-	4,141

See footnotes at end of table.

Table 16.--Records of wells and test holes in and near the Boles well field, Otero County, N. Mex. 1/ - Continued.

Location	Well no. 2/	Water level: Below land surface datum (feet) 7/	Water level: Date of measurement	Test Performance: Date	Test Performance: Yield (gpm) 7/	Test Performance: Draw down (feet) 7/	Test Performance: Duration of test (hours)	Chemical Analysis 8/	Remarks
17.10.19.141	15	74R 80.0 80.3	Aug. 1950 1/24/55 1/ 6/56	- 2/ 2/55 Summer 1955	375R 250 230R	196R 113	- 48	x	Temperature: 65°F. (R).
19.142	14	77R 83.0 84.1	May 1950 1/24/55 1/ 6/56	May 1950 Summer 1955	125R 131R	148R	-	x	Temperature: 68°F.
19.144	5	74R 80.6 81.1	May 1948 1/24/55 1/ 6/56	1948 - Summer 1955	220R 180R 127R	76R 131R	- -	x	Temperature: 68°F. (R); see log.
19.214	4	85R 98.3 97.2	Mar. 1948 8/25/54 1/ 6/56	- -	125R	169R	-	x	Casing pulled; see log.
19.234	21	92.0	8/25/54	-	-	-	-	x	Uncased test hole.
19.241	22	93.9	8/26/54	-	-	-	-	x	Do.
19.244	-	45	Sept. 1911	-	-	-	-	-	Dug well; now filled and abandoned; Meinzer's well 1730.
19.311	-	55	Sept. 1911	-	-	-	-	-	Dug well at school house; now abandoned; Meinzer's well 1731.
19.321	27	81R	7/28/53	-	-	-	-	-	Uncased test hole; see log.

See footnotes at end of table.

Table 16.--Records of wells and test holes in and near the Boles well field, Otero County, N. Mex. 1/ - Continued.

Location	Well no. 2/	Landowner 3/	Driller 4/	Date completed	Depth of well (feet) 5/	Diameter of well (inches)	Altitude of land surface (feet) 6/
17.10.19.321a	30	W. E. Groom, et al.	Harold Doty	Sept. 1953	260	20, 10	4,140.7
19.323	29	do.	U. S. A. F.	Aug. 1953	-	-	4,135
19.323a	31	do.	Harold Doty	Sept. 1953	240	20, 10	4,135.2

See footnotes at end of table.

Table 16.--Records of wells and test holes in and near the Boles well field, Otero County, N. Mex. 1/ - Continued.

Location	Well no. 2/	Water level: Below land surface datum (feet) 7/	Water level: Date of measurement	Test Performance: Date	Test Performance: Yield (gpm) 7/	Test Performance: Draw down (feet) 7/	Test Performance: Duration of test (hours)	Chemical Analysis 8/	Remarks
17.10.19.321a	30	55R 81.5 78.2	9/13/53 7/20/54 1/24/55	9/13/53	35R	175R	5	-	Unused; see log.
19.323	29	76	8/13/53	-	-	-	-	-	Uncased test hole; see log.
19.323a	31	82R 74.9	9/24/53 2/17/55	9/29/53	67R	133R	1	-	Unused; see log.

1/ See table 17 for data on well construction.

2/ See cross index of well numbers, p. 11.

3/ From Corps of Engineers map of Real Estate, Holloman AFB, map no. 69, dated 16 Mar. 1951.

4/ Well drilled by Air Installations personnel where U. S. Air Force shown as driller.

5/ Depth to which measured, otherwise depth to which cased, or if uncased depth to which test hole drilled; see table 17 for additional data.

6/ E - estimated from topographic map; others determined by instrumental leveling and given to 0.1 foot except where exact well location or land surface datum uncertain; then given to nearest foot.

7/ R - reported.

8/ Chemical analysis given in table 20.

Table 17.--Construction data for production and test wells in Boles well field, Otero County, N. Mex.

Well no.	Date completed	Depth 1/ (feet)	Casing and screens: Depth of setting (feet)	Casing and screens: Length (feet)	Casing and screens: Description	Remarks
1	May 1947	162	140	140	8-inch, steel; zone perforated not known.	Well abandoned.
2	Aug. 1947	250	240	240	10-inch, steel; zone perforated not known.	Production well.
5	May 1948	205	205	205	do.	Production well.
9	Oct. 1948	250	-	-	-	244 feet of 10-inch steel casing pulled and hole filled.
10	Nov. 1948	260	260	260	10-inch, steel; zone perforated not known.	Production well.
12	Feb. 1950	215	-	-	-	213 feet of 8-inch steel casing, perforated from 134 to 213 feet, pulled and hole filled.
13	Mar. 1950	270	65 251	65 186	10-inch, steel, blank. 10-inch, steel, perforated with $\frac{1}{4}$ x 14" slots.	Well filled and abandoned.

See footnotes at end of table.

Table 17.--Construction data for production and test wells in Boles well field, Otero County, N. Mex. - Continued.

Well no.	Date completed	Depth 1/ (feet)	Casing and screens: Depth of setting (feet)	Casing and screens: Length (feet)	Casing and screens: Description	Remarks
14	May 1950	295	78	78	10-inch, steel, blank.	Production well.
			253	175	10-inch, steel, slotted.	
15	July 1950	386	87	87	10-inch, steel, blank.	Production well.
			270	183	10-inch, steel, perforated with slots $\frac{1}{4}$" wide.	
16	May 1952	261	50	50	10-inch, steel, blank.	Production well.
			217	167	10-inch, steel, slotted.	
17	Aug. 1952	265	40	40	12-inch, steel, blank surface pipe.	Production well.
			243	243	10-inch, steel; zone perforated not known.	
25	June 1953	250	210	210	12-inch, steel, blank.	Unused.
			243	33	12-inch, steel, slotted.	

See footnotes at end of table.

Table 17.--Construction data for production and test wells in Boles well field, Otero County, N. Mex. - Continued.

Well no.	Date completed	Depth 1/ (feet)	Casing and screens			Remarks
			Depth of setting (feet)	Length (feet)	Description	
26	July 1953	250	50	50	20-inch surface pipe cemented with 150 sacks of cement.	Production well; 10-inch steel casing centered in 19-inch hole below 50 feet; well is gravel-walled; cleanout lines of 2½-inch pipe in gravel wall extend to 240 feet, and 180 feet, on opposite sides of the well.
			120	120	10-inch, steel, blank.	
			130	10	10-inch, steel, slotted.	
			170	40	10-inch, steel, blank.	
			180	10	10-inch, steel, slotted.	
			210	30	10-inch, steel, blank.	
			250	40	10-inch, steel, slotted.	
28	Aug. 1953	260	50	50	20-inch, steel surface pipe cemented with 144 sacks of cement.	Unused; 10-inch steel casing centered in 19-inch hole below 50 feet; well is gravel-walled; clean-out lines of 2½-inch pipe in gravel wall extend to 250 feet on east side and 168 feet on west side of well.
			120	120	10-inch, steel, blank.	
			130	10	10-inch, steel, slotted.	
			160	30	10-inch, steel, blank.	
			170	10	10-inch, steel, slotted.	
			190	20	10-inch, steel, blank.	
			200	10	10-inch, steel, slotted.	
			230	30	10-inch, steel, blank.	
			260	30	10-inch, steel, slotted.	

See footnotes at end of table.

Table 17.--Construction data for production and test wells in Boles well field, Otero County, N. Mex. - Continued.

Well no.	Date completed	Depth 1/ (feet)	Casing and screens: Depth of setting (feet)	Casing and screens: Length (feet)	Casing and screens: Description	Remarks
30	Sept. 1953	260	50	50	20-inch, steel surface pipe cemented with 125 sacks of cement.	Unused; 10-inch steel casing centered in 19-inch hole below 50 feet; well is gravel-walled; clean-out lines of 2½-inch pipe in gravel wall extend to 250 feet on west side and 148 feet on east side of well.
			90	90	10-inch, steel, blank.	
			110	20	10-inch, steel, slotted.	
			130	20	10-inch, steel, blank.	
			150	20	10-inch, steel, slotted.	
			240	90	10-inch, steel, blank.	
			260	20	10-inch, steel, slotted.	
31	Sept. 1953	245	50	50	20-inch, steel surface pipe cemented with 150 sacks of cement.	Unused; 10-inch steel casing centered in 19-inch hole below 50 feet; well is gravel-walled; clean-out line of 2½-inch pipe in gravel wall extend to 150 feet on east side and 230 feet on west side of well.
			90	90	10-inch, steel, blank.	
			110	20	10-inch, steel, slotted.	
			130	20	10-inch, steel, blank.	
			150	20	10-inch, steel, slotted.	
			220	70	10-inch, steel, blank.	
			240	20	10-inch, steel, slotted.	
32	Oct. 1953	232	91	91	6-inch, steel, blank.	Production well.
			175	84	6-inch, steel, perforated with 62 feet of ~~slots at undetermined~~ zones.	

See footnotes at end of table.

Table 17.--Construction data for production and test wells in Boles well field, Otero County, N. Mex. - Continued.

Well no.	Date completed	Depth 1/ (feet)	Casing and screens			Remarks
			Depth of setting (feet)	Length (feet)	Description	
33	1951	231	71 231	71 160	8-inch, steel, blank. 8-inch, steel, slotted.	Production well.
34	Apr. 1955	285	23 255	23 232	10-inch, steel, blank. 10-inch, steel, slotted.	Intended for production.
35	May 1955	280	60 236	60 170	10-inch, steel, blank. 10-inch, steel, slotted.	Intended for production.

1/ Depth to which well was drilled.

Table 18.--Records of private and municipal wells and springs in vicinity of Holloman Air Force Base, Otero County, N. Mex. 1/

Location no.	Meinzer's no. 2/	Owner	Driller	Date completed	Depth of well (feet)	Diameter of well (inches)	Altitude of land surface (feet) 3/
16.9.3.422	-	Wade Maupin	Perry	1950	200	12	4404 E
5.120	-	Harvey Land and Cattle Co.	-	-	-	12	4255 E
8.222 ?	-	Charles Nichols	-	-	-	12	4265 ? E
8.432	-	State of New Mexico	Western Water-Works Co.	1931	525	-	4260 E
13.322	-	E. A. Steinhoff	-	-	-	-	4372 E
23.242	-	J. I. Collins	J. I. Collins	1953	189	12	4325 E
25.220	-	Don L. and John L. Stevens	-	1944	190	8	-
25.242	-	Alamogordo Swimming Pool	-	-	-	-	4327 E
26.200	1630	-	-	Old	1,004	12, 8	-
26.341	-	R. J. Turner	-	-	84	8	4260 E
32.343	-	State of New Mexico	-	Old	-	6	4150 E

See footnotes at end of table.

Table 18.--Records of private and municipal wells and springs in vicinity of Holloman Air Force Base, Otero County, N. Mex. 1/ - Continued.

Location no.	Meinzer's no. 2/	Water level: Below land surface datum (feet) 4/	Water level: Date of measurement	Method of lift 5/	Use of water 5/	Remarks
16.9.3.422	-	122.3	4/30/55	T, E	Irr.	Reported yield: 300 gpm; see chemical analysis.
5.120	-	-	-	T, G	Irr, S	
8.222	-	55.4 57.2	4/ 7/52 2/21/55	N	None	Intended for irrigation.
8.432	-	43.R	1931	N	None	State Engineer's "Alamogordo" test well; see log.
13.322	-	90.9 95.3	4/14/52 2/21/55	T, E30	Irr.	See chemical analyses.
23.242	-	67.3 69.7	2/21/54 2/ 9/56	N	None	Well drilled to 210 feet; casing: 12-inch to 189 feet, perforated from 35 to 189 feet; reported yield: 347 gpm; well intended for irrigation; see log.
25.220	-	13 R	-	T, -	-	Reported yield: 400 gpm; see chemical analysis.
25.242	-	-	-	-	-	See chemical analysis.
26.200	1630	35	Sept. 1911	N	None	Deep test well drilled by Southern Pacific; see log; see chemical analysis.
26.341	-	26.3 27.2	4/14/52 2/21/55	T, E10	Irr, S	
32.343	-	-	-	C, W	S	See chemical analysis; temperature: 66°F.

See footnotes at end of table.

Table 18.--Records of private and municipal wells and springs in vicinity of Holloman Air Force Base, Otero County, N. Mex. 1/ - Continued.

Location no.	Meinzer's no. 2/	Owner	Driller	Date completed	Depth of well (feet)	Diameter of well (inches)	Altitude of land surface (feet) 3/
16.10.5.133	-	V. E. Clark	-	1954	240	8	4575 E
5.343	-	Dr. Baumgartner	-	1953	270	8	4545 E
6.231	-	Joe Bickle	J. I. Collins; James McNatt	1954	321	8	4530 E
7.233	-	Otero County	-	-	-	-	4405 E
7.420	-	James McNatt	James McNatt	1952	238	12, 10	4375 E
8.344	-	Claude Holguin	-	-	-	-	4420 E
17.343	-	Tice Elkins	-	1950	200	-	4390 E
18.231	-	Town of Alamogordo	-	-	-	-	4360 E
18.241	-	New Mexico School For Visually Handicapped	-	-	-	-	4365 E
29.243	-	Town of Alamogordo	-	1913	300	10, 8	4438 E
30.422	-	H. J. Falkenberry	-	-	270	8	4365 E
30.432	-	Earl Haggard	-	1952	240	6	4328 E

See footnotes at end of table.

Table 18.--Records of private and municipal wells and springs in vicinity of Holloman Air Force Base, Otero County, N. Mex. 1/ - Continued.

Location no.	Meinzer's no. 2/	Water level		Method of lift 5/	Use of water 5/	Remarks
		Below land surface datum (feet) 4/	Date of measurement			
16.10.5.133	-	179 R	1954	N	None	Reported yield: 70 gpm; see chemical analysis; intended for domestic and stock use.
5.343	-	-	-	-	D	See chemical analysis.
6.231	-	200.4	7/12/54	N	None	
7.233	-	-	-	T, E	D, S	See chemical analysis.
7.420	-	73 R	-	T, -	Irr.	Reported yield: 400 gpm.
8.344	-	-	-	C, W, E	S, Irr.	See chemical analysis.
17.343	-	-	-	-	Irr.	Reported yield: 80 gpm; see chemical analysis.
18.231	-	-	-	T, E	Irr.	At reservoir in city park; see chemical analysis.
18.241	-	-	-	T, -	Irr.	Reported yield: 500 gpm; see chemical analysis.
29.243	-	135 R	-	T, E	PS	"French well;" reported yield: 155 gpm; used only to supplement other supplies; see chemical analysis.
30.422	-	100 R	-	T, G	Irr.	Yield: 50 gpm, estimated May 19, 1955; temperature: 66°F; see chemical analysis.
30.432	-	-	-	-	D	See chemical analysis.

See footnotes at end of table.

Table 18.--Records of private and municipal wells and springs in vicinity of Holloman Air Force Base, Otero County, N. Mex. 1/ - Continued.

Location no.	Meinzer's no. 2/	Owner	Driller	Date completed	Depth of well (feet)	Diameter of well (inches)	Altitude of land surface (feet) 3/
16.10.31.220	-	Town of Alamogordo (?)	James McNatt	1946	235	10, 8	-
32.122	-	(Formerly LeBriton)	-	-	142	-	-
33.340	-	-	Layne-Texas Co.	1945	648	-	4625 E
33.440	-	-	do.	1945	647	-	4750 E
17.7.23.412	1702	U. S. Government	-	Old	10	60x120	3969 A
17.8.6.220	S-29	C. A. McNatt	-	-	Spring	-	4045
13.231	-	Holloman AFB	Holloman Air Installations Office	1949	110	6	4081 A
13.311	-	do.	do.	1945	120	5	4077 E

See footnotes at end of table.

Table 18.--Records of private and municipal wells and springs in vicinity of Holloman Air Force Base, Otero County, N. Mex. 1/ - Continued.

Location no.	Meinzer's no. 2/	Water level: Below land surface datum (feet) 4/	Water level: Date of measurement	Method of lift 5/	Use of water 5/	Remarks
16.10.31.220	-	100 R	-	N	None	Test well for Town of Alamogordo; reported yield: 40 gpm; reported quality: "No good".
32.122	-	-	-	-	Irr.	See chemical analysis.
33.340	-	210 R	June 1945	N	None	Test well no. 2, drilled for Town of Alamogordo; drawdown reported to 400 feet while pumping 100 gpm; see driller's log and chemical analyses.
33.440	-	-	-	N	None	Test well no. 1; drilled for Town of Alamogordo; reported yield: 40 gpm; well reportedly could be bailed dry; see log.
17.7.23.412	1702	5.0 8.6 7.1	Nov. 1911 4/13/54 4/ 1/55	C, W	S	Dug well at abandoned Walters Ranch on White Sands National Monument; see chemical analyses.
17.8.6.220	S-29	-	-	-	-	"Salt spring;" see chemical analysis.
13.231	-	9.1 8.7 8.7	9/16/54 4/ 1/55 2/10/56	N	None	Drilled for grounding electrical system at Bur. of Recl. substation on base; see chemical analysis.
13.311	-	-	-	N	None	Unused; drilled to 160 feet; casing: 5½-inch to 120 feet, perforated from 103 to 116 feet; formerly supplied swimming pool; see log and chemical analysis.

See footnotes at end of table.

Table 18.--Records of private and municipal wells and springs in vicinity of Holloman Air Force Base, Otero County, N. Mex. 1/ - Continued.

Location no.	Meinzer's no. 2/	Owner	Driller	Date completed	Depth of well (feet)	Diameter of well (inches)	Altitude of land surface (feet) 3/
17.8.28.312	S-30	C. A. McNatt	-	-	Spring	-	4050 E
17.9.1.112	-	McNatt	-	1944	145	8, 7	4260 E
1.141	-	Fambeau	James McNatt	1954	-	-	4251 A
1.311	1703	-	-	Old	7/	-	-
1.440	1704	-	-	Old	104	-	-
2.111	-	A. B. Garrett	-	Old	132	8, 6	4208 E
2.331	-	L. H. Dyvad	-	-	140	5	4193 A
5.122	-	Leon Green	-	-	58	6	4155 A
8.244	-	do.	-	-	-	7	-
8.422	-	do.	-	-	-	8	4133 A
12.422	-	H. J. Pruiett	James McNatt	1953	200	12	4291 A

See footnotes at end of table.

Table 18.--Records of private and municipal wells and springs in vicinity of Holloman Air Force Base, Otero County, N. Mex. 1/ - Continued.

Location no.	Meinzer's no. 2/	Water level		Method of lift 5/	Use of water 5/	Remarks
		Below land surface datum (feet) 4/	Date of measurement			
17.8.28.312	S-30	-	-	N	None	"Herd Spring;" water surface at land surface but no longer flows; see chemical analysis.
17.9.1.112	-	130 R	-	-	D, Irr.	Reported yield: 200 gpm; see chemical analysis.
1.141	-	57.5 6/	4/ 2/54	J, E	D	See chemical analysis.
1.311	1703	50	Sept. 1911	-	-	Dug well; see chemical analysis.
1.440	1704	98	do.	-	-	Dug well; see chemical analysis.
2.111	-	24 R	-	-	-	Reported yield: 450 gpm; see chemical analysis.
2.331	-	42.0 43.0 44.1	9/22/54 4/ 6/55 2/10/56	N	None	
5.122	-	34.8 8/	4/15/54	C, W	S	"Dillard well;" well drilled in old dug well; see chemical analysis.
8.244	-	-	-	C, W	S	"Huss well;" see chemical analysis.
8.422	-	24.2 25.7 23.3	4/15/54 4/ 1/55 2/10/56	C, W	None	"Brownfield well;" unused stock well.
12.422	-	99.1 101.3	4/ 6/54 2/10/56	T, E15	Irr.	Well drilled to 270 feet; reported yield: 300 gpm; see chemical analysis.

See footnotes at end of table.

Table 18.--Records of private and municipal wells and springs in vicinity of Holloman Air Force Base, Otero County, N. Mex. 1/ - Continued.

Location no.	Meinzer's no. 2/	Owner	Driller	Date com-pleted	Depth of well (feet)	Diameter of well (inches)	Altitude of land surface (feet) 3/
17.9.12.422	-	H. J. Pruiett	James McNatt	1954	300	12	-
12.433	-	M. H. Magee	do.	-	163	8	-
14.422	-	Oscar Kunkel	-	-	-	7	-
14.422a	-	do.	-	-	-	-	-
15.240	1721	-	-	Old	62	7	-
19.142	-	C. A. McNatt	-	-	-	8	-
23.310	1722	-	-	Old	85	-	-
23.310a	1723	-	-	Old	50	-	-
25.111	-	Dora Prather Cooley	-	Old	-	7	4120 E
25.112	-	do.	J. I. Collins	1953	250	-	4120 E
25.132	-	T. T. Mann	do.	1953	250	-	4110 E
25.300	1726	-	-	Old	45	-	-

See footnotes at end of table.

Table 18.--Records of private and municipal wells and springs in vicinity of Holloman Air Force Base, Otero County, N. Mex. 1/ - Continued.

Location no.	Meinzer's no. 2/	Water level		Method of lift 5/	Use of water 5/	Remarks
		Below land surface datum (feet) 4/	Date of measurement			
17.9.12.442	-	100.0	5/17/55	N	None	Intended for irrigation use.
12.433	-	71 R	-	J, E	D, Irr.	See chemical analysis.
14.422	-	-	-	C, W	D, S	See chemical analysis.
14.422a	-	-	-	N	None	Drilled for irrigation use; reported yield: 160 gpm; insufficient for intended purpose; casing pulled.
15.240	1721	31	Sept.1911	-	-	Dug and cased; formerly used for irrigation; reported yield: 125 gpm; see chemical analysis.
19.142	-	-	-	N	None	"Martin Lewis well;" filled.
23.310	1722	30	1911	-	-	See chemical analysis.
23.310a	1723	30	do.	-	-	See chemical analysis.
25.111	-	-	-	C, W	S	See chemical analyses.
25.112	-	49.0	8/17/54	N	None	Town of Alamogordo test well no. 1; see log and chemical analyses.
25.132	-	-	-	N	None	Town of Alamogordo test well no. 2; see log and chemical analyses.
25.300	1726	37	1911	-	-	Dug well; see chemical analysis.

See footnotes at end of table.

Table 18.--Records of private and municipal wells and springs in vicinity of Holloman Air Force Base, Otero County, N. Mex. 1/ - Continued.

Location no.	Meinzer's no. 2/	Owner	Driller	Date completed	Depth of well (feet)	Diameter of well (inches)	Altitude of land surface (feet) 3/
17.9.35.242	-	Dora Prather Cooley	Payne and Ballard	1954	298	14	4085 A
35.331	-	Dora Prather Cooley	-	-	75	7	4061 A
35.332	-	do.	James McNatt	1945	100	7	4062 E
35.444	-	do.	Payne and Ballard	1954	297	14	4077 A

See footnotes at end of table.

Table 18.--Records of private and municipal wells and springs in vicinity of Holloman Air Force Base, Otero County, N. Mex. 1/ - Continued.

Location no.	Meinzer's no. 2/	Water level: Below land surface datum (feet) 4/	Water level: Date of measurement	Method of lift 5/	Use of water 5/	Remarks
17.9.35.242	-	43.0 42.9 44.4 45.0	4/ 1/54 5/11/54 4/ 6/55 1/ 6/56	T, E150	PS	Town of Alamogordo production well no. 1; casing: 14-inch to 298 feet, perforated from 118 to 298 feet; gravel-walled by pouring 19 cubic yards of gravel into annulus between well face and casing; drawdown reported when drilled: 70 feet while pumping 972 gpm; drawdown reported Dec. 7, 1954: 68 feet while pumping 760 gpm, after pumping 76 hours; temperature: 66°F.; see log and chemical analyses.
35.331	-	40.2 41.1	4/ 8/54 4/ 6/55	C, G	S	
35.332	-	41.1	4/ 8/54	C, W	D, S	See chemical analysis.
35.444	-	45.8	8/26/54	N	None	Town of Alamogordo production well no. 2, unequipped; casing: 14-inch to 297 feet, perforated from 117 to 297 feet, with torch-cut slots $\frac{1}{4}$ to 3/8-inch wide by 11 to 14 inches long; 14-inch casing centered in 24-inch hole and gravel-walled by pouring 30 cubic yards of gravel into annulus; drawdown reported on Nov. 27, 1954: 50 feet while pumping 440 gpm, after pumping 4 hours; see log and chemical analysis.

See footnotes at end of table.

Table 18.--Records of private and municipal wells and springs in vicinity of Holloman Air Force Base, Otero County, N. Mex. 1/ - Continued.

Location no.	Meinzer's no. 2/	Owner	Driller	Date com-pleted	Depth of well (feet)	Diameter of well (inches)	Altitude of land surface (feet) 3/
17.9.36.120	-	State of New Mexico	Western Water-works Co.	1930	402	-	-
36.222	-	do.	-	-	-	6	-
17.10.6.122	-	Walter Ray	James McNatt	1953	302	16	-
6.132	-	do.	-	-	210	8	4316 A
6.311	-	L. O. Najera	-	-	140	8	-
29.314	-	Don Taylor	Don Taylor	1947	222	8	4219 A
30.130	-	do.	-	-	213	8	4127 A
33.234	-	-	-	-	Spring	-	-
18.7.1.321	-	U. S. Government	-	1936	12	-	-

See footnotes at end of table.

Table 18.--Records of private and municipal wells and springs in vicinity of Holloman Air Force Base, Otero County, N. Mex. 1/ - Continued.

Location no.	Meinzer's no. 2/	Water level: Below land surface datum (feet) 4/	Water level: Date of measurement	Method of lift 5/	Use of water 5/	Remarks
17.9.36.120	-	50 R	1930	N	None	Drilled by State Engineer during ground-water investigation; see log.
36.222	-	64.2 64.7	8/17/54 1/ 6/56	N	None	No casing; appears to be old shothole.
17.10.6.122	-	169 R	-	T, E	Irr.	Reported yield: 790 gpm; temperature: 70°F.; see chemical analyses.
6.132	-	121.9 124.8	4/17/52 2/21/55	T, G	Irr, S	Reported yield: 500 gpm; see chemical analysis.
6.311	-	-	-	C, G	Irr.	Estimated yield: 20 gpm; temperature: 66°F.; see chemical analysis.
29.314	-	174.5 175.4	4/29/54 4/ 6/55	T, E15	Irr, S	Casing: 8-inch to 222 feet, perforated from 165 to 222 feet; reported pumping level: 185 feet, while pumping 300 gpm; see chemical analysis.
30.130	-	72.8 73.6	4/ 6/55 1/ 6/56	C, -	None	
33.234	-	Flows	-	N	D, S	Water piped from San Andres Canyon to Don Taylor ranch house; water issues from Lower Paleozoic rocks; see chemical analysis.
18.7.1.321	-	-	-	N	None	Dug well in White Sands at White Sands National Monument; quality of water very poor.

See footnotes at end of table.

Table 18.--Records of private and municipal wells and springs in vicinity of Holloman Air Force Base, Otero County, N. Mex. 1/ - Continued.

Location no.	Meinzer's no. 2/	Owner	Driller	Date completed	Depth of well (feet)	Diameter of well (inches)	Altitude of land surface (feet) 3/
18.7.14.233	-	U. S. Government	-	Old	29	49x49	3977 A
14.330	1802	do.	-	Old.	-	-	-
25.342	-	-	-	Old	46	72x72	3982 A
18.8.5.342	-	U. S. Government	-	1916	-	-	-
5.431	-	do.	G. E. Moffett	1916	989	10	4020 E
12.113	-	G. B. Oliver	-	-	40	76x42	4035 A
17.412	-	do.	-	-	Spring	-	4020 E
18.9.1.442	-	Gene Towers	-	Old	-	6	-

See footnotes at end of table.

Table 18.--Records of private and municipal wells and springs in vicinity of Holloman Air Force Base, Otero County, N. Mex. 1/ - Continued.

Location no.	Meinzer's no. 2/	Water level		Method of lift 5/	Use of water 5/	Remarks
		Below land surface datum (feet) 4/	Date of measurement			
18.7.14.233	-	28.1 27.8	4/ 2/54 4/ 1/55	C, W	None	Dug well in White Sands at vacant motel at White Sands National Monument.
14.330	1802	8	Sept. 1911	-	-	See chemical analysis.
25.342	-	28.5	4/ 1/55	C, W	None	"Roberts well;" unused dug well at vacant ranch house on White Sands Proving Ground.
18.8.5.342	-	-	-	-	-	Oil test at White Sands National Monument; "a few hundred feet" from Garton well but no cavernous limestone encountered.
5.431	-	Flows	3/30/54	N	WL	"Garton well;" an oil test, abandoned owing to flowing water encountered from 889 to 892 feet; reported flow: 40 to 50 gpm; see log and chemical analysis; water is warm.
12.113	-	24.0 31.4	4/ 8/54 4/ 1/55	C, W	S	"Harrington well;" dug well.
17.412	-	Flows	4/ 8/54	N	S	"Harrington Spring;" water rises in porous conduit and discharges from top of gypsite hill; estimated yield: 15 gpm; temperature: 81°F.; see chemical analysis.
18.9.1.442	-	-	-	N	None	Filled stock and domestic well.

See footnotes at end of table.

Table 18.--Records of private and municipal wells and springs in vicinity of Holloman Air Force Base, Otero County, N. Mex. 1/ - Continued.

Location no.	Meinzer's no. 2/	Owner	Driller	Date com-pleted	Depth of well (feet)	Diameter of well (inches)	Altitude of land surface (feet) 3/
18.9.10.443	1805	Jack Prather	-	Old	40+	-	4030 E
12.333	-	Bud Prather	-	-	85	-	4050 E
13.331	-	-	-	Old	28	36	4035 E
13.431	1809	-	-	Old	103	8	4045 E
14.233	1810	Jack Prather	-	Old	160	10	4030 E
20.440	-	do.	-	Old	32	6	4030 E
23.442	-	Buster Prather	-	-	-	-	4027 E
25.222	1812	-	-	Old	-	-	4035 E
26.311	1813	Jack Prather	-	Old	100	-	4013 E
34.212	-	Bill Moss	-	-	-	6	4010 E
18.10.6.234	-	Mrs. B. D. Douglas	James McNatt	1953	177	10	4132 E

See footnotes at end of table.

Table 18.--Records of private and municipal wells and springs in vicinity of Holloman Air Force Base, Otero County, N. Mex. 1/ - Continued.

Location no.	Meinzer's no. 2/	Water level		Method of lift 5/	Use of water 5/	Remarks
		Below land surface datum (feet) 4/	Date of measurement			
18.9.10.443	1805	34	Sept. 1911	C, G	S	Dug and drilled well; see chemical analysis.
12.333	-	-	-	C, W	D, S	Old well, 50 feet deep, at same location, went dry.
13.331	-	Dry	4/ 8/54	N	None	Dug well.
13.431	1809	41 45.5 45.7	Sept. 1911 4/ 8/54 4/ 6/55	N	None	Unused domestic and stock well at vacant ranch house; see chemical analysis.
14.233	1810	38 36.4 36.7	Sept. 1911 4/ 7/54 4/ 6/55	N	None	Yield reported in 1911: 140 gpm.
20.440	-	Dry	4/ 7/54	N	None	
23.442	-	-	-	C, W	S	See chemical analysis.
25.222	1812	24	Sept. 1911	-	-	See chemical analysis.
26.311	1813	30 25.3	Sept. 1911 4/ 7/54	C, W	S	Dug to 50 feet; drilled to 100 feet; see chemical analysis.
34.212	-	28.7	do.	C, W	S	
18.10.6.234	-	99.8 100.1	4/ 6/54 4/ 6/55	N	None	Intended for irrigation use; well drilled to 195 feet; casing: 10-inch to 180 feet, perforated from land surface to 180 feet; reported yield: 37 gpm; see log.

See footnotes at end of table.

Table 18.--Records of private and municipal wells and springs in vicinity of Holloman Air Force Base, Otero County, N. Mex. 1/ - Continued.

Location no.	Meinzer's no. 2/	Owner	Driller	Date com-pleted	Depth of well (feet)	Diameter of well (inches)	Altitude of land surface (feet) 3/
18.10.6.241	-	Mrs. B. D. Douglas	James McNatt	-	154	60, 6	4160 E
15.113	-	-	-	-	Spring	-	-
17.232	-	-	-	Old	104	7	4135 E
17.313	-	-	-	Old	95	8	4075 E
18.224	-	Homer Barnwell, Jr.	James McNatt	-	196	14	4095 E
21.312	-	-	-	Old	200+	10	4115 E
28.141	-	Tom Fairchild	-	Old	-	-	4095 E
30.242	-	-	-	Old	-	-	4055 E
31.221	-	Ray Prather	-	Old	-	-	4053 E
33.434	-	Dick Gatlin	-	1946	-	6	4095 E
35.313	-	Sam Fairchild	-	-	-	8	4235 E

See footnotes at end of table.

Table 18.--Records of private and municipal wells and springs in vicinity of Holloman Air Force Base, Otero County, N. Mex. 1/ - Continued.

Location no.	Meinzer's no. 2/	Water level		Method of lift 5/	Use of water 5/	Remarks
		Below land surface datum (feet) 4/	Date of measurement			
18.10.6.241	-	119.5	4/ 6/54	T, E5	D, S Irr.	Dug and drilled well; reported yield: 80 gpm; see chemical analysis.
15.113	-	Flows	-	-	None	"Dog Canyon spring;" water issues from Lower Paleozoic limestone; temperature: 66°F.; see chemical analysis.
17.232	-	Dry	4/ 8/54	N	None	
17.313	-	Dry	do.	C, W	None	
18.224	-	74.2 74.2	do. 4/ 6/55	N	None	Intended for irrigation, domestic, and stock use.
21.312	-	72.2	3/25/55	N	None	Dug and drilled well with 10-inch casing to land surface.
28.141	-	-	-	C, W	D, S	Two wells at ranch house pump into common storage tank; see chemical analyses.
30.242	-	-	-	C, W	S	See chemical analysis.
31.221	-	61.6	3/25/55	C, W	S	See chemical analysis.
33.434	-	89.2	do.	C, W	S	
35.313	-	-	-	C, W	S	See chemical analysis.

See footnotes at end of table.

Table 18.--Records of private and municipal wells and springs in vicinity of Holloman Air Force Base, Otero County, N. Mex. 1/ - Continued.

Location no.	Meinzer's no. 2/	Owner	Driller	Date completed	Depth of well (feet)	Diameter of well (inches)	Altitude of land surface (feet) 3/
19.9.1.111	-	Ray Prather	-	Old	-	-	4024 E
34.331	-	-	-	-	-	7	4020 E
19.10.4.124	-	Langford Ranch	-	Old	-	-	4080 E
10.331	-	do.	-	-	-	6	4160 E
17.231	-	do.	-	1946	240	8	4115 E
17.233	-	do.	-	-	150	-	-
28.444	-	do.	-	New	-	6	4230 E
32.113	-	do.	-	Old	-	8	4140 E

See footnotes at end of table.

Table 18.--Records of private and municipal wells and springs in vicinity of Holloman Air Force Base, Otero County, N. Mex. 1/ - Continued.

Location no.	Meinzer's no. 2/	Water level: Below land surface datum (feet) 4/	Water level: Date of measurement	Method of lift 5/	Use of water 5/	Remarks
19.9.1.111	-	42.5	3/25/55	C, W	S	At vacant ranch headquarters.
34.331	-	177.5	3/30/55	C, W	None	
19.10.4.124	-	-	-	C, W	S	See chemical analyses.
10.331	-	166.5	3/25/55	C, W	S	
17.231	-	220 R	-	C, W	D, S	Well on north side of ranch house; see chemical analysis.
17.233	-	-	-	-	-	One of 2 old wells on south side of ranch house; see chemical analysis.
28.444	-	-	-	N	None	Intended for stock use; casing sealed with welded steel plate.
32.113	-	184.7	3/30/55	C, W	S	

See footnotes at end of table.

Table 18.--Records of private and municipal wells and springs in vicinity of Holloman Air Force Base, Otero County, N. Mex. 1/ - Continued.

Footnotes

1/ Excluding wells and test holes in Boles well field area.

2/ From Water-Supply Paper 343.

3/ A, determined by aneroid altimeter. E, estimated from topographic map. All others by instrumental leveling.

4/ R, reported.

5/ Abbreviations:

C - Cylinder pump	N - None
D - Domestic	PS - Public supply
E - Electric motor; number denotes horsepower	T - Turbine pump
G - Gasoline or butane	S - Stock
Irr. - Irrigation	W - Windmill
J - Jet pump	WL - Wildlife refuge

6/ Measured while well being drilled, on day when drilling rig shut down.

7/ Dug to depth just below water level.

8/ Measured after well had been pumped very slowly.

Table 19.--Analyses of water from test holes drilled in 1954 in vicinity of Boles well field, Otero County, N. Mex.

Analyses by U. S. Geological Survey. (Chemical constituents in parts per million.)

Location	Test well no.	Owner	Sampling zone (feet)	Date of collection	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)
17.9.13.244	T-22	Dept. of Interior	95-120	Dec. 24, 1954	14	117	61	94
13.244	T-22	do.	168-310	do.	16	131	63	95
23.333	T-3	-	38-46	Oct. 19, 1954	26	887	827	2,020
23.333	T-3	-	107-208	Oct. 18, 1954	22	540	253	362
23.431	T-1	Dept. of Interior	45-51	Oct. 9, 1954	20	278	124	257
23.431	T-1	do.	147-300	do.	15	179	69	126
24.142	T-8	A. Stafford and W. B. Blakemore	66-80	Nov. 29, 1954	18	131	59	90
24.142	T-8	do.	143-312	do.	20	141	63	86
24.222	T-9	Pearl Harrington et al.	77-100	Dec. 3, 1954	17	105	38	48
24.222	T-9	do.	149-314	Dec. 2, 1954	15	100	40	60
25.123	T-21	Leah Henry	61-80	Dec. 9, 1954	18	106	46	60
25.123	T-21	do.	149-312	do.	21	105	47	66
25.324	T-7	L. L. Pate, et ux.	59-80	Nov. 2, 1954	20	103	45	84
25.324	T-7	do.	169-517	do.	19	81	39	68
25.324	T-7	do.	300	Jan. 18, 1955	-	-	-	-

Table 19.--Analyses of water from test holes drilled in 1954 in vicinity of Boles well field, Otero County, N. Mex. - Continued.

Analyses by U. S. Geological Survey. (Chemical constituents in parts per million.)

Location	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Hardness as $CaCO_3$		Percent sodium (% Na)	Sodium-adsorption ratio (SAR)	Specific conductance (micromhos at 25°C)	pH
							Noncarbonate	Total				
17.9.13.244	a/144	507	68	0.3	5.6	938	425	543	27	1.8	1,330	-
13.244	176	487	96	0.3	5.2	980	442	586	26	1.7	1,380	-
23.333	373	3,290	4,440	0.6	26	11,700	5,310	5,610	44	12	15,800	-
23.333	244	2,100	545	0.3	24	3,970	2,190	2,390	25	3.2	4,720	-
23.431	350	1,190	161	0.3	11	2,210	916	1,200	32	3.2	2,590	-
23.431	155	686	110	0.6	7.9	1,270	603	730	27	2.0	1,700	-
24.142	222	374	112	0.2	4.0	889	354	536	27	1.7	1,320	-
24.142	192	446	120	0.2	7.6	978	454	611	23	1.5	1,410	-
24.222	242	248	45	0.3	1.8	622	220	418	20	1.0	908	-
24.222	198	290	54	0.2	4.5	661	252	414	24	1.3	975	-
25.123	238	301	50	0.4	4.2	703	258	454	22	1.2	1,020	-
25.123	185	336	65	0.3	4.7	736	304	456	24	1.3	1,070	-
25.324	226	273	107	0.2	5.0	748	257	442	29	1.7	1,260	7.5
25.324	179	281	48	0.6	2.5	627	216	362	29	1.6	946	7.8
25.324	-	-	31	-	-	-	-	-	-	-	852	-

See footnotes at end of table.

Table 19.--Analyses of water from test holes drilled in 1954 in vicinity of Boles well field, Otero County, N. Mex. - Continued.

Analyses by U. S. Geological Survey. (Chemical constituents in parts per million.)

Location	Test well no.	Owner	Sampling zone (feet)	Date of collection	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)
17.9.25.444	T-11	Virginia Leonard	64-80	Nov. 23, 1954	23	122	52	-
25.444	T-11	do.	251-307	Nov. 22, 1954	19	48	23	-
26.431	T-4	Dept. of Interior	44-60	Oct. 24, 1954	20	218	90	117
26.431	T-4	do.	100-209	Oct. 23, 1954	20	191	83	118
36.414	T-20	State of New Mexico	59-75	Dec. 15, 1954	23	103	45	52
36.414	T-20	do.	189-312	do.	26	69	37	63

Table 19.--Analyses of water from test holes drilled in 1954 in vicinity of Boles well field, Otero County, N. Mex. - Continued.

Analyses by U. S. Geological Survey. (Chemical constituents in parts per million.)

Location	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Hardness as $CaCO_3$		Percent sodium (% Na)	Sodium-adsorption-ratio (SAR)	Specific conductance (micromhos at 25°C)	pH
							Noncarbonate	Total				
17.9.25.444	262	298	-	0.2	2.4	-	304	518	-	-	-	-
25.444	b/184	203	-	0.9	0.8	-	64	214	-	-	-	-
26.431	225	756	135	0.2	5.9	1,450	730	914	22	1.7	1,910	-
26.431	194	703	125	0.4	6.8	1,340	659	818	24	1.8	1,790	7.6
36.414	252	270	45	0.4	3.5	666	236	442	20	1.1	984	-
36.414	183	240	41	0.6	1.4	586	174	324	30	1.5	868	-

a/ Includes 7 ppm CO_3.

b/ Includes 8 ppm CO_3.

Table 20.--Analyses of water from wells and test wells in Boles well field, Otero County, N. Mex.

Analyses by U. S. Geological Survey. (Chemical constituents in parts per million.)

Location	Well no. a/	Land owner (Lessor)	Depth of well (feet)	Date of collection	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)
17.9.24.342	33	W. L. McCommon	231	Feb. 28, 1952	-	107	43	27
				Jan. 5, 1954	-	107	47	21
				Aug. 30, 1954	-	-	-	-
				May 16, 1955	20	99	46	33
				Sept. 16, 1955	-	-	-	-
24.343	34	do.	255	Apr. 30, 1955	24	109	63	21
25.212	35	L. C. Boles	236	May 25, 1955	19	89	47	15

See footnotes at end of table.

Table 20.--Analyses of water from wells and test wells in Boles well field, Otero County, N. Mex. - Continued.

Analyses by U. S. Geological Survey. (Chemical constituents in parts per million.)

Location	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Hardness as $CaCO_3$		Percent sodium	Sodium-adsorption-ratio (SAR)	Specific conductance (micromhos at 25°C)	pH
							Non-carbonate	Total				
17.9.24.342	218	250	45	-	2.0	581	266	444	12	-	938	7.8
	222	247	46	-	1.7	579	278	460	9	-	930	-
	224	252	42	-	-	-	-	-	-	-	917	-
	216	260	41	0.2	1.4	607	259	436	14	0.7	920	7.3
	220	272	46	-	-	-	260	440	-	-	939	7.5
24.343	212	308	56	0.2	3.0	688	358	531	8	0.4	1,020	7.3
25.212	217	213	33	0.2	1.4	525	238	416	7	0.3	810	7.3

See footnotes at end of table.

Table 20.--Analyses of water from wells and test wells in Boles well field, Otero County, N. Mex. - Continued.

Analyses by U. S. Geological Survey. (Chemical constituents in parts per million.)

Location	Well no. a/	Land owner (Lessor)	Depth of well (feet)	Date of collection	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)
17.9.25.213	17	L. C. Boles	243	Sept. 2, 1952	-	104	45	20
				Nov. 22, 1952	-	99	41	33
				June 25, 1953	-	104	43	23
				May 26, 1954	-	100	42	29
				Aug. 9, 1954	-	95	38	41
25.222	16	do.	217	May 12, 1952	-	95	39	19
				May 19, 1952	-	94	40	14
				June 25, 1953	-	98	40	12
				Aug. 9, 1954	-	94	32	35
				Aug. 16, 1955	-	86	40	31

See footnotes at end of table.

Table 20.--Analyses of water from wells and test wells in Boles well field, Otero County, N. Mex. - Continued.

Analyses by U. S. Geological Survey. (Chemical constituents in parts per million.)

Location	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Hardness as $CaCO_3$		Percent sodium	Sodium-adsorption-ratio (SAR)	Specific conductance (micromhos at 25°C)	pH
							Non-carbonate	Total				
17.9.25.213	224	244	34	-	1.9	559	261	444	9	-	876	-
	219	245	36	-	1.3	563	236	416	15	-	867	7.3
	230	235	36	-	2.0	556	248	436	10	-	867	7.5
	226	242	34	-	1.1	559	237	422	13	-	859	7.5
	227	238	34	-	1.2	559	207	393	19	0.9	862	7.8
25.222	227	201	31	-	0.9	498	212	398	9	-	798	-
	224	200	26	-	1.3	485	216	399	7	-	786	7.7
	244	198	31	-	2.0	491	226	409	6	-	795	7.5
	227	205	30	-	1.3	509	180	366	17	0.8	799	7.8
	223	212	30	-	1.5	510	196	379	15	0.69	805	7.8

See footnotes at end of table.

Table 20.--Analyses of water from wells and test wells in Boles well field, Otero County, N. Mex. - Continued.

Analyses by U. S. Geological Survey. (Chemical constituents in parts per million.)

Location	Well no. a/	Land owner (Lessor)	Depth of well (feet)	Date of collection	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)
17.10.18.424	3	R. G. Walker	128	Mar. 1948	-	103	46	46
18.424a	9	do.	244	Mar. 17, 1949	-	93	38	36
18.432	24	Harold Striker	150	May 25, 1953 b,c/	-	-	-	-
			250	June 2, 1953	-	94	48	14
18.432a	28	do.	260	Apr. 26, 1954	-	-	-	-
				May 20, 1954	39	92	41	41

See footnotes at end of table.

Table 20.--Analyses of water from wells and test wells in Boles well field, Otero County, N. Mex. - Continued.

Analyses by U. S. Geological Survey. (Chemical constituents in parts per million.)

Location	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Hardness as $CaCO_3$		Percent sodium	Sodium-adsorption-ratio (SAR)	Specific conductance (micromhos at 25°C)	pH
							Noncarbonate	Total				
17.10.18.424	260	279	28	0.6	0.6	631	233	446	-	-	958	-
18.424a	228	211	41	-	1.8	533	201	388	17	-	832	7.8
18.432	-	-	34	-	-	-	-	-	-	-	-	7.8
	178	255	36	-	0.2	535	286	434	7	-	844	7.6
18.432a	212	-	31	-	-	-	-	-	-	-	841	-
	226	240	30	3.6	1.0	599	213	398	18	-	889	-

See footnotes at end of table.

Table 20.--Analyses of water from wells and test wells in Boles well field, Otero County, N. Mex. - Continued.

Analyses by U. S. Geological Survey. (Chemical constituents in parts per million.)

Location	Well no. a/	Land owner (Lessor)	Depth of well (feet)	Date of collection	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)
17.10.18.434	20	Harold Striker	250	Apr. 10, 1953	-	89	45	12
18.442	19	do.	110	Feb. 27, 1953 b,c/	-	-	-	-
			160	Mar. 10, 1953 b,c/	-	-	-	-
			190	Mar. 11, 1953 c/	-	96	43	3.9
18.442a	26	do.	250	Aug. 12, 1953	-	92	38	20
				Aug. 11, 1954	-	93	36	22
				May 16, 1955	20	85	39	29
18.443	23	do.	250	May 18, 1953	-	95	45	10

See footnotes at end of table.

Table 20.--Analyses of water from wells and test wells in Boles well field, Otero County, N. Mex. - Continued.

Analyses by U. S. Geological Survey. (Chemical constituents in parts per million.)

Location	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Hardness as $CaCO_3$		Percent sodium	Sodium-adsorption-ratio (SAR)	Specific conductance (micromhos at 25°C)	pH
							Noncarbonate	Total				
17.10.18.434	197	224	27	-	0.2	494	246	407	6	-	788	7.9
18.442	-	-	42	-	-	-	-	-	-	-	-	-
	-	-	38	-	-	-	-	-	-	-	-	-
	205	210	27	-	0.7	482	248	416	2	-	774	7.7
18.442a	228	197	26	-	1.0	486	198	386	10	-	791	7.4
	232	199	22	-	0.9	487	190	380	11	0.5	792	7.7
	228	202	26	0.2	0.6	514	186	372	14	0.6	783	7.3
18.443	218	216	29	-	0.2	502	244	422	5	-	827	7.2

See footnotes at end of table.

Table 20.--Analyses of water from wells and test wells in Boles well field, Otero County, N. Mex. - Continued.

Analyses by U. S. Geological Survey. (Chemical constituents in parts per million.)

Location	Well no. a/	Land owner (Lessor)	Depth of well (feet)	Date of collection	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium and pottassium (Na+K)
17.10.19.111	-	L. C. Boles	-	Sept. 1911	-	186	86	111
19.112	13	do.	251	Mar. 15, 1950	-	106	45	29
				June 2, 1950	-	106	43	25
				July 6, 1950	-	98	40	27
				June 7, 1951	-	112	40	31
				July 5, 1951	-	110	46	34
				July 12, 1951	-	100	43	36
				July 20, 1951	-	103	43	25
				July 26, 1951	-	103	42	29
				Aug. 9, 1951	-	104	44	25
				Aug. 17, 1951	-	102	44	-
			195	Aug. 22, 1951	-	94	42	20

See footnotes at end of table.

Table 20.--Analyses of water from wells and test wells in Boles well field, Otero County, N. Mex. - Continued.

Analyses by U. S. Geological Survey. (Chemical constituents in parts per million.)

Location	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Hardness as $CaCO_3$: Noncarbonate	Hardness as $CaCO_3$: Total	Percent sodium	Sodium-adsorption-ratio (SAR)	Specific conductance (micromhos at 25°C)	pH
17.10.19.111	260	481	244	-	-	1,363	-	-	-	-	-	-
19.112	227	275	28	-	0.6	596	264	450	12	-	913	7.6
	227	258	29	-	0.7	574	256	442	11	-	888	7.8
	226	236	26	-	1.0	539	224	409	13	-	847	7.5
	225	272	30	-	0.8	597	260	444	13	-	913	7.7
	229	292	33	-	0.6	629	276	464	14	-	925	7.8
	227	263	31	-	0.8	586	240	426	15	-	880	8.0
	228	249	29	-	0.6	562	247	434	11	-	874	8.0
	232	249	30	-	0.7	568	240	430	13	-	876	8.0
	224	256	31	-	0.8	571	257	440	11	-	888	7.5
	224	-	32	-	0.8	-	252	436	-	-	871	7.9
	237	208	28	-	0.7	510	213	407	10	-	809	7.6

See footnotes at end of table.

Table 20.--Analyses of water from wells and test wells in Boles well field, Otero County, N. Mex. - Continued.

Analyses by U. S. Geological Survey. (Chemical constituents in parts per million.)

Location	Well no. a/	Land owner (Lessor)	Depth of well (feet)	Date of collection	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)
17.10.19.112	13	L. C. Boles	251	Aug. 29, 1951	-	104	44	24
				Sept. 7, 1951	-	106	44	21
				Sept. 17, 1951	-	102	43	22
				Oct. 4, 1951	-	102	42	25
				Oct. 11, 1951	-	103	42	28
				Dec. 5, 1951	-	108	46	11
				Dec. 27, 1951	-	109	48	4.8
				Feb. 15, 1952	-	106	42	28
				May 19, 1952	-	101	45	21
				June 18, 1952	-	100	43	23
				Aug. 5, 1952	-	100	40	20
				Sept. 8, 1952	-	134	56	34
				Oct. 20, 1952	-	94	45	11
				Nov. 17, 1952	-	98	41	17
				Jan. 16, 1953	-	94	43	24

See footnotes at end of table.

Table 20.--Analyses of water from wells and test wells in Boles well field, Otero County, N. Mex. - Continued.

Analyses by U. S. Geological Survey. (Chemical constituents in parts per million.)

Location	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Hardness as $CaCO_3$: Noncarbonate	Hardness as $CaCO_3$: Total	Percent sodium	Sodium-adsorption-ratio (SAR)	Specific conductance (micromhos at 25°C)	pH
17.10.19.112	224	258	29	-	0.8	570	257	440	11	-	892	7.6
	227	252	29	-	1.0	565	260	446	9	-	881	7.5
	224	241	32	-	0.9	551	248	432	10	-	-	7.9
	226	245	29	-	0.5	554	242	427	11	-	875	7.7
	223	255	29	-	0.4	567	247	430	12	-	890	7.6
	224	247	29	-	0.8	552	275	458	5	-	864	7.7
	222	245	30	-	0.8	547	288	470	2	-	868	7.6
	229	256	30	-	0.8	576	250	437	12	-	899	7.6
	228	244	29	-	0.9	553	250	437	9	-	867	7.8
	230	238	28	-	1.3	546	238	426	10	-	863	7.5
	230	221	28	-	0.7	523	226	414	10	-	829	7.8
	226	303	97	-	1.8	737	380	565	12	-	1,140	7.5
	224	212	28	-	0.9	501	236	420	6	-	822	7.6
	227	219	26	-	0.5	514	227	413	8	-	811	7.5
	226	228	29	-	0.8	530	226	412	11	-	825	7.4

See footnotes at end of table.

Table 20.--Analyses of water from wells and test wells in Boles well field, Otero County, N. Mex. - Continued.

Analyses by U. S. Geological Survey. (Chemical constituents in parts per million.)

Location	Well no. a/	Land owner (Lessor)	Depth of well (feet)	Date of collection	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)
17.10.19.112	13	L. C. Boles	-	Mar. 3, 1953	-	97	42	20
				Aug. 17, 1953	-	106	51	29
19.112a	25	do.	110	June 13, 1953 b,c/	-	-	-	-
			130	June 15, 1953 b,c/	-	-	-	-
			243	June 24, 1953 b,c/	-	-	-	-
19.113	32	do.	175	May 25, 1955	19	87	37	27
19.121	1	do.	140	Apr. 1, 1947 b/	17	-	-	-
				July 28, 1947 b/	12	-	-	-
				Sept. 16, 1947 b/	22	-	-	-
				Nov. 14, 1947 d/	21	90	37	29
				Dec. 22, 1947	-	94	40	18

See footnotes at end of table.

Table 20.--Analyses of water from wells and test wells in Boles well field, Otero County, N. Mex. --Continued.

Analyses by U. S. Geological Survey. (Chemical constituents in parts per million.)

Location	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Hardness as $CaCO_3$		Percent sodium	Sodium-adsorption-ratio (SAR)	Specific conductance (micromhos at 25°C)	pH
							Noncarbonate	Total				
17.10.19.112	230	220	28	-	1.5	522	226	414	9	-	848	7.7
	221	296	34	-	0.6	626	293	474	12	-	962	7.4
19.112a	-	-	73	-	-	-	-	-	-	-	-	7.7
	-	-	60	-	-	500	-	-	-	-	-	7.7
	-	-	44	-	-	-	-	-	-	-	-	7.7
19.113	228	189	30	0.2	1.5	505	182	369	14	0.6	771	7.3
19.121	-	181	-	-	-	480	-	-	-	-	-	-
	222	194	-	-	-	590	-	-	-	-	-	-
	213	206	-	-	-	620	-	-	-	-	-	-
	242	192	27	0.3	0.8	516	178	376	-	-	775	7.7
	244	195	23	0.5	0.6	491	199	399	-	-	779	-

See footnotes at end of table.

Table 20.--Analyses of water from wells and test wells in Boles well field, Otero County, N. Mex. - Continued.

Analyses by U. S. Geological Survey. (Chemical constituents in parts per million.)

Location	Well no. a/	Land owner (Lessor)	Depth of well (feet)	Date of collection	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)
17.10.19.121	1	L. C. Boles	-	Dec. 29, 1947	-	91	42	13
				Jan. 5, 1948	-	91	37	32
				Jan. 12, 1948	-	80	38	34
				Jan. 27, 1948	-	90	38	24
				Feb. 9, 1948	-	92	38	25
				Feb. 23, 1948	-	90	41	13
				Mar. 8, 1948	-	89	37	31
				Mar. 22, 1948	-	94	35	28
				Apr. 5, 1948	-	94	38	21
				May 3, 1948	-	93	39	22
				May 18, 1948	-	94	39	21
				June 1, 1948	-	94	40	29
				June 14, 1948	-	97	40	27

See footnotes at end of table.

Table 20.--Analyses of water from wells and test wells in Boles well field, Otero County, N. Mex. - Continued.

Analyses by U. S. Geological Survey. (Chemical constituents in parts per million.)

Location	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Hardness as $CaCO_3$		Percent sodium	Sodium-adsorption-ratio (SAR)	Specific conductance (micromhos at 25°C)	pH
							Noncarbonate	Total				
17.10.19.121	240	186	25	0.3	0.5	476	203	400	-	-	776	-
	243	211	21	-	0.5	512	180	379	-	-	791	-
	237	198	21	-	0.8	488	162	356	-	-	786	-
	241	194	23	-	0.5	488	183	380	-	-	775	-
	241	200	24	-	0.4	498	188	386	-	-	781	-
	238	188	22	-	0.7	472	198	393	-	-	778	-
	243	202	22	-	0.6	501	175	374	-	-	790	-
	235	201	26	-	0.8	501	186	378	-	-	791	7.7
	239	198	24	-	0.7	493	194	390	-	-	791	7.8
	238	201	25	-	0.7	498	198	392	-	-	791	7.6
	238	198	28	-	1.2	498	200	395	-	-	797	7.6
	236	212	33	-	1.7	526	206	399	-	-	821	-
	237	216	32	-	2.0	531	212	406	-	-	829	7.7

See footnotes at end of table.

Table 20.--Analyses of water from wells and test wells in Boles well field, Otero County, N. Mex. - Continued.

Analyses by U. S. Geological Survey. (Chemical constituents in parts per million.)

Location	Well no. a/	Land owner (Lessor)	Depth of well (feet)	Date of collection	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)
17.10.19.121	1	L. C. Boles	-	June 28, 1948	-	105	42	29
				Aug. 6, 1948	-	150	61	37
				Sept. 15, 1948	-	135	57	30
				Sept. 21, 1948	-	98	40	32
				Sept. 30, 1948	-	163	69	31
				Dec. 27, 1948	-	120	51	32
19.121a	10	do.	260	Dec. 6, 1948	-	148	61	38
				Apr. 5, 1949	-	150	64	42
				May 20, 1949	-	125	52	34
				June 20, 1949	-	122	50	32

See footnotes at end of table.

Table 20.--Analyses of water from wells and test wells in Boles well field, Otero County, N. Mex. - Continued.

Analyses by U. S. Geological Survey. (Chemical constituents in parts per million.)

Location	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Hardness as $CaCO_3$ Noncarbonate	Hardness as $CaCO_3$ Total	Percent sodium	Sodium-adsorption-ratio (SAR)	Specific conductance (micromhos at 25°C)	pH
17.10.19.121	236	242	35	-	2.6	572	241	434	-	-	878	7.7
	220	448	39	0.6	3.9	848	445	626	-	-	1,230	-
	232	375	39	-	2.3	753	382	572	-	-	1,090	7.7
	235	231	28	-	1.6	544	212	404	-	-	845	7.7
	223	497	39	-	3.8	913	508	690	-	-	1,280	7.8
	230	322	38	-	1.7	678	320	509	-	-	1,010	-
19.121a	229	437	42	0.2	2.3	841	433	620	-	-	1,210	7.6
	228	464	41	-	1.8	875	450	638	13	-	1,240	7.8
	229	339	41	-	1.2	705	338	526	12	-	1,050	7.8
	233	323	37	-	1.3	680	319	510	12	-	1,010	-

See footnotes at end of table.

Table 20.--Analyses of water from wells and test wells in Boles well field, Otero County, N. Mex. - Continued.

Analyses by U. S. Geological Survey. (Chemical constituents in parts per million.)

Location	Well no. a/	Land owner (Lessor)	Depth of well (feet)	Date of collection	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)
17.10.19.121a	10	L. C. Boles	260	July 1, 1949	-	123	52	31
				July 15, 1949	-	124	50	34
				July 27, 1949	-	122	50	27
				Aug. 5, 1949	-	96	42	26
				Aug. 29, 1949	-	97	42	28
				Sept. 12, 1949	-	118	50	30
				Oct. 5, 1949	-	117	50	30
				Oct. 13, 1949	-	123	52	32
				Oct. 24, 1949	-	96	43	27
				Dec. 6, 1949	21	125	52	36
				Dec. 14, 1949	-	121	50	32
				Jan. 19, 1950	21	130	51	28
				Feb. 13, 1950	-	122	50	34

See footnotes at end of table.

Table 20.--Analyses of water from wells and test wells in Boles well field, Otero County, N. Mex. - Continued.

Analyses by U. S. Geological Survey. (Chemical constituents in parts per million.)

Location	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Hardness as $CaCO_3$ Noncarbonate	Hardness as $CaCO_3$ Total	Percent sodium	Sodium-adsorption-ratio (SAR)	Specific conductance (micromhos at 25°C)	pH
17.10.19.121a	228	324	44	-	1.3	688	334	521	11	-	1,030	7.8
	224	330	44	-	1.0	693	332	515	13	-	1,030	-
	226	312	41	-	1.5	665	325	510	10	-	1,020	-
	224	230	31	-	0.9	535	226	410	12	-	857	7.6
	232	228	33	-	0.5	543	224	414	13	-	855	7.4
	228	309	39	-	1.2	660	313	500	11	-	1,010	7.4
	222	314	38	-	0.6	659	316	498	12	-	987	7.8
	228	323	47	-	1.2	690	334	521	12	-	1,040	7.4
	230	232	32	-	1.1	544	228	416	12	-	845	7.5
	222	354	38	-	1.3	737	344	526	13	-	1,060	-
	226	325	38	-	1.1	678	322	508	12	-	1,010	7.7
	227	337	40	-	0.8	720	348	534	10	-	1,050	-
	228	328	39	-	1.4	686	323	510	13	-	1,040	7.8

See footnotes at end of table.

Table 20.--Analyses of water from wells and test wells in Boles well field, Otero County, N. Mex. - Continued.

Analyses by U. S. Geological Survey. (Chemical constituents in parts per million.)

Location	Well no. a/	Land owner (Lessor)	Depth of well (feet)	Date of collection	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)
17.10.19.121a	10	L. C. Boles	260	Mar. 22, 1950	-	125	49	30
				Apr. 7, 1950	-	120	50	32
				May 2, 1950	-	121	50	33
				May 19, 1950	-	118	50	29
				June 1, 1950	-	122	51	33
				June 26, 1950	-	118	50	21
				July 13, 1950	-	112	46	39
				Aug. 8, 1950	24	140	57	34
				Aug. 25, 1950	20	138	55	35
				Oct. 23, 1950	-	111	48	28
				Nov. 13, 1950	-	138	58	32
				Nov. 22, 1950	-	132	56	32
				Dec. 5, 1950	-	140	60	34
				Dec. 7, 1950	-	138	59	34
				Mar. 8, 1951	-	138	56	34

See footnotes at end of table.

Table 20.--Analyses of water from wells and test wells in Boles well field, Otero County, N. Mex. - Continued.

Analyses by U. S. Geological Survey. (Chemical constituents in parts per million.)

Location	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Hardness as $CaCO_3$		Percent sodium	Sodium-adsorption-ratio (SAR)	Specific conductance (micromhos at 25°C)	pH
							Noncarbonate	Total				
17.10.19.121a	224	322	42	-	1.1	679	330	514	11	-	1,010	7.4
	228	311	44	-	1.0	670	318	505	12	-	1,010	7.3
	229	310	48	-	1.0	676	320	508	12	-	1,030	-
	229	297	46	-	0.9	654	312	500	11	-	997	7.8
	227	314	51	-	0.9	684	328	514	12	-	1,030	7.7
	224	274	55	-	0.9	629	316	500	9	-	1,030	7.8
	227	283	43	-	11.0	646	278	464	16	-	940	7.8
	224	358	72	-	1.5	796	400	584	11	-	1,160	-
	224	361	61	-	1.7	782	387	570	12	-	1,130	7.8
	225	281	41	-	1.3	621	290	474	11	-	962	7.8
	225	372	56	-	1.4	768	398	583	11	-	1,150	7.9
	223	356	54	-	1.6	742	378	560	11	-	1,080	7.9
	223	388	58	-	1.5	792	414	596	11	-	1,170	7.4
	226	377	58	-	1.5	778	402	587	11	-	1,140	7.5
	227	358	64	-	1.1	763	389	575	12	-	1,150	7.4

See footnotes at end of table.

Table 20.--Analyses of water from wells and test wells in Boles well field, Otero County, N. Mex. - Continued.

Analyses by U. S. Geological Survey. (Chemical constituents in parts per million.)

Location	Well no. a/	Land owner (Lessor)	Depth of well (feet)	Date of collection	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)
17.10.19.121a	10	L. C. Boles	260	Mar. 22, 1951	-	143	57	33
				Apr. 5, 1951	-	143	59	32
				Apr. 19, 1951	-	136	56	29
				May 17, 1951	-	138	55	24
				June 7, 1951	-	145	54	37
				June 14, 1951	-	146	54	41
				July 5, 1951	-	129	54	38
				July 20, 1951	-	148	61	33
				Aug. 3, 1951	-	133	54	30
				Aug. 10, 1951	-	175	71	35
				Aug. 23, 1951	-	140	58	30
				Aug. 30, 1951	-	139	58	30
				Sept. 20, 1951 d/	-	179	74	41
				Sept. 24, 1951	-	162	65	37

See footnotes at end of table.

Table 20.--Analyses of water from wells and test wells in Boles well field, Otero County, N. Mex. - Continued.

Analyses by U. S. Geological Survey. (Chemical constituents in parts per million.)

Location	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Hardness as $CaCO_3$		Percent sodium	Sodium-adsorption-ratio (SAR)	Specific conductance (micromhos at 25°C)	pH
							Noncarbonate	Total				
17.10.19.121a	228	368	66	-	1.1	780	404	592	11	-	1,170	7.8
	229	368	69	-	1.2	785	412	600	10	-	1,170	7.7
	230	341	63	-	1.2	739	382	570	10	-	1,120	7.7
	224	334	64	-	1.0	726	387	570	8	-	1,120	7.8
	229	347	82	-	1.2	779	396	584	12	-	1,190	7.7
	228	351	87	-	1.3	792	400	586	13	-	1,200	7.7
	231	309	82	-	1.3	727	354	544	13	-	1,100	7.6
	232	328	113	-	1.5	798	430	620	10	-	1,250	7.9
	227	294	89	-	1.7	714	368	554	11	-	1,130	7.8
	222	386	154	-	3.6	934	546	728	9	-	1,450	7.5
	227	309	102	-	1.7	753	402	588	10	-	1,190	7.6
	233	308	98	-	1.6	750	394	586	10	-	1,190	7.7
	226	400	167	-	4.9	977	566	751	11	-	1,510	7.8
	227	360	135	-	2.3	873	486	672	11	-	1,340	7.7

See footnotes at end of table.

Table 20.--Analyses of water from wells and test wells in Boles well field, Otero County, N. Mex. - Continued.

Analyses by U. S. Geological Survey. (Chemical constituents in parts per million.)

Location	Well no. a/	Land owner (Lessor)	Depth of well (feet)	Date of collection	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)
17.10.19.121a	10	L. C. Boles	260	Sept. 25, 1951	-	146	60	36
				Sept. 26, 1951	-	141	57	37
				Sept. 27, 1951	-	138	56	32
				Sept. 28, 1951	-	136	55	29
				May 9, 1952	-	156	69	25
				July 2, 1952	-	164	70	32
				Aug. 12, 1952	-	133	58	34
				Sept. 16, 1952	-	134	56	25
				Oct. 17, 1952	-	145	63	47
				Dec. 8, 1952	-	165	54	62
				Apr. 14, 1953	-	136	57	32
				Aug. 10, 1954	-	131	51	28
				May 17, 1955	24	139	62	39

See footnotes at end of table.

Table 20.--Analyses of water from wells and test wells in Boles well Field, Otero County, N. Mex. - Continued.

Analyses by U. S. Geological Survey. (Chemical Constituents in parts per million.)

Location	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Hardness as $CaCO_3$		Percent sodium	Sodium-adsorption-ratio (SAR)	Specific conductance (micromhos at 25°C)	pH
							Non-carbonate	Total				
17.10.19.121a	232	327	112	-	1.9	797	421	611	11	-	1,240	7.7
	226	322	104	-	1.8	774	402	586	12	-	1,190	7.8
	226	305	100	-	1.8	744	390	575	11	-	1,170	7.8
	226	293	97	-	2.0	723	380	566	10	-	1,150	7.8
	233	361	112	-	2.4	840	482	672	7	-	1,290	-
	228	336	159	-	5.3	878	510	697	9	-	1,380	7.6
	227	294	107	-	1.2	739	384	570	11	-	1,180	-
	207	303	94	-	1.8	716	396	565	9	-	1,150	7.2
	228	377	100	-	2.6	847	434	621	14	-	1,220	7.7
	229	368	139	-	2.4	903	446	634	18	-	1,360	7.7
	227	312	91	-	2.0	741	386	572	11	-	1,170	7.5
	232	281	80	-	1.7	687	346	536	10	0.5	1,080	7.7
	230	325	111	0.4	2.3	816	414	602	12	0.7	1,230	7.6

See footnotes at end of table.

Table 20.--Analyses of water from wells and test wells in Boles well field, Otero County, N. Mex. - Continued.

Analyses by U. S. Geological Survey. (Chemical constituents in parts per million.)

Location	Well of a/	Land owner (Lessor)	Depth of well (feet)	Date of collection	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)
17.10.19.122	12	L. C. Boles	215	Feb. 21, 1950	-	94	43	27
19.123	2	do.	240	July 28, 1947 b/	16	-	-	-
				Sept. 16, 1947 b/	54	-	-	-
				Nov. 14, 1947 e/	20	89	38	33
				Dec. 22, 1947	-	96	41	13
				Dec. 29, 1947	-	92	40	23
				Jan. 5, 1948	-	92	38	34
				Jan. 12, 1948	-	88	39	34
				Jan. 20, 1948	-	91	28	42
				Feb. 3, 1948	-	92	40	23
				Feb. 16, 1948	-	90	38	31
				Feb. 23, 1948	-	90	41	27

See footnotes at end of table.

Table 20.--Analyses of water from wells and test wells in Boles well field, Otero County, N. Mex. - Continued.

Analyses by U. S. Geological Survey. (Chemical constituents in parts per million.)

Location	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Hardness as $CaCO_3$		Percent sodium	Sodium-adsorption-ratio (SAR)	Specific conductance (micromhos at 25°C)	pH
							Noncarbonate	Total				
17.10.19.122	230	229	30	-	1.1	537	223	412	13	-	833	7.9
19.123	253	198	-	-	-	650	-	-	-	-	-	-
	210	200	-	-	-	710	-	-	-	-	-	-
	231	208	29	0.1	0.8	532	188	378	-	-	784	7.9
	212	214	27	0.1	0.7	496	234	408	-	-	780	-
	229	207	28	0.3	0.9	504	206	394	-	-	807	-
	229	226	25	-	0.6	528	198	386	-	-	803	-
	226	224	25	-	1.0	522	195	380	-	-	806	-
	232	205	21	-	0.8	502	152	342	-	-	800	-
	231	209	26	-	0.7	504	204	394	-	-	796	-
	230	213	26	-	0.8	512	192	380	-	-	794	-
	234	214	26	-	0.7	514	202	393	-	-	790	-

See footnotes at end of table.

Table 20.--Analyses of water from wells and test wells in Boles well field, Otero County, N. Mex. - Continued.

Analyses by U. S. Geological Survey. (Chemical constituents in parts per million.)

Location	Well no. a/	Land owner (Lessor)	Depth of well (feet)	Date of collection	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)
17.10.19.123	2	L. C. Boles	240	Mar. 8, 1948	-	90	39	29
				Mar. 29, 1948	-	92	40	22
				Apr. 4, 1948	-	96	39	23
				Apr. 20, 1948	-	92	38	30
				Apr. 27, 1948	-	92	40	25
				May 10, 1948	-	94	40	21
				May 24, 1948	-	93	41	20
				June 7, 1948	-	94	40	23
				June 21, 1948	-	90	38	30
				July 28, 1948	-	91	39	32
				Aug. 30, 1948	-	90	40	25
				Sept. 23, 1948	-	91	40	25
				Oct. 28, 1948	-	90	39	37
				Mar. 9, 1949	-	92	38	28
				Mar. 15, 1949	-	91	40	24

See footnotes at end of table.

Table 20.--Analyses of water from wells and test wells in Boles well Field, Otero County, N. Mex. - Continued.

Analyses by U. S. Geological Survey. (Chemical constituents in parts per million.)

Location	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Hardness as $CaCO_3$		Percent sodium	Sodium-adsorption-ratio (SAR)	Specific conductance (micromhos at 25°C)	pH
							Non-carbonate	Total				
17.10.19.123	235	211	25	-	0.7	510	192	385	-	-	774	-
	232	208	25	-	0.9	502	204	394	-	-	798	7.7
	234	212	26	-	-	512	208	400	-	-	776	7.6
	231	215	26	-	0.5	515	196	386	-	-	797	-
	235	212	25	-	0.6	510	202	394	-	-	800	8.0
	232	211	25	-	0.5	506	209	399	-	-	801	7.5
	231	209	25	-	0.6	502	211	400	-	-	794	-
	234	212	26	-	0.5	511	208	399	-	-	798	7.7
	230	208	28	-	0.8	508	192	380	-	-	809	7.7
	235	218	26	0.3	0.9	523	195	388	-	-	811	-
	232	207	26	-	1.0	503	194	389	-	-	799	-
	232	211	26	-	0.6	508	202	392	-	-	789	7.9
	236	226	25	-	0.9	534	192	385	-	-	803	7.9
	237	207	26	-	0.8	508	192	386	14	-	797	7.9
	235	207	25	-	0.7	504	199	392	12	-	793	8.1

See footnotes at end of table.

Table 20.--Analyses of water from wells and test wells in Boles well field, Otero County, N. Mex. - Continued.

Analyses by U. S. Geological Survey. (Chemical constituents in parts per million.)

Location	Well no. a/	Land owner (Lessor)	Depth of well (feet)	Date of collection	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)
17.10.19.123	2	L. C. Boles	240	Mar. 25, 1949	-	93	39	33
				Apr. 20, 1949	-	92	39	29
				May 9, 1949	-	94	39	22
				June 23, 1949	-	95	38	27
				June 29, 1949	-	94	39	25
				July 5, 1949	-	90	40	19
				July 15, 1949	-	93	39	27
				Sept. 12, 1949	-	94	39	19
				Oct. 5, 1949	-	91	40	25
				Oct. 13, 1949	-	92	40	24
				Nov. 25, 1949	-	92	40	25
				Jan. 16, 1950	21	92	42	18
				Jan. 26, 1950	-	93	42	18
				Feb. 1, 1950	-	92	37	30
				Feb. 9, 1950	-	92	40	24
				Feb. 28, 1950	-	92	39	23

See footnotes at end of table.

Table 20.--Analyses of water from wells and test wells in Boles well field, Otero County, N. Mex. - Continued.

Analyses by U. S. Geological Survey. (Chemical constituents in parts per million.)

Location	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Hardness as $CaCO_3$		Percent sodium	Sodium-adsorption-ratio (SAR)	Specific conductance (micromhos at 25°C)	pH
							Noncarbonate	Total				
17.10.19.123	228	226	28	-	2.0	533	206	392	15	-	794	7.7
	236	214	26	-	0.4	517	196	390	14	-	794	7.7
	238	202	26	-	0.7	501	200	395	11	-	801	7.9
	228	216	28	-	1.0	517	206	393	13	-	805	-
	238	209	26	-	0.7	511	200	395	12	-	800	7.8
	222	203	26	-	0.7	488	207	389	10	-	793	7.8
	236	212	26	-	0.6	514	199	392	13	-	801	-
	234	195	29	-	0.5	492	204	395	9	-	803	7.3
	232	213	24	-	1.1	508	202	392	12	-	792	7.8
	234	209	26	-	0.9	507	202	394	12	-	800	7.4
	228	214	27	-	0.8	511	207	394	12	-	815	7.6
	228	205	28	-	0.8	519	215	402	9	-	800	7.6
	232	208	26	-	0.8	502	214	404	9	-	807	7.7
	235	208	26	-	0.6	509	189	382	14	-	797	7.8
	235	207	27	-	0.7	507	202	394	12	-	799	7.6
	232	203	26	-	1.1	498	200	390	11	-	797	7.4

See footnotes at end of table.

Table 20.--Analyses of water from wells and test wells in Boles well field, Otero County, N. Mex. - Continued.

Analyses by U. S. Geological Survey. (Chemical Constituents in parts per million.)

Location	Well no. a/	Land owner (Lessor)	Depth of well (feet)	Date of collection	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)
17.10.19.123	2	L. C. Boles	240	Apr. 25, 1950	-	94	39	25
				May 11, 1950	-	94	42	19
				Aug. 30, 1950	25	96	39	31
				Sept. 11, 1950	20	96	39	28
				Sept. 26, 1950	-	91	40	22
				Oct. 3, 1950	-	92	40	23
				Nov. 14, 1950	-	94	40	28
				Feb. 7, 1951	-	94	40	20
				Feb. 15, 1951	-	94	38	23
				Feb. 20, 1951	-	91	39	27
				Mar. 1, 1951	-	93	39	21
				Mar. 22, 1951	-	96	38	24
				Mar. 30, 1951	-	96	40	20
				Apr. 12, 1951	-	97	41	17
				Apr. 19, 1951	-	98	40	19

See footnotes at end of table.

Table 20.--Analyses of water from wells and test wells in Boles well field, Otero County, N. Mex. - Continued.

Analyses by U. S. Geological Survey. (Chemical constituents in parts per million.)

Location	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Hardness as $CaCO_3$		Percent sodium	Sodium-adsorption-ratio (SAR)	Specific conductance (micromhos at 25°C)	pH
							Noncarbonate	Total				
17.10.19.123	239	209	25	-	0.4	510	199	395	12	-	799	7.8
	240	206	26	-	0.6	506	210	407	9	-	804	-
	245	221	25	-	0.9	559	199	400	14	-	809	7.9
	232	225	26	-	1.0	549	210	400	13	-	805	7.9
	226	203	30	-	1.0	498	206	392	11	-	810	7.4
	223	213	27	-	1.0	506	212	394	11	-	816	7.5
	231	212	28	-	0.8	517	210	399	14	-	800	8.0
	230	205	28	-	0.9	501	210	399	10	-	806	-
	232	202	28	-	0.7	500	200	390	11	-	807	-
	234	208	27	-	0.8	508	196	388	13	-	802	7.7
	236	200	26	-	0.7	496	199	392	10	-	805	7.5
	234	209	27	-	0.9	510	204	396	12	-	804	7.8
	240	212	22	-	0.5	508	208	404	10	-	807	7.8
	233	212	26	-	0.9	509	220	410	8	-	803	7.8
	238	211	25	-	0.9	511	214	409	9	-	808	7.8

See footnotes at end of table.

Table 20.--Analyses of water from wells and test wells in Boles well field, Otero County, N. Mex. - Continued

Analyses by U. S. Geological Survey. (Chemical constituents in parts per million.)

Location	Well no. a/	Land owner (Lessor)	Depth of well (feet)	Date of collection	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)
17.10.19.123	2	L. C. Boles	240	Apr. 26, 1951	-	94	39	30
				May 4, 1951	21	95	40	25
				May 10, 1951	-	97	40	18
				May 17, 1951	-	102	40	13
				June 14, 1951	-	105	38	24
				June 21, 1951	-	94	41	23
				June 28, 1951	-	95	42	15
				July 5, 1951	-	95	40	25
				July 12, 1951	-	92	38	34
				July 20, 1951	-	94	40	21
				July 26, 1951	-	96	38	24
				Aug. 7, 1951	-	92	39	20
				Aug. 13, 1951	-	96	38	24
				Aug. 21, 1951	-	102	45	23
				Aug. 28, 1951	-	102	40	13
				Sept. 5, 1951	-	94	37	26

See footnotes at end of table.

Table 20.--Analyses of water from wells and test wells in Boles well field, Otero County, N. Mex. - Continued.

Analyses by U. S. Geological Survey. (Chemical constituents in parts per million.)

Location	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Hardness as $CaCO_3$ Noncarbonate	Hardness as $CaCO_3$ Total	Percent sodium	Sodium-adsorption-ratio (SAR)	Specific conductance (micromhos at 25°C)	pH
17.10.19.123	238	222	24	-	0.8	527	200	395	14	-	797	-
	231	223	24	-	0.7	543	212	402	12	-	801	7.7
	236	209	24	-	0.7	505	213	406	9	-	810	7.9
	234	212	24	-	0.6	507	228	419	6	-	808	7.9
	222	241	26	-	1.0	544	236	418	11	-	865	7.7
	236	208	30	-	0.6	513	210	403	11	-	807	7.8
	234	206	26	-	0.4	499	218	410	8	-	807	7.5
	239	213	27	-	0.6	519	206	402	25	-	811	7.8
	243	212	27	-	1.3	524	186	386	16	-	814	8.0
	236	204	27	-	0.6	503	206	399	10	-	811	7.9
	235	208	27	-	0.6	510	203	396	12	-	804	8.1
	233	198	26	-	0.8	491	199	390	10	-	805	7.9
	234	207	28	-	0.7	509	204	396	12	-	806	7.6
	222	254	30	-	0.8	564	258	440	10	-	879	7.5
	236	206	27	-	0.8	505	226	416	6	-	811	7.7
	228	211	26	-	0.8	507	200	386	13	-	807	7.3

See footnotes at end of table.

Table 20.--Analyses of water from wells and test wells in Boles well field, Otero County, N. Mex. - Continued.

Analyses by U. S. Geological Survey. (Chemical constituents in parts per million.)

Location	Well no. a/	Land owner (Lessor)	Depth of well (feet)	Date of collection	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)
17.10.19.123	2	L. C. Boles	240	Sept. 12, 1951	-	93	39	28
				Sept. 19, 1951	-	96	42	23
				Sept. 21, 1951	-	91	40	23
				Oct. 16, 1951	-	90	41	26
				Nov. 13, 1951	-	96	39	21
				Dec. 14, 1951	-	98	44	7.8
				Feb. 1, 1952	-	95	39	19
				Mar. 21, 1952	26	96	40	20
				May 29, 1952	-	94	40	24
				July 11, 1952	-	92	39	37
				Aug. 27, 1952	-	94	41	18
				Oct. 3, 1952	-	89	39	33
				Nov. 8, 1952	-	93	41	23
				Dec. 9, 1952	-	92	42	22
				Dec. 31, 1952	-	90	44	18
				Mar. 19, 1953	-	92	39	17
				May 16, 1955	22	87	42	26

See footnotes at end of table.

Table 20.--Analyses of water from wells and test wells in Boles well field, Otero County, N. Mex. - Continued.

Analyses by U. S. Geological Survey. (Chemical constituents in parts per million.)

Location	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Hardness as $CaCO_3$		Percent sodium	Sodium-adsorption-ratio (SAR)	Specific conductance (micromhos at 25°C)	pH
							Non-carbonate	Total				
17.10.19.123	234	214	27	-	1.0	517	201	392	13	-	807	7.2
	245	214	27	-	0.6	524	211	412	11	-	841	7.9
	234	201	28	-	0.8	499	200	392	11	-	811	7.9
	242	208	24	-	0.3	508	194	393	12	-	819	7.3
	228	210	28	-	1.0	507	213	400	10	-	802	-
	228	207	28	-	0.8	498	238	426	4	-	801	7.7
	232	203	26	-	0.8	497	208	398	9	-	801	7.5
	230	214	26	-	0.6	536	216	404	10	-	808	7.7
	235	212	27	-	0.8	514	206	399	12	-	810	7.9
	235	228	28	-	0.9	541	198	390	17	-	811	7.9
	233	203	28	-	1.0	500	212	403	9	-	807	-
	227	219	28	-	0.9	521	196	382	16	-	819	7.5
	230	214	28	-	0.9	513	212	400	11	-	800	7.6
	225	215	29	-	0.9	512	218	402	11	-	803	7.8
	230	210	27	-	0.8	503	217	406	9	-	800	7.6
	236	184	29	-	1.0	478	196	390	9	-	803	7.5
	230	206	30	0.2	0.8	527	201	390	13	0.6	807	7.5

See footnotes at end of table.

Table 20.--Analyses of water from wells and test wells in Boles well field, Otero County, N. Mex. - Continued.

Analyses by U. S. Geological Survey. (Chemical constituents in parts per million.)

Location	Well no. a/	Land owner (Lessor)	Depth of well (feet)	Date of collection	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)
17.10.19.141	15	L. C. Boles	370	Aug. 17, 1950	24	93	40	25
				Aug. 25, 1950	27	96	39	26
				Jan. 11, 1952	23	98	42	16
				Feb. 21, 1952	-	104	40	24
				Mar. 14, 1952	25	92	39	29
				June 6, 1952	-	94	40	25
				July 27, 1952	-	93	39	46
				Sept. 2, 1952	-	96	42	16
				Oct. 9, 1952	-	91	40	33
				Nov. 17, 1952	-	91	41	23
				Dec. 19, 1952	-	89	44	20
				Feb. 2, 1953	-	93	40	22

See footnotes at end of table.

Table 20.--Analyses of water from wells and test wells in Boles well field, Otero County, N. Mex. - Continued.

Analyses by U. S. Geological Survey. (Chemical constituents in parts per million.)

Location	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Hardness as $CaCO_3$ Noncarbonate	Hardness as $CaCO_3$ Total	Percent sodium	Sodium-adsorption-ratio (SAR)	Specific conductance (micromhos at 25°C)	pH
17.10.19.141	221	225	24	-	1.0	541	216	396	12	-	812	7.5
	234	218	27	-	1.0	549	208	400	13	-	812	7.9
	223	221	27	-	0.8	538	234	417	8	-	818	7.8
	250	225	26	-	0.8	543	219	424	11	-	844	7.8
	227	221	26	-	0.4	519	204	390	14	-	820	7.6
	226	219	28	-	0.6	518	214	399	12	-	814	7.9
	268	225	28	-	0.7	564	173	392	20	-	812	7.5
	222	216	28	-	1.0	508	230	412	8	-	816	-
	221	231	29	-	0.8	534	210	342	15	-	823	7.7
	223	218	26	-	0.6	510	213	396	11	-	806	7.6
	223	221	23	-	0.8	508	220	403	10	-	818	7.5
	223	216	26	-	0.9	508	214	396	11	-	819	7.2

See footnotes at end of table.

Table 20.--Analyses of water from well and test wells in Boles well field, Otero County, N. Mex. - Continued.

Analyses by U. S. Geological Survey. (Chemical constituents in parts per million.)

Location	Well no. a/	Land owner (Lessor)	Depth of well (feet)	Date of collection	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)
17.10.19.142	14	L. C. Boles	253	May 10, 1950	-	96	41	33
				June 30, 1950	-	96	40	32
				Sept. 20, 1950	-	94	40	33
				Feb. 21, 1951	-	98	41	27
				Mar. 30, 1951	-	98	42	27
				Apr. 26, 1951	-	98	42	29
				May 4, 1951	23	100	42	27
				May 10, 1951	-	100	42	21
				May 24, 1951	-	96	42	26
				May 31, 1951	-	95	43	19
				June 7, 1951	-	102	35	32
				June 14, 1951	-	102	37	29
				June 21, 1951	-	98	43	24
				June 28, 1951	-	103	43	13
				July 5, 1951	-	98	43	27
				July 12, 1951	-	98	41	29

See footnotes at end of table.

Table 20.--Analyses of water from wells and test wells in Boles well field, Otero County, N. Mex. - Continued.

Analyses by U. S. Geological Survey. (Chemical constituents in parts per million.)

Location	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Hardness as $CaCO_3$		Percent sodium	Sodium-adsorption-ratio (SAR)	Specific conductance (micromhos at 25°C)	pH
							Non-carbonate	Total				
17.10.19.142	238	233	29	-	0.7	550	213	408	15	-	845	7.6
	232	230	31	-	1.1	544	214	404	15	-	856	7.6
	241	222	29	-	0.6	538	202	399	15	-	842	7.8
	253	219	26	-	0.6	537	206	413	12	-	834	7.6
	254	222	25	-	0.5	540	209	417	12	-	838	7.8
	250	230	24	-	0.8	547	212	417	13	-	837	-
	248	231	26	-	0.7	572	219	422	12	-	835	7.6
	251	221	23	-	0.7	532	216	422	10	-	835	7.9
	245	221	27	-	0.8	534	211	412	12	-	835	7.4
	247	209	25	-	0.2	513	212	414	9	-	837	7.3
	253	215	26	-	0.7	536	191	398	15	-	840	7.6
	255	216	25	-	0.8	536	198	406	14	-	838	7.7
	251	219	28	-	0.5	536	216	422	11	-	838	7.8
	245	215	26	-	0.5	522	233	434	6	-	837	7.4
	249	227	28	-	0.7	547	18	422	12	-	839	7.7
	252	221	27	-	0.9	541	206	413	13	-	841	8.0

See footnotes at end of table.

Table 20.--Analyses of water from wells and test wells in Boles well field, Otero County, N. Mex. - Continued.

Analyses by U. S. Geological Survey. (Chemical constituents in parts per million.)

Location	Well no. a/	Land owner (Lessor)	Depth of well (feet)	Date of collection	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)
17.10.19.142	14	L. C. Boles	253	July 20, 1951	-	97	41	28
				July 26, 1951	-	103	40	13
				Aug. 2, 1951	-	106	43	23
				Aug. 8, 1951	-	98	42	21
				Aug. 15, 1951	-	104	41	14
				Aug. 27, 1951	-	95	43	24
				Sept. 6, 1951	-	96	41	28
				Oct. 3, 1951	-	98	41	27
				Oct. 15, 1951	-	96	39	25
				Nov. 11, 1951	-	96	41	25
				Jan. 25, 1952	-	99	41	20
				Feb. 29, 1952	-	99	40	28
				Mar. 28, 1952	29	100	42	20
				May 1, 1952	-	104	45	20
				June 18, 1952	-	100	44	27
				July 29, 1952	-	122	50	22

See footnotes at end of table.

Table 20.--Analyses of water from wells and test wells in Boles well field, Otero County, N. Mex. - Continued.

Analyses by U. S. Geological Survey. (Chemical constituents in parts per million.)

Location	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Hardness as $CaCO_3$		Percent sodium	Sodium-adsorption-ratio (SAR)	Specific conductance (micromhos at 25°C)	pH
							Non-carbonate	Total				
17.10.19.142	256	216	26	-	0.6	535	200	410	13	-	840	8.0
	247	200	27	-	0.6	506	219	422	6	-	837	8.0
	226	254	29	-	0.8	567	256	442	10	-	884	7.8
	243	216	27	-	0.8	525	218	417	10	-	838	7.5
	244	210	28	-	0.9	518	228	428	7	-	838	7.7
	248	217	26	-	0.6	528	211	414	11	-	839	7.6
	248	219	26	-	0.8	533	205	408	13	-	843	7.6
	252	220	26	-	0.9	537	206	413	13	-	854	7.6
	237	214	26	-	0.3	517	206	400	12	-	840	7.5
	238	219	28	-	0.8	527	213	408	12	-	833	7.4
	248	212	25	-	0.7	520	212	416	10	-	835	7.4
	249	219	28	-	0.8	538	208	412	13	-	838	7.8
	247	219	25	-	0.7	558	220	422	10	-	840	7.5
	243	232	33	-	0.7	555	246	444	9	-	877	7.6
	246	215	45	-	1.3	553	229	430	12	-	883	7.5
	232	221	97	-	1.1	627	320	510	9	-	1,020	7.8

See footnotes at end of table.

Table 20.--Analyses of water from wells and test wells in Boles well field, Otero County, N. Mex. - Continued.

Analyses by U. S. Geological Survey. (Chemical constituents in parts per million.)

Location	Well no. a/	Land owner (Lessor)	Depth of well (feet)	Date of collection	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)
17.10.19.142	14	L. C. Boles	253	May 23, 1955	23	268	143	2.1
				Aug. 24, 1955	23	472	221	12
19.144	5	do.	75	May 25, 1948 c/	-	172	71	185
			100	May 25, 1948 c/	-	162	59	230
			205	July 20, 1948	-	101	43	17
				Aug. 18, 1948	-	95	40	28
				June 8, 1950	-	96	42	33
				June 16, 1950	-	98	42	29
				June 19, 1950	24	96	40	27
				Aug. 3, 1950	24	99	43	23
				Sept. 29, 1950	-	94	42	17
				Nov. 28, 1950	-	94	42	27
				Dec. 6, 1950	-	98	43	26
				Feb. 15, 1951	-	97	41	26
				Mar. 1, 1951	-	95	41	28
				Apr. 5, 1951	-	102	43	20

See footnotes at end of table.

Table 20.--Analyses of water from wells and test wells in Boles well field, Otero County, N. Mex. - Continued.

Analyses by U. S. Geological Survey. (Chemical constituents in parts per million.)

Location	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Hardness as $CaCO_3$ Noncarbonate	Hardness as $CaCO_3$ Total	Percent sodium	Sodium-adsorption-ratio (SAR)	Specific conductance (micromhos at 25°C)	pH
17.10.19.142	104	321	605	0.4	5.4	1,400	1,150	1,260	0.3	0.0	2,610	7.8
	204	654	885	0.1	20	2,390	1,920	2,090	13	0.1	3,790	7.2
19.144	284	536	235	-	1.0	1,340	488	721	-	-	2,020	-
	263	627	197	-	0.6	1,410	431	646	-	-	2,050	-
	242	221	27	-	0.8	529	230	429	-	-	830	8.0
	239	222	24	-	1.1	528	206	402	-	-	839	-
	243	237	26	-	1.4	555	213	412	15	-	837	7.5
	243	232	27	-	1.3	549	218	417	13	-	840	7.5
	234	225	26	-	0.8	554	212	404	13	-	838	7.7
	242	226	27	-	1.1	561	226	424	10	-	842	-
	214	220	27	-	0.8	506	232	407	8	-	835	7.7
	236	223	28	-	1.3	531	214	407	13	-	817	7.6
	241	232	28	-	0.9	547	224	422	12	-	835	7.5
	243	220	27	-	0.8	532	212	410	12	-	839	-
	246	220	25	-	0.7	531	204	406	15	-	836	7.5
	244	232	24	-	0.7	542	232	432	9	-	842	7.8

See footnotes at end of table.

Table 20.--Analyses of water from wells and test wells in Boles well field, Otero County, N. Mex. - Continued.

Analyses by U. S. Geological Survey. (Chemical Constituents in parts per million.)

Location	Well no. a/	Land owner (Lessor)	Depth of well (feet)	Date of collection	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)
17.10.19.144	5	L. C. Boles	205	Apr. 12, 1951	-	101	43	19
				May 24, 1951	-	94	41	30
				May 31, 1951	-	93	41	24
				June 28, 1951	-	97	42	23
				July 5, 1951	-	98	43	26
				July 12, 1951	-	98	40	29
				July 20, 1951	-	98	42	22
				July 26, 1951	-	97	41	29
				Aug. 6, 1951	-	96	41	33
				Aug. 16, 1951	-	97	39	30
				Aug. 20, 1951	-	94	42	-
				Aug. 24, 1951	-	98	44	20
				Aug. 31, 1951	-	98	41	25
				Sept. 4, 1951	-	97	41	25
				Sept. 11, 1951	-	98	41	27

See footnotes at end of table.

Table 20.--Analyses of water from wells and test wells in Boles well field, Otero County, N. Mex. - Continued.

Analyses by U. S. Geological Survey. (Chemical constituents in parts per million.)

Location	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Hardness as $CaCO_3$		Percent sodium	Sodium-adsorption-ratio (SAR)	Specific conductance (micromhos at 25°C)	pH
							Noncarbonate	Total				
17.10.19.144	247	222	25	-	0.9	533	226	429	9	-	835	7.8
	247	219	26	-	0.8	533	200	403	14	-	838	7.3
	239	220	25	-	0.1	524	212	408	11	-	835	7.3
	241	221	26	-	0.6	529	217	414	11	-	835	7.5
	243	229	28	-	0.7	545	222	422	12	-	836	7.7
	242	223	28	-	1.0	538	210	409	13	-	835	7.8
	246	215	27	-	0.6	526	216	417	10	-	838	8.1
	251	221	27	-	0.6	540	205	410	13	-	840	8.0
	243	235	25	-	0.8	551	209	408	15	-	839	7.9
	242	221	28	-	0.9	535	204	402	14	-	838	7.7
	239	-	27	-	0.8	-	211	407	-	-	837	7.7
	244	221	28	-	0.7	532	226	426	9	-	839	7.7
	245	221	25	-	0.7	532	212	413	12	-	841	7.6
	242	221	25	-	0.8	529	212	410	12	-	839	7.7
	243	226	26	-	0.4	538	214	413	12	-	839	7.4

See footnotes at end of table.

Table 20.--Analyses of water from wells and test wells in Boles well field, Otero County, N. Mex. - Continued.

Analyses by U. S. Geological Survey. (Chemical constituents in parts per million.)

Location	Well no. a/	Land owner (Lessor)	Depth of well (feet)	Date of collection	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)
17.10.19.144	5	L. C. Boles	205	Sept. 13, 1951	-	100	39	28
				Sept. 18, 1951	-	92	44	21
				Oct. 2, 1951	-	95	40	33
				Oct. 17, 1951	-	98	41	23
				Oct. 29, 1951	-	98	43	22
				Jan. 2, 1952	22	106	44	5.5
				Feb. 2, 1952	-	104	43	15
				Apr. 24, 1952	-	98	44	13
				May 23, 1952	-	98	43	23
				July 14, 1952	-	96	42	28
				Aug. 18, 1952	-	103	45	18
				Sept. 23, 1952	23	102	44	9.9
				Mar. 24, 1953	-	102	42	18
				Apr. 2, 1953	-	100	48	11
				May 16, 1955	21	95	43	31

See footnotes at end of table.

Table 20.--Analyses of water from wells and test wells in Boles well field, Otero County, N. Mex. --Continued.

Analyses by U. S. Geological Survey. (Chemical Constituents in parts per million.)

Location	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Hardness as $CaCO_3$: Noncarbonate	Hardness as $CaCO_3$: Total	Percent sodium	Sodium-adsorption-ratio (SAR)	Specific conductance (micromhos at 25°C)	pH
17.10.19.144	244	222	28	-	0.9	538	210	410	13	-	836	7.5
	243	212	26	-	0.7	516	212	410	10	-	841	7.8
	251	221	27	-	0.6	541	196	402	15	-	843	7.6
	245	219	24	-	0.5	526	212	413	11	-	848	7.6
	240	227	26	-	0.8	535	225	422	10	-	835	7.6
	239	219	23	-	1.1	539	250	446	3	-	836	7.7
	245	223	26	-	0.7	533	236	436	7	-	846	7.7
	245	212	23	-	0.7	512	224	426	6	-	836	-
	240	226	28	-	0.8	537	225	422	11	-	840	7.8
	252	221	26	-	0.7	538	206	412	13	-	851	7.9
	253	224	28	-	0.7	544	234	442	8	-	853	-
	235	225	21	-	1.2	542	243	436	5	-	830	7.8
	247	218	26	-	0.6	528	224	427	8	-	845	7.9
	244	224	26	-	1.1	530	247	447	5	-	841	7.6
	244	223	34	0.2	0.8	568	214	414	14	0.7	862	7.4

See footnotes at end of table.

Table 20.--Analyses of water from wells and test wells in Boles well field, Otero County, N. Mex. - Continued.

Analyses by U. S. Geological Survey. (Chemical constituents in parts per million.)

Location	Well no. a/	Land owner (Lessor)	Depth of well (feet)	Date of collection	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)
17.10.19.214	4	R. N. Nolley	140	Apr. 1, 1948 c/	-	101	43	26
19.234	21	do.	110	Apr. 16, 1953 b,c/	-	-	-	-
			250	Apr. 24, 1953	-	122	49	24
19.241	22	do.	110	Apr. 27, 1953 b,c/	-	-	-	-
			250	May 1, 1953	-	102	46	22

See footnotes at end of table.

Table 20.--Analyses of water from wells and test wells in Boles well field, Otero County, N. Mex. - Continued.

Analyses by U. S. Geological Survey. (Chemical constituents in parts per million.)

Location	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Hardness as $CaCO_3$		Percent sodium	Sodium-adsorption-ratio (SAR)	Specific conductance (micromhos at 25°C)	pH
							Non-carbonate	Total				
17.10.19.214	237	243	26	-	0.8	556	233	427	-	-	840	7.5
19.234	-	-	35	-	-	-	-	-	-	-	-	7.9
	235	292	42	-	2.2	647	314	506	9	-	997	7.5
19.241	-	-	37	-	-	-	-	-	-	-	-	7.8
	234	242	33	-	0.8	561	252	444	11	-	873	7.5

a/ See cross indices of well numbers, p. 11.

b/ Analysis reported by Holloman Air Force Base, N. Mex.

c/ Sampled while drilling.

d/ Bailed from surface of water in well for special test of quality versus pumpage.

e/ Contained 0.12 ppm Fe.

Table 21.--Analyses of water from private and municipal wells in vicinity of Holloman Air Force Base, Otero County, N. Mex.

Location	Well no. in W.S.P. 343	Owner	Depth of well (feet)	Date of collection	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)
16.9.3.422	-	Wade Maupin	200	June 25, 1954	-	-	-	135
13.320	-	E. A. Steinhoff	80	Apr. 18, 1950 a/	-	173	62	120
	-	do.	225	May 10, 1950	-	161	62	119
25.220	-	Don and John Stevens	190	Apr. 1947	-	566	350	1,500
26.200	1630	-	1,004	Sept. 1911	-	598	86	201
32.343	-	State of New Mexico	-	Apr. 15, 1954	-	-	-	52
16.10.5.133	-	V. E. Clark	240	May 26, 1955	-	-	-	-
5.342	-	Dr. Baumgartner	270	do.	-	-	-	-
7.223	-	Otero County Fair Assn.	-	Apr. 1951 b/	20	-	-	-
	-	do.	-	July 21, 1954	-	-	-	-
8.344	-	Claude Holguin	-	Mar. 10, 1955	-	-	-	-
17.342	-	Tice Elkins	200	July 22, 1954	-	-	-	-
18.231	-	Town of Alamogordo	-	May 14, 1954	-	-	-	341
18.241	-	New Mexico School for Visually Handicapped	-	Aug. 2, 1945 b/	20	632	283	-

See footnotes at end of table.

Table 21.--Analyses of water from private and municipal wells in vicinity of Holloman Air Force Base, Otero County, N. Mex. - Continued.

Location	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Hardness as $CaCO_3$		Percent sodium (% Na)	Sodium-adsorption-ratio (SAR)	Specific conductance (micromhos at 25°C)	pH
							Noncarbonate	Total				
16.9.3.422	250	425	192	-	-	-	421	626	32	2.3	1,720	-
13.320	283	450	174	-	1.4	1,120	454	686	28	-	1,700	7.9
	248	445	175	-	2.8	1,090	454	656	28	-	1,680	-
25.220	354	-	435	-	-	-	2,560	2,850	-	-	5,470	-
26.200	110	1,801	210	-	-	3,049	-	-	-	-	-	-
32.343	131	466	340	-	1.1	-	822	930	11	-	1,980	-
16.10.5.133	243	550	230	-	-	-	626	825	-	-	1,930	7.2
5.342	247	473	200	-	-	-	588	790	-	-	1,750	7.2
7.223	266	597	-	-	-	1,380	-	787	-	-	-	7.2
	-	570	196	-	-	1,370	-	-	-	-	1,910	-
8.344	155	2,560	295	-	-	-	2,420	2,550	-	-	4,680	-
17.342	-	3,060	640	-	-	5,950	-	-	-	-	6,400	-
18.231	251	1,550	455	-	-	-	1,510	1,720	30	-	3,940	-
18.241	54	1,541	1,400	-	390	4,880	-	-	-	-	-	-

See footnotes at end of table.

Table 21.--Analyses of water from private and municipal wells in vicinity of Holloman Air Force Base, Otero County, N. Mex. - Continued.

Location	Well no. in W.S.P. 343	Owner	Depth of well (feet)	Date of collection	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)
16.10.19.238	-	Alamogordo Swimming Pool	-	July 1945 b/	69	580	280	-
29.243	-	Town of Alamogordo	300	1945 b/	27	229	72	-
30.422	-	H. J. Falkenberry	270	May 19, 1955	-	-	-	-
30.432	-	Earl Haggard	240	July 21, 1954	-	-	-	-
32.122	-	(formerly Le Briton)	142	1945 b/	43	301	159	-
	-	do.	142	Dec. 1947	-	302	151	197
33.340	-	Town of Alamogordo	300	June 1945 a,b/	18	136	68	-
	-	do.	-	do. b,c/	41	88	54	-
17.7.23.412	1702	U. S. Government	10	Nov. 1911	-	558	214	322
	-	do.	10	Apr. 13, 1954	-	-	-	224
17.8.6.220	S-29	do.	Spring	1911	-	585	144	1,734
13.231	-	do.	110	Mar. 1, 1949 d/	-	965	3,360	12,600
13.311	-	do.	160	June 1945 c/	327	3,070	1,715	9,900
28.312	S-30	do.	Spring	1911	-	623	187	2,060

See footnotes at end of table.

Table 21.--Analyses of water from private and municipal wells in vicinity of Holloman Air Force Base, Otero County, N. Mex. - Continued.

Location	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Hardness as $CaCO_3$ Noncarbonate	Hardness as $CaCO_3$ Total	Percent sodium (% Na)	Sodium-adsorption-ratio (SAR)	Specific conductance (micromhos at 25°C)	pH
16.10.19.238	-	1,840	930	-	-	4,880	2,404	2,600	-	-	-	7.4
29.243	230	660	175	-	-	1,516	684	871	-	-	-	7.3
30.422	199	1,760	810	-	-	-	2,240	2,400	-	-	4,990	7.0
30.432	-	1,630	1,120	-	-	4,740	-	-	-	-	5,760	-
32.122	179	1,193	244	-	-	2,442	1,156	1,303	-	-	-	7.2
	184	1,190	280	0.4	20	2,230	1,220	1,370	-	-	2,960	-
33.340	151	358	104	-	-	889	467	591	-	-	-	7.4
	202	362	46	-	-	655	242	410	-	-	-	-
17.7.23.412	95	2,329	336	-	-	4,196	-	-	-	-	-	-
	183	1,970	224	-	-	-	1,880	2,030	19	-	3,710	-
17.8.6.220	152	2,570	2,143	-	-	7,504	-	-	-	-	-	-
13.231	208	9,280	24,000	-	-	50,300	16,100	16,200	63	-	61,700	6.7
13.311	-	1,940	15,000	-	-	32,000	14,400	14,500	-	-	-	7.6
28.312	173	2,971	2,526	-	-	8,970	-	-	-	-	-	-

See footnotes at end of table.

Table 21.--Analyses of water from private and municipal wells in vicinity of Holloman Air Force Base, Otero County, N. Mex. - Continued.

Location	Well no. in W.S.P. 343	Owner	Depth of well (feet)	Date of collection	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)
17.9.1.112	-	A. G. McMath	145	July 21, 1954	-	-	-	-
1.141	-	- - Frambeau	-	do.	-	-	-	-
1.311	1703	-	50	Sept. 1911 [f]	-	426	307	802
1.440	1704	-	104	do.	-	262	137	233
2.111	-	A. B. Garrett	132	July 22, 1954	-	-	-	-
5.122	-	L. Green	58	Apr. 15, 1954	-	-	-	600
8.244	-	do.	-	do.	-	-	-	341
12.422	-	J. H. Pruiett	200	July 20, 1954	-	-	-	-
	-	do.	200	May 18, 1955	-	-	-	-
12.433	-	M. H. McGee	163	Oct. 16, 1954	-	-	-	109
14.422	-	Oscar Kunkel	-	Apr. 7, 1954	-	-	-	95
15.240	1721	-	62	Sept. 1911	-	755	750	1,482
23.310	1722	-	85	1911	-	241	120	201
23.310a	1723	-	50	do.	-	525	184	392

See footnotes at end of table.

Table 21.--Analyses of water from private and municipal wells in vicinity of Holloman Air Force Base, Otero County, N. Mex. - Continued.

Location	Well no. in W.S.P. 343	Owner	Depth of well (feet)	Date of collection	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)
17.9.25.111	-	Dora Prather Cooley	75	Dec. 12, 1952	-	122	40	66
	-	do.	75	Jan. 8, 1953	-	116	56	40
	-	do.	75	Apr. 1953 b/	20	120	76	-
	-	do.	75	Apr. 14, 1954	-	-	-	48
25.112	-	do.	85g/	May 1953 a,b/	-	170	91	-
	-	do.	137g/	do. a,b/	-	180	96	-
	-	do.	250	do. b/	-	185	100	-
25.132	-	T. T. Mann	125g/	June 1953 a,b/	-	178	89	-
	-	do.	173g/	do. a,b/	-	194	94	-
	-	do.	250	do. b/	-	162	88	-
25.300	1726	-	45	1911	-	197	94	106
35.242	-	Dora Prather Cooley	298	May 20, 1954	22	110	51	40
35.332	-	do.	100	Apr. 1953 b/	15	190	134	-
	-	do.	100	Apr. 8, 1954	-	-	-	76
35.444	-	do.	297	Aug. 21, 1954 b/	-	-	-	85
	-	do.	297	Aug. 23, 1954	36	95	48	59
17.10.6.122	-	Walter Ray	302	Apr. 6, 1954	-	-	-	230

See footnotes at end of table

Table 21.--Analyses of water from private and municipal wells in vicinity of Holloman Air Force Base, Otero County, N. Mex. - Continued.

Location	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Hardness as $CaCO_3$		Percent sodium (% Na)	Sodium-adsorption-ratio (SAR)	Specific conductance (micromhos at 25°C)	pH
							Noncarbonate	Total				
17.9.25.111	234	328	55	-	2.5	728	278	469	23	-	1,080	7.8
	232	329	51	-	2.7	709	330	520	14	-	1,070	7.3
	-	315	70	-	-	850	-	470	-	-	-	7.1
	242	316	53	-	2.4	-	302	500	17	-	1,100	-
25.112	-	305	80	-	-	706	-	530	-	-	-	-
	-	330	70	-	-	743	-	560	-	-	-	-
	-	360	86	-	-	798	-	570	-	-	-	-
25.132	-	292	58	-	-	728	-	540	-	-	-	-
	-	378	66	-	-	808	-	580	-	-	-	-
	-	326	68	-	-	730	-	510	-	-	-	-
25.300	301	689	104	-	-	1,463	-	-	-	-	-	-
35.242	223	299	53	0.2	2.0	687	302	484	15	-	1,010	-
35.332	-	511	112	-	-	850	-	660	-	-	-	7.1
	187	505	104	-	-	-	507	660	20	-	1,460	-
35.444	-	-	-	-	-	660	-	397	32	-	1,086	8.1
	204	322	41	0.6	1.0	703	268	434	23	1.2	1,010	-
17.10.6.122	201	1,120	305	-	-	-	1,100	1,260	28	-	2,920	-

See footnotes at end of table.

Table 21.--Analyses of water from private and municipal wells in vicinity of Holloman Air Force Base, Otero County, N. Mex. - Continued.

Location	Well no. in W.S.P. 343	Owner	Depth of well (feet)	Date of collection	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)
17.10.6.132	-	Walter Ray	140	Feb. 22, 1945	22	230	128	-
	-	do.	140	Jan. 15, 1949	-	253	125	147
	-	do.	216	Jan. 25, 1950	-	304	136	140
	-	do.	216	May 18, 1955	-	-	-	-
6.311	-	L. O. Najera	140	Apr. 6, 1954	-	-	-	68
29.314	-	Don Taylor	222	Apr. 29, 1954	-	-	-	47
30.130	-	do.	213	Mar. 8, 1948	-	66	36	24
33.234	-	do.	Spring	Mar. 29, 1954	-	-	-	58
18.7.14.330	1802	U. S. Government	8	Sept. 1911	-	539	335	261
18.8.5.431	-	do.	989	Sept. 5, 1926 [h]	-	719	192	1,926
	-	do.	989	Mar. 30, 1954 [k,m]	-	-	-	-
12.113	-	G. B. Oliver	40	Apr. 8, 1954	-	-	-	550
17.412	-	do.	Spring	do. [n]	-	-	-	1,320
18.9.10.443	1805	Jack Prather	35	Sept. 1911	-	312	290	392
	1805	do.	40+	Apr. 1, 1954	-	-	-	441
13.431	1809	-	103	Sept. 1911	-	216	116	150
23.442	-	Buster Prather	-	Mar. 25, 1955	-	-	-	-

See footnotes at end of table.

Table 21.--Analyses of water from private and municipal wells in vicinity of Holloman Air Force Base, Otero County, N. Mex. - Continued.

Location	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Hardness as $CaCO_3$ Noncarbonate	Hardness as $CaCO_3$ Total	Percent sodium (% Na)	Sodium-adsorption-ratio (SAR)	Specific conductance (micromhos at 25°C)	pH
17.10.6.132	193	827	215	-	-	1,905	911	1,071	-	-	-	7.4
	200	919	235	-	15	1,790	981	1,140	-	-	2,440	7.8
	175	1,060	252	-	23	2,000	1,170	1,320	19	-	2,740	7.8
	197	1,000	270	-	-	-	1,180	1,340	-	-	2,610	7.1
6.311	201	592	161	-	-	-	696	860	15	-	1,760	-
29.314	219	309	40	-	0.0	-	276	455	18	-	997	-
30.130	64	251	36	-	0.1	445	260	312	-	-	716	-
33.234	246	449	58	-	0.1	-	424	625	17	-	1,280	-
18.7.14.330	183	2,769	188	-	-	4,080	-	-	-	-	-	-
18.8.5.431	117 j/	2,970	2,540	-	-	8,406	-	2,585	-	-	-	-
	128	-	2,670	-	-	-	-	-	-	-	11,700	-
12.113	-	2,070	865	-	-	-	2,180	2,250	35	-	5,510	-
17.412	119	1,510	2,670	-	-	-	2,470	2,570	53	-	11,600	-
18.9.10.443	197	1,811	566	-	-	3,751	-	-	-	-	-	-
	200	1,720	520	-	-	-	1,570	1,730	36	-	4,280	-
13.431	244	827	199	-	-	1,804	-	-	-	-	-	-
23.442	222	1,390	302	-	-	-	1,330	1,510	-	-	3,300	7.8

See footnotes at end of table.

Table 21.--Analyses of water from private and municipal wells in vicinity of Holloman Air Force Base, Otero County, N. Mex. - Continued.

Location	Well no. in W.S.P. 343	Owner	Depth of well (feet)	Date of collection	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)
18.9.26.311	1812	Jack Prather	50	Sept. 1911	-	611	304	829
	-	do.	100	Apr. 7, 1954	-	-	-	618
18.10.6.241	-	Mrs. B. D. Douglas	154	Apr. 6, 1954	-	-	-	48
15.113	-	U. S. Government	Spring	Apr. 7, 1954	13	-	-	18
28.141	-	Tom Fairchild	93	May 7, 1944	-	92	49	36
	-	do.	-	Mar. 25, 1955 p/	-	-	-	-
30.242	-	do.	-	do.	-	-	-	-
31.221	-	Ray Prather	-	do.	-	-	-	-
35.313	-	Sam Fairchild	-	do.	-	-	-	-
19.10.4.124	-	Langford Ranch	-	do.	-	-	-	-
17.231	-	do.	240	do.	-	-	-	-
17.233	-	do.	150	May 1944	-	64	48	68

See footnotes at end of table.

Table 21.--Analyses of water from private and municipal wells in vicinity of Holloman Air Force Base, Otero County, N. Mex. - Continued.

Location	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Hardness as $CaCO_3$		Percent sodium (% Na)	Sodium-adsorption-ratio (SAR)	Specific conductance (micromhos at 25°C)	pH
							Non-carbonate	Total				
18.9.26.311	122	3,016	953	-	-	6,912	-	-	-	-	-	-
	156	2,690	1,060	-	-	-	2,950	3,080	30	-	6,860	-
18.10.6.241	220	380	69	-	-	-	390	570	15	-	1,210	-
15.113	296	206	30	-	0.8	-	218	460	8	-	886	-
28.141	218	253	45	-	3.6	586	252	431	-	-	947	-
	201	263	46	-	-	-	290	455	-	-	928	7.7
30.242	218	1,200	700	-	-	-	1,830	2,010	-	-	3,980	7.2
31.221	225	747	152	-	-	-	826	1,010	-	-	1,970	7.9
35.313	207	251	39	-	-	-	296	465	-	-	882	7.5
19.10.4.124	229	273	61	-	-	-	322	510	-	-	1,010	7.4
17.231	184	265	63	-	-	-	254	405	-	-	962	7.4
17.233	170	255	70	-	1.0	590	218	357	-	-	932	-

a/ Sample taken while well being drilled.
b/ Analysis reported by town of Alamogordo.
c/ Samples below 300 feet.
d/ Density: 1.036 grams per milliliter.
e/ Analysis reported by Holloman Air Force Base.
f/ Depth just below water level at depth cited.
g/ Approximate.
h/ Density: 1.0032 grams per milliliter.
j/ Includes 9.6 ppm carbonate (CO_3).
k/ Density: 1.004 grams per milliliter
m/ Includes 0.3 ppm boron (B).
n/ Includes 0.18 ppm boron (B).
p/ Composite of water from 2 wells pumped into common storage tank.

Table 22.--Analyses of water from Alamo Springs, Otero County, N. Mex. a/

Analyses by U. S. Geological Survey. (Chemical constituents in parts per million.)

Date of collection	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids
Jan. 5, 1943	120	29	9.7	277	176	20	-	1.6	493
Apr. 15, 1943 b/	133	29	12	311	182	21	0.2	2.1	534
Oct. 5, 1950	122	27	12	313	147	21	-	2.0	485
Feb. 11, 1952	127	27	3.7	316	143	18	0.2	2.3	477
May 1, 1953	131	29	12	325	170	18	-	2.4	522
Apr. 15, 1954	-	-	-	340	-	11	-	-	-

Table 22.--Analyses of water from Alamo Springs. a/ - Continued.

Date of collection	Hardness as $CaCO_3$		Percent sodium (% Na)	Specific conductance (micromhos at 25°C)	pH
	Non-carbonate	Total			
Jan. 5, 1943	-	418	-	807	-
Apr. 15, 1943 b/	-	451	-	796	8.2
Oct. 5, 1950	159	416	6	778	8.1
Feb. 11, 1952	169	428	2	773	7.9
May 1, 1953	180	446	5	818	7.7
Apr. 15, 1954	-	-	-	768	-

a/ Composite of all springs, sampled from Alamogordo reservoir and/or pipeline.

b/ Contained no borates (BO_3) and 0.05 ppm iron (Fe).

Table 23.--Analyses of water from La Luz-Fresnal Canyons watershed, Otero County, N. Mex.

Analyses by U. S. Geological Survey. (Chemical constituents in parts per million.)

Source	Date of collection	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)
Karr Canyon Spring, Fresnal watershed a/	Apr. 15, 1943	134	28	10
La Luz Canyon, 3 miles N. of High Rolls b/	do.	156	41	139
Mouth of La Luz Canyon c/	do.	189	59	116
Pipeline discharging into Alamogordo reservoir	Oct. 5, 1950	166	45	150
Do.	Feb. 11, 1952	188	43	139
Do.	May 1, 1953	189	43	159

Table 23.--Analyses of water from La Luz-Fresnal Canyons watershed. - Continued.

Date of collection	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Hardness as $CaCO_3$		Percent sodium (% Na)	Specific conductance (micromhos at 25°C)	pH
							Noncarbonate	Total			
Apr. 15, 1943	388	142	14	0.0	3.7	488	-	450	-	752	7.8
Do.	316	305	199	0.3	2.0	998	-	558	-	1,530	7.8
Do.	223	530	162	0.3	3.9	1,170	-	714	-	1,252	8.0
Oct. 5, 1950	330	307	235	0.4	3.0	1,070	328	599	35	1,710	7.8
Feb. 11, 1952	350	314	235	0.2	3.0	1,090	359	646	32	1,770	7.6
May 1, 1953	358	336	247	-	1.7	1,150	355	648	35	1,800	7.6

a/ Contained no borates (BO_3) and 0.05 ppm iron (Fe).

b/ Contained 0.1 ppm borates (BO_3) and 0.05 ppm iron (Fe).

c/ Contained 0.2 ppm borates (BO_3) and 0.05 ppm iron (Fe).

Table 24.--Chemical analyses of water from the Bonito Lake water system, Lincoln County, N. Mex. Analyses by U. S. Geological Survey. (Chemical constituents in parts per million.)

Date of collection	Point of collection	Calcium (Ca)	Magnesium (Mg)	Sodium plus potassium (Na+K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)
May 24, 1955	Parshall flume above Bonito Lake	36	14	1.2	59	83	10
June 14, 1955	do.	42	9.4	13	68	97	9.5
Do.	Pipeline below Bonito Dam	59	13	16	96	130	13
Sept. 1, 1955	do.	56	14	10	97	117	11
Apr. 27, 1955	Diversion dam on Eagle Creek	-	-	-	53	45	7.0
May 20, 1955	do.	26	8.3	6.9	56	54	8.0
June 14, 1955	do.	33	5.9	9.2	75	53	6.2
Do.	Inflow to Nogal Reservoir	58	13	16	95	130	12
Do.	Outflow from Nogal Reservoir	59	13	14	95	129	12

Table 24.--Chemical analyses of water from the Bonito Lake water system, Lincoln County, N. Mex. - Continued.

Analyses by U. S. Geological Survey. (Chemical constituents in parts per million.)

Date of collection	Point of collection	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Hardness as $CaCO_3$		Percent sodium (% Na)	Specific conductance (micromhos at 25°C)	pH
					Non-carbonate	Total			
May 24, 1955	Parshall flume above Bonito Lake	0.2	0.5	188	99	148	2	308	7.7
June 14, 1955	do.	0.7	0.2	217	88	144	17	349	7.7
Do.	Pipeline below Bonito Dam	0.7	0.5	286	122	200	15	459	7.2
Sept. 1, 1955	do.	0.6	0.9	269	118	197	-	430	7.2
Apr. 27, 1955	Diversion dam on Eagle Creek	-	-	-	60	104	-	208	8.7
May 20, 1955	do.	0.2	0.3	144	53	99	13	232	7.3
June 14, 1955	do.	0.5	0.5	157	46	107	16	265	7.7
Do.	Inflow to Nogal Reservoir	0.6	0.3	283	120	198	15	461	7.3
Do.	Outflow from Nogal Reservoir	0.6	0.2	282	122	200	13	459	7.2