UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
Albuquerque, New Mexico

Drilling and testing of well 340, Fort Wingate Army Depot, McKinley County, New Mexico

by

John W. Shomaker

Open-file report

Prepared by the U.S. Geological Survey in cooperation with
Fort Wingate Army Depot

July 1969

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
Water Resources Division
P. O. Box 4369
Albuquerque, New Mexico 87106

31 July 1969

CERTIFIED MAIL

Memorandum

To : U.S. Geological Survey Library
Washington, D.C.

William E. Hale

From : W. E. Hale, District Chief, WRD
Albuquerque, New Mexico

Subject: PUBLICATIONS - REPORT: "Drilling and testing of well 340, Fort Wingate Army Depot, McKinley County, New Mexico, by John W. Shomaker

In connection with the distribution of the subject open-file report, four copies are transmitted herewith for your records.

Enclosures 4

Contents

Illustrations

Tables

Drilling and testing of well 340, Fort Wingate Army Depot, McKinley County, New Mexico

by

John W. Shomaker

Introduction

The U.S. Geological Survey was requested by Fort Wingate Army Depot to designate a well location, suggest construction and testing procedures, and provide continuing technical advice with respect to the drilling of a new production well. The location was determined during a brief preliminary study of the Depot's water supply which is summarized in a report transmitted to the Depot in April of 1968[1/], and the Geological Survey's suggestions for construction and testing are contained in the specifications written by the Post Engineer at the Depot as part of the well-drilling contract. A representative of the the Geological Survey was present during most of the drilling and testing of the well.

1/ Shomaker, J. W., 1968, Site study for a water well, Fort Wingate Army Ordnance Depot, McKinley County, New Mexico: U.S. Geol. Survey open-file report, 28 p.

Location of the well

Fort Wingate Army Depot is located upon the broad, northwest-plunging anticline at the northern end of the Zuni uplift in McKinley County, New Mexico. The only rock unit beneath the Depot area known to contain water of good quality is the San Andres Limestone-Glorieta Sandstone aquifer. The well location was chosen so as to take advantage of the geologic structure and tap that aquifer at a reasonable depth, to interfere as little as possible with the existing well (well 68, fig. 1) and to realize the advantages of nearness to the aquifer's recharge area.

The well is in the SW¼SE¼SE¼SW¼ sec. 30 (projected), T. 15 N., R. 16 W., N. M. P. M. (fig. 1) at an altitude of 6,805 feet.

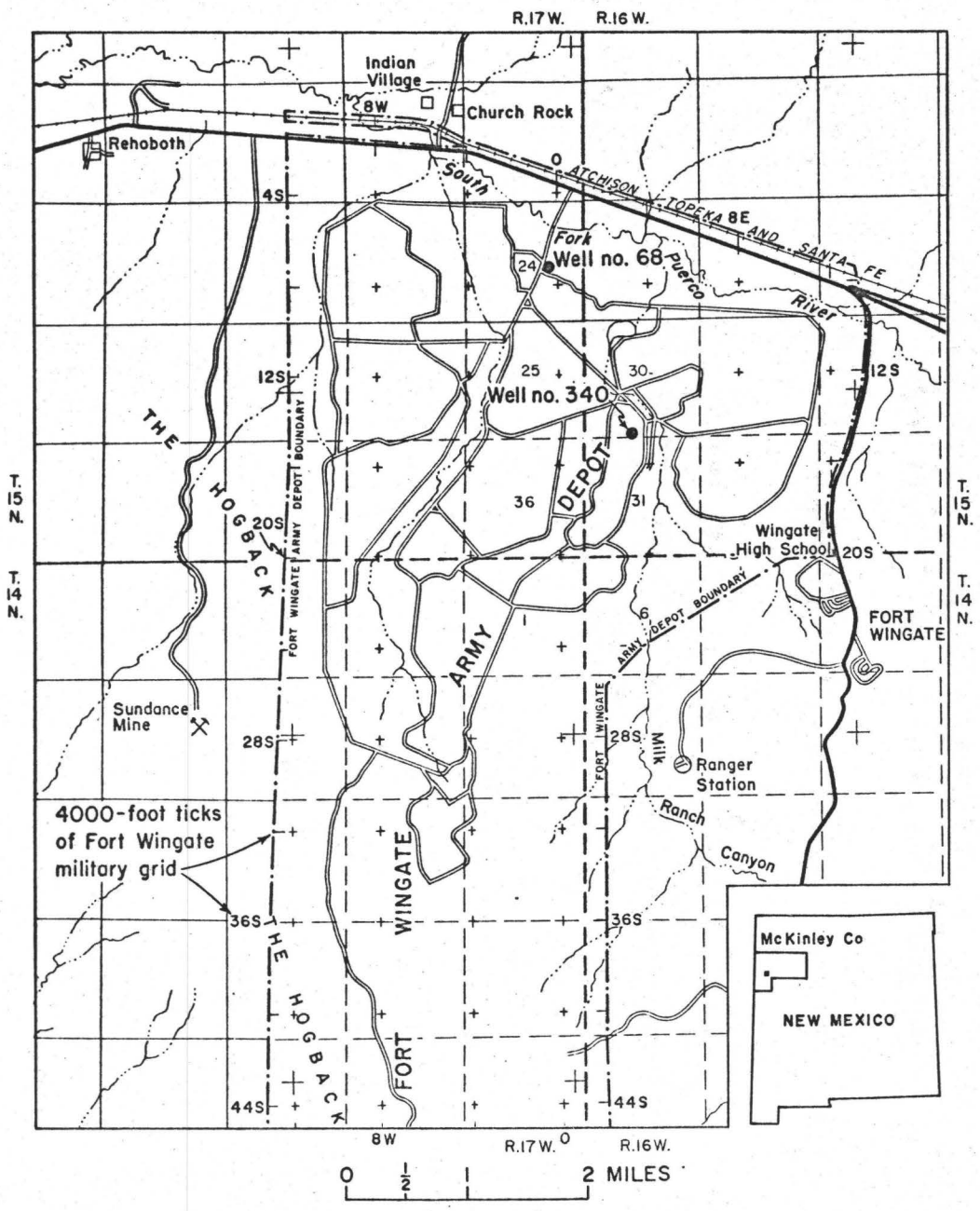

Figure 1.--Location of well 340 within Fort Wingate Army Depot, McKinley County, N. Mex.

Construction and testing of the well

The well was begun July 30, 1968 by Coffey Drilling Co. of Ramah, N. Mex. A 7 7/8-inch pilot hole was drilled to a depth of about 100 feet by the rotary method with air, then extended to 628 feet using bentonite-base drilling mud. After gamma ray-neutron, microlog, caliper, induction, and spontaneous potential logs were made by Schlumberger Well Service Co. (fig. 2) the pilot hole was reamed and cased with 624 feet of 8 5/8-inch steel pipe to prevent caving. The 7 7/8-inch hole was then drilled to 1,930 feet (including a 12-foot core taken between 1,842 and 1,854) and a 4-inch core hole was drilled from 1,930 to 1,945 feet. Schlumberger logged the hole from the bottom of the 8 5/8-inch casing to total depth. Cuttings were sampled at 10-foot intervals and a sample-description log (table 1) was made.

A packer was set at 1,284 feet, and a swab was operated inside the drill pipe to withdraw water from the zone between the packer and the bottom of the hole. About 1,255 gallons of poor quality water was removed (table 2). After swabbing, the recovery of the water level was measured for 18 hours, at the end of which time the shut-in pressure was 120 psi (pounds per square inch) at the pressure gage, which was 8.6 feet above land surface, or approximately equal to a head of 286 feet above land surface.

A Lynes inflatable plug was set with bottom at 1,307 feet and Cal-seal cement placed above it by Halliburton Co. to make a plug 24 feet long.

The testing packer was reset at 996 feet to test the 996-to-1,283-foot zone. About 150 gallons of water were removed with the swab. The amount that could be removed was somewhat less than the volume of the drill pipe that had been filled for setting the packer, and after about 19 hours the water level in the pipe had not risen appreciably, so it must be assumed that the zone will yield little water.

Another inflatable plug was set at 996 feet and cement placed to 972 feet. The testing packer was set at 716 feet and swabbing of water from the proposed production zone began. A total of about 7,300 gallons were removed at a rate of about 15 gpm (gallons per minute) in three swabbing periods, and water-level recovery was measured for about 15 hours after swabbing stopped.

After the swab testing was completed and the temporary casing removed, the well was reamed to 20-inch diameter from land surface to 150 feet and 16-inch O.D. casing was set and cemented. From 150 to 710 feet the hole was reamed to 16 inches to accept 12 3/4-inch casing and was reamed to 11 inches from 710 to 980 feet. The hole caved at about 635 feet so that the 12 3/4-inch pipe was run from the surface to 615 feet and 10-inch pipe from that point to 710 feet. The 12 3/4-inch and 10-inch casing strings were cemented in from bottom to top. Slotted 8 5/8-inch pipe was set through the producing section from 710 to 980 feet and sealed to the 10-inch pipe with a lead swedge nipple (fig. 3).

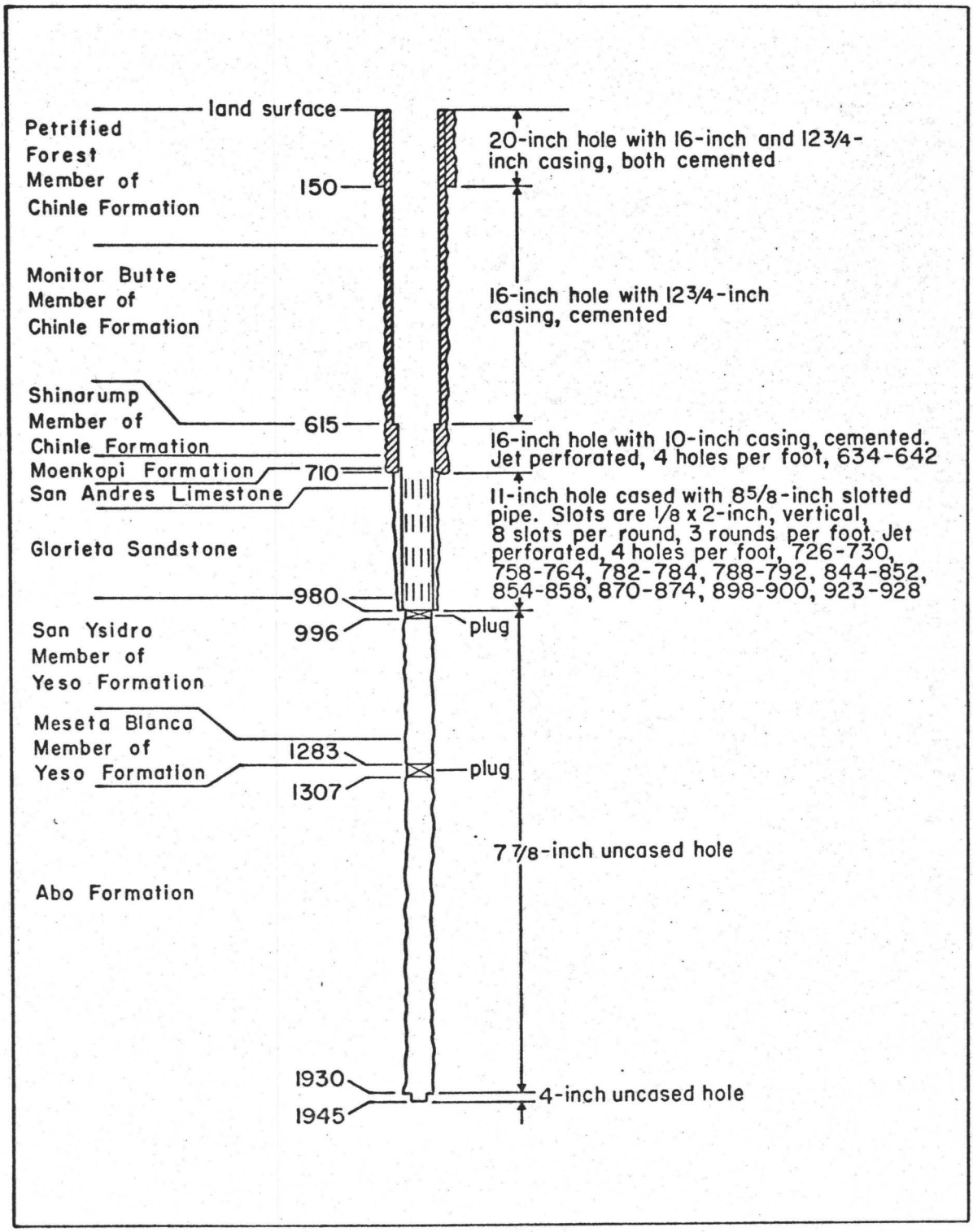

Figure 3.--Construction details of well 340.

Static water level in the well after 68 days without swabbing, bailing, or pumping was 57.5 feet below land surface.

The well was bailed and surged with a close-fitting surge block for about 48 hours to remove drilling mud and to develop the aquifer. A lineshaft turbine pump was installed with impellers at 400 feet. The well was test-pumped and surged for 24 hours as required by the contract, but did not improve beyond the 15 to 20 gpm yield of the first few hours.

An attempt was made to improve the yield by introducing 1,000 gallons of approximately 5 percent sulfamic acid solution at the bottom of the producing section, but no improvement was discernible.

On February 18, 1969, the casing and the first few inches of the hole wall were perforated with Welex shaped-charge jet shots; 188 shots were fired, with four shots per foot in the following zones: 634-642, 726-730, 758-764, 782-874, 788-792, 844-852, 854-858, 870-874, 898-900, and 923-928. The shots were placed in the zones of greatest permeability (according to the microlog) in order to penetrate any plugging of permeability near the bore. The zone from 634 to 642 feet (a permeable zone in the Shinarump Member of the Chinle Formation) had been cased and cemented; all of the other perforations were in zones that had been open to the slotted casing before perforating.

Just after the perforating had been completed (February 18 at 1300 hrs.), the water level stood 56.54 feet below land surface; in 2½ hours the water level rose to 56.18 feet below land surface, and after 10 days (February 28) the water level had risen to 52.78 feet.

On March 21, 1969, the well was treated with 3,000 gallons of acid (12% HCl, 3% HF) to break down and flush out any mud that might plug the permeable zones, to dissolve carbonate cement in the Glorieta Sandstone, and to enlarge fractures and cavities in the San Andres Limestone. After the acid treatment, the well was thoroughly cleaned by bailing to prepare it for an aquifer test.

Aquifer testing after completion

A submersible pump was installed at 918 feet on March 27, 1969, and a 24-hour preliminary test was made. At the end of the test, the pump was producing 45 gpm from a pumping level 796.4 feet below land surface. After a 24-hour recovery period, the well was pumped at a nearly constant rate of 30.5 gpm for 72 hours (fig. 4) and then allowed to recover for 24 hours (fig. 5). The pumping level after 72 hours was 571.3 feet below land surface, or 518.1 feet below the static water level before pumping began, which was 49.4 feet below land surface. The specific capacity of the well was 0.06 gpm per foot of drawdown. Transmissivity (T) of the aquifer was estimated from the specific capacity at 20.7 ft^2/day (cubic feet per day flow through a section one foot wide and the full thickness of the aquifer under a hydraulic gradient of 100 percent). The estimate was based on a hole diameter of 11 inches. Neither the water-level drawdown data nor the recovery data were adequate to define a reliable value for transmissivity, but the shapes of the latter parts of the curves (figs. 5 and 6) appear to substantiate the estimate in a general way.

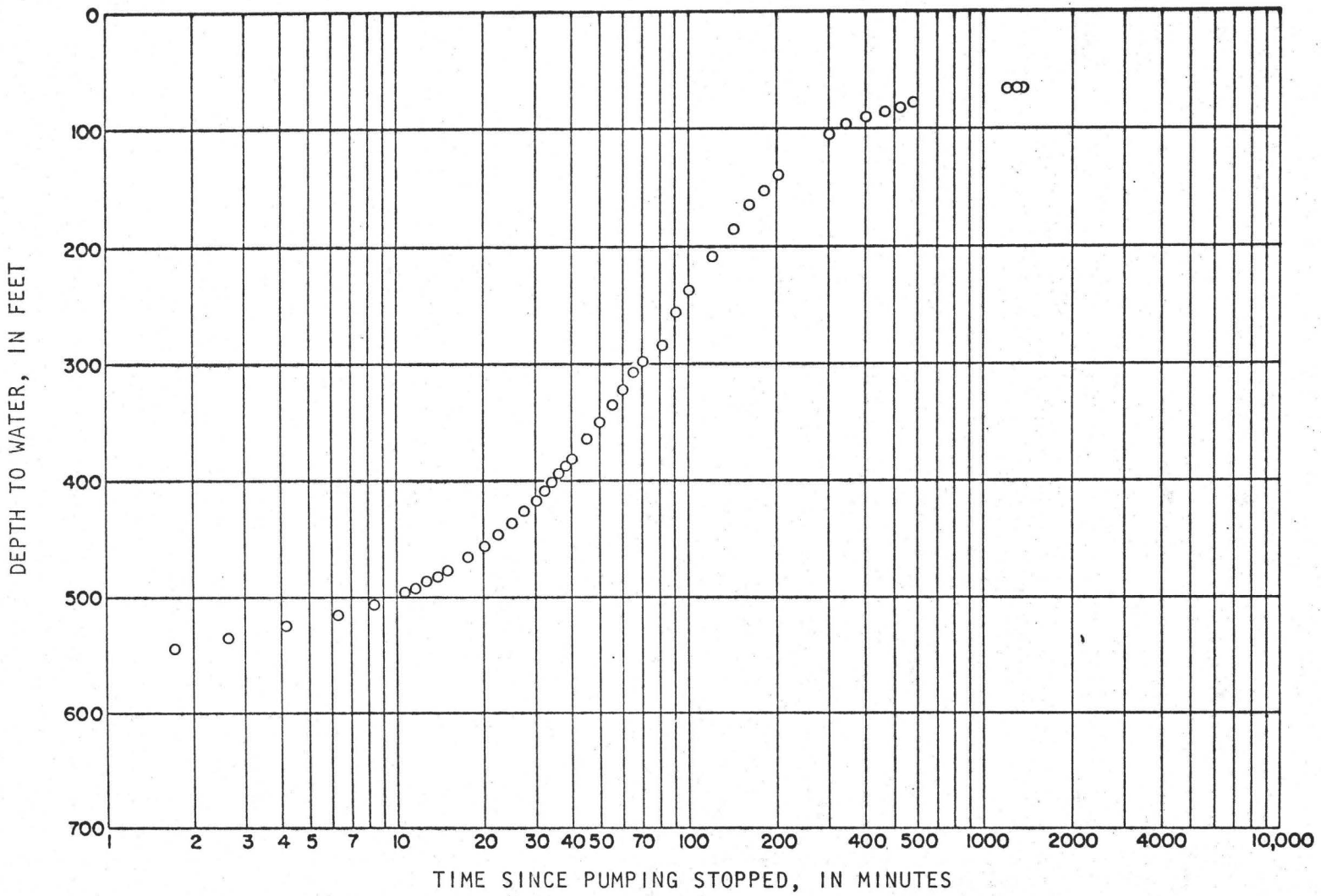

Figure 5.--Recovery of water level after pumping stopped, aquifer test of March 28 to April 1, 1969.

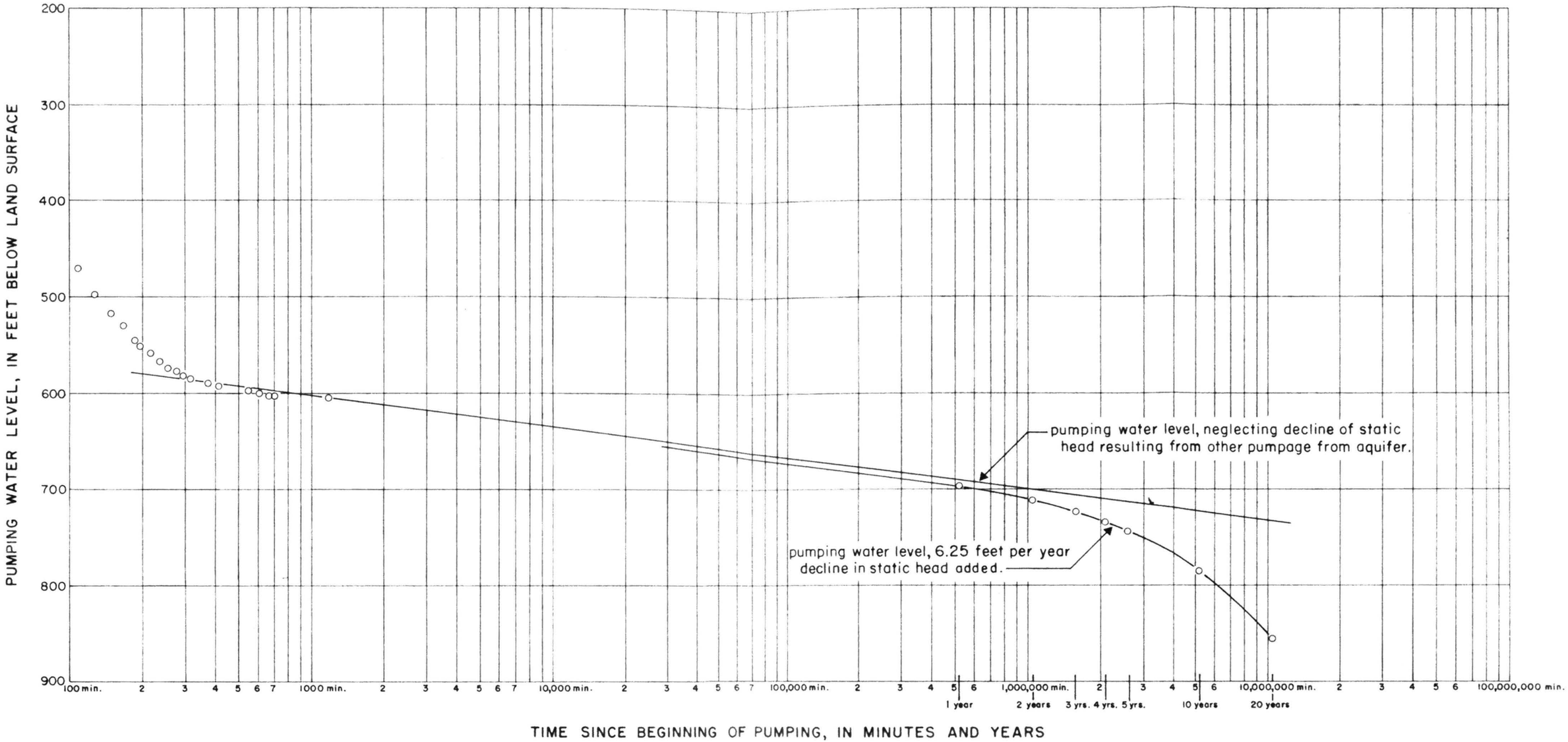

Figure 6.-- Projected pumping water level in well 340 at a constant pumping rate of 30.9 gpm.

The storage coefficient (S) of the aquifer was estimated by assuming that the pumping level at 45 gpm (796.4 feet, or 747.0 feet of drawdown below the static level) applied at a radius of 1 foot from the center of the well bore. The storage coefficient thus obtained is 7.6×10^{-5}, which is in general agreement with a more reliable value of 3.7×10^{-5} obtained in an aquifer test at Rehoboth Mission.

In figure 6, the most reliable part of the drawdown curve has been projected to provide an estimate of the pumping water level for the next 20 years at a constant discharge of 30.9 gpm (upper curve) and, in the lower curve, an additional decline of 6.25 feet per year has been included to represent decline in static water level caused by pumping from other wells. The lower curve, then, gives an approximation of the life of well 340 at a constant discharge of 30.9 gpm.

The transmissivity and storage values were used to calculate projected pumping water levels at a constant discharge of 45 gpm; at the 45 gpm rate, the pumping level would be (theoretically) at the bottom of the well in less than a year.

The well was improved very little, if any, by the perforating or acid treatment; it is not likely that any further efforts to improve it would be successful.

Chemical quality of water

Abo Formation and Meseta Blanca Sandstone Member of Yeso Formation: The zone between the 1,284-foot packer setting and the bottom of the test hole is comprised of the lower part of the Meseta Blanca Member of the Yeso Formation and, probably, most of the Abo Formation. The water removed from the zone by swabbing, however, probably came from the Meseta Blanca Sandstone Member near the opening in the packer. The specific conductance of the water removed was measured with a portable meter each time the swab was pulled up through the drill pipe, and a sample was taken after about 175 gallons of water of uniform conductance had been removed. A chemical analysis of that sample appears in table 2.

The water has a dissolved solids content of 4,580 mg/l (milligrams per liter), largely made up of sodium and sulfate ions. Total iron content is also very high (115 mg/l), but could be greatly reduced by precipitation if the water were otherwise suitable for some use. The water is too hard for use at the Depot, and the Depot's present softening facilities would be of little help in treating it because the system relies upon exchange of sodium for calcium and magnesium to reduce hardness.

It would seem from the induction log (fig. 2) that the quality of water in the formation at the packer setting, which the sample probably represents, is about equivalent to the best water in the hole below.

San Ysidro Member of Yeso Formation: The test interval between 996 and 1,283 feet corresponds approximately with the San Ysidro Member of the Yeso Formation. The zone was isolated, and the head of water above it taken off, but no water could be recovered from it for sampling. The induction log (fig. 2) indicates that water in the zone would be similar in total dissolved solids content to that of the overlying Glorieta Sandstone.

San Andres Limestone and Glorieta Sandstone: After the San Andres Limestone-Glorieta Sandstone aquifer was isolated for sampling, the water recovered was at first similar to that of the 1,284 - 1,945-foot zone (about 6,000 micromhos conductance), and improved gradually to about 3,800 micromhos conductance at the time the test was discontinued. After development by surging and bailing, and some pumping, the conductance had declined to about 2,200 micromhos. In all probability, the part of the hole below 1,284 feet contributed poor quality water to the San Andres-Glorieta aquifer from the time drilling reached the lower zone until the plugs were set to isolate it.

By the end of the aquifer test of March 28 - April 1, 1969, the conductance had become stabilized at about 1,390 micromhos as determined with a portable meter. An analysis of a water sample taken at the end of the test (table 2) shows it to be similar in every respect to water from well 68.

Chinle and Moenkopi(?) Formations: Water from the Chinle and Moenkopi(?) Formations was not sampled during the testing of well 340. However, some idea of the water quality can be gained from the induction log (fig. 2). Though the interpretation of the log is subject to error, it would seem that the conductance of water in the Chinle Formation above the Shinarump Member is approximately 10 times that of water from the San Andres Limestone and Glorieta Sandstone, and therefore too highly mineralized to be of much value to the Depot. Water in the Shinarump Member of the Chinle Formation and in the Moenkopi(?) Formation probably is about the same as water in the San Andres-Glorieta aquifer.

Summary

Well 340 was a successful test of formations beneath the San Andres Limestone-Glorieta Sandstone aquifer, and provided valuable, though negative, information about the water-bearing characteristics of the lower rock units. The hydrologic and stratigraphic information obtained relative to the San Andres Limestone and Glorieta Sandstone and overlying rocks will also prove to be of great value in the comprehensive evaluation of ground-water resources available to the Depot.

The test has shown that good quality water is not obtainable from bedrock units to a depth of 1,945 feet or more beneath the Depot other than the San Andres Limestone and the Glorieta Sandstone, and that there is no apparent way of predicting in which areas those strata are permeable enough to yield sufficient water for the Depot's use. Well 340 penetrates the aquifer in a tightly cemented area, and therefore probably cannot be improved much by further work.

The well should be reliable for about 20 years at a constant production rate of about 30 gpm, barring a significant increase in pumping from other wells finished in the same aquifer. At 45 gpm, on the other hand, the well would probably last less than a year before the pumping rate would have to be reduced. Water quality should remain almost constant throughout the life of the well.

Table 1.--Sample description log of well 340, Fort Wingate Army Depot.

(Note: samples were taken at 10-foot intervals, and represent only the material being drilled at the time the sample was caught. An effort was made to identify cavings from up the hole in each sample, and exclude them from the description. Grain-size terminology is as follows:

Coarse sand	0.5 to 1.0 mm
Medium-grained sand	0.25 to 0.5
Fine-grained sand	0.10 to 0.25
Very fine grained sand	0.05 to 0.10
Silt	0.005 to 0.05
Clay	less than 0.005

Color symbols in parentheses following the color of the rock are from the "Rock-Color Chart", 1963, distributed by the Geological Society of America, New York, N. Y.

Material	Depth interval (feet)
Quaternary System	
Alluvium	
Alluvium, unconsolidated, composed of rounded fragments of sandstone and siltstone, with abundant vein calcite and pale-red (5 R 6/2) clay ----------	0-10
Triassic System	
Chinle Formation	
Petrified Forest Member (Sonsela Sandstone Bed)	
Sandstone, light-brownish-gray (5 YR 6/1), very fine- to coarse-grained, very poorly sorted; composed of angular-to-rounded, clear and amber quartz with abundant white and brown clay and dark minerals, highly calcareous ----------	10-20

Table 1.--Sample description log of well 340, Fort Wingate Army Depot. - continued

Material	Depth interval (feet)
Triassic System - continued	
Chinle Formation - continued	
Petrified Forest Member (lower part)	
Claystone, light greenish-gray (5 GY 8/1), and light grayish-red (5 R 5/2), highly calcareous; common finely crystalline white calcite and occasional fine or very fine detritals (clear quartz and mica) --------	20-30
Claystone, silty, pale grayish red-purple (5 RP 5/2), with common grayish-red (5 R 4/2) and light greenish-gray (5 GY 8/1) clay; common white, finely crystalline calcite; siltstone is highly calcareous and firmly cemented ----------	30-60
Sandstone, silty, light brownish-gray (5 YR 6/1), very fine- to fine-grained, poorly sorted; composed of angular-to-subround, clear or yellowish, very slightly frosted quartz grains with abundant brown and white, slightly calcareous clay and common dark detritals ---	60-80

Table 1.--Sample description log of well 340, Fort Wingate Army Depot. - continued

Material	Depth interval (feet)
Triassic System - continued	
Chinle Formation - continued	
Petrified Forest Member (lower part) - continued	
Claystone, grayish red-purple (5 RP 4/2), and white (N9), with abundant finely crystalline calcite ----------	80-90
Claystone, grayish-red (5 R 4/2), and silty claystone, light brownish-gray (5 YR 6/1), with common dark accessory minerals ------	90-100
Sandstone, very light brownish-gray (5 YR 7/1), very fine- to fine-grained, well sorted; composed of subangular to rounded, clear quartz grains with a few amber grains and rare biotite and other accessory minerals; very weak, calcareous cement and abundant argillaceous material ----------	100-110
Claystone, medium-gray (N5), calcareous; contains abundant fine, clear, rounded quartz grains, and minor brown clay -----	110-120

Table 1.--Sample description log of well 340, Fort Wingate Army Depot. - continued

Material	Depth interval (feet)
Triassic System - continued	
Chinle Formation - continued	
Petrified Forest Member (lower part) - continued	
Claystone, medium-gray (N5), calcareous; contains some fine sand ----------	120-140
Sandstone, pinkish-gray (5 YR 8/1), fine- to very fine-grained, well sorted; composed of subangular to subrounded, slightly frosted quartz grains with abundant accessory green fluorite(?); abundant white clay cement ----------	140-150
Claystone, medium dark-gray (N4), non-calcareous	150-160
Claystone, medium light-gray (N6); contains some very fine sand- and silt-size clear, rounded quartz grains; minor grayish-red (5 R 4/2) clay, and white (N9) clay ------	160-170
Claystone, very light-gray (N8); minor biotite(?) and other dark minerals -------	170-180

Table 1.--Sample description log of well 340, Fort Wingate Army Depot. - continued

Material	Depth interval (feet)
Triassic System - continued	
Chinle Formation - continued	
Petrified Forest Member (lower part) - continued	
Claystone, pale grayish-purple (5 P 5/2), mottled with very light-greenish-gray (5 GY 9/1); non-calcareous; minor silt-size dark minerals	180-190
Claystone, pale grayish-purple (5 P 5/2), mottled with very light-greenish-gray (5 GY 9/1), and grayish-red (5 R 4/2). Grayish-red clay highly calcareous	190-200
Claystone, medium light-gray (N6); slightly calcareous	200-210
Claystone, silty, pinkish-gray (5 YR 8/1); silt-size material includes clear and amber quartz and slightly altered biotite; some medium light-gray (N6) claystone	210-220

Table 1.--Sample description log of well 340, Fort Wingate Army Depot. - continued

Material	Depth interval (feet)
Triassic System - continued	
Chinle Formation - continued	
Petrified Forest Member (lower part) - continued	
Claystone, medium light-gray (N6), and grayish-purple (5 P 4/2); slightly calcareous; minor calcite	220-230
Claystone, grayish-purple (5 P 4/2), and white (N9) in about equal proportion; highly calcareous	230-240
Claystone, pale grayish-purple (5 P 5/2), and white (N9), with minor moderate brown (5 YR 3/4), common white calcite	240-250
Claystone, grayish-purple (5 P 4/2), mottled with greenish-white (5 GY 9/1). Calcareous-	250-260
Claystone, pale grayish-purple (5 P 5/2), white (N9), and medium light-gray (N6); calcareous	260-270
Claystone, grayish-purple (5 P 4/2), mottled with light greenish-gray (5 GY 8/1), some medium light-gray (N6); calcareous	270-280

Table 1.--Sample description log of well 340, Fort Wingate Army Depot. - continued

Material	Depth interval (feet)
Triassic System - continued	
Chinle Formation - continued	
Petrified Forest Member (lower part) - continued	
Claystone, very light-gray (N8), and light-gray (N7), some slightly silty. Contains minor weathered mica ----------	280-290
Monitor Butte Member	
Claystone, silty, grayish-red (5 R 4/2), and white; some medium dark-gray (N4) --------	290-330
Siltstone, pale red-purple (5 RP 6/2), and light greenish-gray (5 GY 8/1). Some claystone, medium dark-gray (N4), minor muscovite ----------	330-340
Claystone, dark reddish-brown (10 R 3/4), and medium light-gray (N6); slightly calcareous-	340-350
Claystone, grayish-red (5 R 4/2), and white (N9). Some white calcite with grayish-red mottling ----------	350-360
Claystone, grayish-red (5 R 4/2), mottled with light greenish-gray (5 GY 8/1), and white (N9); calcareous ----------	360-370

Table 1.--Sample description log of well 340, Fort Wingate Army Depot. - continued

Material	Depth interval (feet)
Triassic System - continued	
Chinle Formation - continued	
Monitor Butte Member - continued	
Claystone, silty, grayish-red (5 R 4/2), mottled with light greenish-gray (5 GY 8/1); calcareous	370-380
Claystone, mottled pale-purple (5 P 6/2), grayish-red (5 R 4/2), and light-gray (N7); some silt; calcareous	380-400
Claystone, mottled pale-purple (5 P 6/2), grayish-red (5 R 4/2), and light-gray (N7); calcareous	400-410
Claystone, medium light-gray (N6), and pale-purple (5 P 6/2); calcareous	410-420
Claystone, grayish-purple (5 P 4/2), and light-gray (N7); not calcareous	420-430
Claystone, mottled grayish-purple (5 P 4/2), mottled pale purple (5 P 6/2), grayish-red (5 R 4/2), and medium light-gray (N6); calcareous	430-480

Table 1.--Sample description log of well 340, Fort Wingate Army Depot. - continued

Material	Depth interval (feet)
Triassic System - continued	
Chinle Formation - continued	
Monitor Butte Member - continued	
Claystone, mottled grayish red-purple (5 RP 4/2), dusky-red (5 R 3/4), and minor light-gray (N7); calcareous	480-500
Claystone, mottled grayish-purple (5 P 4/2), and medium light-gray (N6); minor hard, white limestone	500-510
Claystone, mottled grayish-purple (5 P 4/2), grayish-red (5 R 4/2), and medium light-gray (N6); calcareous	510-530
Claystone, light greenish-gray (5 GY 8/1), mottled grayish-purple (5 P 4/2), dusky-red (5 R 3/4), and light-gray (N7); calcareous-	530-540
Claystone, mottled grayish-purple (5 P 4/2), dusky-red (5 R 3/4), and light-gray (N7); calcareous	540-550

Table 1.--Sample description log of well 340, Fort Wingate Army Depot. - continued

Material	Depth interval (feet)
Triassic System - continued	
Chinle Formation - continued	
Monitor Butte Member - continued	
Claystone, medium-gray (N5) (with biotite), and mottled grayish red-purple (5 RP 4/2), and very light-gray (N8); calcareous; some vein calcite	550-560
Claystone, dark-gray (N3), grayish-red (10 R 4/2), and light-gray (N7); light-gray clay contains fresh biotite	560-570
Claystone, dark-gray (N3), mottled light-gray (N7), and very dark-red (5 R 2/6), and grayish-purple (5 P 4/2), calcareous; some calcite in veins and masses	570-580
Claystone, grayish red-purple (5 RP 4/2), slightly calcareous; some light-gray (N7), clay with carbonaceous(?) material	580-590
Claystone, medium dark-gray (N4), to very light-gray (N8), calcareous; minor grayish red-purple (5 RP 4/2) claystone; minor vein calcite	590-600

Table 1.--Sample description log of well 340, Fort Wingate Army Depot. - continued

Material	Depth interval (feet)
Triassic System - continued	
Chinle Formation - continued	
Monitor Butte Member - continued	
Siltstone, grayish-red (10 R 4/2), firmly cemented, calcareous in part; some light-gray (N7) claystone	600-610
Siltstone, grayish-red (5 R 4/2), or blackish-red (5 R 2/2), firmly cemented, non-calcareous; some light-gray (N8) claystone; some brown (10 R 3/4) calcareous claystone; rare vein calcite	610-620
Shinarump Member	
Claystone, light greenish-gray (5 GY 8/1), moderate-red (5 R 5/4), and grayish red-purple (5 RP 4/2), silty, some sand; abundant pale reddish-brown (10 R 5/4), rounded quartz pebbles; some firmly cemented conglomeratic sandstone made up of white and pale-brown quartz sand and pebbles in white clay matrix	620-630

Table 1.--Sample description log of well 340, Fort Wingate Army Depot. - continued

Material	Depth interval (feet)
Triassic System - continued	
Chinle Formation - continued	
Shinarump Member - continued	
Conglomerate; chiefy white and pale reddish-brown (10 R 5/4) quartz, up to ½ inch, sub-rounded to well-rounded; abundant medium light-gray (N6) claystone; some very dark-red (5 R 2/6) silty claystone; some very hard grayish-pink (5 R 8/2) arkosic silt-stone with grayish-red (10 R 4/2) bands -	630-640
Sandstone, moderate-red (5 R 5/4), fine- to very fine-grained, angular-to-sub-angular, fairly well-sorted; chiefly clear and brown quartz, but dark minerals abundant, contains rare muscovite, firmly cemented with brown clay, some medium gray and brown claystone, some yellow quartz pebbles ----------	640-650

Table 1.--Sample description log of well 340, Fort Wingate Army Depot. - continued

Material	Depth interval (feet)
Triassic System - continued	
Chinle Formation - continued	
Shinarump Member - continued	
Siltstone, sandy, grayish-red (10 R 4/2); sand-size material includes clear, angular quartz, muscovite, and dark minerals; some medium-gray (N5), and light greenish-gray (5 G 8/1) claystone ----------	650-670
Moenkopi(?) Formation (may be part of Chinle Formation)	
Siltstone to very fine-grained sandstone, pale reddish-brown (10 R 5/4); some dark reddish-brown (10 R 3/4), and gray (N5 to N8) claystone ----------	670-680
Sample missing ----------	680-690
Claystone, very light-gray (N8), to medium-gray (N5); some dark reddish-brown (10 R 3/4) claystone; minor pale-red (10 R 6/2) siltstone ----------	690-700

Table 1.--Sample description log of well 340, Fort Wingate Army Depot. - continued

Material	Depth interval (feet)
Permian System	
San Andres Limestone	
Limestone, grayish orange-pink (10 R 8/2), and light-brown (5 YR 6/4), very finely crystalline; slight solution porosity, some sand and silt, some grayish-red (10 R 4/2) siltstone	700-710
Limestone, grayish orange-pink (10 R 8/2), finely crystalline; slight solution porosity, some silt	710-715
Limestone, grayish orange-pink (10 R 8/2), and pale-brown (5 YR 5/2), finely crystalline; slight solution porosity, some grayish red-purple (5 RP 4/2) siltstone	715-726
Glorieta Sandstone	
Sandstone, pale-red (10 R 6/2), fine- to very fine-grained; subangular to rounded, clear or slightly frosted; some grains have a greenish color, dark detritals common, firmly cemented, some medium gray (N5) claystone, some limestone (cavings?), some sandy siltstone	726-728

Table 1.--Sample description log of well 340, Fort Wingate Army Depot. - continued

Material	Depth interval (feet)
Pwrmian System - continued	
Glorieta Sandstone - continued	
Sandstone, dusky-red (5 R 3/4), very fine-grained; composed of subrounded-to-rounded, clear quartz grains with abundant red-clay cement. Limestone, pale yellowish-brown (10 YR 6/2), very finely crystalline; some solution porosity (0.05 to 0.10 mm) ----------	728-730
Limestone, light-brown (5 YR 6/4), and pale grayish-red (10 R 5/2), very finely crystalline; solution porosity (0.1 to 1.0 mm), common dark minerals, minor vein calcite ----------	730-740
Sandstone, light-brown (5 YR 6/4), fine- to medium-grained, fairly well-sorted; composed of subangular-to-subrounded, clear quartz grains, firmly cemented with small amounts of white and brown clay, and some calcite ----------	740-750

Table 1.--Sample description log of well 340, Fort Wingate Army Depot. - continued

Material	Depth interval (feet)
Permian System - continued	
Glorieta Sandstone - continued	
Sandstone, light-brown (5 YR 6/4), fine- to medium-grained, fairly well-sorted; composed of subangular-to-rounded, clear, and yellow quartz with spots of brown and white clay and calcite cement; accessory minerals rare, loosely cemented. Sample contains chips of limestone (cavings?) ----------	750-760
Sandstone, same as 750-760 but without calcite in cement. Sample contains occasional chips of limonite-cemented, very fine-grained sandstone ----------	760-770
Sandstone, moderate orange-pink (5 YR 8/4) to pale reddish brown (10 R 5/4), fine- to medium-grained, fairly well-sorted; composed of subangular-to-rounded, yellow and clear quartz grains with occasional accessory mineral grains, lightly cemented with white clay and calcite ----------	770-780

Table 1.--Sample description log of well 340, Fort Wingate Army Depot. - continued

Material	Depth interval (feet)
Permian System - continued	
Glorieta Sandstone - continued	
Sandstone, moderate orange-pink (5 R 8/4), otherwise same as 770-780. Sample contains chips of white claystone ----------	780-790
Sandstone, moderate orange-pink (5 R 8/4) to pale reddish-brown (10 R 5/4), otherwise same as 770-780; accessory mineral grains may be slightly more abundant ----------	790-800
Sample missing ----------	800-810
Sandstone, pale reddish-brown (10 R 5/4), fine-grained, well-sorted; composed of angular-to-subround, yellow quartz grains with common black accessory minerals and white clay cement. Claystone, grayish-purple (5 P 4/2), gray, brown, and white, (may be cavings from Chinle Formation)----	810-820

Table 1.--Sample description log of well 340, Fort Wingate Army Depot. - continued

Material	Depth interval (feet)
Permian System - continued	
Glorieta Sandstone - continued	
Sandstone, very pale orange-pink (5 YR 9/4) to light-brown (5 YR 6/4), fine-grained, well-sorted; composed of subangular-to-rounded, clear or yellow quartz grains with white clay and limonite cement and common black accessory minerals ----------	820-840
Sandstone, pale-red (5 R 6/2), fine- to medium-grained, well-sorted; composed of angular-to-subangular, clear quartz grains with calcareous brown clay (and limonite?) cement and common dark mineral grains; sample contains chips of white clay -------	840-860
Sandstone, moderate orange-pink (5 YR 8/4), fine-grained, well-sorted; composed of sub-rounded-to-rounded, clear quartz grains with common accessory limonite and white clay; firmly cemented, but has some porosity. Sample contains abundant chips of white clay ------	860-880

Table 1.--Sample description log of well 340, Fort Wingate Army Depot. - continued

Material	Depth interval (feet)
Permian System - continued	
Glorieta Sandstone - continued	
Sandstone, grayish orange-pink (5 R 7/2), fine-grained, well-sorted; compound of subangular, clear quartz with brown clay cement, calcite, and common limonite ----------	890-900
Sandstone, moderate-red (5 R 5/4), fine-grained, well-sorted; composed of subangular-to-well rounded, clear quartz grains with limonite and calcite cement and common black accessory mineral grains ----------	900-910
Sandstone, light-brown (5 YR 6/4), fine-grained, well-sorted; composed of subrounded, clear quartz grains with minor limonite and rare dark accessory minerals; firmly cemented with calcite. Both sandstones described for 900-910 are represented, but the moderate-red, limonite-rich, variety predominates ---------	910-920

Table 1.--Sample description log of well 340, Fort Wingate Army Depot. - continued

Material	Depth interval (feet)
Permian System - continued	
Glorieta Sandstone - continued	
Sandstone, grayish orange-pink (5 YR 7/2) to pale reddish-brown (10 R 5/4), fine-grained, well-sorted; composed of subangular-to-rounded quartz grains with common dark accessory minerals and calcareous white clay and limonite cement. The darker colored rock contains more limonite and dark accessory mineral ----------	920-940
Sandstone, moderate orange-pink (5 YR 8/4), very fine- to fine-grained, well-sorted; composed of clear, subangular quartz grains with rare, red and black accessory mineral grains; firmly cemented with calcite (and silica?). Sample contains some limonite-rich sandstone such as described in the interval 920-930, and some chips of pale reddish-brown (10 R 5/4) limestone, as well as claystone cavings ----------	940-950

Table 1.--Sample description log of well 340, Fort Wingate Army Depot. - continued

Material	Depth interval (feet)
Permian System - continued	
Glorieta Sandstone - continued	
Sandstone, same as 940-950 except that most chips contain slightly more limonite and calcite ----------	950- 960
Yeso Formation	
San Ysidro Member	
Sandstone, grayish-red (10 R 4/2), very fine-grained to silty, quartzose with abundant brown clay and calcite; firmly cemented ---	960- 980
Sandstone, grayish-red (10 R 4/2), very fine-grained to fine-grained, composed of sub-angular and subrounded, clear quartz grains with common black accessory mineral grains and abundant limonite; firmly cemented with calcite ----------	980-1,000
Sandstone, same as 980-1,000. Sample also contains chips of white claystone and of white, very fine-grained quartz sandstone with common limonite, black accessory minerals, and calcite cement ----------	1,000-1,020

Table 1.--Sample description log of well 340, Fort Wingate Army Depot. - continued

Material	Depth interval (feet)
Permian System - continued	
Yeso Formation - continued	
San Ysidro Member - continued	
Anhydrite, white (N9), and clear, massive, extremely finely crystalline; minute fractures are filled with brown clay (or limonite?). Clear portions may be gypsum ----------	1,020-1,030
Anhydrite, white (N9), medium light-gray (N6), and clear (gypsum), finely crystalline ----	1,030-1,040
Sandstone, grayish-red (10 R 4/2), very fine-grained to fine-grained; composed of sub-angular, clear quartz grains with common dark accessory minerals and abundant limonite and calcite cement. Same as 1,030-1,040, except that sandstone makes up a larger proportion of the sample. The anhydrite may be caved material from 1,030-1,040 ----------	1,040-1,050

Table 1.--Sample description log of well 340, Fort Wingate Army Depot. - continued

Material	Depth interval (feet)
Permian System - continued	
Yeso Formation - continued	
San Ysidro Member - continued	
Claystone, sandy, grayish-red (10 R 4/2), with abundant, very fine sand-size, clear, angular, quartz grains. Claystone, light-gray (N7), non-calcareous; with very abundant, very fine sand-size biotite flakes. Anhydrite, white (N9), and clear (may be cavings, but constitutes about 25 percent of sample) ----------	1,050-1,060
Same as 1,050-1,060, but also includes some pale-purple (5 P 6/2) claystone ----------	1,060-1,070
Claystone, sandy, grayish-red (10 R 4/2), with abundant, very fine sand-size, clear, angular quartz grains and common dark mineral grains; highly calcareous. Sample contains some light-gray (N7) and moderate reddish-orange (10 R 6/6), very fine-grained quartz sandstone, some clear and white calcite, and minor white anhydrite ----------	1,070-1,090

Table 1.--Sample description log of well 340, Fort Wingate Army Depot. - continued

Material	Depth interval (feet)
Permian System - continued	
Yeso Formation - continued	
San Ysidro Member - continued	
Claystone, grayish-purple (5 P 4/2), very light-gray (N8), and medium light-gray (N6). Sample contains some sandy claystone like 1,080-1,090, and some anhydrite, which probably is caved material	1,090-1,120
Sandstone, light-gray (N7), very fine-grained; composed of angular grains of clear quartz with common black and occasional red accessory mineral grains and minor brown clay; firmly cemented with calcite. Sample also contains grayish-red (10 R 4/2), grayish-purple (5 P 4/2), and white (N9) claystone and minor white calcite	1,120-1,130
Claystone, grayish-red (10 R 4/2), grayish-purple (5 P 4/2), medium-gray (N5), and white (N9), non-calcareous. Sample also contains chips of sandstone similar to 1,120-1,130, and numereous fragments of well-rounded, fine and medium gravel-size, clear, white, or amber quartz grains	1,130-1,140

Table 1.--Sample description log of well 340, Fort Wingate Army Depot. - continued

Material	Depth interval (feet)
Permian System - continued	
Yeso Formation - continued	
San Ysidro Member - continued	
Same as 1,130-1,140, but also contains some very fine-grained, moderate-brown (5 YR 4/4), and white (N9) quartz sandstone well-cemented with calcite, and fragments of jet-black, calcareous carbonaceous(?) material --------	1,140-1,150
Same as 1,140-1,150. Contains rare, almost perfectly rounded grains of clear quartz ---	1,150-1,160
Anhydrite, medium dark-gray (N4) to white (N9); very finely crystalline. Claystone, grayish-red (10 R 4/2), and grayish-purple (5 P 4/2); non-calcareous. Sandstone, pale-red (5 R 6/2) to grayish-red (10 R 4/2), very fine- to fine-grained, composed of angular-to-subrounded, clear and amber quartz grains with common black accessory mineral grains; well cemented with calcite (Limonite in darker colored variety) ----------	1,160-1,170

Table 1.--Sample description log of well 340, Fort Wingate Army Depot. - continued

Material	Depth interval (feet)
Permian System - continued	
Yeso Formation - continued	
San Ysidro Member - continued	
Claystone, grayish-red (10 R 4/2), grayish-purple (5 P 4/2), medium light-gray (N6), and white (N9); gray variety contains minor pyrite. Sample contains some grayish-red sandstone (similar to 1,160-1,170) and some clear calcite	1,170-1,200
Sandstone, grayish-red (10 R 4/2), very fine-grained to silty, composed of angular, clear, quartz grains with abundant calcareous brown clay and common black accessory mineral grains and occasional clear and white mica flakes. Sample contains minor white calcareous clay	1,200-1,210
Sandstone, same as 1,200-1,210, with minor amount of anhydrite	1,210-1,230

Table 1.--Sample description log of well 340, Fort Wingate Army Depot.

Material	Depth interval (feet)
Permian System - continued	
Yeso Formation - continued	
Meseta Blanca Sandstone Member	
Sandstone, light-brown (5 YR 6/4), very fine-grained, composed of angular, clear and brown quartz with abundant black accessory mineral grains and white mica; firmly cemented with a small amount of brown clay ----------	1,230-1,240
Sandstone, light-brown (5 YR 6/4), very fine-grained, composed of angular, clear, and brown quartz grains with abundant white mica and common black accessory mineral grains; firmly cemented with calcite ----------	1,240-1,260
Sandstone, grayish orange-pink (5 YR 7/2), and light-brown (5 YR 6/4), very fine-grained, composed of subangular, clear, and brown quartz grains with common dark-red and black accessory mineral grains and common white mica; loosely cemented with calcite ----------	1,260-1,270
Sandstone, moderate-brown (5 YR 4/4), composition about the same as 1,260-1,270 ----------	1,270-1,280

Table 1.--Sample description log of well 340, Fort Wingate Army Depot. - continued

Material	Depth interval (feet)
Permian System - continued	
Abo Formation	
Claystone, grayish-red (10 R 4/2), grayish-purple (5 P 4/2), medium light-gray (N6), and white (N9); slightly calcareous. Sample contains minor fine gravel-size white and brown, rounded, quartz grains and fragments ----------	1,280-1,290
Sandstone, grayish-red (10 R 4/2), very fine-grained, composed of angular, clear, and brown quartz grains with common dark red and black accessory mineral grains and white mica; cememted with calcite and limonite ---------	1,290-1,360
Sandstone, same as 1,290-1,360. Limestone, medium light-gray (N6), cryptocrystalline; has no recognizable porosity ----------	1,360-1,370
Same as 1,290-1,360. Sample also contains claystones typical of the interval 1,130-1,140; probably cavings ----------	1,370-1,380

Table 1.--Sample description log of well 340, Fort Wingate Army Depot. - continued

Material	Depth interval (feet)
Permian System - continued	
Abo Formation - continued	
Sandstone, same as 1,290-1,360, and limestone, medium dark-gray (N4) to dark-gray (N3); massive	1,380-1,400
Sandstone, same as 1,290-1,360, and sandstone, pinkish-gray (5 YR 8/1), very fine-grained to silty, composed of subangular, clear quartz grains with common black, red, and orange accessory mineral grains; loosely cemented with calcite	1,400-1,410
Same as 1,290-1,360	1,410-1,420
Sandstone, same as 1,290-1,360, and siltstone, sandy, pale reddish-brown (10 R 5/4), calcareous; contains abundant brown clay	1,420-1,430
Same as 1,290-1,360	1,430-1,450

Table 1.--Sample description log of well 340, Fort Wingate Army Depot. - continued

Material	Depth interval (feet)
Permian System - continued	
Abo Formation - continued	
Sandstone, silty, grayish-red (10 R 4/2), very fine-grained, composed of angular, brown, unfrosted quartz grains with common red and black accessory mineral grains (some fresh biotite); firmly cemented with limonite; slightly calcareous	1,450-1,480
Sandstone, same as 1,450-1,480, and sandstone, very light-gray (N8), very fine-grained, composed of angular, clear quartz grains with common fresh biotite; firmly cemented with calcite; (may be caved material)	1,480-1,490
Sandstone, same as 1,450-1,480 interval, but contains some muscovite (as silt-size flakes), and is mottled with occasional white reduction spots	1,490-1,500
Sandstone, same as 1,450-1,480	1,500-1,520
Sandstone, same as 1,480-1,490; sample also contains abundant vein calcite	1,520-1,530

Table 1.--Sample description log of well 340, Fort Wingate Army Depot. - continued

Material	Depth interval (feet)
Permian System - continued	
Abo Formation - continued	
Sandstone, very light-gray (N8) to light greenish-gray (5 GY 8/1), very fine-grained, composed of angular-to-subrounded, clear quartz grains with common biotite and limonite; weakly-cemented with some dark-brown claystone and rare, rounded, medium gravel-size fragments of coal(?), which may be caved material	1,530-1,540
Sandstone, same as 1,450-1,480	1,540-1,580
Sandstone, same as 1,450-1,480. Sample also contains vein calcite	1,580-1,590
Sandstone, pale reddish-brown (10 R 5/4) to grayish-red (10 R 4/2), same as 1,450-1,480	1,590-1,610
Sandstone, same as 1,450-1,480; contains common muscovite(?)	1,610-1,620
Sandstone, same as 1,450-1,480. Sample contains abundant pale reddish-brown (10 R 5/4) clay	1,620-1,630
Sandstone, same as 1,450-1,480	1,630-1,640

Table 1.--Sample description log of well 340, Fort Wingate Army Depot. - continued

Material	Depth interval (feet)
Permian System - continued	
Abo Formation - continued	
Sandstone, pale greenish-red (10 R 5/2), very fine-grained; composed of subangular and angular, clear and amber, unfrosted quartz grains with abundant limonite, dark mineral grains (some biotite), and calcite cement ----	1,640-1,660
Sandstone, very pale-red (10 R 7/2), to pale grayish-red (10 R 5/2), same as 1,640-1,660 --	1,660-1,670
Sandstone, same as 1,450-1,480 ----------	1,670-1,680
Sandstone, light-gray (N7) to pale-red (10 R 6/2), compositionally the same as 1,640-1,660. The variation in color is due to limonite content -	1,680-1,690
Sandstone, moderate reddish-brown (10 R 4/6), very fine-grained, composed of subangular-to-subrounded, clear quartz grains with abundant limonite and common biotite; weakly cemented with calcite. Sandstone, grayish-pink (5 R 8/2), similar to the pale reddish-brown sandstone in the sample, but contains much less limonite ----------	1,690-1,700

Table 1.--Sample description log of well 340, Fort Wingate Army Depot. - continued

Material	Depth interval (feet)
Permian System - continued	
Abo Formation - continued	
Sandstone, moderate reddish-brown (10 R 4/6), same as that of 1,690-1,700	1,700-1,740
Claystone, silty, grayish-red (10 R 4/2); calcareous. Sandstone, white-to-moderate reddish-brown (10 R 4/6), same as 1,690-1,700, with varying amounts of limonite	1,740-1,750
Sandstone, moderate reddish brown (10 R 4/6), same as that of 1,690-1,700	1,750-1,760
Sandstone and claystone, same as 1,740-1,750 -	1,760-1,770
Sandstone, moderate reddish-brown (10 R 4/6), same as 1,690-1,700. Mica somewhat more abundant	1,770-1,800
Sandstone, same as 1,690-1,700	1,800-1,810
Sandstone, grayish-red (10 R 4/2), very fine-grained to silty, composed of angular, clear quartz grains with abundant limonite, common biotite and muscovite, and abundant calcite cement. Mica flakes are up to 0.5 mm in diameter	1,810-1,820
Sandstone, pale reddish-brown (10 R 5/4), of composition similar to 1,690-1,700	1,820-1,840

Table 1.--Sample description log of well 340, Fort Wingate Army Depot. - continued

Material	Depth interval (feet)
Permian System - continued	
Abo Formation - continued	
(Description of core at 1,847')	
Siltstone, grayish-red (10 R 4/2), composed of brownish angular quartz grains, limonite, and abundant calcite cement ----------	1,840-1,850
Sandstone, grayish-red (10 R 5/2), very fine-grained to silty, composed of angular-to-subangular, clear, and brown, quartz grains with abundant limonite, abundant biotite flakes (up to 0.2 mm), common muscovite, and weak calcite cement. Some fragments lack limonite and are nearly white ----------	1,850-1,870
Sample is made up almost entirely of cavings from the Chinle Formation, though it does contain some sandstone and siltstone typical of 1,850-1,870 ----------	1,870-1,880
Sandstone, same as 1,850-1,870 ----------	1,880-1,890

Table 2.--Analyses of water samples from well 340, Fort Wingate Army Depot.

(Analyses by U.S. Geological Survey. Chemical constituents in milligrams per liter)

Sample interval (feet) Date of collection	1,284-1,945[1] Oct. 2, 1968	710-980 Apr. 1, 1969
Silica (SiO_2)	3.8	13.
Iron (Fe), dissolved [2]	.11	.07
Iron (Fe), total	115.	.38
Calcium (Ca)	264.	140.
Magnesium (Mg)	59.	68.
Sodium (Na)	1,100.	93.
Potassium (K)	21.	
Bicarbonate (HCO_3)	110.	228.
Carbonate (CO_3)	0.	0.
Sulfate (SO_4)	2,990.	613.
Chloride (Cl)	63.	4.4
Fluoride (F)	.4	.3
Nitrate (NO_3)	.1	.0
Dissolved solids		
Sum	4,560.	1,040.
Residue on evaporation at 180°C	4,580.	1,130.
Hardness as $CaCO_3$	900.	630.
Noncarbonate	810.	443.
Specific conductance (micromhos at 25°C)	5,520.	1,400.
pH	7.3	7.7
Color	7.	5.
SAR	16.	1.6

[1] Sample probably represents upper end of interval.

[2] In solution at time of analysis.