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# Summary of wells drilled by White Sands Missile Range from June 1962 to January 1965

By

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## Introduction

Five wells were drilled by the White Sands Missile Range during the period from June 1962 to January 1965. The areas in which these wells were drilled, numbered in sequence of drilling, are shown on figure 1. The first well (10a) drilled was a replacement supply well

Figure 1 (caption on next page) belongs near here.

in the Headquarters area. The second well (T-7) drilled was also in the Headquarters area and was a combined test and observation well. The third well (B-1) was a test well drilled outside the Missile Range boundaries on the Bosque del Apache Wildlife Refuge. The fourth and fifth wells (RC-1 and RC-2) were also test wells and were drilled northwest of Rhodes Canyon Range Center.

Figure 1.--White Sands Missile Range in New Mexico and areas discussed in this report. Circled numbers refer to areas mentioned in text and listed at upper right of this map.

This report is a summary of the drilling operations enumerated above, in accordance with provisions of the continuing cooperative program between White Sands Missile Range and the U.S. Geological Survey. The Geological Survey also provided assistance in selecting the well sites and technical advice to the WSMR inspector during drilling. The three sections of the report contain a map of the area where the well(s) were drilled, a commentary on the drilling of each well, a summary well record, a sample-description and electric log of each well, and aquifer test data plots for those wells tested. The aquifer test data were analyzed by the Theis-Jacob methods described on pages 98-103 of Water Supply Paper 1536-E (Ferris and others, 1962). Results of chemical analyses of water samples from the wells are tabulated in a separate table (table 13) for ease of comparison.

A description of exploration and production drilling at the NASA Apollo Site and the WSMR MAR site is not included herein although the drilling was done within the time period of this report. An account of these drilling programs has been reported separately (Doty, 1963, 1964 and 1964a) and included in the recent summary report of hydrologic investigations in the WSMR area (Davis and Busch, 1965).

## Headquarters area

### Well 22.4.24.212a (10a)

The casing in well 10 in the Headquarters well field (fig. 2)

Figure 2 (caption on next page) belongs near here

failed in 1960 and production diminished to the point that replacement of the well was necessary in 1963. A pilot hole for well 10a was drilled to 825 feet, electric logs were made, and on May 21, 1963, a water sample was collected from a depth of 721 feet by Schlumberger Formation Tester. Analysis of the water sample (table 13) indicated that the sulfate and chloride content and conductance of the sample were higher than for water from other wells in the Headquarters field. A second sample was obtained by air jetting May 29, 1963. A packer was set so that the interval from 687 to 825 feet was open for sampling. The second sample (table 13) was chemically similar to other water in the well field and reaming of the hole to finish the well was allowed to continue.

Figure 2.--Headquarters area, White Sands Missile Range, Dona Ana County, N. Mex.

The sampling device used to collect the first water sample from well 10a is a closed container lowered by cable to the desired depth in a fluid-filled hole. When the container is in position, a packing seal forces the sampler against the sidewall and a small tube, or snorkel, is forced into the formation. Fluid drains through the snorkel into the container. The packing seal and snorkel are retracted after sufficient time has elapsed for the container to fill and the container is withdrawn from the hole by the cable. The advantages of this system are that no pipe column need be run in the hole, fluid supporting the sidewalls of the hole need not be withdrawn, and a very thin zone may be sampled. The prime disadvantage is that the collected sample may be mostly drilling mud, as the snorkel may not penetrate far enough into a permeable zone to withdraw only formation fluid. The high conductance, sulfate, and chloride in the water sample obtained by the Schlumberger Formation Tester probably was the result of an excess amount of drilling fluid in the sample, or contamination in the tester barrel from previous sampling of oil field brine.

Reaming, casing, gravel-packing and developing of well 10a was accomplished without notable difficulty. Test pumping of the well was started seven times; the test pump was dropped in the well and ruined prior to the eighth attempt to test the aquifer by pumping. The production pump was installed in the well, coupled to the test pump engines, and the well was pumped for 10 1/2 hours at 1,000 gpm (gallons per minute). The water level lowered about 28 feet during pumping.

Figures 3 and 4 are plots of water-level drawdown and pumping

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Figure 4 (caption on next page) belongs near here.

rate versus time for test pumping on July 15-16 and July 22-23, 1963. Figures 5 and 6 are semi-logarithmic plots of water-level drawdown

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Figure 6 (caption on next page) belongs near here.

versus time during pumping and after pumping the well at a rate of 1,000 gpm on July 22-23, 1963; these plots were used to compute the coefficient of transmissibility. The coefficient of transmissibility from the drawdown data is 80,000 gpd per foot (gallons per day per foot); the coefficient of transmissibility from the recovery data is 117,000 gpd per foot. These figures compare favorably with those from other high-yield wells in the field.

Table 1 is a summary record of well construction; table 2 is a sample description log; figure 6a is the electrical log and microlog

Figure 6a (caption on next page) belongs near here.

of well 10a.

Figure 3.--Water-level drawdown and pumping rate in well 10a, July 15-16, 1963.

Figure 4.--Water-level drawdown, pumping rate, and residual drawdown in well 10a, July 22-23, 1963.

Figure 5.--Water-level drawdown in well 10a while pumping at 1,000 gpm, July 22-23, 1963.

Figure 6.--Residual drawdown in well 10a after pumping at 1,000 gpm for 10 1/2 hours, July 23, 1963.

Figure 6a.--Electric logs of well 22.4.24.212a (10a)

Table 1.--Record of well 22.4.24.212a (10a)

Location: NE1/4NW1/4NE1/4 sec. 24, T. 22 S., R. 4 E.

Altitude: Land-surface altitude 4,273 feet interpolated from USGS topographic map.

Depth: Pilot hole drilled to 825 feet; well completed at 805 feet.

Date completed: July 23, 1963 (test pumped).

Drilling contractor: Texas Water Wells, Inc., Houston, Texas

Drilling method: Hydraulic rotary.

Casing and well record: Pilot hole drilled with 9 7/8-inch bit to 825 feet, May 9 to May 16, 1963; hole reamed to 36-inch diameter, 805 feet deep, May 21 to June 27, 1963; approximately 50 feet of 42-inch CMP surface casing cemented in, 805 feet of 16-inch steel casing and perforated casing, and 400 feet of 8-inch gravel feed lines, installed June 28 to June 29, 1963; 16-inch casing perforated with mill-cut slots 1/8 x 1 1/2 inches, 40 slots around, 4 rounds per foot, was installed from 405 to 805 feet; approximately 200 yards of 1/8 to 3/8-inch rounded gravel was used to form a gravel envelope, July 2, 1963; the well was developed by bailing, surging with a surge block, treating with 4,800 pounds of mud-cutting chemical and surging and pumping with a test pump.

Well completion record: Concrete well head set; 8-inch turbine pump set at 500 feet and electric motor installed; well placed on stream August 7, 1963.

Table 1.--Record of well 22.4.24.212a (10a) - Concluded

Geologic source and yield: Water obtained from sand and gravel bolson deposits. Well pumped at 1,000 gpm for 10 1/2 hours with 28 feet of drawdown. Initial on-stream production 900 gpm. Nonpumping depth to water 393.18 feet below measuring point.

Formation logs: 1) Sample description 2) Microlog and electric log.

Water sample: See table 13.

Tables 2 and 3.--Sample-description log, well 22.4.24.212a (10a)

| Material | Depth interval (feet) | |
|---|---|---|
| Gravel, and very fine to medium sand | 0 | 30 |
| Gravel, sand, silt, and clay | 30 | 60 |
| Gravel, large, and sand | 60 | 75 |
| Gravel, sand, silt, and brown clay; some large gravel 80 - 85 | 75 | 95 |
| Sand, silt, and clay | 95 | 100 |
| Sand, very coarse | 100 | 105 |
| Gravel, and coarse sand | 105 | 135 |
| Gravel, sand, and clay | 135 | 155 |
| Sand, very coarse | 155 | 165 |
| Sand, very coarse, and large gravel | 165 | 180 |
| Gravel, and sand | 180 | 210 |
| Gravel, sand, and clay | 210 | 235 |
| Gravel, large, and sand | 235 | 245 |
| Gravel, and sand | 245 | 275 |
| Gravel, sand, and some clay | 275 | 290 |
| Gravel, large, sand and some clay | 290 | 300 |
| Gravel and very coarse sand | 300 | 315 |
| Gravel, very coarse sand, and clay | 315 | 325 |
| Gravel and very coarse sand | 325 | 335 |

Tables 2 and 3.--Sample-description log, well 22.4.24.212a (10a) - Concluded

| Material | Depth interval (feet) | |
|---|---|---|
| Gravel, very coarse sand and some clay | 335 | 400 |
| Gravel, some very coarse, and sand | 400 | 410 |
| Gravel, some very coarse, sand, and some clay | 410 | 435 |
| Gravel, some very coarse, sand, silt, and clay | 435 | 505 |
| Sand, very coarse, and some clay and silt | 505 | 525 |
| Clay, sand, and gravel | 525 | 600 |
| Gravel, coarse sand, and clay | 600 | 825 |

Well 10a is properly designed, constructed, and developed, and although it is expected to function as a production well for many years, experience with other wells in the area indicates that periodic rehabilitation of wells may be necessary to maintain performance at, or near, original standards. Well 10a was supplying about 900 gpm to the system when first put on stream; if production is reduced by half in a few years, the yield would still be equal to the original yield of old well 10.

In the past the importance of being able to measure the depth to water was overlooked during well design with the result that an access port for water-level measurement was not included in the construction. In some cases after the well was in service for a few years the yield diminished and the well was sealed so that the depth to water and the fluctuations of water level during pumping could not be measured. Knowledge of the yield-drawdown relationship helps the operator diagnose both the pump efficiency and the capacity of the well. Removal of the pump to determine the cause of diminished yield is a costly and often ineffective substitute for a continuous water-level monitoring program.

Well 10a is the first of the WSMR production wells to include three methods of access for measuring water levels: 1) A standard airline gage; 2) an external gage line that opens into the well casing below the pump setting; and 3) an opening through the pump base into the well casing. The airline gage on well 10a provides the well operator with a means of reading and recording water levels during well operation; the external gage line enables the operator to make accurate independent water-level measurements with which to calibrate or check the airline reading. The opening into the casing through the concrete pump base costs but a few dollars to include in the original construction and provides an alternative method of access for water-level measurement in the event either or both of the other systems fail.

Well 22.5.7.342 (T-7)

Well T-7 was drilled as part of the continuing program of water-resources investigation in the Headquarters area to provide information on the thickness and character of the aquifer and the quality of water in the area east of the well field. Water-level measurements in well T-7 will monitor effects of pumping from new wells (production wells 18, 19, and 20). Samples for chemical analysis will be collected periodically from well T-7 to determine water quality changes indicative of saline-water encroachment in the aquifer from east of the well field.

Details of drilling are listed in table 4, record of well T-7. Table 5 is a sample description log of cuttings from the well, and figure 6b is the induction electrical log and microlog. Table 13

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contains results of chemical analyses of water samples taken from two zones while the well was being drilled and one sample collected during test pumping. Figure 7 is a graph of drawdown, residual

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drawdown and pumping rate versus time when the well was test pumped in August 1963. Figures 8 and 9 are semi-logrithmic plots of draw-

Figure 8 (caption on next page) belongs near here.

Figure 9 (caption on next page) belongs near here.

down and residual drawdown versus time. These data were used to compute the coefficient of transmissibility (T) which was approximately 15,000 gpd per foot from both plots.

Figure 6b.--Electric logs of well 22.5.7.342 (T-7).

Figure 7.--Water-level drawdown and residual drawdown, sediment content of pumped water, and pumping rate, well T-7, August 8-9, 1963.

Figure 8.--Water-level drawdown in well T-7, August 8, 1963.

Figure 9.--Residual drawdown in well T-7, August 8-9, 1963

Table 4.--Record of well 22.5.7.342 (T-7)

Location: NE1/4SE1/4SW1/4 sec. 7, T. 22 S., R. 5 E.

Altitude: Land-surface altitude 4,185 feet, interpolated from USGS topographic map.

Depth: 1,000 feet.

Date completed: August 8, 1963 (test pumped).

Drilling contractor: Layne Texas Co., El Paso, Texas

Drilling method: Hydraulic rotary.

Casing and well record: Eight-inch pilot hole drilled to 1,000 feet, July 16 to July 24, 1963; pilot hole reamed full depth with 11 3/4-inch bit, July 29 to July 30, 1963; well cased with steel casing to full depth, July 30 to July 31, 1963; casing perforated with mill-cut slots 1/8 x 2 inches, 29 slots around, 4 rounds per foot at depth intervals: 326-356, 396-416, 438-448, 471-491, 581-641, 656-671, 701-711, 811-821, 836-851, 956-966; well developed by bailing, treating with 400 pounds detergent, and surging.

Well completion record: Concrete well slab set and well retained as observation well.

Geologic source and yield: Water obtained from sand and gravel bolson deposits. Well pumped at 250 gpm for 8 hours with 21 feet of drawdown. Nonpumping depth to water 339.5 feet below land surface.

Formation logs: 1) Sample description 2) Microlog and induction-electrical log.

Water sample: See table 13.

Tables 5 and 6.--Sample-description log, well 22.5.7.342 (T-7)

| Material | Depth interval (feet) | |
|---|---|---|
| Gravel, pebble, rounded and tan sandy clay | 0 | 25 |
| Clay, and some rounded pebbles | 25 | 30 |
| Clay, sandy, and some rounded pebbles and granules | 30 | 90 |
| Clay, red, and some pebbles and granules | 90 | 100 |
| Clay, tan, sandy, and granule to pebble rock fragments | 100 | 115 |
| Sand, tan, coarse, some clay and rock fragments to pebble size | 115 | 175 |
| Sand, very fine to coarse, silt and clay | 175 | 255 |
| Sand, very fine to coarse, silt and clay, and some granule gravel | 255 | 280 |
| Clay, fine sand and silt | 280 | 285 |
| Sand, very fine to coarse, silt and clay, and some granule gravel | 285 | 305 |
| Clay, some fine sand and silt | 305 | 335 |
| Clay, sandy | 335 | 360 |
| Clay | 360 | 395 |
| Sand, fine to coarse, and some clay | 395 | 420 |
| Clay, sandy | 420 | 437 |
| Rock fragments, gravel size, and clay | 437 | 450 |
| Clay, sandy | 450 | 475 |
| Sand and clay | 475 | 495 |

Tables 5 and 6.--Sample-description log, well 22.5.7.342 (T-7) - Continued.

| Material | Depth interval (feet) | |
|---|---|---|
| Clay and some sand | 495 | 530 |
| Clay and sand | 530 | 540 |
| Clay, sandy | 540 | 595 |
| Sand, clayey | 595 | 615 |
| Sand and clay | 615 | 665 |
| Clay and sand | 665 | 680 |
| Clay, sandy | 680 | 695 |
| Clay | 695 | 715 |
| Sand and clay | 715 | 720 |
| Gravel, fine, sandy, cemented; silt; tan clay | 720 | 730 |
| Clay, tan, sticky | 730 | 735 |
| Clay, tan, sand, and some rounded gravel, less than 5 mm in diameter, some gravel, well cemented | 735 | 765 |
| Sand, very coarse to fine, rounded, loosely cemented, calcareous; tan clay | 765 | 775 |
| No sample | 775 | 780 |
| Clay, tan, and some sand and fine gravel | 780 | 790 |
| Sand, coarse to very coarse and some fine gravel, and clay | 790 | 800 |
| Sand, coarse to very coarse, rounded to subangular, cemented | 800 | 810 |
| Clay, reddish brown, green and gray, noncalcareous; some caliche, sand, and fine gravel | 810 | 840 |

Tables 5 and 6.--Sample-description log, well 22.5.7.342 (T-7) - Concluded.

| Material | Depth interval (feet) | |
|---|---|---|
| Sand, fine to very coarse, well rounded, mixed composition, calcareous cement; some clay | 840 | 865 |
| Clay, tan, sandy | 865 | 895 |
| Sand, very coarse to medium, rounded, cemented; some clay | 895 | 945 |
| Clay, reddish-brown and gray, sandy; some fine gravel and fragments of caliche | 945 | 1,000 |

The permeable beds penetrated by well T-7 are thinner and contain more clay than those penetrated by high-yield production wells farther west in the main well field area. (See sample description and electric logs.) The coefficient of transmissibility is less than that at some of the newer production wells but compares favorably with the overall average of 15,000 postulated by Herrick in the Cantonment report (Herrick, 1960). The quality of water is potable at a depth of 1,000 feet in well T-7. The chemical quality of water from well T-7 is slightly different from that from well 10a (table 13); the most significant differences are an increase in fluoride from 0.5 ppm in 10a to 1.6 ppm in T-7 and a decrease in hardness from 116 to 68 ppm, respectively.

## Bosque del Apache area

### Well 6.1.9.111 (B-1)

A potable water supply for Stallion Range Center has not been found by drilling test wells near the installation. An alternative procedure for supplying the installation with potable water is to pipe it from a well in the Bosque del Apache Wildlife Refuge (fig. 10).

Figure 10 (caption on next page) belongs near here

Wells along the west side of the Rio Grande in the Bosque area were known to produce potable water, but crossing the river and drains with a pipeline would add considerably to the expense of the project. A test well (B-1) was drilled on the east side of the river to determine whether potable water was available there and to determine the change in water quality with depth (table 7).

Figure 10.--Bosque del Apache area, Socorro County, New Mex.

Table 7.--Record of well 6.1.9.111 (B-1)

Location: NW 1/4NW1/4NW1/4 sec. 9, T. 6 S., R. 1 E.

Altitude: Land-surface altitude 4,530 feet interpolated from USGS topographic map.

Depth: Drilled to 500 feet, finished at 167 feet.

Date completed: November 15, 1963 (test pumped)

Drilling contractor: Layne Texas Co., El Paso, Texas

Drilling method: Hydraulic rotary.

Casing and well record: 9 7/8-inch hole drilled to 500 feet; 500 feet of 6-inch steel casing perforated with 1/8 x 4-inch milled slots was set, November 8, 1963; perforated sections of the casing were set at 100 to 160, 320 to 340, and 440 to 460 feet; well backfilled after sampling lower zones by air jetting beneath a packer; packer seized in casing at 271 feet with three 30-foot lengths of 3-inch pipe attached and could not be pulled; well was not developed by bailing because sand ran into casing.

Well completion record: Concrete well head 4-foot square by 1 foot thick centered around casing and casing fitted with hinged metal cover to permit water-level measurement.

Geologic source and yield: Water obtained from Recent river channel alluvium. Well was pumped at 150 gpm for 8 hours with 37 feet of drawdown. Nonpumping depth to water 20.65 feet below land surface.

Formation logs: 1) Sample description 2) Induction electrical log.

Water samples: See table 13.

A cable-tool rig was set up on the designated location and drilling started July 20, 1963. When a depth of about 28 feet was reached, some water began to enter the well, along with loose sand. Casing was started in the hole and was bailed and driven down to a depth of about 100 feet in early August. Sand ran into the hole each time the bit was removed and at a depth of about 100 feet the bit was stuck in the hole and could not be recovered. The contractor asked WSMR for permission to abandon the hole and resume drilling with a rotary drill rig. Drilling with the rotary rig began November 5, 1963, at an alternate location about 150 feet south of the first site. Drilling was completed and an electric log was made November 11, 1963. Premeable zones were identified from the sample-description and electric logs (table 8 and fig. 10a). Casing was installed to prevent the hole from

Figure 10a (caption on next page) belongs near here

collapsing; perforated casing was set adjacent to permeable zones. Three shirt-tail canvas packers were placed on the outside of the casing, as shown on the electric log (fig. 10a) to prevent circulation along the casing between perforated zones. An expansion packer was set above the lowermost perforations and a water sample was air-jetted from beneath the packer. The well was backfilled above the lower casing perforations, the packer was reset above the middle section of perforations, and a sample was jetted. (See table 13 for results of chemical analyses.) The packer stuck in the well at a depth of 271 feet and could not be removed; approximately 90 feet of 3-inch column pipe remained with the packer. A neat cement cap was poured on the packer.

Figure 10a.--Electric log of well 6.1.9.111 (B-1)

Tables 8 and 9.--Sample-description log, well 6.1.9.111 (B-1)

| Material | Depth interval (feet) | |
|---|---|---|
| Sand, tan, very fine | 0 | 11 |
| Gravel, pebble to cobble, well rounded, and very fine sand | 11 | 41 |
| Gravel and sand as in interval 11 - 41 and some clay | 41 | 68 |
| Gravel, pebble, well-rounded, and very fine to very coarse sand | 68 | 113 |
| Sand, gray, very fine to very coarse, and pebble gravel; small percentage of clay | 113 | 173 |
| Gravel and sand, as in interval 113 - 173 | 173 | 200 |
| Gravel and sand, as in interval 113 - 173, with an increased percentage of clay | 200 | 205 |
| Clay, sandy, and pebble gravel | 205 | 245 |
| Gravel, sandy, clayey | 245 | 255 |
| Clay, gravel, and sandy clay | 255 | 265 |
| Clay, and hard layers of gravel | 265 | 325 |
| Sand, gray, very fine to very coarse, tan to gray-green clay, and some granule to pebble gravel, in thin beds | 325 | 340 |
| Clay, with thin interbeds of sand and gravel | 340 | 365 |
| Sand, gravel, and clay in thin beds | 365 | 380 |
| Clay, and sand, some gravel | 380 | 385 |
| Sand, gravel, and clay | 385 | 445 |
| Clay, gravel and sand | 445 | 500 |

A considerable amount of fine sand was brought into the well each time a water sample was jetted, and it was considered likely that the well would fill with fine sand if the standard development techniques listed in the contract specifications were followed. A turbine test pump was installed and the well was pumped for about 30 minutes to clear it of drilling mud. The pump was stopped and the water level recovered to approximately the nonpumping level. Test pumping was started at a rate of about 100 gpm and increased to 150 gpm. Figure 11 is a graph

Figure 11 (caption on next page) belongs near here.

of water level and pumping rate versus time. The water pumped from the well contained sand and small gravel during the first few hours of pumping; the water was clear and contained 0.02 to 0.05 milliliters of fine sand per liter just before the pump was stopped. A chemical analysis of water collected during pumping is included in table 13. After the test pump was removed, 4.13 feet of casing was welded to the top of the casing in the hole to raise the top of the well as far above river level as possible. Earth was bulldozed in around the casing and the wellhead was completed as required by the specifications.

Figure 11.--Depth to water and pumping rate for well B-1, November 15-16, 1963.

The sand and gravel of the river channel deposits at test well B-1 contain potable water to a depth of about 200 feet. The areal extent of this potable water east of the river is not known. Water quality at the test-well location may vary because of flow in the river. Ground water draining from the east toward the river is of poor quality; water infiltrating from the river, and ground water draining into the area from the west side of the river, probably is of good quality. Nonflow in the river, or heavy pumping of irrigation wells west of the river, or both, may allow water of poor quality to move into the test-well locality. A program of monitoring water quality and water levels should be followed for two to three years before production wells are drilled in this locality. Also, prior to drilling production wells, test wells should be drilled to determine the areal and vertical extent and dependability of the supply of potable water east of the river.

Test-pumping data from B-1 could not be used to determine aquifer characteristics because the well was not properly developed. The hydrograph of water level versus time shows that the well was developing during test pumping. The drawdown at the conclusion of pumping was about 30 feet; the specific capacity is, therefore, about 5 gpm per foot. However, the rapidity with which the well recovered suggests that most of the drawdown was well loss. A much higher specific capacity probably would be obtained from a properly constructed and developed well.

The problems of preventing the hole from caving during drilling and of sand filling the well during water sampling illustrate the incoherence of the alluvial aquifer in the Bosque area. Thin beds of uncompacted, well-sorted sand probably contribute most of this freely moving sand. Construction of a successful well will depend on preventing sand from entering, either by placing a well screen with small enough openings to shut out the sand, or by placing a gravel envelope around perforated casing. The test well probably would have filled with sand faster than the sand could have been removed by bailing had the well been developed by the standard method. The sand probably was not stabilized by pumping, and it probably will pour through the slots and fill the well.

Suggestions for construction of production wells in the Bosque area are based on the available information and is subject to change as information from further test drilling becomes available.

Wells should be drilled by the rotary hydraulic method. Wells should be gravel-packed with an envelope of rounded 1/8- to 3/8-inch gravel 4 to 7 inches thick, hydraulically placed. Pilot holes should be drilled at least 100 feet deeper than the finished depth of the well and electric logs of the pilot hole should be made. Water quality should be checked by three samples collected at depths of 100, 175, and 250 feet as the pilot hole is drilled. The pilot hole should be backfilled to production-well depth and at least the 40 feet immediately below production-well depth plugged with neat cement. The pilot hole should be reamed, production-well casing set with perforations opposite permeable zones, the gravel envelope emplaced, and the well developed by a moderate amount of bailing and surging and considerable "overpumping" with the test pump. At the close of development pumping, a step test with 2 hours per step should be made to determine the rate of pumping for a 24-hour, constant-rate aquifer test. A recovery period of 24 hours should be allowed before aquifer testing. Yield of the well is expected to range between 500 and 2,000 gpm and the test pump should be capable of yielding 2,000 gpm against a head of 150 feet. Water from the test pumping should be conveyed by leakproof ditch or pipeline to a point at least 300 feet from the well to minimize recirculation of the pumped water.

Wells in the Bosque area may yield sand despite the well-construction methods used. The aquifer is a heterogeneous mixture of particle sizes; wire-wrapped screens and similar custom designed equipment might not be any more effective in preventing sand entrance than the conventional gravel envelope. Some of the new fused-sand screens might eliminate sand entrance but the effect of surging on these screens is not known. Development by vigorous surging will be needed to dislodge the viscous drilling mud required to prevent caving of the well during drilling. The possibility of needing sand traps at or near the well should not be dismissed until the production well has yielded sand-free water during test pumping at, or above, the expected production rate.

"Overpumping" the well will remove much of the sand brought into the gravel pack by surging and bailing; if the production rate is held below the rate of development pumping, the sand adjacent to the perforations will be more stable at the lower pumping rate and will not move into the well as freely as at the higher pumping rate.

## Rhodes Canyon area

Potable water for Rhodes Canyon Range Center and Salinas installation must be hauled by truck for Mockingbird Gap or Small Missile Range, because potable ground water has not been found at either site. The fan slope at the base of Salinas Peak, Northwest of Rhodes Canyon Range Center, is a geologically favorable area for obtaining potable ground water, and is geographically between the two areas (fig. 12). Two test wells, shown on the map as

Figure 12 (caption on next page) belongs near here.

RC-1 and RC-2, were drilled in search of a joint water supply for Salinas and Rhodes Canyon Range Center installations as part of the program of water-resources exploration in the uprange areas.

Figure 12.--Rhodes Canyon area, White Sands Missile Range, Sierra County, N. Mex.

Wells 12.5.31.434 (RC-1) and 12.5.28.432 (RC-2)

A summary record of wells is included in table 10, sample-description logs are included in table 11, and the electric logs for the wells are included in figure 13. Results of chemical

Figure 13 (caption on next page) belongs near here.

analyses of water samples are included in table 13.

Well 21.5.28.432 (RC-2) was drilled first and yielded water of such poor chemical quality at the first sampling that drilling was stopped. The bolson deposits penetrated by the well were difficult to drill and consisted in large part of volcanic rock fragments which do not contain readily soluble minerals. A study of this material indicated that a well drilled higher on the fan slope west of RC-2 might penetrate permeable materials saturated with potable ground water.

Figure 13.--Electric logs of wells in the Rhodes Canyon area - well 12.5.31.434 (RC-1)

Electric logs of wells in the Rhodes Canyon area - well 12.5.28.432 (RC-2)

Table 10.--Records of wells in the Rhodes Canyon area

Well: 12.5.31.434 (RC-1)

Location: SE1/4SW1/4SE1/4 sec. 31, T. 12 S., R. 5 E.

Altitude: Land-surface altitude 4,550 feet interpolated from USGS topographic map

Depth: 942 feet

Date completed: January 13, 1965 (final electric logging)

Drilling contractor: Layne Texas Co., El Paso, Texas

Drilling method: Cable tool

Casing and well record: Drilling started June 6, 1964 with hydraulic rotary rig; circulation and tool string lost at depth of 270 feet and drilling re-started July 3, 1964 with cable tool rig; cable tool rig lost tools at depth of 100± feet, skidded over and re-started drilling, July 29, 1964; 8-inch hole drilled to 750 feet, electric logs made ~~(by Schlumberger)~~; 6 3/8-inch ID protective casing installed to 746 feet, and hole deepened with 6-inch bit to 942 feet; well sampled and tested for yield by bailing, electric log made ~~(run by Layne Texas)~~ and well abandoned.

Well completion record: Protective casing pulled and well abandoned.

Geologic source and yield: Water obtained from bolson deposits; yield less than 3 gpm. Depth to water 471.5 feet.

Formation logs: 1) Sample description 2) electrical logs

Water samples: See table 13.

Table 10.--Records of wells in the Rhodes Canyon area - Concluded

Well: 12.5.28.432 (RC-2)

Location: NE1/4SW1/4SE1/4 sec. 28, T. 12 S., R. 5 E.

Altitude: Land-surface altitude 4,350 feet interpolated from USGS topographic map

Depth: 358 feet

Date completed: May 12, 1964 (plugged and abandoned)

Drilling contractor: Layne Texas Co., El Paso, Texas

Drilling method: Hydraulic rotary

Casing and well record: 9 7/8-inch hole drilled to 40 feet, 7 7/8-inch hole drilled to 358 feet; temporary 4-inch casing with lowermost 24 feet torch slotted installed in well, May 6, 1964; well bailed for water sample and casing pulled; same casing set on cement plug at 305 feet and well bailed for sample, May 9, 1964.

Well completion record: Plugged and abandoned.

Geologic source and yield: Water obtained from bolson deposits. Well not developed or thoroughly tested for yield. Depth to water 234.2 feet.

Formation logs: 1) Sample description 2) Microlog and induction electrical logs.

Water samples: See table 13.

Tables 11 and 12.--Sample-description logs of wells in the Rhodes Canyon area, well 12.5.31.434 (RC-1)

| Material | Depth interval (feet) | |
|---|---|---|
| Conglomerate, mixed sand and pebble; particles range in size from silt to 10 millimeters in diameter. Particles are dense olive to dark blue-gray limestone; white rhyolite; pink granite; green, yellow, red and black chert; clear milky and yellow quartz; calcareous sandstone; greenstone; yellow-brown quartzite; red, slightly calcareous siltstone. Particle size decreases to granule size or less at 210 feet; less rhyolite and limestone and more red siltstone below about 240 feet. | 0 | 500 |
| Rhyolite, white, comprises about half the sample; other constituents as before. | 500 | 520 |
| Similar to 0-500 interval | 520 | 550 |
| Similar to 500-520 interval | 550 | 560 |
| Similar to 0-500 interval | 560 | 630 |
| Sand, medium to very fine, mostly angular, some rounded grains, composition as in 0-500 interval. | 630 | 655 |
| Similar to 0-500 interval; some tan clay 730-735; more red and purple siltstone | 655 | 750 |

Tables 11 and 12.--Sample-description logs of wells in the Rhodes Canyon area, well 12.5.31.434 (RC-1) - Continued

| Material | Depth interval (feet) | |
|---|---|---|
| Conglomerate, mixed sand and pebble, red; fragments and particles ranging from very fine sand to 10 millimeters, angular to rounded, some carbonate cement on fragments. Most particles are purple to red siltstone and dark to light gray limestone; also some clear quartz and calcite. | 750 | 770 |
| Similar to 750-770 interval except no rhyolite. Some multicolored clay in 820-825 and 860-865 samples. | 770 | 910 |
| Conglomerate, mixed sand and pebble as above, except that samples contain more limestone than siltstone | 910 | 940 |

Tables 11 and 12.--Sample-description logs of wells in the Rhodes Canyon area, well 12.5.28.432 (RC-2) - Concluded

| Material | Depth interval (feet) | |
|---|---|---|
| Gravel, multicolored, mixed, angular to rounded, and some sand. Many fragments are bit-cut chips from cobbles or boulders. Fragments consist of rhyolite to andesite composition extrusive rocks, quartz, feldspar, chert, limestone and sandstone. Some fragments are coated with caliche. | 0 | 15 |
| Rock fragments, mostly angular, similar in composition to 0-15, and probably derived from similar materials. Size of fragments ranges widely between samples. Tan clay noted in samples from intervals 45 to 60, 80 to 100, 115 to 125, 145 to 155, and 210 to 340; clay may have been present in other intervals and washed out of sample during collection. | 15 | 340 |
| Clay, tan, and some sand and gravel as 0-15 interval | 340 | 358 |

Table 13.--Results of chemical analyses of water samples

U.S. DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

WATER RESOURCES DIVISION

Analyses by Geological Survey, United States Department of the Interior
(parts per million)

9-268 q

| | 22.4. 24.212a (10a) | 22.4. 24.212a (10a) | 22.4. 24.212a (10a) | 22.5. 7.342 (T-7) | 22.5. 7.342 (T-7) | 22.5. 7.342 (T-7) |
|---|---|---|---|---|---|---|
| Date of collection | 5-20-63 | 5-29-63 | 7-23-63 | 7-19-63 | 7-25-63 | 8-8-63 |
| Sample interval | 710 | 687-825 | screen | 300-345 | 906-1000 | screen |
| Silica ($SiO_2$) | | | 44 | | | 33 |
| Iron (Fe) | | | .05 | | | |
| Manganese (Mn) | | | | | | |
| Calcium (Ca) | | | 34 | | | 24 |
| Magnesium (Mg) | | | 7.5 | | | 1.9 |
| Sodium (Na) | | | 25 (Na + K) | | | 58 |
| Potassium (K) | | | | | | 1.8 |
| Bicarbonate ($HCO_3$) | | | 123 | 153 | 168 | 130 |
| Carbonate ($CO_3$) | | | 0 | 0 | 0 | 0 |
| Sulfate ($SO_4$) | 210 | 59 | 50 | 76 | 84 | 58 |
| Chloride (Cl) | 388 | 12 | 10 | 21 | 25 | 14 |
| Fluoride (F) | | | .5 | | | 1.6 |
| Nitrate ($NO_3$) | | | 2.4 | | | 8.4 |
| Dissolved solids | | | | | | |
| Calculated | | | 233 | | | 265 |
| Residue on evaporation at 180°C | | | 256 | | | 258 |
| Hardness as $CaCO_3$ | | | 116 | | | 68 |
| Noncarbonate hardness as $CaCO_3$ | | | 15 | | | 0 |
| Alkalinity as $CaCO_3$ | | | 101 | 125 | 138 | 107 |
| Specific conductance (micromhos at 25°C) | 1,980 | 379 | 321 | 480 | 525 | 376 |
| pH | | | 7.4 | 7.7 | 8.1 | 7.5 |
| Color | | | 5 | | | |



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Table 13.--Results of chemical analyses of water samples - Concluded

U.S. DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
WATER RESOURCES DIVISION

Analyses by Geological Survey, United States Department of the Interior
(parts per million)

9-268 q

| | 6.1. 9.111 (B-1) | 6.1. 9.111 (B-1) | 6.1. 9.111 (B-1) | 12.5. 31.434 (RC-1) | 12.5. 28.432 (RC-2) | |
|---|---|---|---|---|---|---|
| Date of collection | 11-12-63 | 11-13-63 | 11-15-63 | 12-11-64 | 5-6-64 | |
| Sample interval | 440-462 | 320-340 | 100-160 | 530-540 | open | |
| Silica ($SiO_2$) | | | 35 | 15 | 21 | |
| Iron (Fe) | | | .11 | | | |
| Manganese (Mn) | | | | | | |
| Calcium (Ca) | | | 6.4 | 85 | 134 | |
| Magnesium (Mg) | | | 1.5 | 40 | 52 | |
| Sodium (Na) | | | 230 | {64 | {961 | |
| Potassium (K) | | | 8.3 | | | |
| Bicarbonate ($HCO_3$) | | | 230 | 204 | 140 | |
| Carbonate ($CO_3$) | | | 0 | 0 | 0 | |
| Sulfate ($SO_4$) | 704 | 258 | 245 | 232 | 1,010 | |
| Chloride (Cl) | 905 | 236 | 56 | 62 | 1,040 | |
| Fluoride (F) | | | 1.4 | 1.6 | 1.8 | |
| Nitrate ($NO_3$) | | | .2 | 18 | .5 | |
| Dissolved solids | | | | | | |
| Calculated | | | 697 | 618 | 3,290 | |
| Residue on evaporation at 180°C | | | | 627 | 3,370 | |
| Hardness as $CaCO_3$ | | | 22 | 376 | 548 | |
| Noncarbonate hardness as $CaCO_3$ | | | 0 | 209 | 434 | |
| Alkalinity as $CaCO_3$ | | | 189 | 167 | 115 | |
| Specific conductance (micromhos at 25°C) | 4,350 | 1,620 | | 967 | 5,150 | |
| pH | | | 8.1 | 8.2 | 7.6 | |
| Color | | | | | | |

Well 12.5.31.434 (RC-1) obtained a small amount of water, less than 3 gpm, at a depth of about 530 feet; the water rose to a depth of about 470 feet. The yield of the well did not increase, or appreciably decrease, as the well was deepened. Drilling was continued past the contract depth of 750 feet on the assumption that saturated permeable material would be penetrated and the yield of the well would increase. The water obtained from the well probably is perched because the yield did not increase after drilling to 942 feet. The lower part of the well is presumed to be relatively impermeable. The total depth of the well is below the level of the saline water in the lower part of the basin; the area near RC-1 is separated from circulation with the main water body of the basin by faulting or low permeability. The small supply of potable water obtained from RC-1 substantiates the premise that geologic conditions are favorable to the existence of fresh ground water in the area, and more test wells should be drilled before the area is rejected as a possible source of potable water.

## Selected references

Davis, Leon V. and Busch, Fred E., 1965, Summary of hydrologic investigations by the United States Geological Survey at White Sands Missile Range, New Mexico: U.S. Geol. Survey open-file rept., released to U.S. Army, 146 p., 27 figs., 17 tables.

Doty, G. C., 1963, Water-supply development at the National Aeronautics and Space Agency-Apollo Propulsion System Development Facility, Dona Ana County, N. Mex.: U.S. Geol. Survey open-file rept., 40 p., 5 figs., 1 table.

_____ 1964, Summary of test wells drilled for MAR site water supply, White Sands Missile Range, New Mexico: U.S. Geol. Survey open-file rept., released to U.S. Army, 21 p., 5 figs., 1 table.

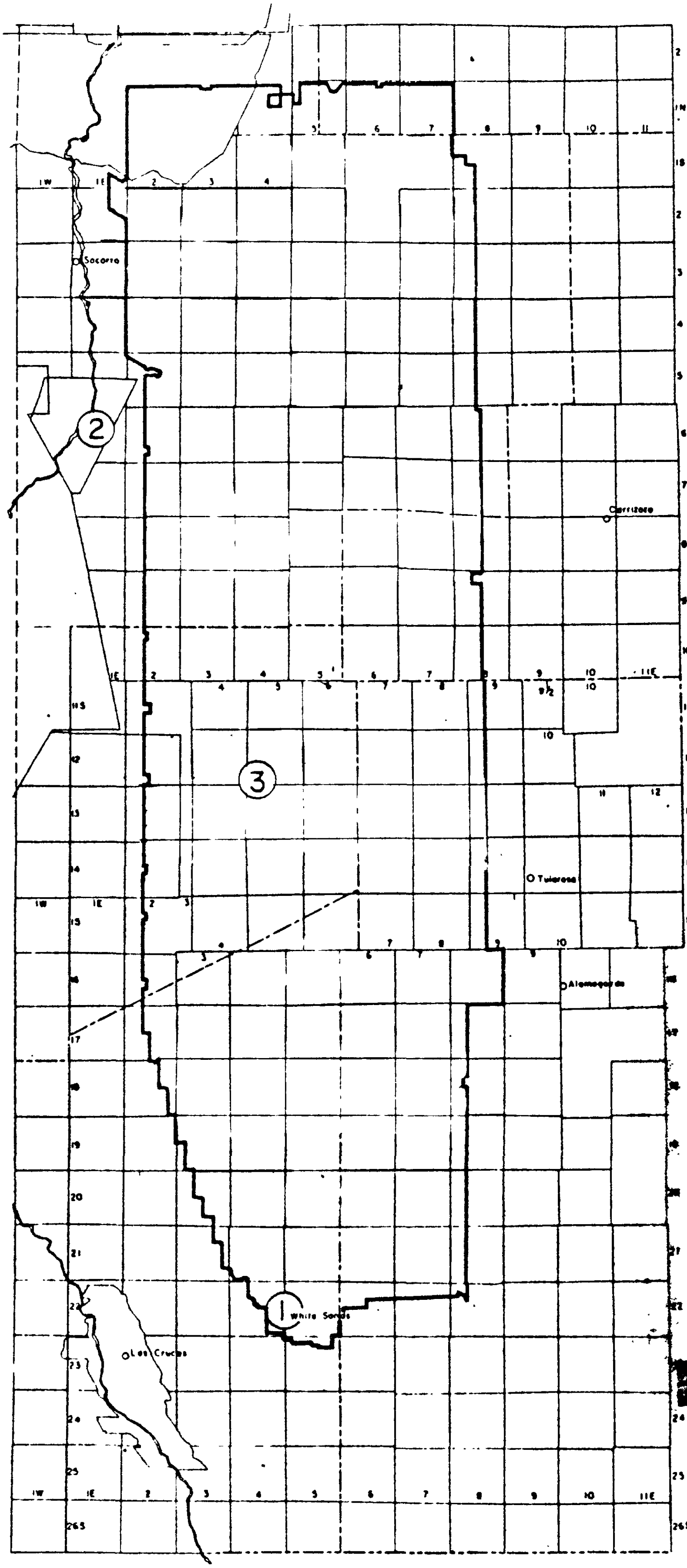
_____ 1964a, Summary of production wells drilled for MAR site water supply, White Sands Missile Range, New Mexico: U.S. Geol. Survey open-file rept., released to U.S. Army, 19 p., 6 figs., 1 table.

Ferris, J. G., Knowles, D. B., Brown, E. H., and Stallman, R. W., 1962, Theory of aquifer tests: U.S. Geol. Survey Water-Supply Paper 1536-E, 173 p., 28 figs., 6 tables.

Herrick, E. H., 1960, Ground-water resources of the Headquarters (cantonment) area, White Sands Proving Ground, Dona Ana County, N. Mex.: U.S. Geol. Survey open-file rept., 203 p., 33 figs.

Hood, J. W., 1963, Ground-water investigations at White Sands Missile Range, New Mexico, July 1960-June 1962: U.S.,Geol. Survey open-file rept., released to U.S. Army, 153 p., 28 figs.

Weir, J. E., Jr., 1964, Geology and availability of ground water in the northern part of the White Sands Missile Range and vicinity, New Mexico: U.S. Geol. Survey Water-Supply Paper 1801, 78 p., 11 figs.

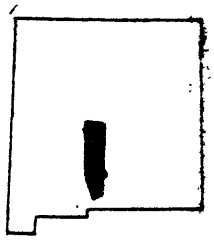



**Areas mentioned in tex**

1. **WSMR Headquarters**
   **Well 10a**
   **Well T-7**

2. **Bosque del Apache**
   **Well B-1**

3. **Rhodes Canyon**
   **Well RC-1**
   **Well RC-2**



LOCATION OF WHITE SANDS MISSILE RANGE IN NEW MEXICO

**Figure 1.—White Sands Missile Range in New Mexico and areas discussed in this report. Circled numbers refer to areas mentioned in text and listed at upper right of this map.**

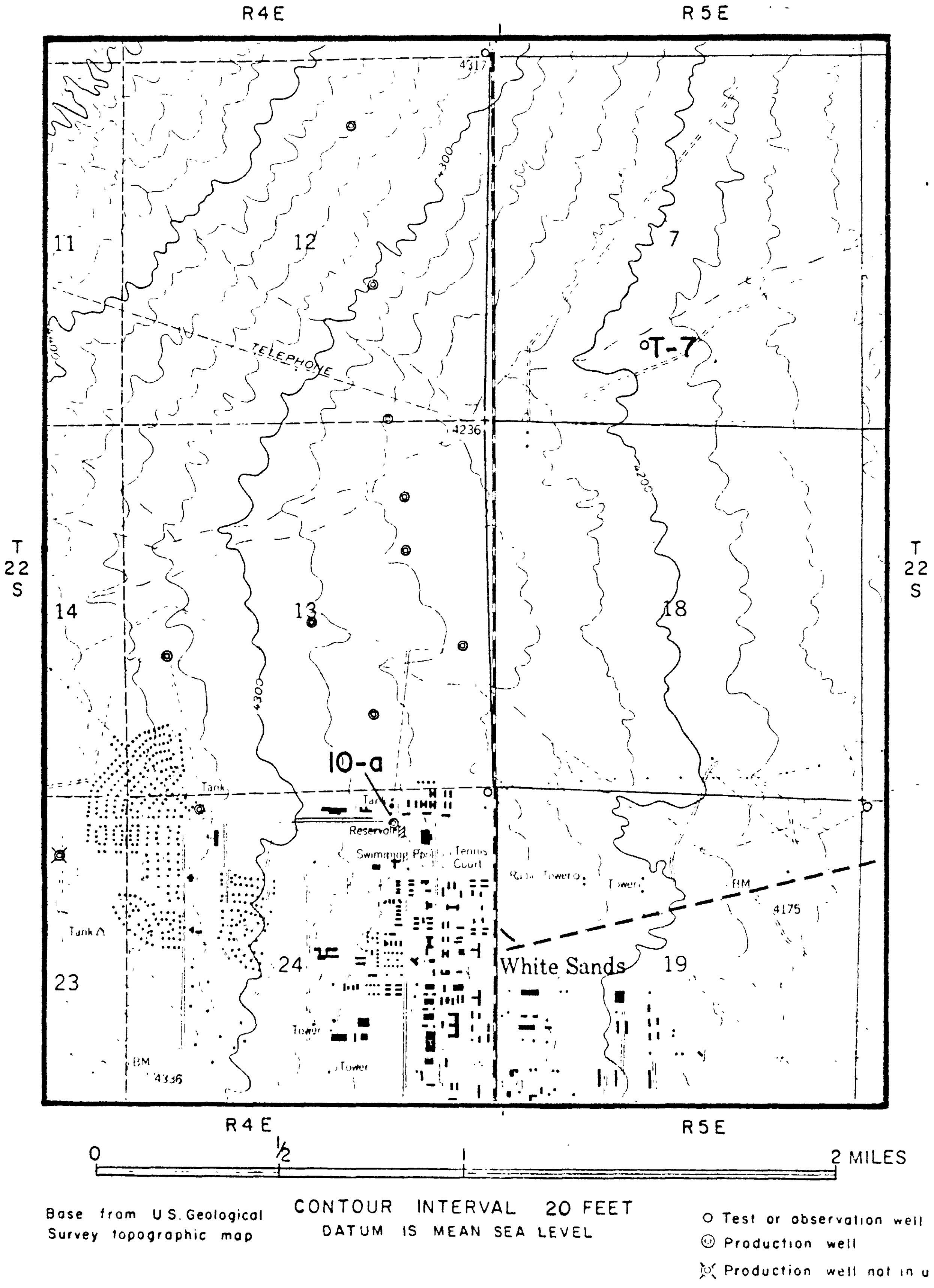



**Figure 2.--Headquarters area, White Sands Missile Range, Dona Ana County, N. Mex.**

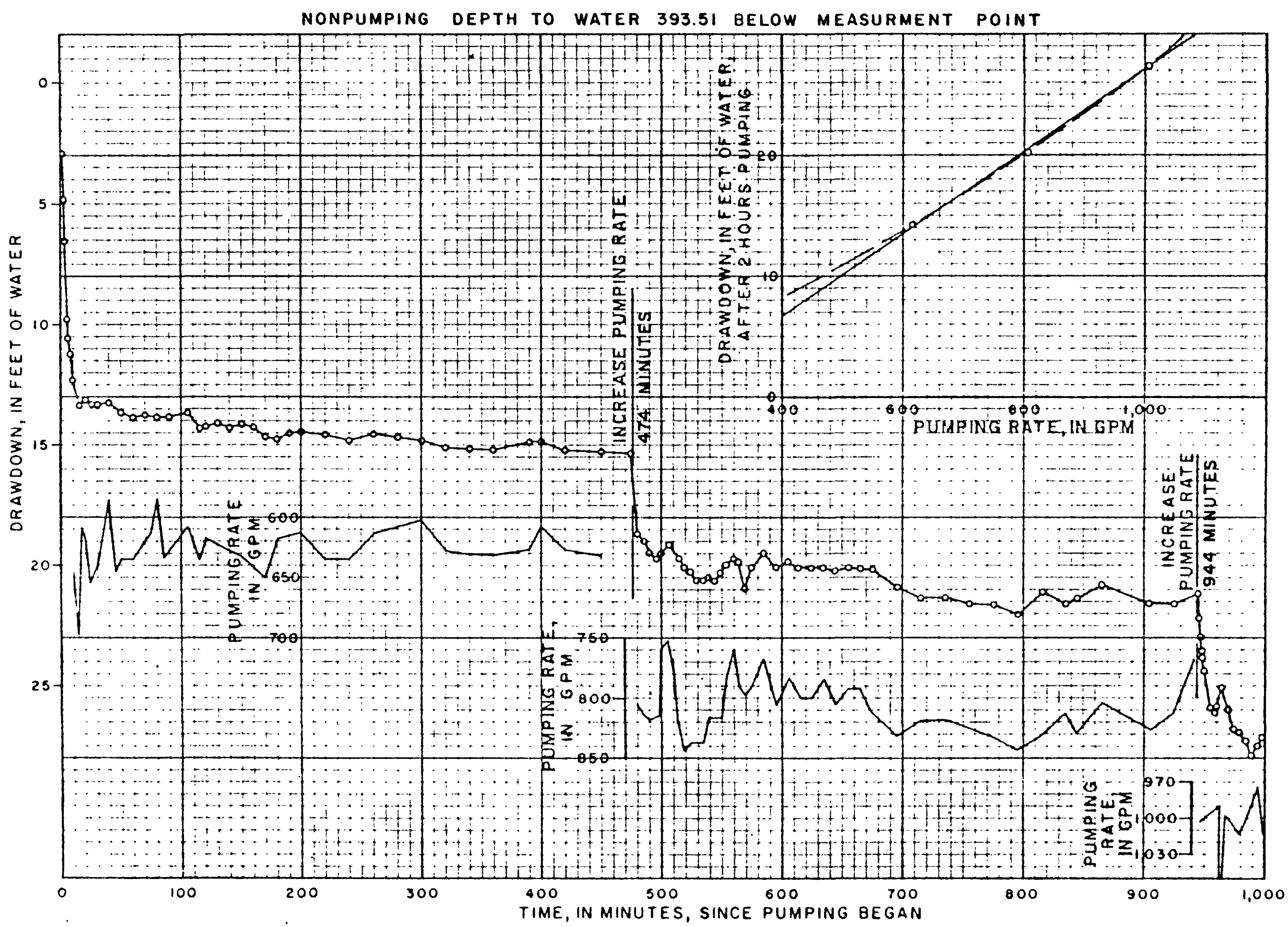



Figure 3.--Water-level drawdown and pumping rate in well 10a, July 15-16, 1963.

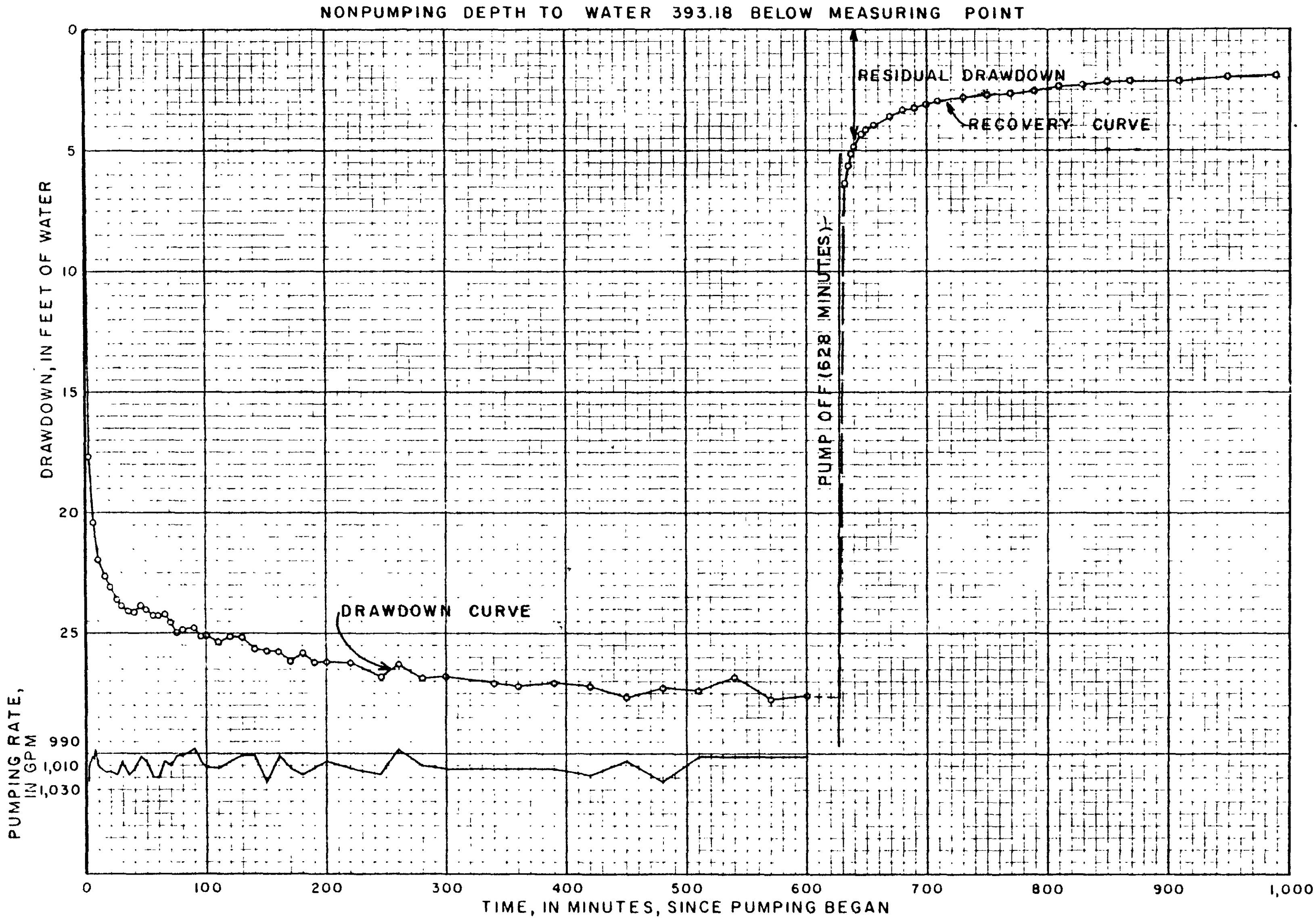



Figure 4.--Water-level drawdown, pumping rate, and residual drawdown in well 10a, July 22-23, 1963

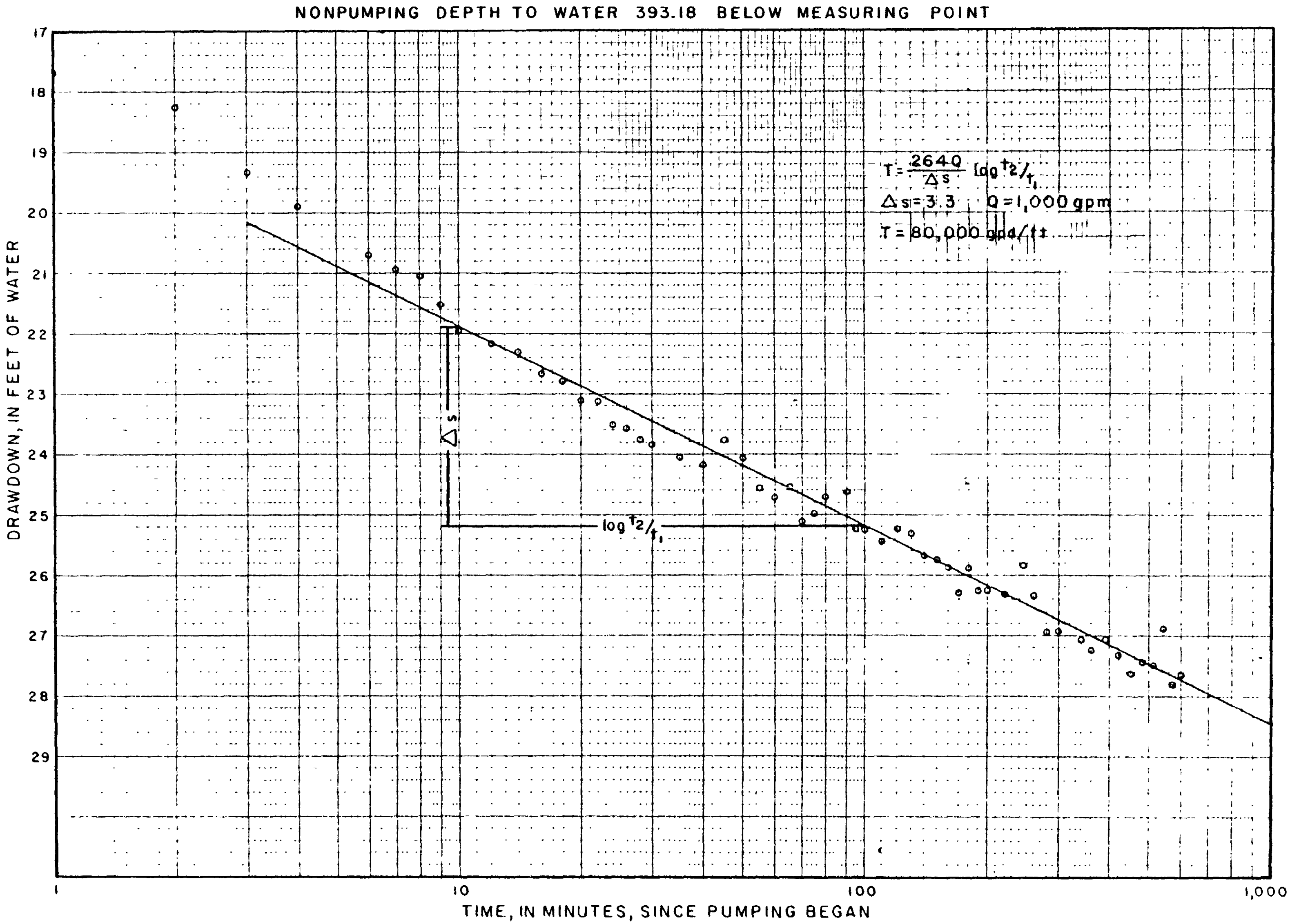



Figure 5.--Water-level drawdown in well 10a while pumping at 1,000 gpm, July 22-23, 1963

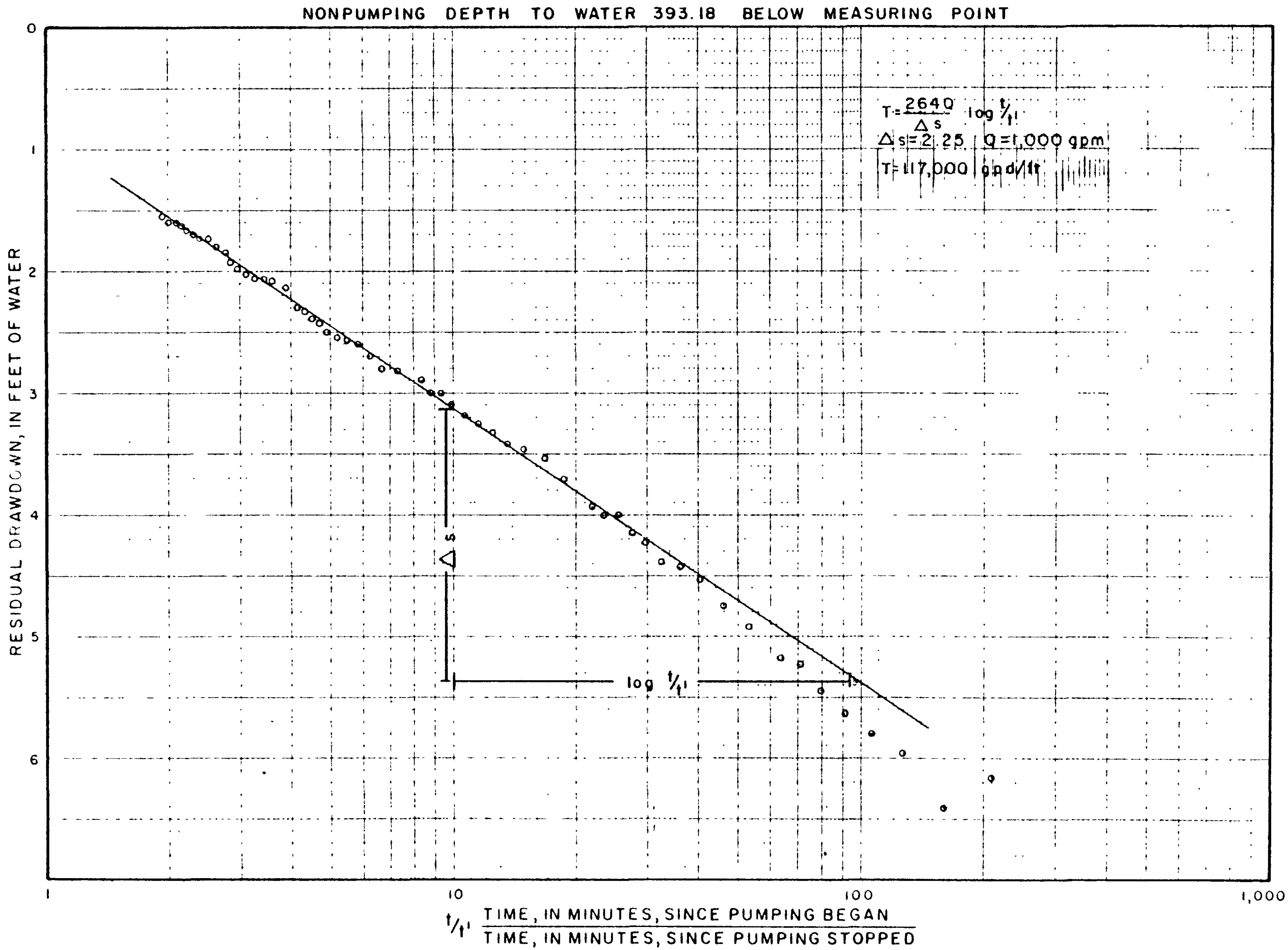



Figure 6.--Residual drawdown in well 10a after pumping at 1,000 gpm for 10 1/2 hours, July 23, 1963.

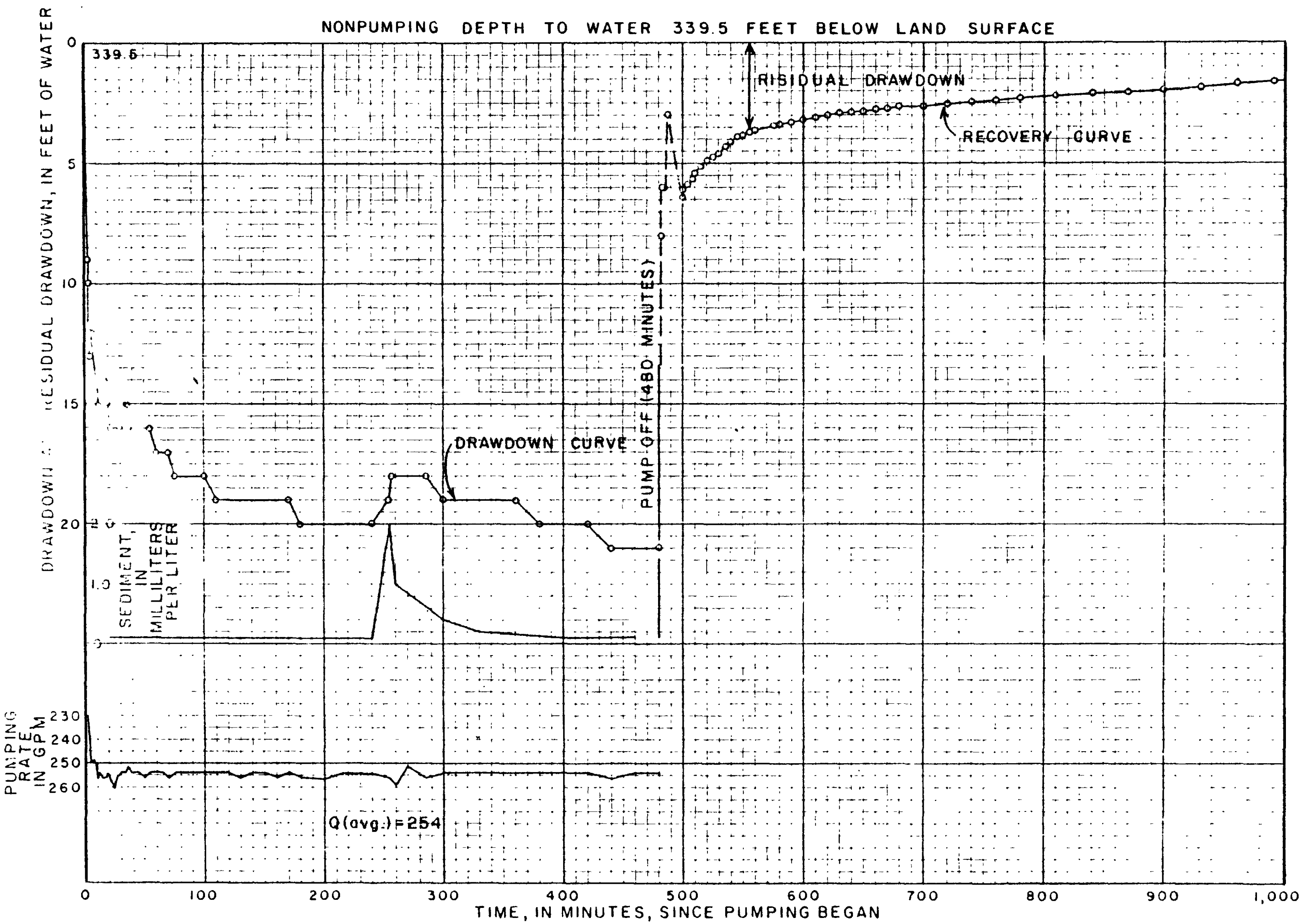



Figure 7.--Water-level drawdown and residual drawdown, sediment content of pumped water, and pumping rate, well T-7, August 8-9, 1963.

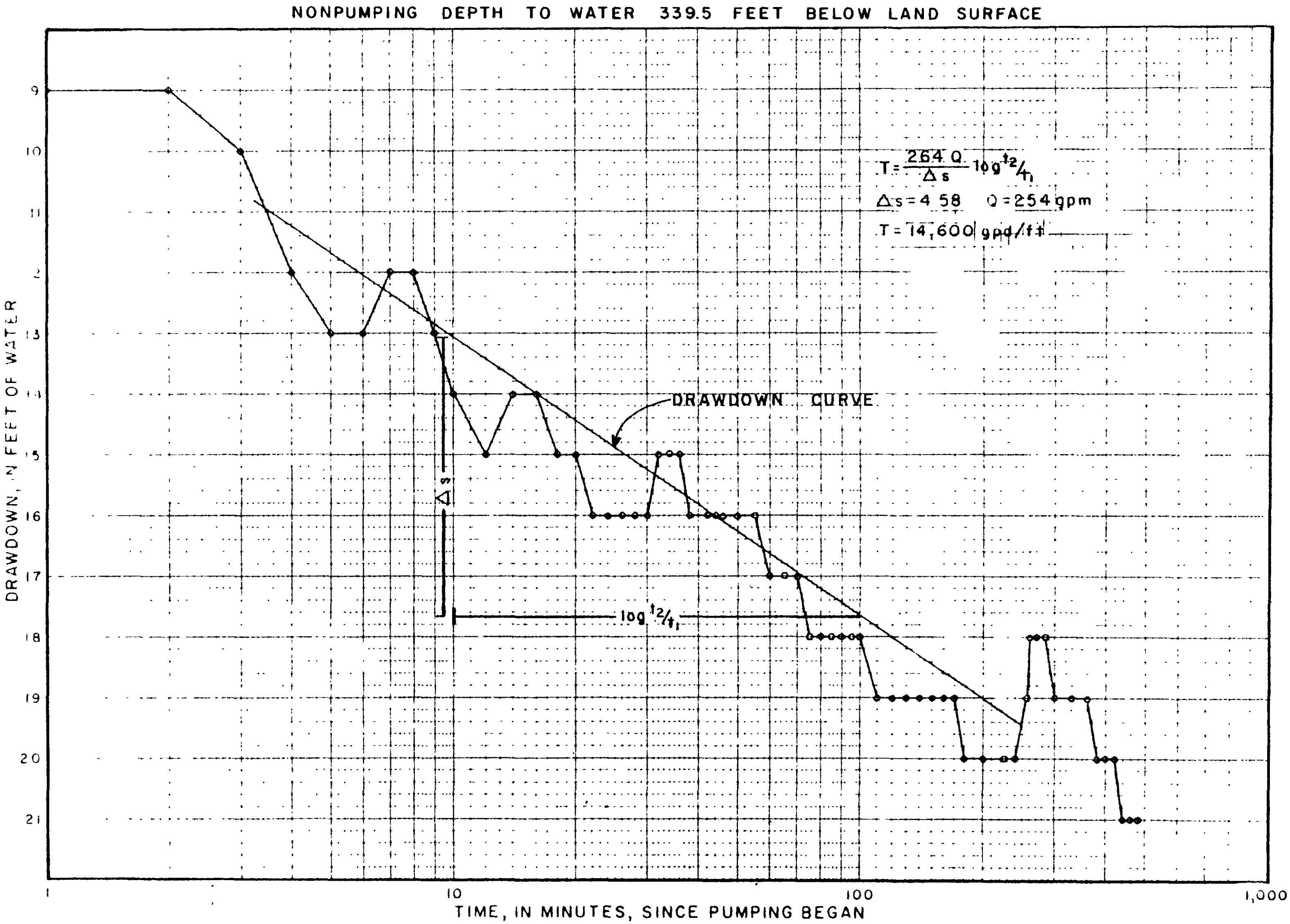



Figure 8.--Water-level drawdown in well T-7, August 8, 1963.

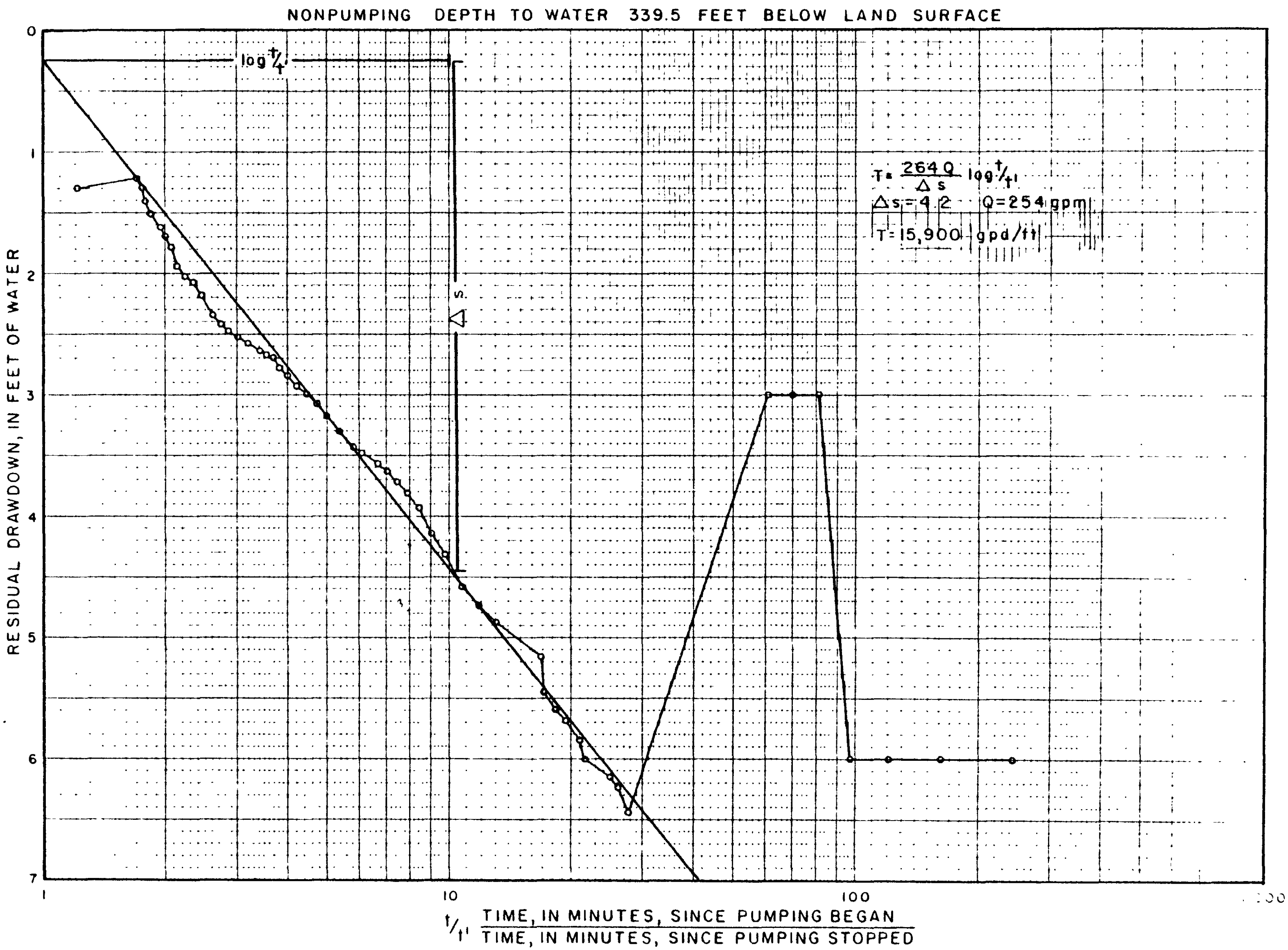



**Figure 9.--Residual drawdown in well T-7, August 8-9, 1963.**

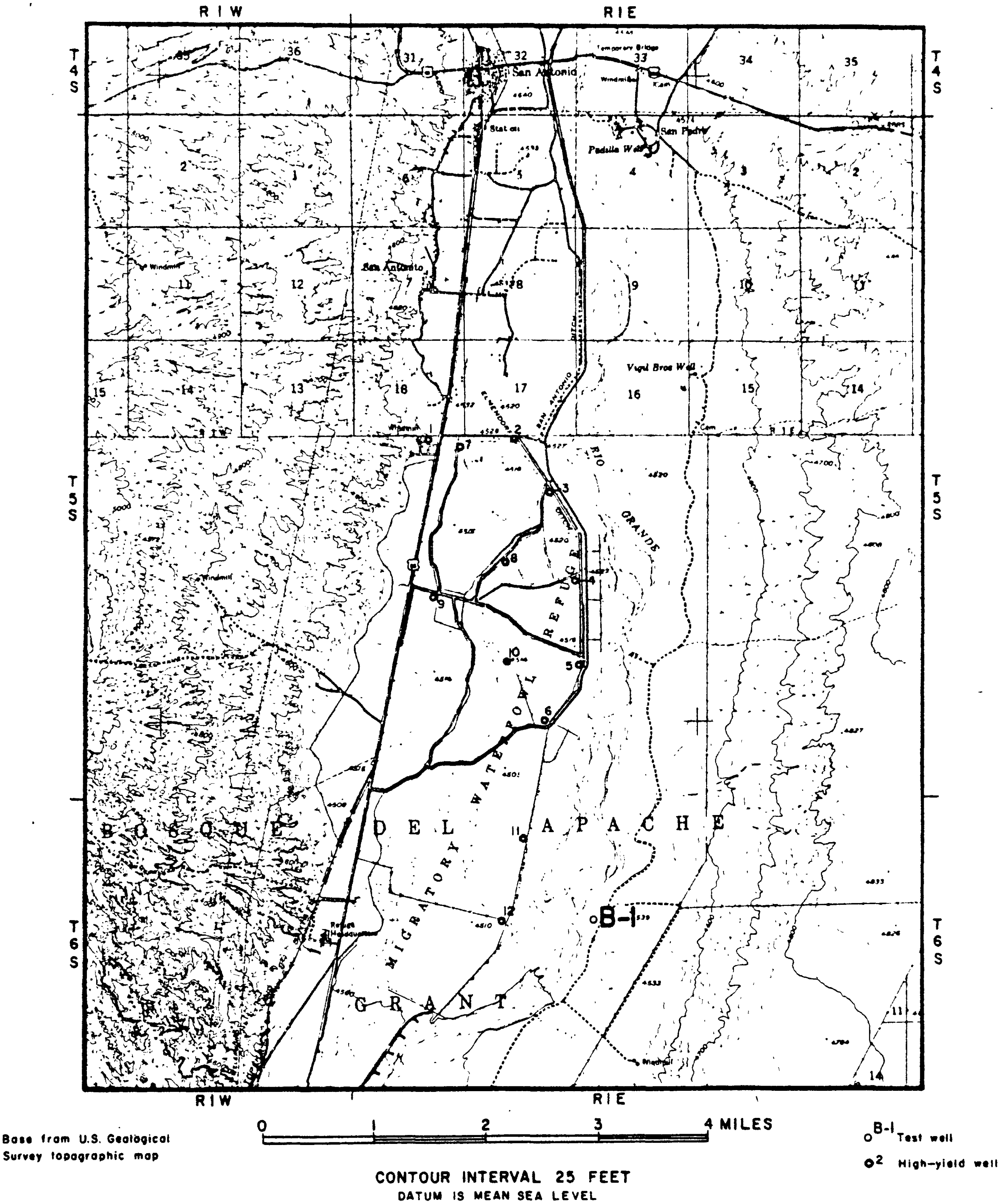



Figure 10.—Bosque del Apache area, Socorro County, N. Mex.

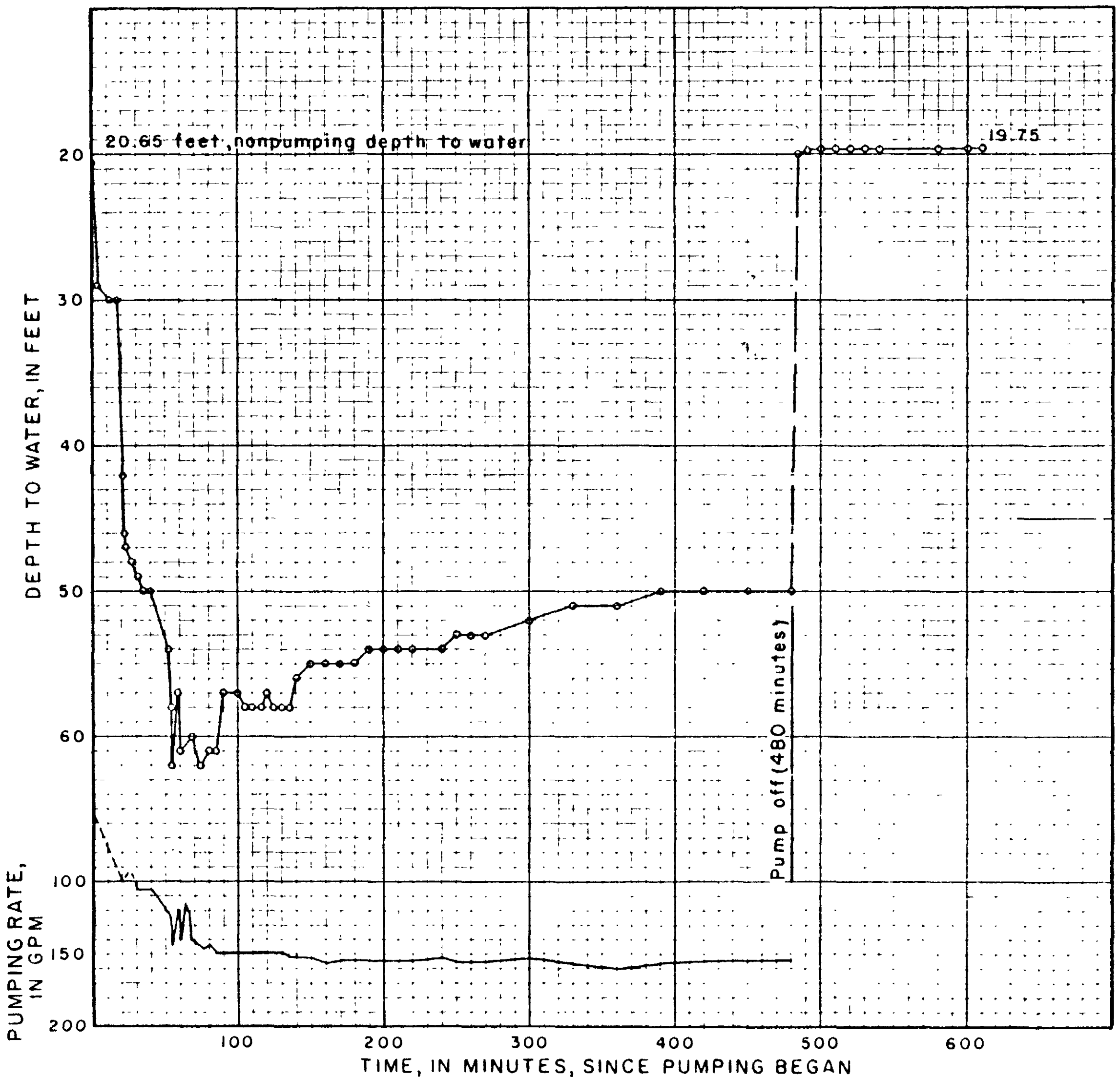



Figure 11.--Depth to water and pumping rate for well B-1, November 15-16, 1963.

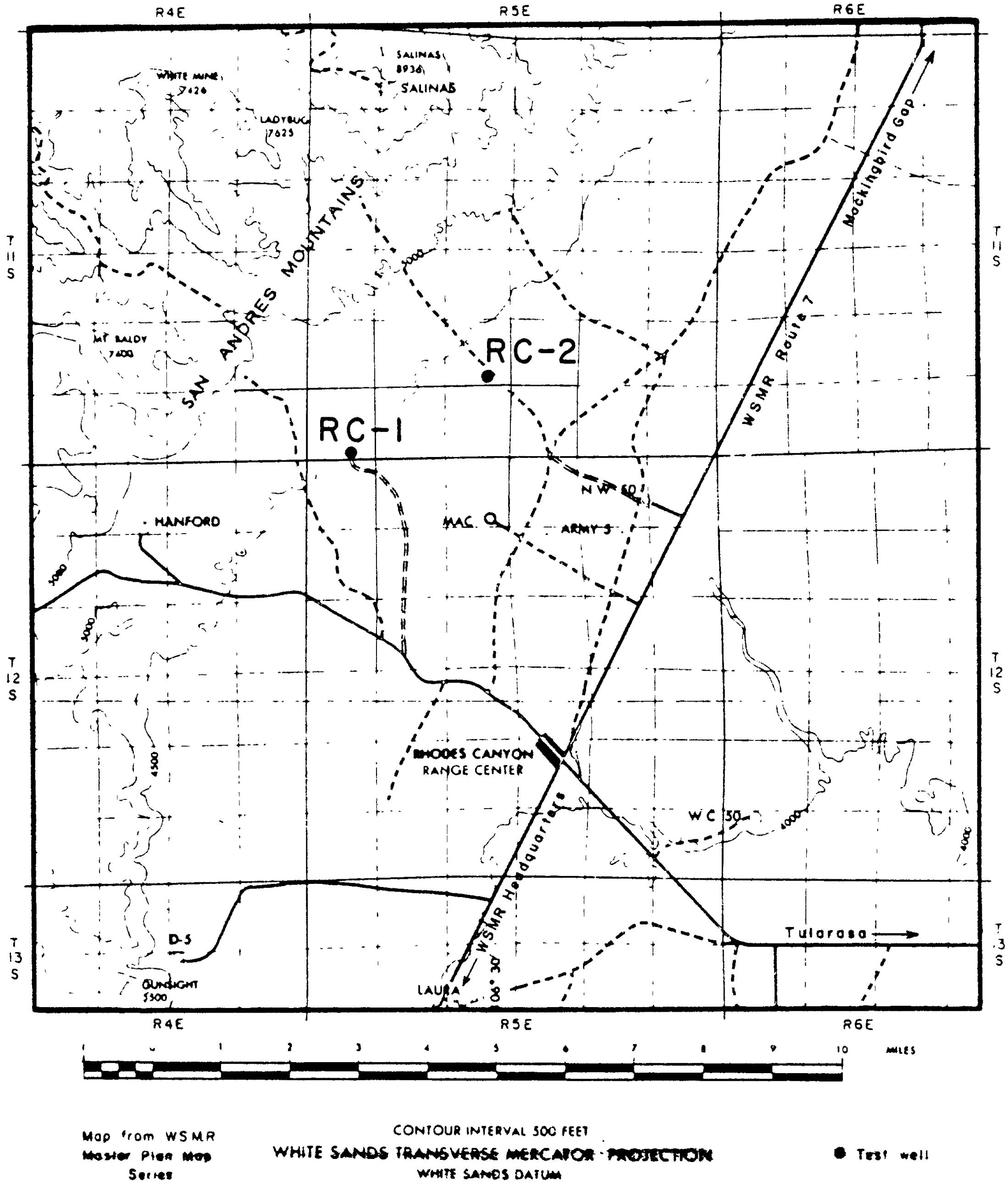



**Figure 12.--Rhodes Canyon area, White Sands Missile Range, Sierra County, N. Mex.**

Figure 13.—Electric logs of wells in the Rhodes Canyon area - Continued

**Well 12.5.31.434 (RC-1)**