Rehabilitation of Wells 13, 15, and 17, Headquarters Area WSMR

By

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UNITED STATES
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Rehabilitation of Wells 13, 15, 16, and 17, Headquarters Area, White Sands Missile Range, New Mexico

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Introduction

Periodic inspection and preventive maintenance are accepted procedure in the operation of most mechanical equipment; however, such procedures are seldom extended to include water wells. The White Sands Missile Range has applied these accepted maintenance principles to the wells in the Headquarters well field to insure the continuing serviceability of pumps and dependability of yield from the wells in both routine and emergency use.

Periodically, certain wells are taken out of service during winter months when water use is at a minimum. The pump is removed from the well and examined for wear and incipient structural deterioration, the well cleaned out and redeveloped, the pumping equipment replaced, and the well test pumped and returned to service. The condition of the well and the pumping equipment is evaluated against the time it has been in service to aid in scheduling the next rehabilitation.

As a part of the scheduled rehabilitation of production wells 13, 15, 16, and 17 (See fig. 1.) the U.S. Geological Survey was requested by White Sands Missile Range to observe redevelopment operations by the contractor, to make certain measurements of drawdown and yield, to advise on methods used in redevelopment, and to obtain comparative performance data for these wells. This report results from compliance with this request and presents data from production pumping of each well during rehabilitation, data from the test pumping of each well after rehabilitation, and miscellaneous associated information that may be helpful in evaluating the effects of rehabilitation.

Specifications for the rehabilitation of these wells were issued by the U.S. Army Engineer District, Albuquerque, Corps of Engineers, Albuquerque, New Mexico, as invitation for bids number DACA 47-67-B-0012, dated 7 September 1966. The successful bidder was Layne-Texas Co., Inc., El Paso, Texas. Work was started in October 26, 1966 and completed in June 1967.

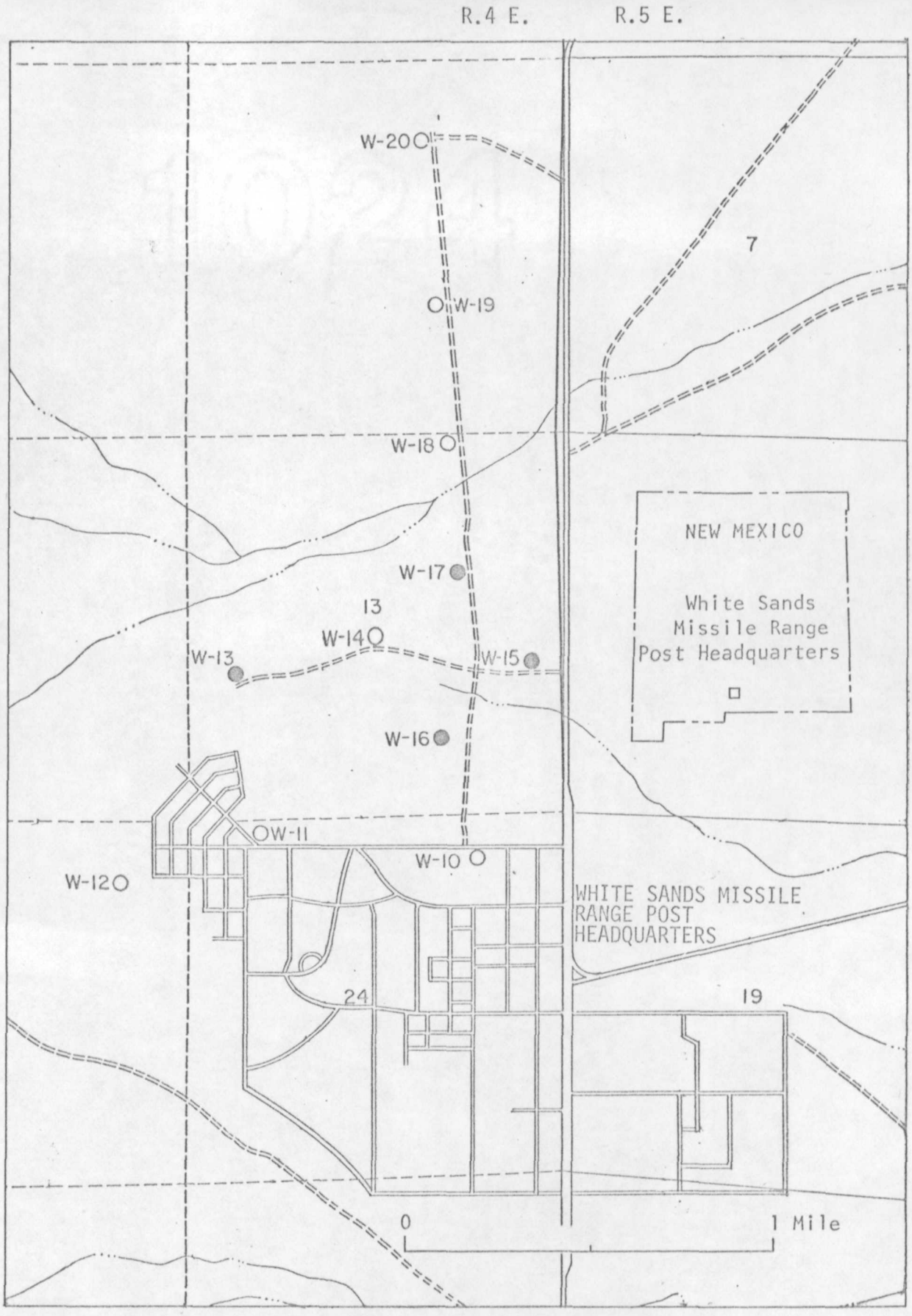

Figure 1.--Well field area and location of water supply wells, Post Headquarters, White Sands Missile Range, N. Mex.

Well 13

Well 13 was drilled in 1951 to a depth of 534 feet. It was cased with 12-inch diameter casing perforated with torch-cut $\frac{1}{4}$ x 4-inch slots at depths of 373 to 393 feet and 470 to 534 feet, and was gravel packed. Prior to 1955 the well was pumped at a rate of about 200 gpm (gallons per minute).

The well was first rehabilitated in 1955. During this rehabilitation a large quantity of clay and sand was pumped from the well which caused the gravel pack to drop (Herrick, 1960, p. 24). Additional gravel was then added to the well. After the redevelopment was completed a pumping test was run. The test indicated that the well could produce 300 gpm with a drawdown of approximately 100 feet. A pumping rate of 250 gpm was recommended to induce a smaller drawdown that would be less likely to move undesirable amounts of sand into the gravel pack.

In 1962 the reported production pumping rate was about 300 gpm and in 1964 about 279 gpm. On December 15, 1966 the well was pumped for 5 hours at an average rate of 228 gpm. The drawdown after 5 hours was 26 feet (table 1).

In January and February 1967 the following procedures were followed in the rehabilitation of the well.

Procedures and results

In January 1967 the production pump was removed and the well was sounded. It was found that the lower 19 feet of the well was filled with sand.

An attempt was made to obtain stereoscopic pictures of the perforated sections of the well casing. However, oil on the surface of the water prevented proper functioning of the camera.

The well was cleaned out to a depth of about 524 feet. During the bailing about 300 feet of galvanized airline was removed that had previously been dropped into the well.

On February 3, the well was treated with Laynite (mud-cutting chemical). Six hundred pounds of dry Laynite were dissolved in water and poured directly into the well and 100 pounds were dissolved and poured into the gravel pack. The gravel pack was then flushed with 1,000 gallons of water so as to distribute the Laynite throughout the pack. Following this the well was surged with a bailer for 2 hours.

After surging the well was left undisturbed for 24 hours. It was then surged with a bailer and the gravel pack flushed with water for a period of 4 hours. During the bailing and surging operations the gravel pack did not lower.

A test pump was installed, with the top of the bowl assembly and the bottom of the airline set at 460 feet. A direct-reading airline gage and a continuous-type airline recorder were installed to determine the depth to water during development and test pumping. The well was pumped and surged at a pumping rate of about 200 gpm on February 9 for a period of about 2 hours (table 2). As this pumping rate was too low to fully complete pump development of the well, the pump was stopped and mechanical adjustments were made in the pump motor and gear train to increase the yield of the pump.

On February 13, the well was pumped at rates up to 430 gpm. During the first 3 hours of this development pumping, the well was frequently surged to free clay and sand from the gravel pack (table 2). During the final 3 hours of development pumping a step test was made at pumping rates of 290 gpm, 330 gpm, and 375 gpm. During the 6 hours of pumping small amounts of clay and sand were removed from the well, and the gravel pack remained stable.

On February 14, the well was pumped continuously for 5 hours at an average rate of 367 gpm. The drawdown after 5 hours was 103.5 feet (table 3). At the end of this pumping test the well was discharging only trace amounts of sand.

On February 16, stereoscopic pictures were taken to show the condition of the casing slots. The pictures above a depth of 450 feet showed some encrustation of the slotted sections, but the slots seemed to be relatively clean and open. However, below that depth many of the slots were badly encrusted and in places were completely filled. The pictures indicated that the lower 24 feet of the well was filled with sand.

After the final set of pictures were taken the well was cleaned out to a depth of 524 feet and preparations were made to install the new production pump. The lowermost 10 feet of fill in the well could not be removed because fragments of the airline prevented the bailer from going down.

Conclusions and recommendations

During rehabilitation small amounts of clay and sand were removed from the well. The gravel pack was not lowered and is assumed to be stable.

The results of the final pumping test on February 14, 1967 are shown graphically in figures 2 and 3. The test indicates that the well is capable of producing 350 gpm for brief periods of pumping. However, under sustained periods of pumping at this rate the drawdown will be greater than 100 feet.

The pictures taken of the well screen indicate that most of the water is yielded from the upper 100 feet of saturation. Supporting this theory are data obtained from the pumping test on February 14 (table 3). After the well had been pumped for about 50 minutes, and the water level lowered to near 380 feet, the water from the well was observed to contain a noticable amount of air. The water probably was cascading into the well when the water level was lowered to the first screen section, trapping air in the well.

From these observations it is recommended that the well not be pumped at a rate of over 300 gpm for any sustained periods. A pumping rate of 250 gpm would result in a drawdown of less than 40 feet and would be less likely to pull undersirable amounts of sand into the gravel pack. The recommended pumping rate would probably safeguard against drawing the pumping water level below a depth of 375 feet during months of increased pumpage.

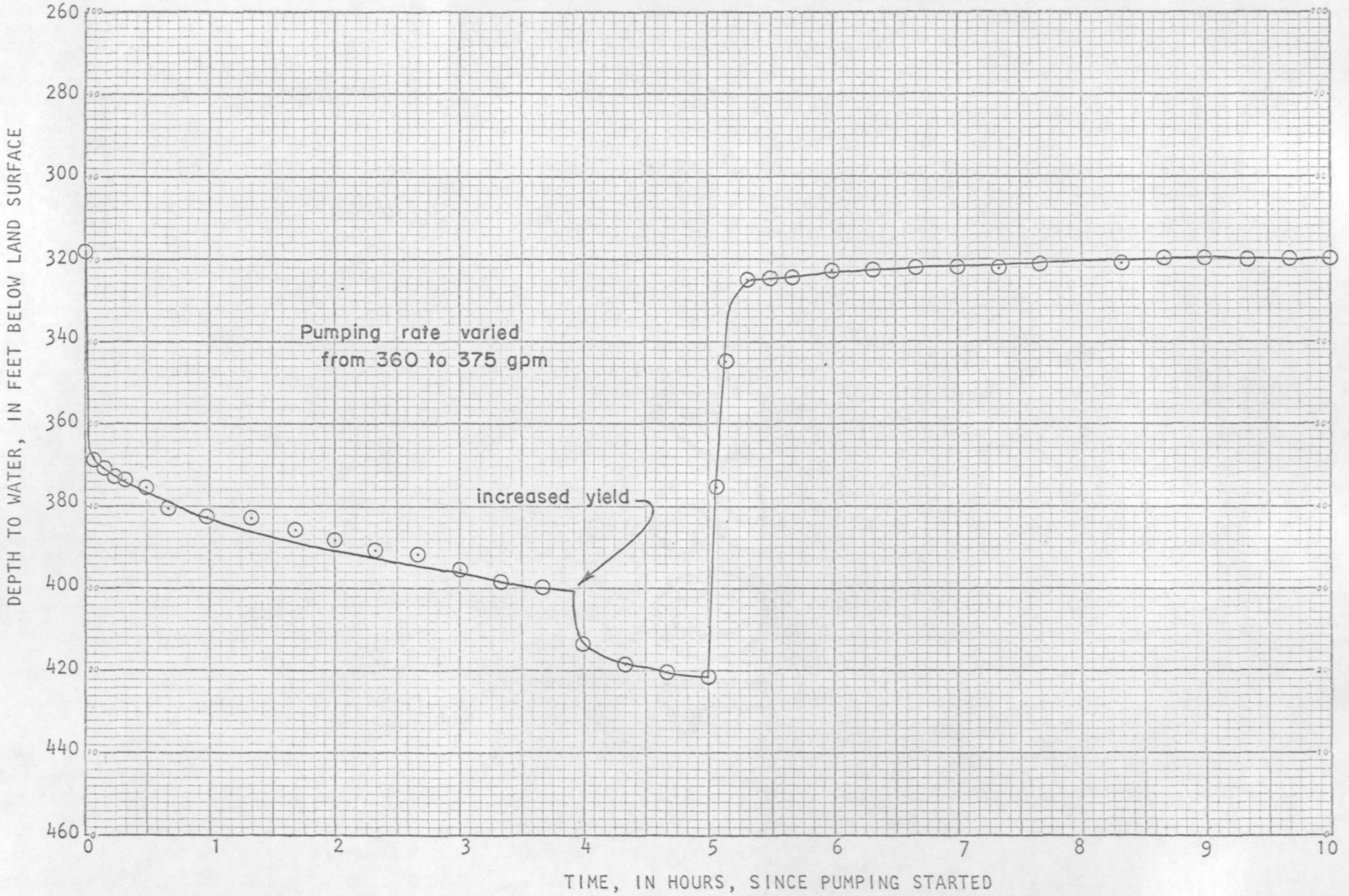

Figure 2.--Drawdown and recovery curve from pumping test of Well 13 on February 14, 1967, after rehabilitation.

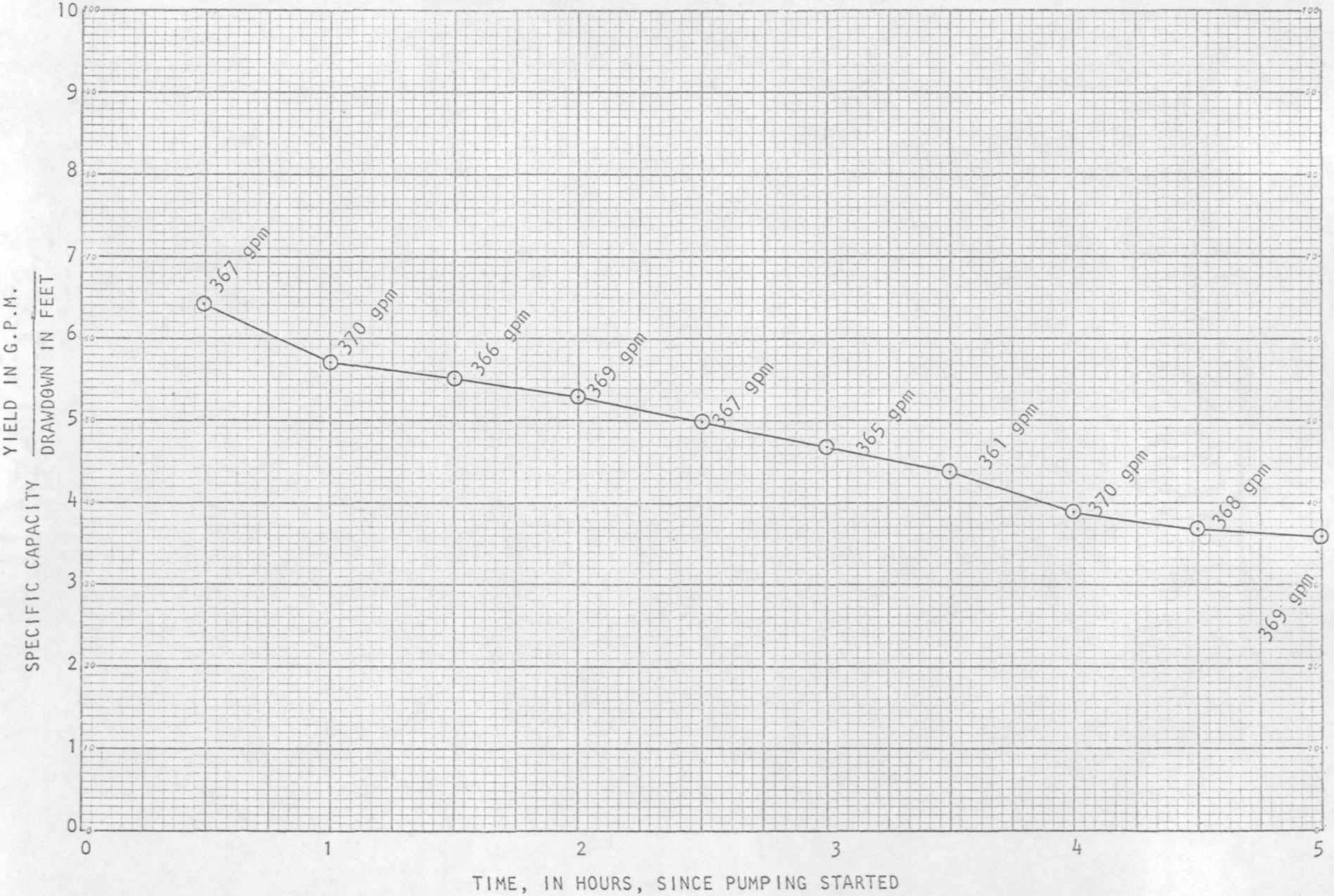

Figure 3.--Specific-capacity curve from pumping test of Well 13 on February 14, 1967, after rehabilitation.

Well 15

Well 15 was drilled in 1954 to a depth of 820 feet. It was cased with 12-inch diameter casing and 12-inch louvered steel screen. The screen was placed at depths of 350 to 440 feet, 486 to 496 feet, 508 to 518 feet, 525 to 565 feet, 598 to 638 feet, 670 to 680 feet, 690 to 700 feet, 710 to 750 feet and 800 to 820 feet. The well was gravel packed. It was test pumped for 40.5 hours at an average rate of 750 gpm. At the end of the pump test the drawdown was 35 feet.

The well was rehabilitated in 1959. It was treated with acid and surged with a surge-block. The well was then pumped and surged until development was believed completed, and was then tested by step pumping. The test steps were at rates of 400, 660, 800, and 961 gpm. The first two steps were 4 hours in duration, the third 6 hours and the final step 2 hours. The drawdown of the water level at the end of each step was 13, 28, 35, and 45.5 feet respectively.

The reported production pumping rate was 500 gpm in 1962 and 600 gpm in 1964. In December 1966 the well was pumped for 5 hours at an average rate of 650 gpm. The drawdown after 5 hours was 24 feet (table 4).

In December 1966 and January 1967 the following procedures were followed in rehabilitation of the well.

Procedures and results

In December 1966 the production pump was removed and the well was sounded. It was found that the lower 22 feet of the well was filled with sand.

On December 14, steroscopic pictures were taken of the well casing and screen below the water level. The pictures showed the screen to be relatively free of encrustation above a depth of 600 feet. Below 600 feet the casing was heavily encrusted and the perforations appeared partially restricted and in some instances completely filled.

On December 16, the well was treated with Laynite. Six hundred pounds of dry Laynite were dissolved in water and poured into the well and 100 pounds were dissolved and poured into the gravel pack. The gravel pack was then flushed with 1,000 gallons of water so as to distribute the Laynite throughout the pack. Following this the well was surged with a bailer for 2 hours.

On the following day, after the well had been left undisturbed for 24 hours, it was again surged and the gravel pack flushed with water for a period of 4 hours. During these surging procedures the gravel pack did not lower.

A test pump was installed with the top of the bowl assembly and the bottom of the airline set at 520 feet. A direct-reading airline gage and a continuous-type airline recorder were installed to measure the depth to water during development and test pumping.

On December 21, the well was pumped at rates up to 750 gpm. During this development period the well was surged frequently (table 5). Each time the well was surged the water became muddy and the clay and sand content of the water increased noticeably. The water suddenly turned very muddy after about 4 hours of development pumping. More sand was observed in the water and the particles had increased in size. Pipe scale and pebble-sized gravel were removed from the well by pumping immediately after each surging period. The pumping rate was decreased from 640 gpm to approximately 200 gpm. After the water had cleared up and the well was producing considerably less sand, the pumping rate was increased to 350 gpm. Almost immediately an increased amount of sand and scale was observed and the water began turning muddy. After pumping at a rate of 350 gpm for about 3 minutes the pump locked. The pump was restarted at a pumping rate of approximately 200 gpm, but after running 5 minutes it again locked.

On December 22, the well was pumped at a rate of about 200 gpm. It was thought that by starting at a low pumping rate and then increasing the rate in small increments the well would be cleaned of the sand and scale. However even the lowest pumping rates possible with the test pump produced enough sand and scale to again lock the pump. The pump impellers were adjusted periodically to maintain the maximum clearance in the bowls in order to pass the sand and scale, however even with pump impeller adjustments and a lower rate of pumping, the longest sustained pumping interval during the first 2 hours was 12 minutes. The sand and scale content of the water had decreased considerably by early afternoon and the pumping rate was increased to 460 gpm. After about 1 hour the water was almost clear and the sand content was back to a reasonable level. The pumping rate was then increased to 670 gpm. The water turned cloudy and began carrying more sand and scale. After pumping only 15 minutes at this rate the pump again locked. Another 3 hours were spent in trying to obtain a sustained pumping period. However, only twice was the well pumped for a period of 10 minutes. The water during these two short periods of pumping was very cloudy and contained much sand and scale.

It was apparent that the well needed further development by bailing to remove the sand and scale accumulated and to correct the admission of sand to the well through the gravel pack.

The test pump was removed and it was found that the lower 12 feet of the well was filled with sand and scale.

On January 10, 1967 steroscopic pictures were taken of the well casing and screen to determine if the casing had separated or if the bottom plug had been loosened allowing sand to enter the well.

The pictures showed continuous casing and screen to a depth of 650 feet. The screen in this section showed general improvement in the removal of encrustation, however in some isolated sections the perforations were still somewhat restricted. Below a depth of 650 feet the water was too cloudy to determine the condition of the screen, and below a depth of 670 feet too cloudy to distinguish between casing and screen.

On January 11, 1,000 gallons of 20 percent inhibited muriatic acid was mixed with the water in the well. On January 12 the well was surged with a bailer for 8 hours. After 4 hours of surging the gravel pack had dropped 2 feet and after 8 hours the gravel pack had dropped a total of 62 feet. Sand had filled the lower 18 feet of the well.

On January 13, gravel was added to the gravel pack and the well was again surged with a bailer. However, the gravel pack remained stable. Surging with the bailer was resumed on the following day for an additional 5 hours. Again the gravel pack remained stable. However, the lower 22 feet of the well was filled with sand. The well was then cleaned out to a depth of 818 feet.

A test pump was installed, with the top of the bowl assembly and the bottom of the airline at 520 feet. A direct-reading airline gage and a continuous-type airline recorder were installed to measure the depth to water during development and test pumping.

On January 17, the well was pumped continuously for 2 hours at an average rate of about 450 gpm. During this time the water did not clear appreciably, but contained considerably less sand than during the previous development periods.

On January 18, the well was pumped for 90 minutes at a rate of 480 gpm; 120 minutes at a rate of 550 gpm; 1 hour at a rate of 610 gpm; 1 hour at a rate of 650 gpm; and 90 minutes at a rate of 720 gpm. The well was then pumped for 1 hour at an average rate of 735 gpm and occasionally surged to free any sand that would move out of the gravel pack. During this pumping period the gravel pack remained stable, the water was clear of mud and only small amounts of clay and sand were in the water.

On January 19, the well was pumped at rates up to 850 gpm. During this time the well was surged frequently. The gravel pack remained stable and only small amounts of sand were removed. During the pumping the water cleared and after 5 hours was only slightly discolored.

On January 20, the well was pumped continuously for 5 hours at an average rate of 754 gpm. The drawdown after 5 hours was 37 feet (table 6) and the water was clear. The sand content of the water had steadily diminished during pumping and after 2 hours no sand was observed in the water.

Conclusions and recommendations

The gravel pack in Well 15 was bridged prior to rehabilitation in 1967. During the development procedures the gravel pack dropped a total of 62 feet and then stabilized. Further development did not cause it to lower. The gravel pack probably is now continuous and will be more effective than before. The possibility of pumping sand has been greatly reduced.

After rehabilitation the well was test pumped. The results are given graphically in figures 4 and 5. The tests indicate that the well is capable of producing 750 gpm for limited periods of pumping. A pumping rate of 650 gpm would result in a drawdown of about 25 feet and be less likely to pull sand into the gravel pack of the well.

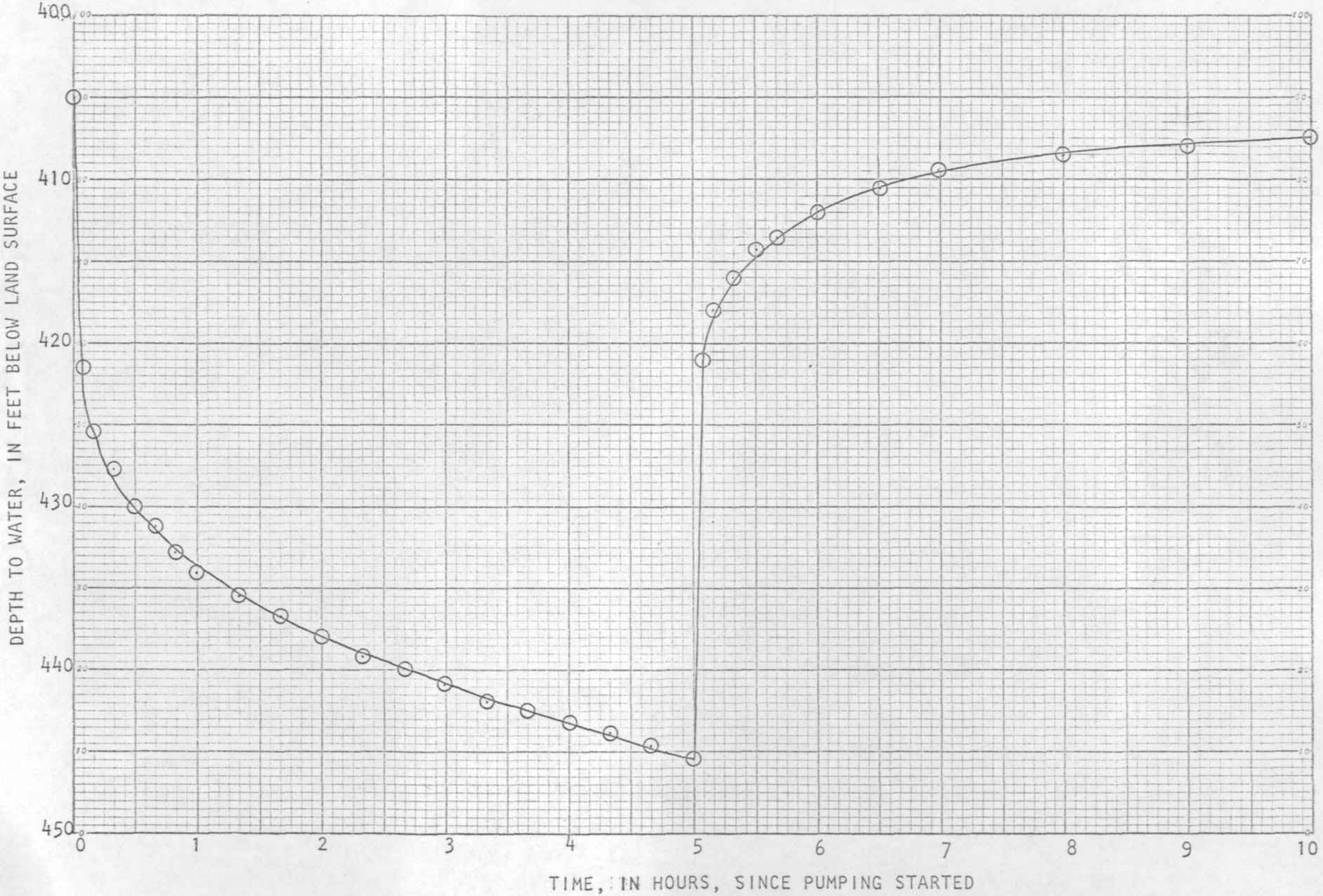

Figure 4.--Drawdown and recovery curve from pumping test of Well 15 on January 20, 1967, after rehabilitation.

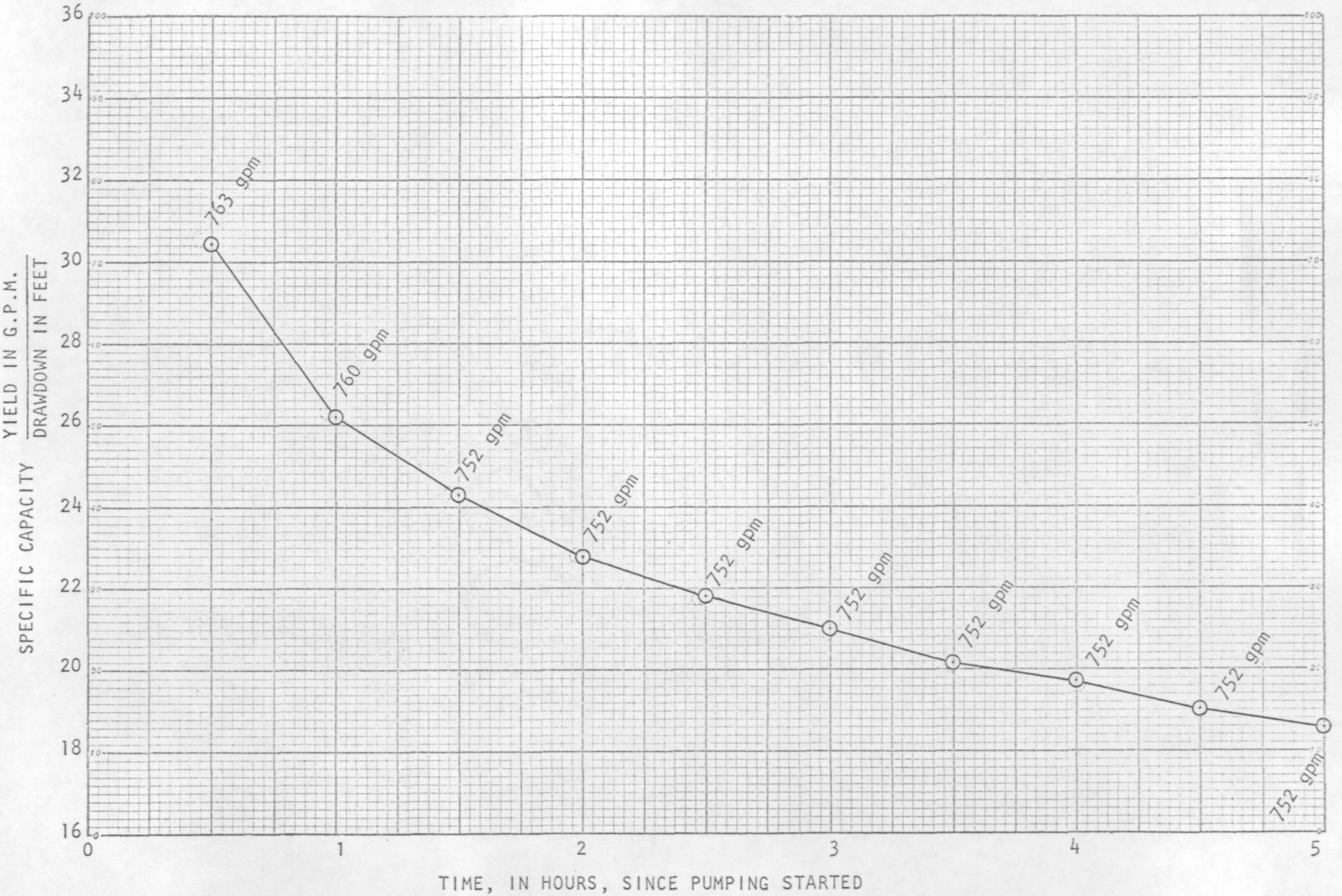

Figure 5.--Specific-capacity curve from pumping test of Well 15 on January 20, 1967, after rehabilitation.

Well 16

Well 16, was drilled in 1954 to a depth of 886 feet. It was cased with 12-inch diameter casing and 12-inch louvered ("Doty") steel screen. The screen was placed at depths of 370 to 410 feet, 415 to 435 feet, 442 to 453 feet, 460 to 479 feet, 486 to 496 feet, 508 to 528 feet, 542 to 571 feet, 588 to 597 feet, 616 to 636 feet, 642 to 652 feet, 657 to 667 feet, 678 to 688 feet, 708 to 718 feet, 724 to 734 feet, 742 to 772 feet, 784 to 794 feet, 802 to 834 feet, and 866 to 886 feet. The well was gravel packed. It was test pumped at an average rate of 600 gpm for 48 hours. The drawdown after 48 hours was 25 feet.

In May 1961, the well was rehabilitated. Prior to rehabilitation an inspection of the casing and screen with a closed-circuit television camera showed that perforations below 600 feet were nearly all obstructed by encrustation. Following rehabilitation closed circuit television inspection showed that the screen below 500 feet still contained some restricted perforations. It was established during rehabilitation that the lower portion of the well contributed little to the yield of the well.

The reported production pumping rate in 1962 was 800 gpm and in 1964 was 776 gpm. On November 3, 1966, the well was pumped for 5 hours at an average rate of 800 gpm. The drawdown after 5 hours was 18.5 feet (table 7).

In November and December 1966, the following procedures were followed in the rehabilitation of the well.

Procedures and results

In November 1966, the production pump was removed and the well was sounded. It was found that the lower 154 feet of the well was filled with sand.

On November 8, stereoscopic pictures were taken of the casing and screen. The pictures showed little or no deterioration of the casing and screen; however, some screen sections were heavily encrusted. Perforations in the upper part of the well seemed to be mostly open. Perforations below 540 feet showed signs of being restricted by encrustation and the perforations below 650 feet appeared mostly closed by encrustation.

On November 9, the well was treated with Laynite. Six hundred pounds of dry Laynite were thoroughly dissolved in water and poured into the well and 100 pounds of the dissolved Laynite were poured into the gravel pack and flushed with 1,000 gallons of water so as to distribute the Laynite throughout the gravel pack. The well was then surged with a bailer for 2 hours.

The well was allowed to remain undisturbed for 24 hours. On the following day the well was again surged with a bailer for a period of 4 hours and cleaned out to a depth of 886 feet. During the surging procedures the gravel pack was not lowered.

A test pump was installed with the top of the bowl assembly and the bottom of the airline set at 497 feet. A direct reading airline gage and a continuous-type airline recorder were installed to determine the depth to water during development and test pumping.

On November 22 and 23, the well was pumped for 6 hours at rates of as much as 1,130 gpm. During this time the well was occasionally surged to free sand and silt from the gravel pack (table 8). At the end of the first 2 hours the gravel pack had lowered 2 feet and the water was carrying small amounts of sand and silt. After 6 hours pumping and surging the gravel pack was stable and only trace amounts of sand were observed in the water. No measureable amount of sand accumulated in the well during this development.

On November 25, the well was pumped continuously for 5 hours at an average rate of 1,010 gpm. After 5 hours the total drawdown was 23 feet (table 9).

On December 13, a second set of stereoscopic pictures were taken of the screen sections. The screen sections of the well all showed a definite improvement in the removal of encrustation. The screen, however below a depth of 650 feet still shows some encrustation. The intervals 678 to 688 feet and 866 to 886 feet appeared to be badly deteriorated and encrusted.

Conclusions and recommendations

During the initial phases of redevelopment some clay and sand were removed from the well and the gravel pack dropped 2 feet. The gravel pack stabilized and during the remainder of the redevelopment procedures only small amounts of clay and sand were removed.

Much of the encrustation of the screen sections was removed and the performance of the well was improved by the redevelopment procedures.

The results of the final pumping test on November 25, 1966, are given graphically in figures 6 and 7. They indicate that the well is capable of producing 1,000 gpm with a drawdown of about 25 feet. A pumping rate of 800 gpm should result in a drawdown of about 20 feet and would be better suited to longer durations of pumping.

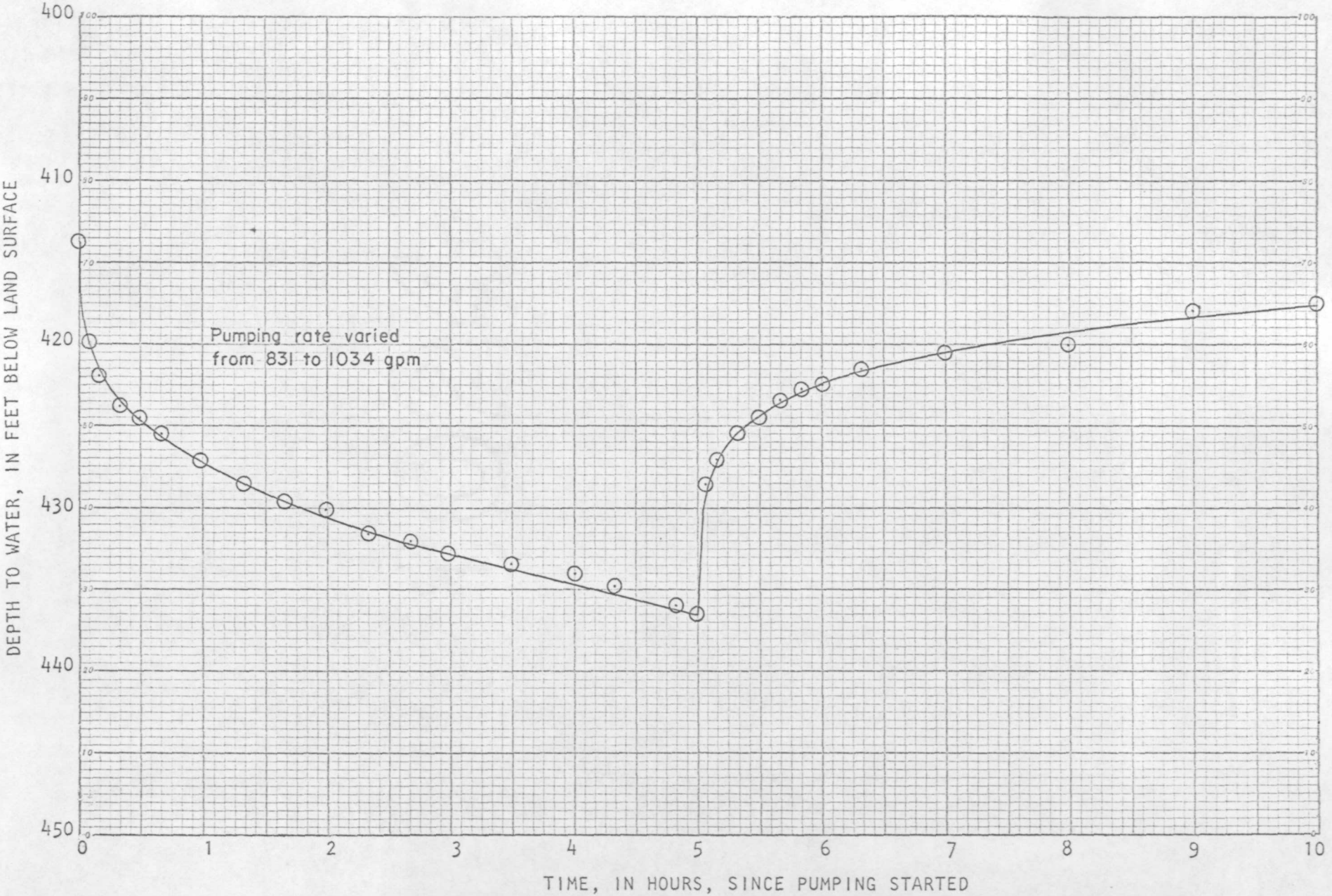

Figure 6.--Drawdown and recovery curve from pumping test of well 16 on November 25, 1966, after rehabilitation.

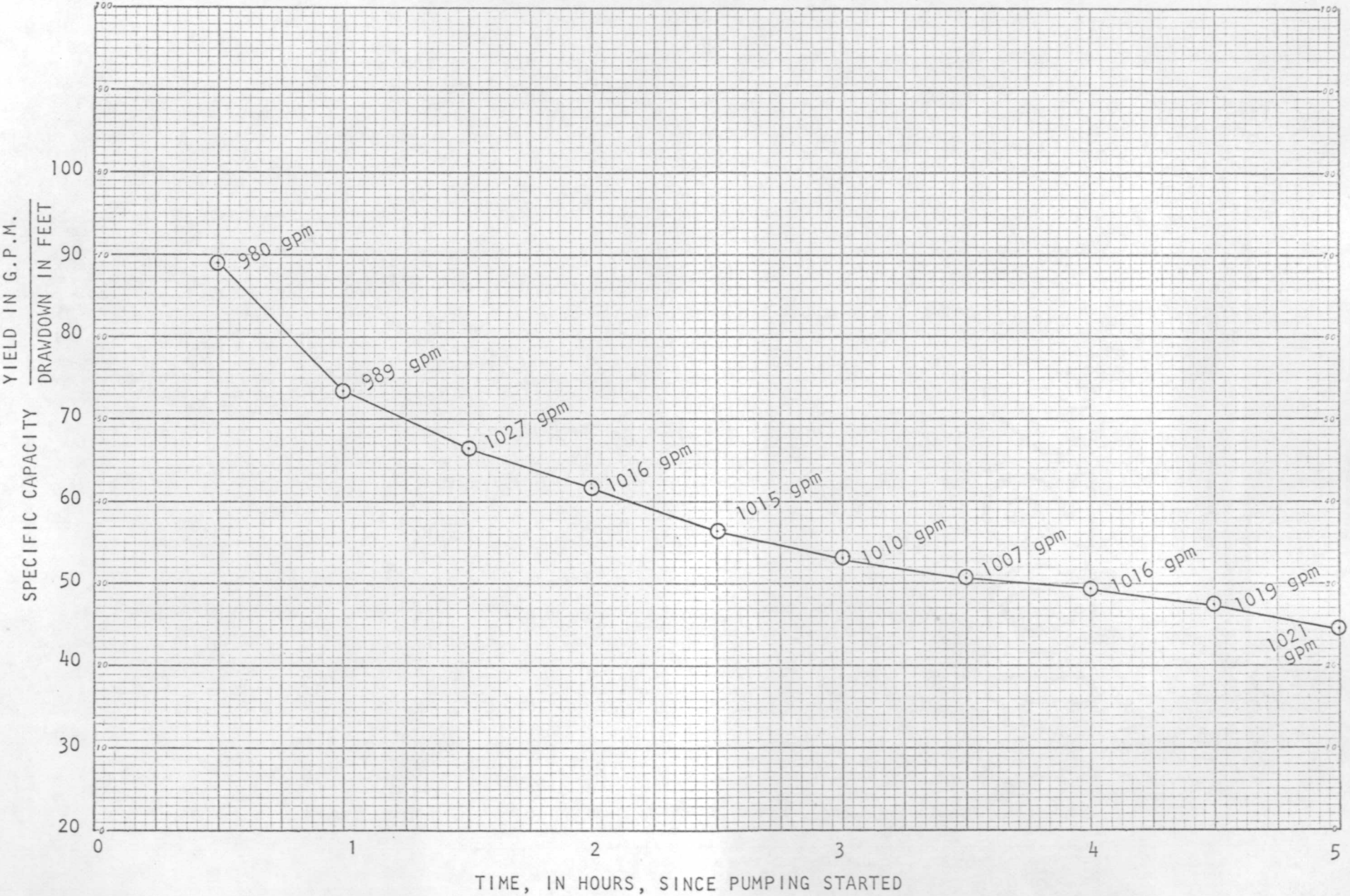

Figure 7.--Specific-capacity curve from pumping test of Well 16 on November 25, 1966, after rehabilitation.

Well 17

Well 17 was drilled in 1960 to a depth of 900 feet. It was cased with 14-inch diameter casing and 14-inch ("Moss") shutter screen. The screen was placed at depths of 436 to 460 feet, 478 to 490 feet, 500 to 536 feet, 556 to 580 feet, 624 to 660 feet, 670 to 706 feet, 730 to 742 feet, 754 to 802 feet, and 814 to 886 feet. The well was gravel packed. Upon completion the contractor, Layne-Texas Co., Inc., tested the well by step pumping. The test steps were at rates of 420, 615, 812, 1,007, 1,170, and 1,000 gpm. The first five steps were 6 hours in duration and the final step 12 hours. The drawdown of the water level at the end of each step was 11, 20, 29, 36, 44, and 46 feet respectively.

In 1962 the reported production pumping rate was 700 gpm and in 1964 was 682 gpm. In September 1966, the well was pumped 5 hours at an average rate of 658 gpm. The drawdown after 5 hours was about 17.5 feet (table 10).

In November and December 1966, the following procedures were followed in the rehabilitation of the well.

Procedures and results

In November 1966, the production pump was removed and the well was sounded. It was found that the lower 15 feet of the well was filled with sand.

On November 8, stereoscopic pictures were taken of the screen section of the well. The pictures showed the screen to be free of excessive encrustation and deterioration. In a few intervals the blank casing was badly encrusted, but the condition of the casing and screen was generally indicated to be good.

On November 29, the well was treated with Laynite. Three hundred pounds of dry Laynite were dissolved in water and poured into the well and 1 hundred pounds were dissolved and poured into the gravel pack. The gravel pack was then flushed with 1,000 gallons of water so as to distribute the Laynite throughout the gravel pack. The well was then surged for 2 hours with a bailer.

After remaining undisturbed for 24 hours, the well was surged with a bailer for an additional 4 hours. During this process the well was cleaned out to a depth of 900 feet.

The production pump was installed with the top of the bowl assembly and the bottom of the airline set at 530 feet. A direct reading airline gage and a continuous-type airline recorder were installed to measure the depth to water during development and test pumping. The well was also accessible for electric-tape measurements. Measurements recorded during the pump test on September 22, and December 8, 1966 are electric-tape readings. Measurements recorded during well development by pumping and surging on December 6, 1966, are airline readings taken from the direct reading gage and interpreted in part from the airline recorder charts.

On December 6, the well was pumped for 6 hours at rates up to about 800 gpm. The well was frequently surged to free clay and sand in the gravel pack (table 11). During these development procedures the gravel pack had not moved and only a small amount of clay and sand was removed from the well.

On December 8, the well was pumped for 5 hours at an average rate of 768 gpm. The drawdown after 5 hours was 23 feet (table 12).

Conclusions and recommendations

During the redevelopment operations only small amounts of clay and sand were removed from the well; the gravel pack was not lowered. The well definitely was in better physical condition than Wells 13, 15, and 16 and at the time of rehabilitation and needed only the routine procedures of washing the gravel pack and removing the accumulated fill and encrustation.

The results of the final pumping test on December 8, 1966, are given graphically in figures 8 and 9. They indicate the well is capable of producing more than 750 gpm. A pumping rate of 750 gpm should result in a drawdown of less than 25 feet.

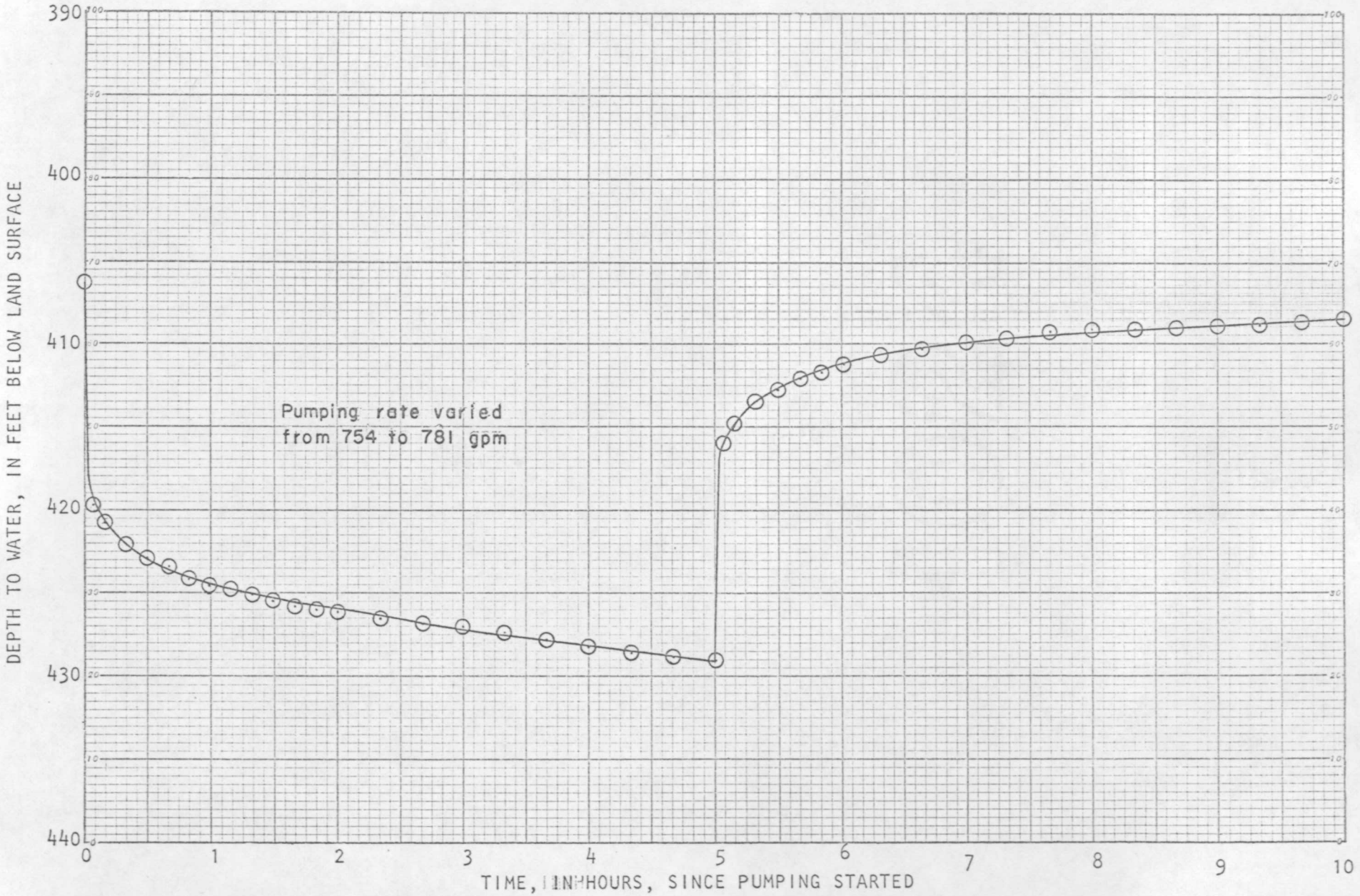

Figure 8.--Drawdown and recovery curve from pumping test of Well 17 on December 8, 1066, after rehabilitation.

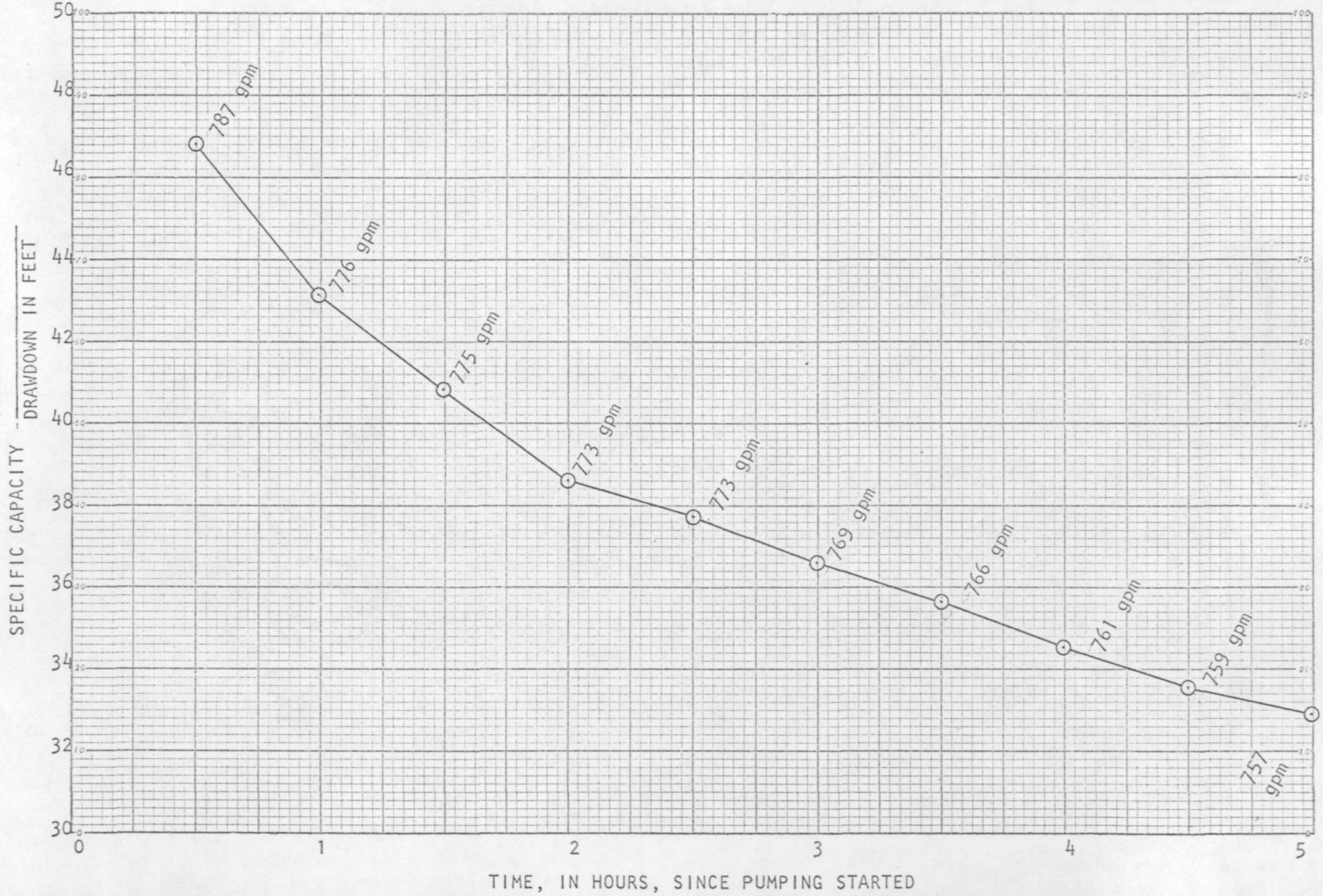

Figure 9.--Specific-capacity curve from pumping test of Well 17 on December 8, 1966, after rehabilitation.

Yield and drawdown characteristics

Calculations were made by the nonequilibrium formula derived by Theis (Ferris and others, 1962, p. 92) to determine the amount of drawdown that might be expected in Wells 13, 15, 16, and 17 when the wells were pumped at the rates of yield, and for time periods, similar to the actual test made on the wells prior to rehabilitation. Coefficients of transmissibility for each well, and an average value for the coefficient of storage for the aquifer, were obtained from W. C. Ballance (oral communication), who has recently made an analog model study of the well field area. It was assumed that each well has an effective diameter of 2 feet. A pumping time of 5 hours for each well was used in the calculations so that direct comparison could be made between the theoretical and actual drawdowns. The values used in the calculations for the coefficient of transmissibility, coefficient of storage, and yield for each well are given below:

Well number	Transmissibility	Storage	Yield (gpm)
13	5,000	0.17	200
15	28,300	.17	650
16	33,000	.17	800
17	30,000	.17	650

Actual drawdown figures obtained from the pump test prior to rehabilitation, and the calculated values of drawdown are as follows:

Well number	Actual drawdown (feet)	Calculated drawdown (feet)
13	25.5	33.0
15	24.0	24.3
16	18.5	26.1
17	17.8	23.1

With the exception of Well 15, calculated drawdowns are much greater than the actual drawdowns observed during the pump test. This indicates that one or more of the values used in the calculations is not valid. Inasmuch as values for the coefficients of transmissibility and storage were obtained from direct field observations they are likely to be more nearly accurate than the value assumed for the effective diameter of the wells, which was not subject to direct observation and measurement. Thus, the radius of thorough development of the gravel pack and surrounding aquifer material around Wells 13, 16, and 17 is suspected to be more than the one foot assumed in the calculations, and may be as much as from 3 to 5 feet.

Data from pump tests, before and after rehabilitation, and the procedures employed during rehabilitation are tabulated for comparison in table 13.

These data indicate a decrease of specific capacity for all wells except Well 16, where a slight increase is noted. The substantial drop in the specific capacity of Wells 13 and 15 cannot be fully explained. Several factors that may be responsible for at least some of the indicated decrease in efficiency are noted here.

1) It is possible that the gravel pack and surrounding water-bearing material were by prior pumping developed to near optimum efficiency. During rehabilitation the material surrounding the well could have been rearranged and compacted so as to cause the well to have a substantially lower specific capacity after rehabilitation than before.

2) The method of measuring discharge rates during the testing of the wells varied. Before rehabilitation of the wells, discharge was measured by an accumulative-type water meter installed in the water distribution system at each well. During and after rehabilitation, discharge was measured by an orifice plate. It was not determined if comparable discharge measurements were obtained from the two methods used.

3) Each well was pumped at a higher rate of discharge after rehabilitation than before rehabilitation. The specific capacity of a well commonly decreases as discharge is increased.

4) Depth-to-water measurements in Wells 13, 15, and 16 were determined from an airline installed in the well. Prior to rehabilitation the water level in the wells could not be measured by direct tape readings. Thus, it was not possible to determine the accuracy of reading obtained by airline. It is possible that in one or more of these wells the reported length of the airlines was in error, or that the airline was defective; either case would result in erroneous readings.

The down-hole photographs revealed that the perforated casing sections had become encrusted and plugged to some extent in each well. Well 17 was the cleanest well of the four; Well 13 had only a few feet of apparent open perforations. The photographs are a useful permanent record of the condition of the well and should be preserved as an aid in determining the extent of deterioration during the pumping period prior to the next rehabilitation.

Procedures that may be helpful during future well rehabilitation work, particularly for comparing the efficiency of the well before and after rehabilitation are:

1) Prior to rehabilitation of wells in the future it seems advisable to pump test the well under controlled conditions, and to compare results of the pump test with the calculated values of drawdown that might be expected. This would indicate whether or not the well is functioning at or near its expected efficiency, and would be a factor in determining whether or not increased yield from the well could be obtained by rehabilitation procedures. If it appears that increased yield could not be expected, no particular advantage would be gained by surging and pumping procedures, and these operations, in individual wells, might be eliminated, or held to a minimum.

2) Pumping rates before and after rehabilitation should be measured by using an orifice plate. This method provides a constant means of measuring discharge and also allows direct observations of sand, air, or other abnormalties in the water discharged from the well.

3) Discharge rates maintained during pumping tests made before and after rehabilitation in a well should be the same. This would enable direct comparision of specific capacities based upon similiar testing conditions.

4) Depth-to-water measurements should be made by a steel tape, or accurate electrical measuring devices throughout pumping tests both before and after rehabilitation. This would eliminate possible errors caused by airline malfunction.

Regardless of the potential for increasing the yield of a well by development procedures, periodic examination of the well casing, and gravel pack examination of pumping equipment and replacement of defective portions, and pump testing the well will result in the knowledge that the well is structurally sound, is capable of optimum water yield, is equipped with an efficient pump, and is subject to less untimely and unexpected breakdowns. For the long term, periodic examination and rehabilitation of water wells is certainly the most efficient way to insure that future water demands will be met when needed and may prove to be far more economical than rehabilitating wells under a "crash program" after total well failure.

Thus, periodic examination of water-supply wells at White Sands Missile Range, as planned by those in charge of the water supply for the Base, is considered to be highly desirable and is recommended as a continuing practice.

References

Herrick, E. H., 1960, Rehabilitation of wells in the Headquarters Area, White Sands Proving Ground, Dona Ana County, New Mexico: U.S. Geol Survey open-file rept., 26 p., 7 figs.

Ferris, J. G., and others, 1962, Theory of aquifer tests: U.S. Geol. Survey Water Supply Paper 1536-E, 174 p., 45 figs.

Table 1.--Pumping test of Well 13, before rehabilitation.

Time	Depth to water (feet below land surface)	Remarks
12/15/66		
0800	324.5	Static water level
0825	324.5	Do.
0830	--	Started pump
0831	344.0	Drawdown measurements
0832	341.5	Pumping rate is 228 gpm
0833	341.2	
0834	341.2	--
0835	341.5	--
0836	341.5	--
0838	342.0	--
0840	343.0	--
0845	343.2	--
0850	344.0	--
0900	345.0	--
0910	345.8	--
0920	345.8	--
0930	346.5	--
0940	346.5	--
1000	347.0	--
1030	348.0	--
1100	348.5	--
1130	349.0	--
1200	349.5	--

Table 1.--Pumping test of Well 13, before rehabilitation, - Concluded

Time	Depth to water (feet below land surface)	Remarks
12/16/66		
1230	349.8	--
1300	350.0	--
1330	350.0	Stopped pump recovery measurements
1331	337.5	Recovery - measurements
1332	335.5	--
1333	332.8	--
1334	330.0	--
1335	328.5	--
1336	328.5	--
1338	328.5	--
1340	328.5	--
1345	327.8	--
1350	327.8	--
1400	327.8	--
1430	326.8	--
1500	326.5	--
1530	326.0	--
1600	326.0	--
1630	326.0	--
1700	326.0	--
1730	325.0	--
1800	325.0	--
1830	325.0	--
0700	324.5	End of test

Table 2.--Development by pumping of Well 13, during rehabilitation

Time	Depth to water (feet below land surface)	Pumping rate (gpm)	Sediment content of water (milliliter per liter)	Remarks
2/9/67				
1145	316.5	--	--	Static water level
1245	--	--	--	Started pump
1250	--	200±	0.2	Pipe scale
1255	--	200±	.2	Scale and sand
1300	--	200±	200.0	Scale-little sand
				Development suspended for mechanical adjustments to increase pumping rate
2/13/67				
0930	318.5	--	--	Static water level
0932	--	--	--	Started pump
0934	376.5	393	10.0	Scale
0938	--	378	.25	--
0940	--	393	.20	--
0942	--	425	.05	--
0945	412.0	430	.20	Water rusty
0955	425.0	430	.10	--
1005	439.5	430	.05	--
				Surged 4 times
1014	--	372	.05	Scale
1016	--	372	.10	--
1020	382.0	366	.05	--

Table 2.--Development by pumping of Well 13, during rehabilitation (Continued)

Time	Depth to water (feet below land surface)	Pumping rate (gpm)	Sediment content of water (milliliter per liter)	Remarks
2/13/67				
1025	386.0	361	0.05	Water milky
1030	391.0	372	< .05	--
1040	396.5	366	Trace	Water, milky with gas
1050	399.5	366	do.	Do.
1100	401.0	361	do.	--
1102				Pumping stopped for mechanical adjustments
1117	--	--	--	Surged 6 times
1135	--	408	Trace	Water rusty
1141	390.0	406	.10	--
1145	396.5	401	.20	--
1150	406.0	411	.05	--
1155	414.0	401	Trace	--
1156	--	--	--	Surged 6 times
1220	--	--	--	Surged 8 times
1250	--	299	.20	Began step test
1255	358.5	282	.10	--
1300	360.0	295	.05	--
1305	360.0	289	.05	--
1310	360.0	292	Trace	--

Table 2.--Development by pumping of Well 13, during rehabilitation (Concluded)

Time	Depth to water (feet below land surface)	Pumping rate (gpm)	Sediment content of water (milliliter per liter)	Remarks
2/13/67				
1315	360.0	292	Trace	--
1320	361.0	289	do.	--
1325	361.0	289	--	--
1330	361.0	289	Trace	--
1331	--	326	--	--
1335	368.8	320	0.05	--
1340	370	332	Trace	--
1345	371	332	do.	--
1350	371	332	do.	--
1355	371.2	332	do.	--
1400	371.2	332	do.	--
1410	372.5	332	do.	--
1420	373.5	332	do.	--
1430	372.8	329	--	--
1431	--	375	--	--
1435	389.0	375	.10	--
1440	392.0	375	Trace	--
1445	395.2	366	do.	Much air in water
1450	397.5	375	do.	Do.
1455	400.5	375	do.	Do.
1500	401.5	366	do.	Do.
1510	406.8	375	do.	Do.
1520	411.0	375	do.	Do.
1530	413.0	375	do.	Do. End of test and development pumping

Table 3.--Pumping test of Well 13, after rehabilitation

Time	Depth to water (feet below land surface)	Pumping rate (gpm)	Sediment content of water (milliliter per liter)	Remarks
2/14/67				
0920	318.5	--	--	Static water level
0921	347.0	--	--	Started pump
0922	352.0	--	--	--
0923	371.5	--	--	--
0924	366.5	--	--	--
0925	369.0	--	--	--
0926	369.0	--	0.05	--
0927	369.0	--	--	--
0928	370.0	--	--	--
0929	370.0	--	--	--
0930	371.0	369	< .05	--
0932	371.5	--	--	--
0934	373.0	--	--	--
0936	373.0	--	< .05	--
0938	373.5	--	--	--
0940	373.5	--	Trace	--
0945	373.5	366	do.	--
0950	375.5	369	do.	--
0955	378.5	372	do.	--
1000	380.5	375	do.	--
1010	379.0	366	do.	Air in water

Table 3.--Pumping test of Well 13, after rehabilitation (Continued)

Time	Depth to water (feet below land surface)	Pumping rate (gpm)	Sediment content of water (milliliter per liter)	Remarks
2/14/67				
1020	383.0	372	Trace	Air in water
1030	384.0	363	do.	Do.
1040	383.0	366	do.	Do.
1050	385.0	369	do.	Do.
1100	386.0	369	do.	Do.
1120	388.5	369	Few grains	Do.
1140	391.0	--	--	--
1200	392.0	--	--	--
1220	395.5	--	--	--
1240	398.5	--	--	--
1300	400.0	360	<0.05	--
1320	414.0	372	Trace	--
1340	418.5	372	do.	--
1400	420.5	369	Few grains	--
1420	422.0	369	--	Stopped pumping
1421	401.5	--	--	Recovery measurements
1422	394.5	--	--	--
1423	389.0	--	--	--
1424	382.5	--	--	--
1425	375.5	--	--	--

Table 3.--Pumping test of Well 13 after rehabilitation (Continued)

Time	Depth to water (feet below land surface)	Pumping rate (gpm)	Sediment content of water (milliliter per liter)	Remarks
2/14/67				
1426	369.0	--	--	--
1427	362.0	--	--	--
1428	357.0	--	--	--
1429	350.0	--	--	--
1430	345.0	--	--	--
1432	337.0	--	--	--
1434	325.0	--	--	--
1436	325.0	--	--	--
1438	325.0	--	--	--
1440	325.0	--	--	--
1445	324.5	--	--	--
1450	324.5	--	--	--
1500	324.5	--	--	--
1510	323.5	--	--	--
1520	322.5	--	--	--
1540	322.5	--	--	--
1600	322.0	--	--	--
1620	322.0	--	--	--
1640	322.0	--	--	--
1700	321.0	--	--	--
1740	321.0	--	--	--

Table 3.--Pumping test of Well 13, after rehabilitation (Concluded)

Time	Depth to water (feet below land surface)	Pumping rate (gpm)	Sediment content of water (milliliter per liter)	Remarks
2/14/67				
1800	320.0	--	--	--
1820	320.0	--	--	--
1840	320.0	--	--	--
1900	320.0	--	--	--
1920	320.0	--	--	End of test.

Table 4.--Pumping test of Well 15, before rehabilitation.

Time	Depth to water (feet below land surface)	Remarks
12/2/66		
0830	413.0	Static water level
0840	413.0	Do.
0841	425.0	Pumping started
0842	425.0	Drawdown measurements
0843	425.0	Pumping rate 650 gpm --
0844	425.0	--
0845	426.0	--
0846	426.0	--
0848	427.5	--
0850	427.5	--
0900	427.5	--
0910	430.0	--
0920	431.0	--
0930	432.0	--
0940	432.0	--
1010	433.5	--
1110	435.0	--
1210	436.0	--
1340	437.0	Pumping stopped
1341	428.5	Recovery measurements
1342	424.0	--
1343	422.0	--
1344	422.0	--

Table 4.--Pumping test of Well 15, before rehabilitation, (Concluded)

Time	Depth to water (feet below land surface)	Remarks
12/2/66		
1345	422.0	--
1350	421.0	--
1355	420.0	--
1400	419.5	--
1430	416.5	--
1500	415.5	--
1530	415.5	--
1600	414.5	--
1630	414.5	--
1700	414.5	--
1730	414.5	--
1800	414.0	--
1840	414.0	End of test
12/5/66		
1400	412.0	Static water level.

Table 5.--Development by pumping of Well 15, during rehabilitation

Time	Depth to water (feet below land surface)	Pumping rate (gpm)	Sediment content of water (milliliter per liter)	Remarks
12/21/66				
0730	402.5	--	--	Static water level
0800	402.5	--	--	Do.
0930	402.2	--	--	Do.
1000	402.2	--	--	Do.
1020	--	--	--	Started pumping
1023	411.8	760	2.00	Muddy
--	--	--	--	Surged
1025	--	760	--	--
1030	--	--	.40	Muddy, very sudsy
1040	--	--	1.25	Do.
1042	422.2	--	--	--
--	--	--	--	Surged
1050	--	--	--	Started pumping
1100	--	680	.50	Muddy, very sudsy
1115	--	--	.10	Cloudy, very sudsy
1116	418.5	--	--	--
--	--	--	--	Surged
1121	--	618	1.30	Cloudy, very sudsy
1125	--	--	--	--
1130	418.5	--	Trace	Cloudy, very sudsy
--	--	--	--	Surged

Table 5.--Development by pumping of Well 15, during rehabilitation-Continued

Time	Depth to water (feet below land surface)	Pumping rate (gpm)	Sediment content of water (milliliter per liter)	Remarks
12-21-66				
1200	416.8	--	--	--
--	--	--	--	Surged
1230	416.8	--	--	--
--	--	--	--	Surged
1235	--	645	2.00	Muddy, sudsy
1245	--	--	.30	Cloudy, sudsy
1250	420.0	--	--	--
--	--	--	--	Surged
1255	--	750	1.40	Very muddy, sudsy
1300	--	750	.30	Cloudy, sudsy
1305	--	750	.20	Do.
1309	422.5	--	--	--
--	--	--	--	Surged
1316	--	672	1.25	Muddy, sudsy
1330	422.5	--	--	--
--	--	--	--	Surged
1350	425.5	--	--	--
--	--	--	--	Surged
1400	--	650	4.00	Very muddy, sudsy
1405	--	650	.70	Cloudy, sudsy
1410	--	650	.30	Do.

Table 5.--Development by pumping of Well 15, during rehabilitation - Continued

Time	Depth to water (feet below land surface)	Pumping rate (gpm)	Sediment content of water (milliliter per liter)	Remarks
12-21-66				
1418	429.0	--	--	--
--	--	--	--	Surged
1424	--	636	50.00	--
1425	--	636	20.00	Very muddy, sudsy
1435	--	636	1.00	Muddy, sudsy
1540	437.2	--	--	--
--	--	--	--	Surged
1545	--	--	> 50.00	--
1550	--	200±	--	--
1555	--	--	1.00	--
1557	--	350±	8.00	--
1559	--	--	4.50	--
1600	418.5	--	--	--
--	--	--	--	Pump locked
1604	--	200±	--	--
1607	--	--	5.00	--
1609	421.8	--	--	--
--	--	--	--	Pump locked
12-22-66				
0948	--	250±	Trace	Began pumping
0953	--	--	--	Cloudy

Table 5.--Development by pumping of Well 15, during rehabilitation-Continued

Time	Depth to water (feet below land surface)	Pumping rate (gpm)	Sediment content of water (milliliter per liter)	Remarks
12-22-66				
--	--	--	--	Pump locked, impellers adjusted
1022	--	--	--	Pump locked after running 15 seconds, impellers adjusted
1026	--	--	--	Do.
1031	--	--	--	Pump locked after running one minute, impellers adjusted
1036	--	250±	--	--
1040	--	250±	0.10	--
1041	--	250±	.10	--
1042	--	250±	.10	--
1043	--	250±	.10	--
1044	--	250±	.10	--
1046	--	250±	.10	--
1048	--	--	2.50	--
--	--	--	--	Pump locked, impellers adjusted
1059	--	--	--	--
--	--	--	--	Pump locked after 45 seconds
1101	--	250±	--	--
1105	--	250±	8.00	--

Table 5.--Development by pumping of Well 15, during rehabilitation-Continued

Time	Depth to water (feet below land surface)	Pumping rate (gpm)	Sediment content of water (milliliter per liter)	Remarks
12-22-66				
1110	--	250±	1.50	--
1112	--	--	--	--
--	--	--	--	Pump locked, impellers adjusted
1117	--	200±	--	--
1125	--	200±	.1	--
1130	--	200±	.5	--
1135	--	200±	.5	--
1142	409.8	200±	--	--
1145	--	200±	.5	--
1200	410.0	--	--	--
1230	410.0	--	--	--
1245	410.0	--	--	Increased pumping rate
1300	416.8	458	1.25	Some granule gravel
1315	--	458	1.00	Some magnetite
1317	419.8	672	--	Almost clear, some suds
1321	--	672	.90	Cloudy
1325	--	--	.60	Little magnetite
1330	427.8	--	--	--
1336	428.8	--	--	--

Table 5.--Development by pumping of Well 15, during rehabilitation-Continued

Time	Depth to water (feet below land surface)	Pumping rate (gpm)	Sediment content of water (milliliter per liter)	Remarks
12-22-66				
--	--	--	--	Pump locked
1347	--	--	0.20	--
--	--	--	--	Pump locked after pumping 7 minutes, impellers adjusted
1353	--	--	--	Pump locked after pumping 30 seconds
1400	--	--	--	Do.
1402	--	--	--	Do.
1407	--	250±	--	--
1415	--	250±	3.00	--
1420	413.2	250±	2.00	Pump locked
				After 1420 hours, eight attempts were made to sustain pumping. Two-ten minute periods of pumping at low rates produced about 3 milliliter per liter sand and scale.
1-17-67				
1415	402.5	--	--	Static water level
1429	--	450±	--	--
1432	--	458	2.00	Muddy
1433	--	458	2.00	Do.

Table 5.--Development by pumping of Well 15, during rehabilitation - Continued

Time	Depth to water (feet below land surface)	Pumping rate (gpm)	Sediment content of water (milliliter per liter)	Remarks
1-17-67				
1435	--	--	2.25	--
1438	--	521	.40	Cloudy
1442	--	--	.10	--
1445	427.8	--	--	--
1447	--	--	.25	--
1450	--	533	.20	--
1452	--	458	.10	--
1515	--	458	.05	--
1516	426.8	--	--	--
1530	--	458	.05	Clear
1535	--	--	--	Cloudy
1545	--	458	Trace	Muddy
1600	--	458	do.	Cloudy
1615	--	458	do.	Do.
1625	429.0	--	--	--
1630	--	458	Trace	Cloudy
1-18-67				
0830	--	500±	--	Do.
0915	--	--	--	Muddy, cleared to cloudy
0955	--	--	.20	--

Table 5.--Development by pumping of Well 15, during rehabilitation - Continued

Time	Depth to water (feet below land surface)	Pumping rate (gpm)	Sediment content of water (milliliter per liter)	Remarks
1-18-67				
1005	432.2	483	--	--
1010	--	545	--	--
1015	--	545	0.30	Muddy
1030	438.0	545	.30	Cloudy
1045	--	545	.25	--
1100	439.5	545	.30	--
1115	--	545	.20	--
1130	--	545	.30	--
1200	--	545	.20	Clear
1215	--	609	--	--
1220	447.0	609	.20	Cloudy
1230	--	--	.25	--
1240	--	609	.25	--
1250	--	654	.25	--
1300	--	654	.25	--
1305	--	654	.40	--
1307	--	654	.60	--
1310	--	654	.70	--
1320	--	--	.60	--
1335	453.2	654	.35	--
1350	--	654	.30	--

Table 5.--Development by pumping of Well 15, during rehabilitation-Continued

Time	Depth to water (feet below land surface)	Pumping rate (gpm)	Sediment content of water (milliliter per liter)	Remarks
1-18-67				
1400	--	654	0.30	--
1405	--	726	--	--
1415	--	726	--	--
1420	--	726	.50	--
1425	--	726	.40	--
1430	463.0	726	.40	--
1445	--	717	.45	--
1500	--	717	.50	--
1515	--	708	.30	--
1530	--	708	.25	--
1535	--	791	--	--
1540	--	791	.30	--
1545	--	784	.45	--
1547	473.0	--	--	Surged
1553	--	735	1.00	--
1554	--	735	.75	--
1555	--	735	1.00	--
1600	--	735	.50	--
1605	--	--	--	Surged
1607	--	735	--	--

Table 5.--Development by pumping of Well 15, during rehabilitation-Continued

Time	Depth to water (feet below land surface)	Pumping rate (gpm)	Sediment content of water (milliliter per liter)	Remarks
1-18-67				
1610	--	735	1.50	--
1612	--	735	.75	--
1615	--	735	.50	--
1620	--	735	.45	--
1625	--	--	.70	--
1630	--	--	.60	--
1-19-67				
0900	407.0	--	--	--
0905	--	600±	--	--
0908	--	609	.80	Cloudy
0910	--	578	1.25	Muddy
0915	--	533	.20	Cloudy
0916	--	681	--	Do.
0918	434.5	--	--	--
--	--	--	--	Surged
0920	--	636	--	--
0924	--	545	2.50	Muddy
0926	--	545	1.25	Cloudy
0930	427.8	--	--	--
--	--	--	--	Surged

Table 5.--Development by pumping of Well 15, during rehabilitation-Continued

Time	Depth to water (feet below land surface)	Pumping rate (gpm)	Sediment content of water (milliliter per liter)	Remarks
1-19-67				
0940	438.0	--	--	--
--	--	--	--	Surged
0955	443.0	--	--	--
--	--	--	--	Surged
0957	--	844	0.30	Cloudy
1000	--	--	.40	Do.
1005	--	851	.30	Do.
1010	--	851	.50	Do.
1015	--	831	.70	Do.
1020	--	831	1.00	Do.
1025	--	708	.80	Do.
1027	459.0	708	.70	Do.
--	--	--	--	Surged
1030	--	791	.80	Muddy
--	--	--	--	Gravel pack has moved about six inches
1035	--	784	.25	Muddy
1040	--	776	.25	Do.
1045	--	776	.30	Cloudy
1050	454.8	776	.25	Do.
--	--	--	--	Surged 3 times

Table 5.--Development by pumping of Well 15, during rehabilitation-Continued

Time	Depth to water (feet below land surface)	Pumping rate (gpm)	Sediment content of water (milliliter per liter)	Remarks
1-19-67				
1102	--	937	0.80	Muddy
1107	--	943	.30	--
1110	--	943	.30	--
1112	--	--	.90	--
1118	472.5	--	--	--
--	--	--	--	Surged 3 times
1130	--	961	1.20	--
1133	--	949	.30	--
1138	--	949	.30	--
1145	468.5	--	--	--
--	--	--	--	Surged 3 times
1217	452.0	--	--	--
--	--	--	--	Surged 3 times
1230	--	1001	.40	Muddy
1235	--	985	.25	Do.
1240	462.5	979	.40	Cloudy
--	--	--	--	Surged 3 times
1252	--	979	.30	Muddy
1255	--	967	.20	Cloudy
1300	--	955	.10	Do.
1305	458.5	943	.30	Do.
--	--	--	--	Surged 5 times

Table 5.--Development by pumping of Well 15, during rehabilitation-Continued

Time	Depth to water (feet below land surface)	Pumping rate (gpm)	sediment content of water (milliliter per liter)	Remarks
1/19/67				
1330		760	0.30	--
1335	436.5	760	.25	Cloudy
--		--	--	Surged-checked equipment
1340	--	812	.10	Cloudy
1345	442.0	805	.20	Do.
--	--	--	--	Surged twice
1355	--	838	.20	Cloudy
1400	--	825	.10	Do.
1405	442.0	825	.10	Cloudy
--	--	--	--	Surged 5 times
1425	--	831	.25	Cloudy
1430	--	831	.10	Do.
1435	--	825	<.10	Do.
1440	441.0	818	<.10	Do.
--	--	--	--	Surged 4 times
1455	--	831	.20	Cloudy
1505	433.5	--	--	--
--	--	--	--	Surged 3 times
1525	--	831	--	--
1526	--	831	.20	Cloudy
1528	442.0	818	--	Do.
--	--	--	--	Surged 3 times

Table 5.--Development by pumping of Well 15, during rehabilitation-Concluded

Time	Depth to water (feet below land surface)	Pumping rate (gpm)	Sediment content of water (milliliter per liter)	Remarks
1-19-67				
1552	--	838	0.30	Cloudy
1558	--	--	.10	Do.
1600	420.0	--	--	Do.
1601	--	--	--	--
--	--	--	--	Pump locked
1604	--	844	--	Cloudy
1607	--	--	.30	Cloudy
1609	--	831	--	Do.
--	--	--	--	Pump locked
1614	--	699	--	Cloudy
1619	--	699	--	Do.
1621	--	672	--	Do.
1630	435.0	--	--	--
1645	436.5	--	--	--
--	--	--	--	Stopped pumping
--	--	--	--	End of development by pumping

Table 6.--Pumping test of Well 15, after rehabilitation

Time	Depth to water (feet below land surface)	Pumping rate (gpm)	Sediment content of water (milliliter per liter)	Remarks
1/20/67				
1115	405.0	--	--	Static water level
1125	--	--	--	Started pump
1126	414.2	--	--	Drawdown measurements
1127	414.2	--	--	--
1128	418.5	--	--	--
1129	421.0	--	--	--
1130	421.5	--	--	--
1131	422.0	--	--	--
1132	423.5	--	--	--
1133	424.0	--	--	--
1134	424.5	--	--	--
1135	424.5	768	0.20	Cloudy
1137	425.5	--	--	--
1139	426.0	--	--	Clear
1141	426.5	--	--	--
1143	427.0	--	--	--
1145	427.8	760	Trace	Clear
1150	429.0	760	--	--
1155	430.0	760	Trace	--
1200	430.8	760	--	--
1205	431.2	760	--	--
1210	432.0	760	--	--

Table 6.--Pumping test of Well 15, after rehabilitation (Continued)

Time	Depth to water (feet below land surface)	Pumping rate (gpm)	Sediment content of water (milliliter per liter)	Remarks
1/20/67				
1215	432.8	--	--	--
1225	434.0	760	Few grains	--
1235	434.5	--	--	--
1245	435.5	--	--	--
1255	436.0	752	Few grains	--
1305	436.8	752	None	--
1325	438.0	752	--	--
1345	439.2	752	--	--
1405	440.0	--	--	--
1425	440.8	752	None	--
1445	442.0	752	--	--
1505	442.5	752	None	--
1525	443.2	752	do.	--
1545	444.0	752	--	--
1605	444.8	752	--	--
1625	445.5	752	None	--
--	--	--	--	Pumping stopped
1626	436.0	--	--	Recovery measurements
1627	431.0	--	--	--
1628	427.8	--	--	--

Table 6.--Pumping test of Well 15, after rehabilitation (Continued)

Time	Depth to water (feet below land surface)	Pumping rate (gpm)	Sediment content of water (milliliter per liter)	Remarks
1/20/67				
1629	424.5	--	--	--
1630	421.0	--	--	--
1631	420.0	--	--	--
1632	419.5	--	--	--
1633	418.8	--	--	--
1634	418.5	--	--	--
1635	418.0	--	--	--
1636	417.5	--	--	--
1637	417.5	--	--	--
1639	416.8	--	--	--
1641	416.8	--	--	--
1643	416.5	--	--	--
1645	416.0	--	--	--
1650	415.0	--	--	--
1655	414.2	--	--	--
1705	413.5	--	--	--
1715	412.5	--	--	--
1725	412.0	--	--	--
1755	410.5	--	--	--

Table 6.--Pumping test of Well 15, after rehabilitation (Concluded)

Time	Depth to water (feet below land surface)	Pumping rate (gpm)	Sediment content of water (milliliter per liter)	Remarks
1/20/67				
1825	409.5	--	--	--
1925	408.5	--	--	--
2025	408.0	--	--	--
2125	407.5	--	--	--
1/21/67				
0225	406.8	--	--	--
0525	406.0	--	--	End of test.

Table 7.--Pumping test of Well 16, before rehabilitation.

Time	Depth to water (feet below land surface)	Remarks
11/3/66		
0755	419.0	Static water level
0800		Started pump
0801	424.5	Pumping rate is 800 gpm
0805	425.8	
0810	427.0	
0815	427.5	
0820	428.5	
0830	429.8	
0840	430.2	
0850	430.8	
0900	431.5	
0930	433.0	
1000	434.2	
1100	435.2	
1200	436.5	
1300	437.5	
1322	437.5	Stopped pump - End of test.

Table 8.--Development by pumping of Well 16, during rehabilitation

Time	Depth to water (feet below land surface)	Pumping rate (gpm)	Sediment content of water (milliliter per liter)	Remarks
11/22/66				
1450	--	857	1.70	Surged twice
1458	422.2	831	.50	Surged
1502	422.0	--	--	Surged twice
1512	421.5	--	--	Surged
1517	422.0	863	.70	--
1521	423.0	--	--	Surged
1527	423.0	--	--	Do.
1538	424.0	--	--	Do.
1543	424.0	834	1.00	--
1547	424.5	--	--	Surged
1552	424.0	802	1.00	--
1553	424.5	--	--	Surged
1600	425.0	869	1.00	--
1602	425.0	--	--	Surged
1608	425.0	895	.30	--
1610	425.5	--	--	Surged
1620	424.0	844	1.50	--
1624	425.0	--	--	Surged
1630	425.0	879	.80	Gravel pack down about 2 feet
1633	425.5	--	--	--
1640	425.0	844	--	Surged, and stopped pump

Table 8.--Development by pumping of Well 16, during rehabilitation (Continued)

Time	Depth to water (feet below land surface)	Pumping rate (gpm)	Sediment content of water (milliliter per liter)	Remarks
11/23/66				
0915	415.0	0	--	--
1016	--	--	--	Cloudy, some soap
1020	421.0	996	1.00	Cloudy, soapy
1023	423.0	1,001	.10	Do. Surged
1026	421.0	1,135	.50	--
1037	426.0	1,130	.20	--
1047	428.0	1,130	.10	--
1055	429.0	1,130	.10	--
1102	429.5	1,122	.10	--
1107	430.2	1,125	.20	Cloudy
1110	430.2	--	--	Surged twice
1115	426.0	931	.60	Cloudy, Surged twice
1125	427.0	1,034	.90	--
1130	429.0	1,034	.20	Surged
1138	428.0	1,078	.30	--
1140	429.0	--	--	Surged
1155	427.0	1,056	.70	--
1210	427.0	1,034	.90	Surged 3 times
1225	429.0	--	--	Surged
1232	429.0	--	--	Do.

Table 8.--Development by pumping of Well 16, during rehabilitation (Concluded)

Time	Depth to water (feet below land surface)	Pumping rate (gpm)	Sediment content of water (milliliter per liter)	Remarks
11/23/66				
1235	428.0	1,067	1.00	--
1242	430.0	1,067	.10	Cloudy
1246	431.0	1,067	.10	Do.
1249	431.0	1,067	< .10	Do.
1258	431.2	1,067	< .10	Cloudy, some soap
1259	431.2	--	--	Surged 5 times
1310	427.0	1,067	1.50	Very muddy
1315	429.0	1,062	.10	Cloudy, sudsy
1320	430.2	1,051	Trace	Cloudy
1325	431.2	1,051	Trace	Almost clear
1327	431.2	--	--	Surged twice
1346	427.0	1,050±	2.00	--
1347	427.0	--	--	Surged
1406	425.0	818	.40	--
1410	427.0	851	.10	Almost clear
1413	427.0	--	--	Surged
1422	427.0	974	.20	--
1423	427.0	863	--	Surged 3 times End of test

Table 9.--Pumping test of Well 16, after rehabilitation

Time	Depth to water (feet below land surface)	Pumping rate (gpm)	Sediment content of water (milliliter per liter)	Remarks
11/25/66				
1030	413.8	--	--	Static water level
1155	413.8	--	--	Do.
1156	--	--	--	--
1157	428.0	--	--	Started pump
1158	428.0	943	--	Pump stopped
1106	413.8	0	--	--
1107	418.10	831	--	Pump started
1108	418.5	831	--	Drawdown measurements
1109	419.0	869	0.10	Cloudy
1110	419.5	937	--	--
1111	420.0	985	--	--
1112	420.8	990	.10	Cloudy
1113	421.0	996	--	--
1114	421.2	996	--	--
1115	421.8	1,001	.10	Cloudy
1116	422.0	1,001	--	--
1118	422,2	996	--	--
1120	422.8	996	.05	Cloudy
1122	423.0	1,001	--	--
1124	423.0	998	.05	Cloudy
1127	423.8	998	<.05	Do.

Table 9.--Pumping test of Well 16, after rehabilitation (Continued)

Time	Depth to water (feet below land surface)	Pumping rate (gpm)	Sediment content of water (milliliter per liter)	Remarks
11/25/66				
1132	424.0	998	Trace	Cloudy
1137	424.5	996	do.	Do.
1142	425.0	990	do.	Do.
1147	425.5	1,004	do.	Clear
1157	426.5	985	do.	Do.
1207	427.0	985	do.	Do.
1217	428.0	1,034	do.	Do.
1227	428.5	1,029	do.	Do.
1237	429.0	1,018	do.	Do.
1247	429.5	1,018	do.	Do.
1257	430.0	--	--	--
1307	430.0	--	--	--
1317	431.2	--	--	--
1327	431.2	--	--	--
1337	431.2	--	--	--
1347	431.8	1,015	Few grains	Clear
1407	432.2	--	--	--
1417	433.0	1,018	Few grains	Clear
1437	433.5	1,018	do.	Do.
1457	434.0	1,015	do.	--
1507	434.0	1,018	do.	--

Table 9.--Pumping test of Well 16 after rehabilitation (Continued)

Time	Depth to water (feet below land surface)	Pumping rate (gpm)	Sediment content of water (milliliter per liter)	Remarks
11/25/67				
1527	434.8	1,018	--	--
1557	436.0	1,020	None	--
1607	436.5	1,023	do.	Stopped pump
1608	431.2	--	--	Recovery measurements
1609	428.0	--	--	--
1610	429.0	--	--	--
1611	429.0	--	--	--
1612	428.0	--	--	--
1613	428.0	--	--	--
1614	427.5	--	--	--
1615	427.2	--	--	--
1616	427.0	--	--	--
1617	427.0	--	--	--
1622	426.0	--	--	--
1627	425.5	--	--	--
1632	425.0	--	--	--
1637	424.5	--	--	--
1642	424.0	--	--	--
1647	423.5	--	--	--
1652	423.0	--	--	--

Table 9.--Pumping test of Well 16, after rehabilitation (Concluded)

Time	Depth to water (feet below land surface)	Pumping rate (gpm)	Sediment content of water (milliliter per liter)	Remarks
11/25/66				
1657	422.8	--	--	--
1707	422.5	--	--	--
1717	422.0	--	--	--
1727	421.5	--	--	--
1737	421.0	--	--	--
1807	420.5	--	--	--
1907	420.0	--	--	--
2007	418.0	--	--	--
2107	417.5	--	--	--
2207	417.0	--	--	End of test.

Table 10.--Pumping test of Well 17, before rehabilitation.

Time	Depth to water (feet below land surface)	Pumping rate (gpm)	Remarks
9/22/66			
0915	413.22	--	Static water level
0925	413.22	--	DO.
0930	423.75	670	Started to pump
0935	424.58	670	--
0940	425.23	670	--
0950	426.06	665	--
1030	427.53	665	--
1113	428.61	660	--
1204	429.50	660	--
1310	430.14	655	--
1405	430.65	655	--
1455	431.24	655	--
1515	431.05	655	Stopped pumping - End of test.

Table 11.--Development by pumping of Well 17, during rehabilitation

Time	Depth to water (feet below land surface)	Pumping rate (gpm)	Sediment content of water (milliliter per liter)	Remarks
12/6/66				
1230	--	800±	--	Surged
1300	--	800±	0.10	Cloudy, surged
1330	--	800±	.10	Cloudy
1345	--	--	--	Surged 6 times
1420	426.0	800±	--	Surged 5 times
1450	426.8	800±	--	Surged 6 times
1510	425.0	800±	--	Surged 6 times
1530	--	--	.05	Cloudy
1550	425.0	800±	--	Surged
1600	--	--	.05	Cloudy
1605	426.8	800±	--	Surged twice
1610	--	--	< .05	Cloudy
1620	427.5	786	Few grains	Clear
1630	428.5	786	do.	Do.
1645	429.2	786	do.	Do.
1700	429.5	786	Few grains	Clear, but sudsy
1730	430.0	786	Trace	Sudsy
1815	431.0	786	Few grains	Do.
1845	431.0	781	No sand	End of test.

Table 12--Pumping test of Well17, after rehabilitation

Time	Depth to water (feet below land surface)	Pumping rate (gpm)	Sediment content of water (milliliter per liter)	Remarks
12/8/66				
1023	406.33	--	--	Static water level
1102	406.17	--	--	Do.
1104	--	--	--	Started pump
1105	417.90	--	--	Drawdown measurements
1106	418.40	--	--	--
1107	418.95	--	--	--
1108	419.38	--	--	--
1109	419.80	820	--	--
1110	420.10	--	--	--
1111	420.26	--	--	--
1112	420.23	--	--	--
1113	420.41	--	--	--
1114	420.66	781	--	--
1116	420.98	--	Trace	--
1118	421.28	776	--	--
1120	421.57	--	--	--
1122	421.84	--	--	--
1124	422.05	--	--	--
1126	422.21	--	--	--
1128	422.38	--	--	--
1130	422.54	--	--	--

Table 12.--Pumping test of Well 17, after rehabilitation (Continued)

Time	Depth to water (feet below land surface)	Pumping rate (gpm)	Sediment content of water (milliliter per liter)	Remarks
12/8/66				
1132	422.82	--	--	--
1134	422.95	--	--	--
1139	423.29	781	Trace	--
1144	423.55	--	--	--
1149	423.82	781	--	--
1154	424.03	--	--	--
1159	424.24	--	--	--
1204	424.38	--	--	--
1209	424.54	770	Trace	--
1214	424.70	--	--	--
1219	424.84	--	--	--
1224	424.99	776	--	--
1229	425.29	778	--	--
1234	425.42	776	Trace	--
1244	425.66	776	--	--
1254	425.87	773	--	--
1304	426.10	770	Trace	--
1314	426.26	770	--	--
1324	426.46	770	--	--
1334	426.61	768	Trace	--

Table 12.--Pumping test of Well 17, after rehabilitation (Continued)

Time	Depth to water (feet below land surface)	Pumping rate (gpm)	Sediment content of water (milliliter per liter)	Remarks
12/8/66				
1344	426.77	768	--	--
1354	426.90	765	--	--
1404	427.05	765	Trace	--
1414	427.22	762	--	--
1424	427.42	762	--	--
1444	427.82	759	--	--
1504	428.19	759	0.05	--
1524	428.49	759	Trace	--
1544	428.71	754	Do.	--
1603	428.91	754	Trace	--
1604	--	--	--	Stopped pump
1605	413.81	--	--	Recovery measurements
1606	415.76	--	--	--
1607	416.32	--	--	--
1608	416.17	--	--	--
1609	415.91	--	--	--
1610	415.62	--	--	--
1611	415.39	--	--	--
1612	415.17	--	--	--
1613	414.94	--	--	--
1614	414.77	--	--	--

Table12.--Pumping test of Well17, after rehabilitation (Continued)

Time	Depth to water (feet below land surface)	Pumping rate (gpm)	Sediment content of water (milliliter per liter)	Remarks
12/8/66				
1615	414.60	--	--	--
1616	414.45	--	--	--
1617	414.28	--	--	--
1618	414.17	--	--	--
1619	414.02	--	--	--
1620	413.89	--	--	--
1621	413.78	--	--	--
1622	413.67	--	--	--
1623	413.57	--	--	--
1624	413.46	--	--	--
1626	413.28	--	--	--
1628	413.10	--	--	--
1630	412.94	--	--	--
1632	412.80	--	--	--
1634	412.67	--	--	--
1639	412.35	--	--	--
1644	412.10	--	--	--
1649	411.85	--	--	--
1654	411.66	--	--	--
1659	411.45	--	--	--
1704	411.30	--	--	--
1709	411.15	--	--	--

Table12.--Pumping test of Well17, after rehabilitation (Concluded)

Time	Depth to water (feet below land surface)	Pumping rate (gpm)	Sediment content of water (milliliter per liter)	Remarks
12/8/66				
1714	411.02	--	--	--
1719	410.88	--	--	--
1724	410.73	--	--	--
1729	410.68	--	--	--
1734	410.54	--	--	--
1744	410.35	--	--	--
1754	410.16	--	--	--
1804	409.99	--	--	--
1814	409.83	--	--	--
1824	409.69	--	--	--
1834	409.58	--	--	--
1844	409.44	--	--	--
1854	409.34	--	--	--
1904	409.25	--	--	--
1924	409.16	--	--	--
1944	409.11	--	--	--
2004	409.03	--	--	--
2024	408.89	--	--	--
2044	408.76	--	--	--
2104	408.63	--	--	--
12/9/66				
0856	406.48	--	--	End of test.

Table 13.--General summary of results of rehabilitation of wells at White Sands Missile Range, New Mexico.

Well No.	Well characteristics prior to rehabilitation 1/							Rehabilitation procedures							Well characteristics after rehabilitation 1/							Recommended pumping rate
	Non-pumping depth to water		Pumping test data												Non-pumping depth to water		Pumping test data					
	Date measured	Feet below land surface	Date of test	Average yield (gpm) 3/	Hours pumped	Drawdown (feet)	Specific capacity (gpm per ft.) 2/	Stereoscopic pictures - before	Treated with Laynite	Surged with bailer	Surged with pump	Treated with muriatic acid	Gravel added to gravel pack	Stereoscopic pictures - after	Date measured	Feet below land surface	Date of test	Average yield (gpm) 4/	Hours pumped	Drawdown (feet)	Specific capacity (gpm per ft.) 2/	
13	12-15-66	324	12-15-66	228	5	25.5	8.9		X	X	X			X	2-14-67	318	2-14-67	367	5	103.5	3.5	250
15	12- 2-66	413	12- 2-66	650	5	24.0	27.1	X	X	X	X	X	X	X	1-20-67	405	1-20-67	754	5	40.5	18.6	650
16	11- 3-66	419	11- 3-66	800	5⅓	18.5	43.2	X	X	X	X			X	11-25-66	414	11-25-66	1010	5	22.5	44.9	800
17	9-22-66	413	9-22-66	658	5⅚	17.8	37.0	X	X	X	X				12- 8-66	406	12- 8-66	768	5	22.7	33.8	750

1/ Non-pumping depths to water and drawdowns for wells 13, 15 and 16 were determined by airline and for well 17 by electric tape.

2/ For similar well conditions and for a given length of pumping time, the specific capacity is less for a high rate of pumping than for a low rate.

3/ Pumping rates determined by using water meter located in line at each well site.

4/ Pumping rates determined by orifice plate.