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Underground Leakage from Artesian Wells in the Flowell Area, Near Fillmore, Utah

By

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UNDERGROUND LEAKAGE FROM ARTESIAN WELLS IN THE FLOWELL AREA, NEAR FILLMORE, UTAH

By Penn Livingston and George B. Maxey

Introduction

Location of the area.—The town of Fillmore is a little southwest of the geographical center of Utah and lies on the west side of and near the base of the Pavant Mountains which trend north and south. The outwashed material from the west slope of the mountains extends westward several miles beyond Fillmore toward the Beaver Mountains some 30 miles away. The Flowell area is about 5 miles west of Fillmore where the slope of the surface has decreased to approximately 40 feet to the mile. It lies in Tps. 21 and 22 S., R. 5 W., Salt Lake base and meridian. The part in which flowing wells have been obtained is about 1½ miles wide and 5 miles long. The western limit of the area is bounded by a large lava flow. The north and south limits have been assumed arbitrarily where artesian water conditions are a little different and warrant placing the Pavant area to the north and the Meadow district to the south in other hydrologic units.

Purpose of the investigation.—Some of the artesian wells in the Flowell area have a continuous flow of water up around the outside of the casing, others seem to be in this condition only when they are capped and have no surface flow from the casing. During recent years a few of the well casings have been perforated at several depths in an effort to increase the flow. Some of the wells flowed less after they were perforated than they did before. These observations led to the belief that there might be a large amount of leakage underground from the wells and that the drop of artesian pressure during the last 15 years might be caused in part by this underground waste. This survey of underground leakage was made with the deep-well meter during the period April 13 to May 24, 1943. In addition to the well exploration with the meter, measurements were made of the flow of each well, the diameter of the casing, and the height to which the artesian water

surface would rise, either above or below the land surface when the well was not discharging.

Acknowledgments.—The survey of the underground leakage in the Flowell area was made as part of the general ground-water investigation in the vicinity of Fillmore by the United States Geological Survey, Department of the Interior, and the State Engineer of Utah. The general investigation has been conducted by George B. Maxey. P. E. Dennis, who is in charge of ground water in Utah for the Geological Survey, and H. R. McDonald spent several days in the field.

Methods of Well Construction

All the wells in the Flowell area, about one hundred in number, have been drilled with cable tools. The first three wells were put down in 1913. Most of the wells were drilled between 1915 and 1931. Only three wells have been drilled since 1931 and no wells have been drilled since 1938.

The wells were put down by several well drillers, some of whom have left the country. There are practically no written records as to the material penetrated, volume of flow or pressure in the water-bearing sands or gravels when the wells were first drilled, size or amount of casing, or even the depth of the wells. The wells have all been cased with screw joint casing, most of which originally was used pipe in bad condition.

The material penetrated is believed to be largely outwash material from the mountains to the east and deposits of Pleistocene lakes, and it consists largely of alternate beds of clay, sand, and gravel irregularly deposited. Overlying the alluvial deposits are a few feet of lake deposits that generally are not water bearing. Lying at one or more levels in the unconsolidated outwash material, along the western edge of the Flowell area, lava beds 10 to 20 feet thick have been reported. The lava is said to be very hard and difficult to penetrate with the drill, but no information is available of wells being abandoned on account of the lava nor is there any information that the casing could not be forced through the lava. While drilling a well for Johnson, (C-21-5) 8ccc1, during the latter part of 1943 the drill penetrated a 40-foot bed of volcanic lapillae but no lava. There are rumors that in a few cases water flowed up on the outside of the casing during the time some of the wells were being drilled but stopped flowing on the

outside during the course of a few months. When the casing in a well was reduced in size below the land surface the larger casing was allowed to overlap the lower smaller casing and nothing was placed between them to keep the well from leaking through the annular space between the casings. The wells were left open at the bottom and there is no information available indicating that any casing was cemented. The openings for the water to enter the casings were made with a casing "perforator or ripper" at the selected water-bearing horizons after the drilling had been completed. In the absence of information as to the size and depth and length of the casing it was assumed, for the leakage tests, that the casing in each well was the same size all the way down unless definite information was obtained during the test indicating that the casing was smaller below the surface.

Very few of the wells are provided with valves to control the flow. The flow is sometimes stopped by a wooden block placed on top of the casing and held down by means of bolts attached to an iron casing clamp.

Methods of Testing Wells for Underground Leakage

The method of testing wells that was used in the Flowell area has been developed by the United States Geological Survey during the past twenty years and has been used successfully in several investigations and in many miscellaneous wells throughout the country.* The principal instrument used for measuring the leakage from artesian wells is the deep-well meter designed by Carl H. Au in 1924. A view of this meter is shown in plate 1. The main parts of the meter are the vertical shaft with attached vanes, the needle-point bearing at the lower end, the commutator head at the upper end, and the shell which is 3 inches in outside diameter. The meter is placed in a 3-inch tube and lowered into the well on a double conductor wire cable. Flowing water in the well rotates the vertical

*McCombs, John, Methods of exploring and repairing leaky artesian wells on the Island of Oahu, Hawaii: U. S. Geological Survey Water-Supply Paper 596-A, pp. 4-24, 1927.

Fiedler, A. G., The Au deep-well current meter and its uses in the Roswell artesian basin, N. Mex.: U. S. Geol. Survey Water-Supply Paper 596-A, pp. 24-32, 1927.

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Livingston, Penn, Underground leakage from artesian wells in the Las Vegas area, Nevada: U. S. Geol. Survey Water-Supply Paper 849-D, 1941.

Livingston, Penn, and McDonald, Harris R., Underground leakage from artesian wells in Malad Valley, Idaho: U. S. Geol. Survey Water-Supply Paper in preparation.

Livingston, Penn, Equipment for exploring wells: The Johnson National Driller's Journal, Vol. 14, No. 4, pp. 10-13, 1942.

shaft and for each revolution an electrical circuit is completed in the commutator head by an insulated wire making an "off center" contact with the shaft. The completed circuit is energized by a small battery which causes a click for each revolution of the vanes in ear phones worn by the observer. The meter has been rated by observing the number of revolutions per minute of the meter for different rates of flow in several different sizes of pipe. Therefore, by knowing the size of the casing and observing the revolutions per minute of the meter it is possible to determine the rate of flow in the well at any point desired. Obviously the greatest refinement can be obtained in casings of small diameter. Increments of less than a gallon a minute can be measured in a 4-inch pipe whereas increments of 5 gallons a minute are barely noticeable in 8-inch pipe, provided of course that the flows are all very small. When searching for small leaks a diaphram is placed around the meter tube in such a way as to direct all the flow through the 3-inch meter tube. In this way an increment of only a fraction of a gallon a minute is readily noticeable.

A survey of a well can be made while the well has a fairly large flow at the surface but because small increments of flow are less noticeable in large flows it is desirable to have no surface flow during the test. (See pls. 2, 3, 4, and 5). If the well casing has good threads it is not difficult to attach the necessary fitting to provide a water-tight connection. In order to obtain good threads to attach the temporary fittings, it is sometimes necessary, however, to remove fittings on the well. Very few wells in the Flowell area could be tested with the use of screw fittings. Some of the fittings were welded and some were so badly corroded that they could not be removed. Usually the threads on the end of the casing were damaged; in many cases the pipe had been cut off with a torch or saw. For all the flowing wells in the Flowell area, therefore, a cap was used consisting of a circular steel plate one-half inch thick, somewhat larger than the casing, through the center of which a four-inch nipple was welded. On the bottom of the plate a disk of conveyor belting was cemented. The plate was placed on top of the casing and held down by one-half inch bolts attached to iron clamps around the casing. In most cases the conveyor belting made a water-tight seal but in some cases when the top of the casing was jagged, automobile inner tubes were placed next to the pipe. The four-inch pipe was closed at the top with suiatble bushing and a packing gland to

complete the water-tight connections. A view of the cap and fittings used for testing wells in the Flowell area is shown in plate 2, A.

The well is tested for leaks by lowering the meter slowly in the well and observing simultaneously the rate at which the meter is turning. At intervals of 10 feet the instrument is held stationary for a few minutes while the revolutions per minute of the meter are observed. By moving the meter slowly up or down and observing the change in the revolutions per minute it is easy to determine whether the water in the well is flowing up or down.

It is sometimes difficult to interpret correctly the changes in velocity in a well that has casings of different sizes unless a good casing record is available. Changes from a larger to a smaller casing result in an increase in the velocity of the water. Such a change might be interpreted as a leak unless it can be determined that the casing actually is smaller in size. Usually a reduction in size can be determined by opening the valve at the surface and allowing some water to escape while making a second observation of the revolutions per minute above and below the point suspected. Sometimes it is necessary to make several such observations with different rates of flow, each being measured in gallons a minute at the surface, of course, before satisfactory results are obtained. The determination of the size of the casing by this method is especially difficult if there is a leak from the well at the top of the reduction, which frequently happens. Mechanical methods can be used for measuring the size of the pipe but the amount of work and the length of time required to complete the test is thereby considerably increased.

Two types of equipment are used for lowering and raising the meter in the well, namely, the power-driven winch and the hand-operated reel. The power-driven winch is used in deep wells or in wells that have large leaks where it might be dangerous to use light hand equipment. The power-driven equipment was used for only a few of the first wells that were tested in the Flowell area. A view of this equipment is shown in plate 6. The cable is one-fourth inch in diameter provided with a multiple copper wire core insulated with cotton and rubber. The meter tube is eight feet long and is of light weight tubing about 3¼ inches outside diameter.

The hand-operated reel was found to be satisfactory for most of the wells tested in the Flowell area. A view

of the reel is shown in plate 2, B. The cable is one-eighth inch in diameter and made of 33 strands of steel wire, preformed reverse lay, with 18 and 15 strands per lay respectively. The inner core is of multiple steel and copper wires insulated with several layers of wax-saturated cotton. The breaking strength is about 1500 pounds. The meter tube is of light weight galvanized iron, about 3⅛ inches outside diameter and about 2½ feet long. The cable has been marked so that the depth indicator can be corrected every 50 feet as the meter is lowered into the well. The artesian pressure head on each well was measured with a mercury manometer from connections through the valve at the top of the well. (See pl. 5, B). The flow of the well was usually determined by removing the four-inch bushing in the side of the four-inch tee and measuring with a 20-gallon tub and stop watch. Flows up to 200 gallons a minute that were measured by this method are considered fairly accurate but above that rate the flow as recorded is apt to be too large owing to trapped air with the water that was difficult to estimate. Very large wells may flow more than is indicated by these measurements owing to the fact that the additional friction caused by the four-inch tee may reduce the rate of flow. In some cases the large flows were measured in an open ditch by means of a current meter.

Results of Tests for Underground Leakage

The results of the tests made during the period from April 13 to May 24, 1943, in the Flowell area, near Fillmore, are given below. The locations of the wells are shown in figure 1. All measurements of depth and water level were taken from the top of the casing. The depth refers to the depth to which the meter (three inches in diameter) was lowered into the well. In some cases the meter did not reach the bottom of the well owing to some obstruction. The artesian water level is given as the distance from the top of the casing to the water surface in the well for non-flowing wells. For flowing wells it is given as the height to which the water rose when all flow above the land surface was stopped. The depth to water was measured with a steel tape and the water pressure by means of a mercury manometer. Unless otherwise noted the natural flow at land surface was measured by means of a 20-gallon container and stop watch. Usually the flow passed through a four-inch tee about half a foot above the top of the casing. Unless otherwise noted all natural

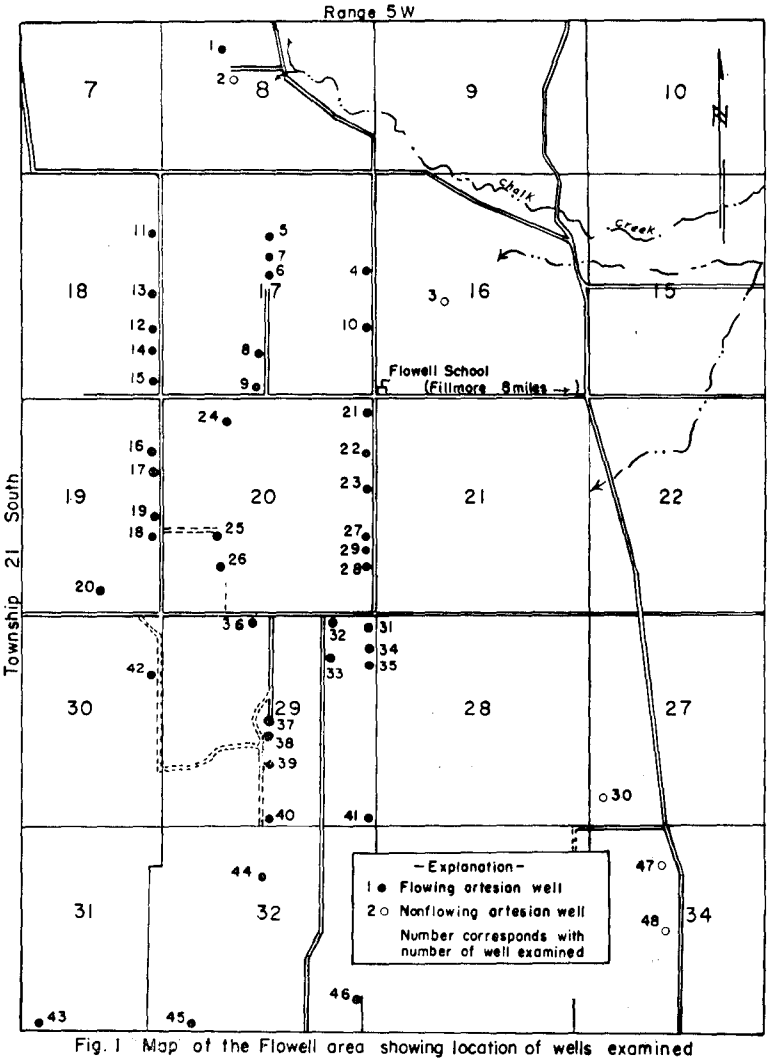


Fig. 1 Map of the Flowell area showing location of wells examined

flow from the well casing at the land surface was stopped during the test with the well meter.

Well 1

Owner, L. B. Owens; location number (C-21-5)8bdc1; State Claim 1374; date, April 26; depth 317 feet; natural flow at top of casing, 10 gallons a minute; artesian water level, +1.65 feet; top of casing above land surface, at land surface; inside diameter of casing, 6 inches.

Remarks: The artesian pressure and the natural flow from this well vary from time to time, depending upon the effectiveness of rags that have been placed about 15 feet below the surface to stop the underground leakage. A flow amounting to about 20 gallons a minute was found entering the well between 313 and 137 feet. The water flowed up the well and escaped between 14 and 17 feet from the surface.

Well 2

Owner, M. J. Warner; location number (C-21-5)8cab1; State Claim 16622; date, April 26; depth 257 feet; natural flow at top of casing, none; artesian water level, −10.3 feet; top of casing above land surface, 1½ feet; inside diameter of casing, 8 inches.

Remarks: No underground leakage was found.

Well 3

Owner, O. E. Brower; location number (C-21-5)16cab1; State Claim, none; date, April 13; depth 335 feet; natural flow at top of casing, none; artesian water level, −3.71 feet; top of casing above land surface, at land surface; inside diameter of casing, 6¼ inches.

Remarks: No underground leakage was found.

Well 4

Owner, Noall Brothers Farm Company; location number (C-21-5)17add2; State Claim 8775; date, May 13; depth 22 feet; natural flow at top of casing, estimated at 50 gallons a minute through hole in casing near land surface; artesian water level, −3.0 feet; top of casing above land surface, 3 feet; inside diameter of casing, 6¼ inches.

Remarks: Water can be seen flowing up around the outside of the well casing. In order to increase the yield the owner had cut an opening in the side of the casing near

ground level through which water flows into an open ditch. The flow from the opening was stopped while the meter was lowered into the well. An obstruction was found at 17.5 feet below the top of the casing and the meter caught at that depth but was released with considerable difficulty. At one time the meter passed the obstruction to a depth of 22 feet and a velocity recorded that indicated a leak of about 100 gallons a minute. It appears likely, therefore, that most of the leakage from this well occurs within 20 feet of the land surface. The total flow from this well was measured with a current meter as 90 gallons a minute, a large part of which could be regarded as leakage below the land surface.

Well 5

Owner, D. A. Brinkerhoff; location number (C-21-5)-17bda1; State Claims 4718, 8812, 11207, 20321; date, April 29; depth 340 feet; natural flow at top of casing, 350 gallons a minute; artesian water level, +19.7 feet; top of casing above land surface, at land surface; inside diameter of casing 6⅛ inches.

Remarks: A flow slightly less than 20 gallons a minute was found entering the well between 322 and 340 feet. It flowed up the well and about 10 gallons a minute leaked out between 222 and 232 feet while the remainder escaped between 122 and 132 feet. There was only a negligible amount of leakage through the fittings at the surface during the test.

Well 6

Owner, D. A. Brinkerhoff; location number (C-21-5)-17bddl; State Claims 11209, 8813, 4716; date, April 30; depth 392 feet; natural flow at top of casing, 270 gallons a minute; artesian water level, +20.6 feet; top of casing above land surface, 1 foot; inside diameter of casing, 6⅛ inches.

Remarks: An obstruction was found at 288.5 feet that was interpreted as a reduction in the size of the casing, probably to five inches in diameter. During the test about 25 or 30 gallons a minute of water entered the casing below a depth of 380 feet. It flowed up the well, a few gallons a minute being lost between 230 and 240 feet and the remainder escaping between 109 and 112 feet.

Well 7

Owner, D. A. Brinkerhoff; location number (C-21-5)-17bdd2; State Claims 11208, 4717, 8811; date, April 29, depth 366 feet; natural flow at top of casing, 120 gallons a minute; artesian water level, +14.7 feet; top of casing above land surface, at land surface; inside diameter of casing, 6¼ inches.

Remarks: A flow of about 70 gallons a minute was found to originate below 290 feet and about 50 gallons of this entered the well below 320 feet. The flow of 70 gallons a minute moved up the well to 144 feet; about 50 gallons a minute escaped from the well between 133 and 144 feet and about half of the remaining 20 gallons a minute escaped between 80 and 85 feet; all of the flow escaped below 75 feet.

Well 8

Owner, J. C. Christensen; location number (C-21-5)-17cda1; State Claim 1375; date, April 30; depth 410 feet; natural flow at top of casing, 250 gallons a minute; artesian water level, +25.5 feet; top of casing above land surface, 3 feet; inside diameter of casing, 6⅛ inches.

Remarks: An obstruction was found at 304.5 feet which is probably the top of a 4-inch casing reported by the owner. During the test about 35 gallons a minute entered the well between 390 and 410 feet and flowed upward in the well. About 20 gallons a minute of this flow escaped from the well at the top of the 4-inch casing, probably through the annular space between the 4-inch and the 6⅛ inch casings where they overlap. The remaining 15 gallons a minute flowed up the well and escaped at the surface through numerous openings that could not be plugged.

Well 9

Owner, J. C. Christensen; location number (C-21-5)-17cdd1; State Claim 1376; date, April 30; depth 315 feet; natural flow at top of casing, 250 gallons a minute; artesian water level, +13.6 feet; top of casing above land surface, 1 foot; inside diameter of casing, 6½ inches.

Remarks: During the test about 30 gallons a minute entered the well between 313 and 315 feet. The water moved upward, some leakage from the well occurring between 190 and 210 feet and about 20 gallons at 110 feet; none of the flow came within 100 feet of the land surface.

Well 10

Owner, Sarah A. Brower; location number (C-21-5)-17dad1; State Claim 3332; date, April 13; depth 285 feet; natural flow at top of casing, 230 gallons a minute; artesian water level, +12.8 feet; top of casing above land surface, 1 foot; inside diameter of casing, 6¼ inches.

Remarks: A flow amounting to about 15 gallons a minute was found moving from the bottom of the well up to 230 feet, at which depth about half the water escaped from the well while the remainder moved upward and escaped through pipe fittings above the land surface.

Well 11

Owner, Ova Peterson; location number (C-21-5)18ada1; State Claim 2667; date, April 26; depth 453 feet; natural flow at top of casing 13 gallons a minute; artesian water level, +13.0 feet; top of casing above land surface, 2 feet; inside diameter of casing, 6 inches.

Remarks: A flow of 20 gallons a minute was found entering the well between 430 and 453 feet and escaping from the well at about 310 feet.

Well 12

Owner, Ova Peterson; location number (C-21-5)18add1; State Claim 2217; date, April 27; depth 40 feet; natural flow at top of casing, estimated at 30 gallons a minute; artesian water level, +5.1 feet; top of casing above land surface, 3 feet; inside diameter of casing 6¼ inches.

Remarks: Owing to an obstruction in the casing, the meter could not be lowered more than 40 feet below the top of the casing. No underground leakage was found.

Well 13

Owner, Walter Brinkerhoff; location number (C-21-5)-18dad2; State Claim 7673; date, May 24; depth 401 feet; natural flow at top of casing, 60 gallons a minute; artesian water level, +7.8 feet; top of casing above land surface, 1½ feet; inside diameter of casing, 5⅛ inches (originally 6¼ inches).

Remarks: This well has been recognized for many years by the local people as a well that was not comparable with other wells in the neighborhood. Even though it is

situated in an area where artesian wells nearby have pressures of about 20 feet, the pressure on this well was much lower than the others and a few years ago it ceased to flow altogether. Some experimenting was done by Mr. Wells Johnson and others with rags lowered on a wire. It was found that when the rags were lowered to a certain point the water rose and a small flow was obtained. When the writers visited the well on April 24 the water level was about 30 feet below the top of the casing. The meter was lowered in the well to a depth of 345 feet but owing to the presence of debris such as rags, rocks, and wire, the test was not very satisfactory and only a rough estimate of the leakage could be made. A total of about 180 gallons a minute was leaking out of the well mainly between 170 and 180 feet. The well was cleaned out by a well driller and a second test was made with the meter on May 14 which disclosed that about 190 gallons a minute entered the well between 370 and 400 feet and escaped from the well, mainly at 176 feet, but with small leaks at 201 and 74 feet. The driller then suspended 223 feet of 5⅛ inch casing in the well with an improvised lead packer at the lower end. After the driller had expanded the packer a little a third test was made with the meter on May 19. At that time a total of about 40 gallons a minute was leaking, about 10 gallons a minute of which escaped at 262 feet; about 10 gallons a minute from 259 to 242 feet; about 10 gallons a minute at 237.5 feet, and about 10 gallons a minute escaping by the packer. The well had a natural flow of 60 gallons a minute and a pressure head of 7.0 feet.

The driller then tried to expand the packer further and attempted to drill the well deeper but without success. On May 21 a fourth test was made with the meter. The well was found to have a flow of about 110 gallons a minute that entered the well from 370 to 395 feet. It moved up the well, 70 gallons a minute escaping from the well at 240 feet and 40 gallons a minute escaping at 234.5 feet. There was no leakage past the packer. Evidently the drilling tools had opened up two fairly large openings at depths of 240 and 234.5 feet during the unsuccessful attempt to drill the well deeper. The driller then added enough 5⅛ inch pipe to lower the packer to 280 feet and a fifth test with the meter, made on May 24, showed a total leakage of about 35 gallons a minute, 10 gallons a minute of which was lost between 290 and 320 feet, and about 25 gallons a minute leaking by the packer. Repair was discontinued, leaving a natural flow of 60 gallons a minute and a water pressure of 7.8 feet.

Well 14

Owner, Albert and Nolan Jackson; location number (C-21-5)18dda1; State Claim 4714; date, April 27; depth 448 feet; natural flow at top of casing, estimated as 165 gallons a minute; artesian water level, +19.8 feet; top of casing above land surface, at land surface; inside diameter of casing, 6¼ inches.

Remarks: A flow of about 75 gallons a minute was found entering the well between 434 and 448 feet. About 20 gallons a minute of this flow escaped from the well before 340 feet had been reached, about 35 gallons a minute more was lost at 228 feet, 10 gallons a minute at 154 feet, and the remainder at about 137 feet below the surface.

Well 15

Owner, Nolan Jackson; location number (C-21-5)18ddd1; State Claim 4715; date, April 28; depth, obstructed at 26 feet; natural flow at top of casing, 12 gallons a minute; artesian water level, not determined; top of casing above land surface, at land surface; inside diameter of casing, 5 inches.

Remarks: Owing to a corroded casing it was not possible to shut off the flow and therefore a pressure reading was not obtained. No underground leakage was found.

Well 16

Owner, Alonzo Huntsman; location number (C-21-5)-19aad1; State Claim 13528; date, May 12; depth 455 feet; natural flow at top of casing, 120 gallons a minute; artesian water level, +20.0 feet; top of casing above land surface, 2 feet; inside diameter of casing, 6⅛ inches.

Remarks: A flow amounting to about 65 gallons a minute was found entering the well below 440 feet. About 10 gallons a minute of this flow was lost before 370 feet was reached, about 15 gallons a minute was lost between 327 and 342 feet, about 10 gallons a minute was lost at 282 feet, and the remainder escaped between 240 and 242 feet.

Well 17

Owner, Alonzo Huntsman; location number (C-21-5)-19ada1; State Claim 13525; date, April 28; depth 336 feet; natural flow at top of casing, 65 gallons a minute; artesian

water level, +10.5 feet; top of casing above land surface, at land surface; inside diameter of casing 5⅝ inches.

Remarks: A flow of water was found amounting to 20 gallons a minute that entered the well below 333 feet and flowed upward to 281 feet where about half the flow escaped from the well; the remainder escaped below a depth of 272 feet.

Well 18

Owner, Alonzo Huntsman; location number (C-21-5)-19daa1; State Claim 13526; date, April 28; depth 403 feet; natural flow at top of casing, 75 gallons a minute; artesian water level, not determined; top of casing above land surface, 5 feet; inside diameter of casing, 7⅞ inches

Remarks: During the test a flow of water amounting to about 360 gallons a minute was found entering the well between 360 and 403 feet. It moved upward, and about 100 gallons a minute escaped from the well between 43 and 47 feet. The remainder escaped about 10 feet below the top of the casing. In addition to about 75 gallons a minute that flows from the open casing of this well, water can be seen flowing up around the outside of the casing. The total flow was measured with a current meter as 230 gallons a minute on June 2.

Well 19

Owner, Alonzo Huntsman; location number (C-21-5)-19daa2; State Claim 13527; date, April 28; depth 232 feet; natural flow at top of casing, 50 gallons a minute; artesian water level, +7.1 feet; top of casing above land surface, 1½ feet; inside diameter of casing, 7⅝ inches.

Remarks: A flow of water was found at 232 feet but it could not be determined whether there was a large hole in the casing or a reduction in the size of the casing at that depth. It is believed that the well is deeper than 232 feet even though the meter would not go down. Assuming no reduction in the size of the casing, the leakage indicated by the meter at 232 feet would be about 90 gallons a minute. If the casing is smaller than 7⅝ inches below 232 feet the leakage would be smaller in proportion to the squares of the diameters of the casings.

Well 20

Owner, Sam Utley; location number (C-21-5)19dcd2; State Claim 6228; date, May 12; depth 334 feet, natural flow at top of casing, 80 gallons a mintue; artesian water

level, +11.6 feet; top of casing above land surface, 1 foot; inside diameter of casing 7½ inches.

Remarks: No underground leakage was found.

Well 21

Owner, M. L. Robinson; locaion number (C-21-5)-20aaal; State Claim 150; date, May 5; depth 334 feet; natural flow at top of casing 300 gallons a minute; artesian water level, +13.1 feet; top of casing above land surface, 1 foot; inside diameter of casing, 7⅝ inches.

Remarks: An obstruction was found at 240.5 feet that is believed to be the top of a 4-inch casing which is reported to have been placed from 252 feet to 340 feet. During the test about 70 gallons a minute entered the well from 320 to 334 feet and flowed up the well to 240 feet. About 40 gallons a minute escaped from the well between 220 and 240 feet; about 15 gallons a minute escaped between 120 and 140 feet; about 5 gallons a minute escaped through small leaks above 140 feet, and the remainder escaped above the land surface through several leaks in the pipe fittings.

Well 22

Owner, O. L. Robinson; location number (C-21-5)-20 aadl; State Claim 149; date, April 23; depth 272 feet; natural flow at top of casing, estimated as 350 gallons a minute; artesian water level, +16.4 feet; top of casing above land surface, at land surface; inside diameter of casing, 6⅝ inches.

Remarks: A flow of water amounting to about 50 gallons a minute was found in the well at 272 feet. Although the meter could not be lowered more than 272 feet, it is believed that the well is somewhat deeper. The water flowed up the well; 20 gallons a minute escaped between 200 and 210 feet; 10 gallons a minute between 190 and 200 feet; 10 gallons a minute between 120 and 125 feet; and 10 gallons a minute between 115 and 120 feet.

Well 23

Owner, J. L. Robinson; location number (C-21-5)-20 addl; State Claim 151; date, May 1; depth, 271 feet; natural flow at top of casing, 230 gallons a minute; artesian water level, +16.5 feet; top of casing above land surface, at land surface; inside diameter of casing, 6¼ inches.

Remarks: A flow of 30 gallons a minute entered the well below 262 feet and moved up to 202 feet where about 15 gallons a minute escaped from the well, 10 gallons a minute was lost between 182 and 197 feet, and 5 gallons a minute escaped from the well at about 62 feet.

Well 24

Owner, Earl F. Stott; location number (C-21-5)20bab1; State Claim 6333; date, May 13; depth 154 feet; natural flow at top of casing, 75 gallons a minute; artesian water level, +6.5 feet; top of casing above land surface, 1 foot; inside diameter of casing, 6¼ inches.

Remarks: A flow amounting to about 70 gallons a minute was found at 154 feet and therefore the obstruction in the casing at that depth probably does not indicate the bottom of the well. Comparative velocity tests at 140 and 154 feet with 50 gallons a minute flowing at the surface did not indicate a reduction in the size of the casing at 154 feet.

Well 25

Owner, F. M. Christensen; location number (C-21-5)-20cbdl; State Claim 1378; date, May 6; depth 350 feet; natural flow at top of casing, 200 gallons a minute; artesian water level, +20.3 feet; top of casing above land surface, ½ foot; inside diameter f casing, 5⅝ inches.

Remarks: An obstruction was found at 304.5 feet which probably was the top of a smaller size casing. A flow of 10 gallons a minute was found entering the well below 350 feet. The water moved up the well and escaped through small holes between 150 and 214 feet.

Well 26

Owner, F. W. Christensen; location number (C-21-5)-20ccal; State Claim 1377; date, May 11; depth 488 feet; natural flow at top of casing, 200 gallons a minute; artesian water level, +25.0 feet; top of casing above land surface, 1 foot; inside diameter of casing 6¼ inches.

Remarks: A flow of about 130 gallons a minute was found entering the well below 400 feet. It moved upward in the well, losing about 10 gallons a minute between 270 and 350 feet; 40 gallons a minute between 253 and 257 feet; 25 gallons a minute between 232 and 252 feet; 25 gallons a minute between 42 and 52 feet, and 30 gallons a minute between 32 and 42 feet.

Well 27

Owner, Millard School District; location number (C-21-5)20dad1; State Claim 6992; date, May 1; depth 293 feet; natural flow at top of casing, 180 gallons a minute; artesian water level, +18.5 feet; top of casing above land surface, at land surface; inside diameter of casing 6⅛ inches.

Remarks: No underground leakage was found.

Well 28

Owner, M. E. Ray; location number (C-21-5)20dda1; State Claim 3808; date, May 5; depth 320 feet; natural flow at top of casing, 430 gallons a minute; artesian water level, +17.3 feet; top of casing above land surface, 1 foot; inside diameter of casing, 7⅝ inches.

Remarks: An obstruction was found at 155 feet which probably is the top of a 6-inch casing. A flow amounting to about 85 gallons a minute entered the well below 310 feet and escaped from the well at the top of the 6-inch casing at 155 feet.

Well 29

Owner, M. E. Ray; location number (C-21-5)20dda2; State Claim 3809; date, May 3; depth 145 feet; natural flow at top of casing, 40 gallons a minute; artesian water level, +8.1 feet; top of casing above land surface, at land surface; inside diameter of casing, 6⅞ inches.

Remarks: A small leak from this well amounting to about 10 gallons a minute was found at about 38 feet. The water came into the well between 130 and 145 feet below the surface.

Well 30

Owner, A. E. Robinson; location number (C-21-5)-27ccc1; State Claim 13529; date, May 21; depth 136 feet; natural flow at top of casing, none; artesian water level, -23.0 feet; top of casing above land surface, 3 feet; inside diameter of casing, 7½ inches.

Remarks: No underground leakage was found.

Well 31

Owner, Sam Utley, et al; location number (C-21-5)-29aaa1; State Claim 6225; date, May 4; depth 269 feet;

natural flow at top of casing, 110 gallons a minute; artesian water level, +14.1 feet; top of casing above land surface, 1 foot (below land surface); inside diameter of casing, 6⅛ inches.

Remarks: When the well was capped for testing, water could be seen coming up around the outside of the casing. About 30 gallons a minute was found entering the well below 247 feet. The water flowed up the casing losing about 5 gallons a minute before it had risen to 100 feet; 5 gallons a minute was lost at about 30 feet; about 30 gallons a minute was lost at 9 feet; and the remainder was lost above 9 feet, part of which was lost through pipe connections at the surface.

Well 32

Owner, Sam Utley, et al; location number (C-21-5)-29aab1; State Claim 6233; date, May 4; depth 302 feet; natural flow at top of casing, 130 gallons a minute; artesian water level, +9.2 feet; top of casing above land surface, 1½ feet; inside diameter of casing, 6⅛ inches.

Remarks: While the well was capped for testing 80 gallons a minute could be seen coming up around the outside of the casing. A flow of 90 gallons a minute was found entering the well below 280 feet. The water flowed up the well, losing about 10 gallons a minute through small leaks between 20 and 150 feet, and 80 gallons a minute within 20 feet of the surface.

Well 33

Owner, James Smith; location number (C-21-5)29aac1; State Claim 6231; date, May 4; depth 315 feet; natural flow at top of casing, 220 gallons a minute; artesian water level, +20.1 feet; top of casing above land surface, 2 feet; inside diameter of casing, 5⅞ inches.

Remarks: An obstruction was noted at 165.5 feet but no underground leakage was found.

Well 34

Owner, Sam Utley, et al; location number (C-21-5)-aad1; State Claim 6223; date, May 3; depth 290 feet; natural flow at top of casing 240 gallons a minute; artesian water level, +17.3 feet; top of casing above land surface, at land surface; inside diameter of casing, 6⅛ inches.

Remarks: During the test a flow of 20 gallons a minute entered the well between 270 and 290 feet. The water moved upward past 158 feet and 10 gallons a minute was lost between 152 and 158 feet. About 10 gallons a minute escaped from the well at 42 feet below the surface.

Well 35

Owner, Sam Utley, et al; location number (C-21-5)-29aad2; State Claim 6224; date, May 3; depth 534 feet; natural flow at top of casing, 300 gallons a minute; artesian water level, +23.0 feet; top of casing above land surface, at land surface; inside diameter of casing, 6 inches.

Remarks: A flow of less than 20 gallons a minute was found entering the casing below 332 feet. The water flowed up the casing, losing a few gallons here and there through small openings until at 225 feet the flow was less than 10 gallons a minute, this amount escaping through other small openings below 150 feet except for about 2 gallons a minute that leaked through connections above the land surface. The combined flow from wells 34 and 35 was measured with a current meter downstream from well 34 as 460 gallons a minute on June 2.

Well 36

Owner, Von Utley; location number (C-21-5)29baa1; State Claim 6222; date, May 7; depth, obstructed at 60 feet; natural flow at top of casing, 110 gallons a minute; artesian water level, +19.3 feet; top of casing above land surface, 1 foot; inside diameter of casing, 6⅝ inches.

Remarks: An obstruction was found at 60 feet that could not be dislodged. No underground leakage was found.

Well 37

Owner, Ras Rasmussen; location number (C-21-5)-29bdd1; State Claim 2670; date, May 11; depth 207 feet; natural flow at top of casing 150 gallons a minute; artesian water level, +19.1 feet; top of casing above land surface, 3 feet; inside diameter of casing, 7½ inches.

Remarks: No movement of water was found at the bottom of the well but a flow of about 40 gallons a minute was found entering the well below 192 feet that moved upward to 127 feet. The entire flow escaped from the well between 124 and 127 feet.

Well 38

Owner, Ras Rasmussen; location number (C-21-5)-29caa1; State Claim 2669; date, May 7; depth 314 feet; natural flow at top of casing, 130 gallons a minute; artesian water level, +26.5 feet; top of casing above land surface, at land surface; inside diameter of casing, 6¼ inches.

Remarks: No underground leakage was found.

39

Owner, Ras Rasmussen; location number (C-21-5)-29cad1; State Claim 2668; date, May 7; depth 440 feet; natural flow at top of casing, 300 gallons a minute; artesian water level, +30.5 feet; top of casing above land surface, 1 foot (below land surface); inside diameter of casing, 6⅛ inches.

Remarks: A slight obstruction was noted at 193 feet. A flow amounting to 55 gallons a minute was found entering the well between 372 and 440 feet; about 35 gallons a minute of this flow came from below 432 feet. The water flowed up the casing; 50 gallons a minute escaped between 191 and 194 feet; and 5 gallons a minute escaped from the well at 67 feet.

Well 40

Owner, John Carling; location number (C-21-5)29cdd1; State Claim 3334; date, May 7; depth 366 feet; natural flow at top of casing, measured 300 gallons a minute with current meter on June 2; artesian water level, +10.9 feet; top of casing above land surface, at land surface; inside diameter of casing 9½ inches.

Remarks: It has been known for many years that when this well is capped, numerous springs appear in the immediate vicinity of the well. It is reported that a well driller tested a casing perforator in this well a short distance below the land surface several years ago. Evidently the casing perforator made holes in the casing and ruined the well at the same time. During the test a flow was found amounting to about 300 gallons a minute that was entering the well between 300 and 366 feet. The water flowed upward in the well losing about 25 gallons a minute between 82 and 100 feet; about 175 gallons a minute between 67 and 82 feet; about 40 gallons a minute between 10 and 22 feet, and 60 gallons a minute between 7 and 10 feet. It is evident that the underground leakage from the

well while it was capped is about equal to its normal flow at the surface.

Well 41

Owner, Flowell Farms Inc.; location number (C-21-5)-29ddd1; State Claim 14350; date, May 14; depth 277 feet; natural flow at top of casing, 220 gallons a minute; artesian water level, +12.2 feet; top of casing above land surface, 4 feet; inside diameter of casing, 6⅛ inches.

Remarks: This well is one of the few wells in the Flowell area that is provided with a valve to control the flow. A flow of water amounting to about 40 gallons a minute was found entering the well between 270 and 277 feet. The water moved upward in the well and escaped between 230 and 235 feet.

Well 42

Owner, Sam Utley, et al; location number (C-21-5)-30ada1; State Claim 3299; date, May 12; depth 205 feet; natural flow at top of casing, 90 gallons a minute; artesian water level, +36.2 feet; top of casing above land surface, 1 foot; inside diameter of casing, 8 inches.

Remarks: The meter was held up at 24 feet by what seemed to be a loose rock or rocks. The obstruction was dislodged every foot or two down to a depth of 205 feet. Although the obstruction could not be dislodged, it is believed that the well is considerably deeper. No underground leakage was found in this well.

Well 43

Owner, Sam Utley; location number (C-21-5)31cdd1; State Claim 6236; date, May 19; depth 252 feet; natural flow at top of casing, 120 gallons a minute; artesian water level, +4.9 feet; top of casing above land surface, 1 foot; inside diameter of casing, 6⅛ inches.

Remarks: After this well had been capped for testing, water could be seen flowing up on the outside of the casing. A flow was found amounting to about 130 gallons a minute that flowed up the well to within 22 feet of the ground surface; about 50 gallons a minute escaped from the well between 17 and 22 feet; and the raminder escaped between 4 and 7 feet below the top of the casing. The artesian water pressure was low because of the large amount of leakage. The total surface flow from the well was measured with a current meter on June 2 as 150 gallons a minute.

Well 44

Owner, Flowell Farms, Inc.; location number (C-21-5)-32acb1; State Claim 18884; date, May 15; depth 250 feet; natural flow at top of casing, 100 gallons a minute; artesian water level, +14.5 feet; top of casing above land surface, 3 feet; inside diameter of casing, 10½ inches.

Remarks: This well is provided with a valve to control the flow. No underground leakage was found.

Well 45

Owner, Sam Utley; location number (C-21-5)32ccd1; State Claims 13519, 73; date, May 20; depth 284 feet; natural flow at top of casing, estimated as 300 gallons a minute; artesian water level, +14.8 feet; top of casing above land surface, 1½ feet; inside diameter of casing, 6 inches.

Remarks: No underground leakage was found.

Well 46

Owner, E. L. Hart; location number (C-21-5)32dda1; State Claim 3297; date, May 20; depth 238 feet; natural flow at top of casing, 250 gallons a minute; artesian water level, +12.3 feet; top of casing above land surface, at land surface; inside diameter of casing 6¼ inches.

Remarks: A small flow of about 5 gallons a minute was found entering the well between 227 and 237 feet that moved upward in the well and escaped at about 146 feet.

Well 47

Owner, Frank W. Sweeting Estate; location number (C-21-5)34baa1; State Claim 17381; date, May 21; depth 123 feet; natural flow at top of casing, none; artesian water level, -41.68 feet; top of casing above land surface, 1 foot; inside diameter of casing, 7¾ inches.

Remarks: This well is on higher ground than the height to which the artesian water would rise and therefore the well does not have a flow at the surface. No underground leakage was found.

Well 48

Owner, Frank W. Sweeting Estate; location number (C-21-5)34bdd1; State Claim 4722; date, May 21; depth 126 feet; natural flow at top of casing, none; artesian water level, -43.5 feet; top of casing above land surface, at land surface; inside diameter of casing, 8¾ inches.

Remarks: This well is on higher ground than the height to which the artesian water would rise and therefore the well does not have a flow at the surface. No underground leakage was found.

Summary of Leakage Tests

An effort was made to test the underground leakage of 48 out of approximately 100 artesian wells that have been drilled in the Flowell area. Of this number four wells were obstructed near the surface and the meter could not be lowered far enough for a satisfactory test.

In any area in which water is being drawn unequally from several water-bearing beds it may be assumed that the artesian pressures in the aquifers tapped are not the same. If a well that penetrates two or more of these beds is capped and not allowed to flow at the surface, it will be found that water flows in the well from the aquifers having the highest pressures to the one having the lowest pressure. Such conditions exist in the Flowell area. In view of the fact that the artesian pressure probably is naturally greater as the depths to the artesian beds increase and also that a greater draft on the shallower horizons has lowered the pressure in the shallower beds, water flows from the lower beds into beds nearer the surface. Well 29, owned by M. E. Ray, is only 145 feet deep and was the shallowest one tested in the irrigated area. In the absence of any other information regarding the depth to the upper artesian water horizon it has been assumed that the depth to the first artesian bed is greater than 125 feet. On this basis, any water lost from a well below a depth of 125 feet would be flowing from one artesian aquifer to another and would not necessarily represent a loss from the artesian system.

In the 48 wells that were explored, the total leakage, or loss of water from the wells, between certain depths is as follows:

Depth in feet	Leakage in gallons a minute	Depth in feet	Leakage in gallons a minute
0 to 125	1260	250 - 275	40
125 - 150	90	275 - 300	100
150 - 175	180	300 - 325	0
175 - 200	260	325 - 350	40
200 - 225	30	350 - 375	20
225 - 250	250	375 - 400	10
		TOTAL	2280

The table shows that about 1,020 gallons a minute of the leakage that was measured occurred below 125 feet and 1,260 gallons above that depth. Of the 1,260 gallons a minute that escaped from the well within 125 feet of the surface it was found that 760 gallons a minute came up to the land surface on the outside of the casing and 500 gallons a minute escaped into water-bearing beds below the land surface. It appears, therefore, that in the 44 wells tested, a total of about 1,260 gallons a minute during the winter months and 500 gallons a minute during the irrigation season was lost for all useful purposes when the wells were securely capped at the surface.

The amount of underground leakage in the Flowell area seems insignificant when it is compared with the total flow from the artesian wells in the area. During September, 1943, Mr. Maxey measured the flow from each artesian well in the area and found the total flow to be 11,200 gallons a minute the most of which was being used beneficially. During the following winter, or non-irrigation season, of five months duration, he estimated the total flow to be 4,200 gallons a minute the most of which was wasted.

If the wells are capped during the winter months to conserve the artesian water the flow that comes up on the outside of the casing is out of control and because it serves no useful purpose the water is wasted and should be classified with the underground waste. The movement of water from one water-bearing horizon to another as well as leakage from the well above all artesian water-bearing beds will always be less, of course, when the wells are not capped.

Although tests were made on less than half the wells in the area it is believed that the underground leakage measured in these wells is more than three-fourths the total leakage in the area because a special effort was made to pick out wells that were suspected of leaking.

It is, of course, impossible to determine the amount of leakage from the artesian aquifers that may occur on the outside of the casings. It is not likely that so many wells could be drilled into the artesian system without some of them leaking on the outside. There probably are enough sand and gravel beds near the surface to absorb such flow and therefore the leakage might not appear at the surface. As far as is known no special effort, such as cementing, has been made by the well drillers to prevent leakage on the outside of the casing.

Suggestions for Repairing Leaky Wells in the Fowell Area

Obviously the first step toward a conservation or sealing program is to cap all wells when they are not in use and shut off all unnecessary flow at the surface. The amount of water saved by a program of repairing leaky wells would be small when compared with the water wasted at the surface, most of which waste could be prevented at practically no cost. A commendable start toward the control of the flowing wells has already been made in the organization by the well owners of a water district, and rules regarding the dates of opening and closing of wells have been agreed upon. These regulations adopted by the well owners are administered through the office of the State Engineer. Many wells are capped on or about November 1 of each year and opened on or about April 1 of the following year. However, a considerable number of wells flow uncontrolled and unused for six months out of the year, and many others are poorly capped. The total amount of water thus wasted is so large compared to that lost from leaky wells that it would be inconsistent to inaugurate a program of repairs without insisting upon strict enforcement of the regulations governing the capping of wells during the winter season and at other times when not in use.

If loss of water from a well below 125 feet serves to recharge the shallower artesian beds, only leaks above that depth should be considered in a well sealing program. It appears from the tests made that only a few wells would warrant the cost of repairing them. Wells having large leaks near the surface are 4, 18, 26, 31, 32, 40, and 43.

These wells probably could be repaired without much cost by setting a casing of larger size over the defective casing and filling the annual space between the two casings with cement. The obstructions, if any, should be removed first. The larger sized casing, probably three or four inches larger than the original well casing, should be washed down at least five feet below the lowest leak in the casing to be shut off and the space between the casings washed out thoroughly. The flow from the well should be shut off by means of a plumber's soil plug with extension pipes or with a canvas bag filled with some material that expands when placed in water, such as sawdust or beans. The bag should be forced down below the hole in the casing and held there several hours until the material has expanded enough to shut off the flow. The space above the plug should be filled with sand to prevent the cement grout from flowing into the well when it is placed between the casings. If the

plug is placed as much as 50 feet below the ground surface probably it would be desirable to carry the weight of the sand on a pipe or wire extending to the surface. The cement grout should be placed at the bottom of the annular space between the casings through a pipe about one-inch in diameter and the space completely filled before the grouting pipe is removed. After the cement has set for a few days the sand in the well above the plug can be washed out with circulating water and then the plug removed.

Wells of large diameter could be repaired by placing a liner about three inches smaller in diameter, on the inside of the old casing and filling the annular space between the casings with cement. The natural flow from wells repaired in this manner could be stopped by means of a canvas bag filled with one of the swelling materials mentioned in the previous paragraph and filling the well with sand to a point above the bottom of the liner. Considerable trouble might be experienced in providing a tight packer at the lower end of the liner that would prevent the cement from running through it into the well. The flow could be cut off also by pumping a heavy clay fluid to the bottom of the well through a small pipe one or two inches in diameter. By the time the mud fluid had risen to the land surface the flow would have ceased. The cement should be placed between the two casings through a small pipe extending to the bottom of the liner. It is advisable to use cement without sand owing to the probability that sand will separate from the cement with only a slight circulation of water.

It is suggested that an attempt be made to stop some of the deep seated leaks by pumping into the wells, through a small pipe extending to the bottom, a fiberous stable material such as asbestos. The well should be capped at the surface, of course, while the asbestos is being pumped into the well. Theoretically the fibres should be carried through the hole in the casing by the flowing water and clog up the interstices between the sand grains and prevent the escape of water. Probably the asbestos should be thoroughly disintegrated and fed slowly into the well to prevent the forming of a blanket over the hole on the inside of the casing, that would peel off when the well was again allowed to flow. Possibly a better seal could be obtained by mixing a small amount of asbestos with a thick clay fluid. The commonly used commercial asbestos is chrysolite, which is a hydrous silicate of magnesia. This material probably would be permanently stable under all conditions found in water wells in this area. The cost of the asbestos increases somewhat with the length of fibre. During 1943 the cost

of commercial asbestos ranged from $2.00 to $4.00 a hundred pounds. Probably 200 pounds per well would be sufficient for the preliminary experimental tests.

Conclusions

The results of the underground leakage tests in the Flowell area indicate that the total leakage is probably less than 3,000 gallons a minute. A large part of this leakage is from one artesian water-bearing bed to another, which can not be considered as water wasted. About 500 gallons a minute was found to be leaking into material near the surface where it is not recovered for irrigation purposes. It was estimated that about 100 gallons a minute was being wasted in this manner from wells that were not tested, making a total of about 600 gallons a minute wasted into near surface material. The measured flow that came to the land surface on the outside of the casing while the wells were capped for testing amounted to 760 gallons a minute. Because all wells that appeared to be leaking on the outside of the casings were selected for testing, it is estimated that the total flow around the outside of the casing amounted to very little more or a total of about 800 gallons a minute.

During the irrigation season the total waste of artesian water amounted to about 600 gallons a minute. During the non-irrigation season the flow around the outside of the casing amounting to about 800 gallons a minute could not be controlled and therefore the waste during that period probably was about 1,400 gallons a minute.

During the irrigation season most of the total flow from the wells, amounting to 11,200 gallons a minute, was used beneficially but during the winter following the 1943 irrigation season most of the total flow, estimated as 4,200 gallons a minute, was wasted.

In view of the fact that many of the wells are allowed to flow continuously throughout the year it is evident that a program to repair the leaky wells should be accompanied or preceded by strict control of the natural flow from the wells.

Wells that are leaking close to the surface may be repaired by placing a larger casing over the defective casing or a smaller one inside, and the annular space filled with cement. Wells in which leaks occur more than 125 feet below the surface need not be repaired because water that escapes from the well serves to replenish other artesian water-bearing beds, provided of course that the water does not flow all the way to the surface on the outside of the casing.

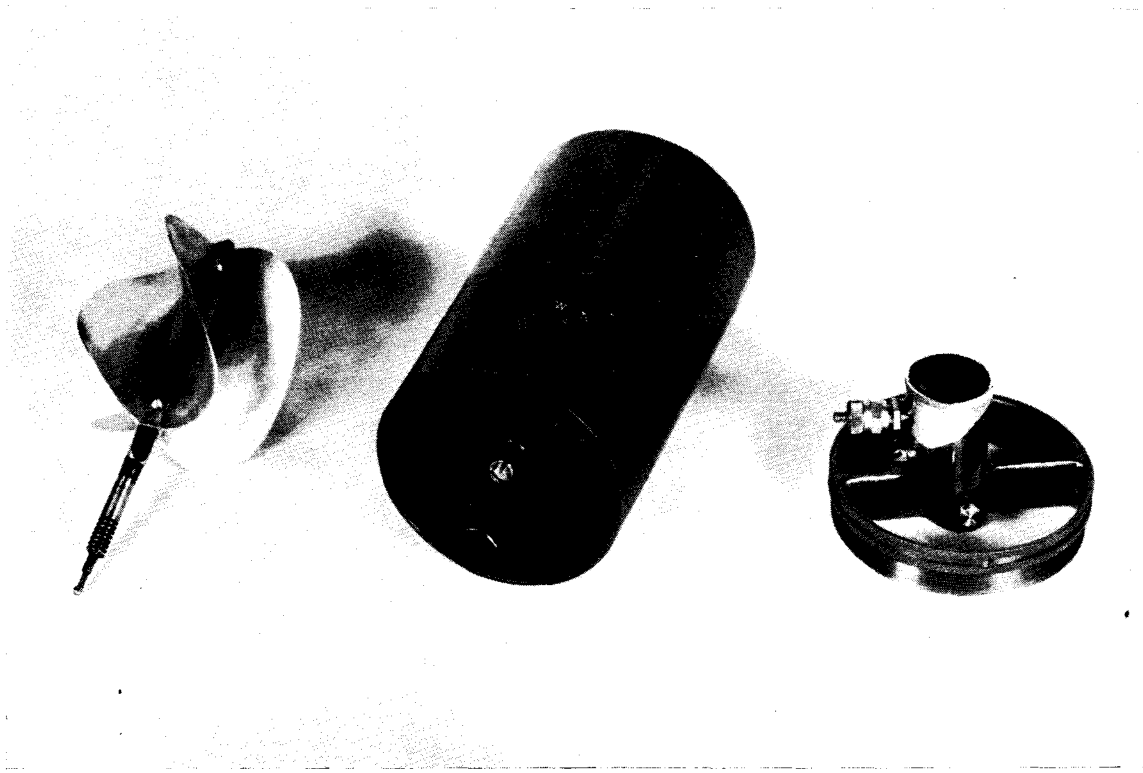
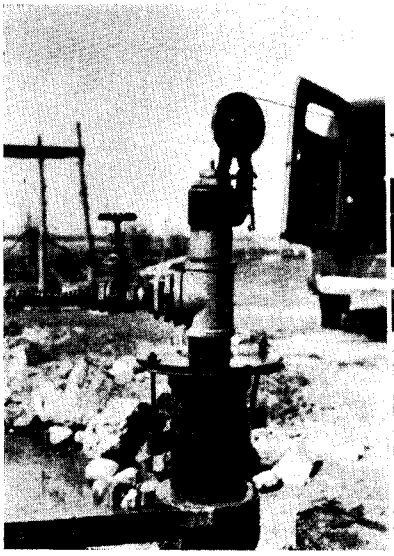


Plate 1.—Deep-well meter.

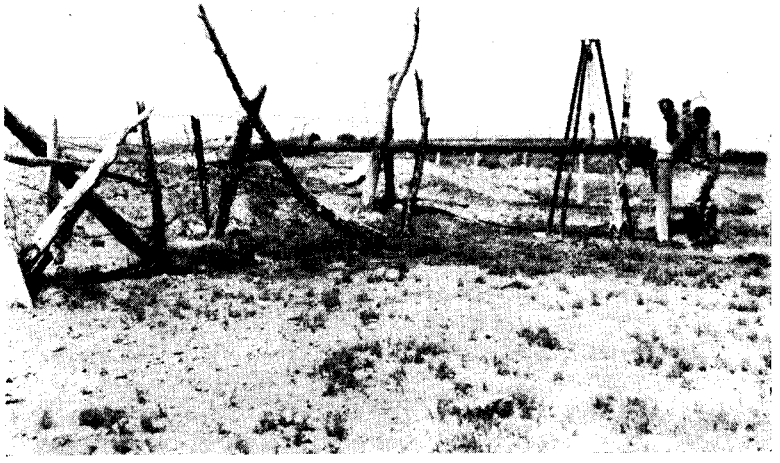
Plate 2



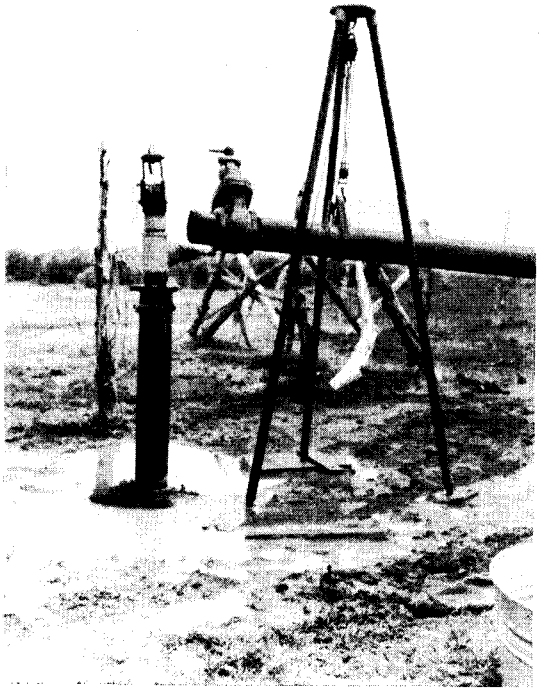
A. Device for controlling flow during test (well 37).

B. Hand reel for lowering and raising meter (well 37).

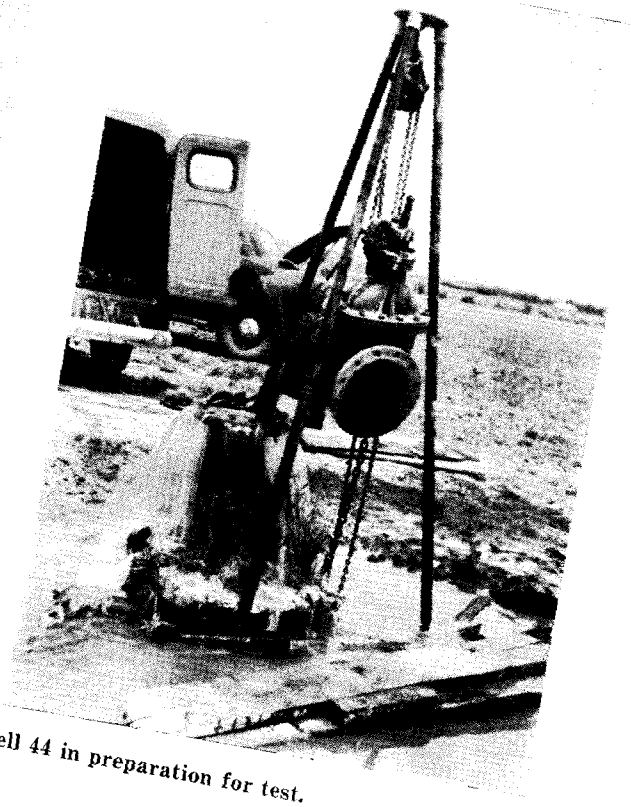
C. Well 37, under control and test in progress.



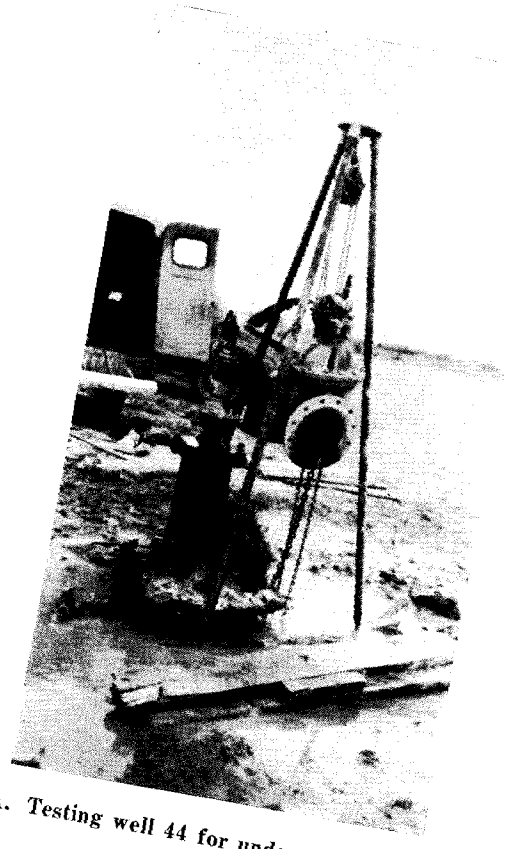
A. Removing fittings from well 41 in preparation for test.



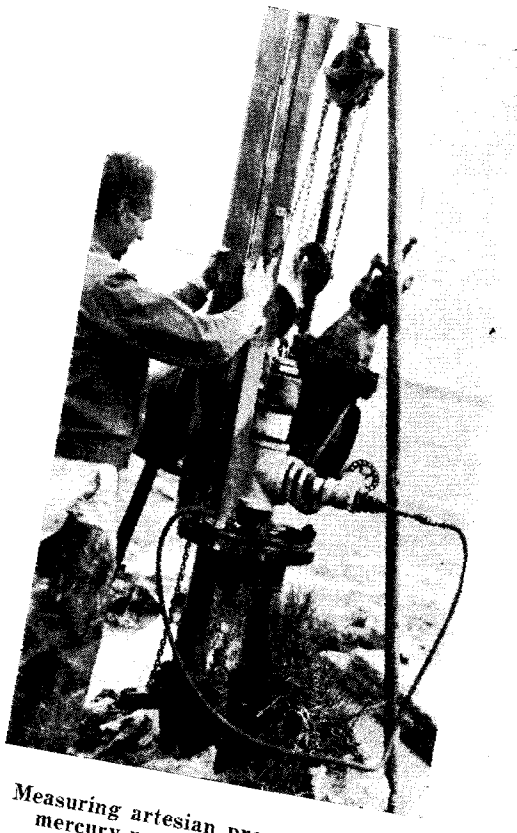
B. Well 41 under control and test in progress.



A. and B. Removing fittings from well 44 in preparation for test.



A. Testing well 44 for underground leaks.



B. Measuring artesian pressure head with mercury manometer (well 44).

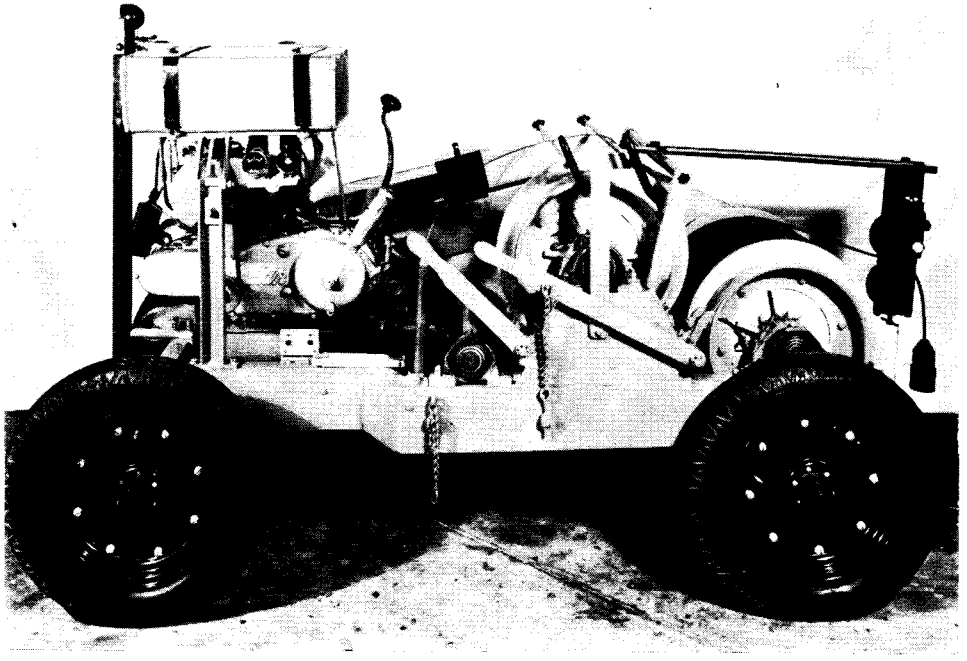


Plate 6—Power-driven winch for lowering and raising meter and other instruments in well.