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PROBLEMS AND CONTROL OF LEAKING ARTESIAN WELLS [1]

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In the early days of ground-water development in Utah, there was no regulation or control of the types of wells that were constructed or of the drillers that put down wells, and many wells were placed in operation that would not meet present-day standards. In many artesian areas, for example, wells were drilled hundreds of feet into the unconsolidated valley alluvium and were finished with only a few feet of casing in the upper part of the hole. Most of these have long since lost their identity as flowing wells and now appear as large "blue springs," in the middle of swampy areas. In other instances, inferior well casings have become corroded after long years of use or have become badly damaged, with the result that these wells also are uncontrollable in their present condition. It was estimated in 1940 that more than 27,500 wells were in operation in Utah, and that as much as 40,700 acre-feet of ground water was being wasted annually from uncontrolled and leaking flowing wells. This waste ~~represented~~ about 25 percent of the total amount of ground water used in the State. Of this quantity an estimated 15,000 acre-feet of water was wasted by well owners ~~persistent violators~~ who failed to close their wells, and an estimated 25,700 acre-feet of water was wasted from wells that could not be controlled because of quicksand conditions or because of defective wells or casings. It was also estimated that the annual rental value of this wasted ground water would amount to approximately $32,000, and that ~~the~~ salvage ~~of~~ this water ~~was~~ undoubtedly the cheapest of all water available to users in the State.

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When the first wells were drilled in Utah they were usually allowed to flow continuously with little or no attempt to close them during periods of non-use. As long as there were but few wells flowing, little decrease in ground-water pressures was noted. As drilling continued, however, the need for the control and regulation of ground-water use and development became apparent. Thus, the ground-water law of the State of Utah was passed, and became effective March 22, 1935. This law placed upon the individual well owner the responsibility of controlling the flow of ground water, and specified that no well should be allowed to flow or be pumped when the water could not be put to beneficial use. Thus, according to the law (Tracy, 1953, p. 7), "All waters in this state, whether above or under the ground are declared to be the property of the public . . ." and "Beneficial use shall be the basis, the measure and the limit of all rights to the use of water in this state." By this law, the State Engineer was assigned the responsibility of administering the newly created state water laws, and specifically, ~~to~~ of preventing waste, loss, or pollution of both surface and underground water. Thus, the systematic inspection of all wells was begun in the summer of 1935, and the prodigious problem of bringing under control all wasting wells was soon realized.

The waste of underground water cannot always be controlled by merely asking the well owner to close the valve on his well. Where water comes to the surface ~~around the~~ outside of the casing or through a hole in the ground where the casing once was, the only satisfactory method of control is to place a watertight plug around the casing or in the hole, just below the impervious confining layer which formerly held the water under pressure. The plugging or sealing of flowing wells frequently requires expensive machinery and equipment. For this reason, and because of a lack of experience and technical knowledge, well owners have been unable to cope with the problem of leaking wells, and as a last resort, have turned to the State Engineer for help. Thus, little was accomplished in the way of sealing wasting wells in Utah until passage of an enabling act by the State Legislature in 1945. This act provided the State Engineer with funds for the purchase of necessary equipment and with the authority on behalf of the State to enter into cooperative agreements with the well owners. Thus, the law reads, in part (Tracy, 1953, p. 19):

"73-2-21. Artesian Wells - Wasting Public Water - State Engineer, Power to Plug, Repair or Control - Cooperative Agreements with Owners.

"The state engineer is authorized to plug, repair, or to otherwise control artesian wells which are wasting public water. He may, on behalf of the state, enter into cooperative agreements with well owners by the terms of which the state may agree to provide all necessary equipment and supervision for such well control operations or shall otherwise share the expense and the well owner shall supply material in an amount not to exceed $50.00 for each well, and power, provided that the state engineer shall exercise all reasonable precautions to preserve the flow of water from such wells.

"Abandoned wells on public land may be plugged entirely at the expence of the state. Wasting wells on private lands which cannot be plugged under cooperative agreement with the owner of the lands or wells, may be plugged entirely at the expense of the State. * * * The state engineer, through the state department of finance, may purchase pumps, compressors, and all other necessary equipment and material and may employ all necessary assistance to enable him to perform his duties under this act."

During the summer of 1945 the program of plugging and repairing leaky wells was begun, and the State Engineer's office furnished a "mud jack" machine and two trained men to assist well owners in controlling their wasting wells. All materials used were provided by the well owners, and new replacement wells were drilled at the owners' expense. During the 9 years from 1945 to 1953, incl., the State Engineer's office has assisted in the sealing of 367 wells, which were flowing a combined total of 23,288 gallons per minute, or approximately 52 cubic feet per second. Thus, the water from these wells that previously wasted is now being stored in the ground for subsequent use. Many well owners, who previously let their wells flow the entire year because they were not conscious of the wastage of underground water, now close their wells when the water cannot be used beneficially. Under this type of management, these artesian basins are operating as extensive underground storage reservoirs during periods of little or no use, and several times 52 second-feet of salvaged ground water is being put to beneficial use.

At first, many well owners were doubtful that wells such as the one shown in Slide 1 could be successfully controlled.

This shows a well in northern Utah County in which the upper part of the well casing has completely corroded away, allowing the ground water to flow from the artesian water-bearing strata to the surface of the ground by coming up around the outside of the well casing. This was originally a 2-inch cased well, but uncontrolled flow has carried with it great quantities of sand and silt, causing the ground to cave. As a result, a hole approximately 14 ft. in diameter and 25 ft. deep was created from which water at the rate of 160 gallons per minute ~~flows~~. The quantity of water that is discharged from a hole like this in a year is very large as compared with the portion beneficially used to irrigate the land. In many places such flows have caused large swampy areas and have made it necessary to abandon valuable farm land.

Slide 2 is a picture of an old well near American Fork, Utah that wastes about 110 gallons per minute from a hole 20 ft. deep by 20 ft. in diameter. The water flowing from this "blue spring" prevents 3 acres of land ~~from being cultivated.~~

Slide 3 is a picture of an excellent crop of onions grown during 1948 on ground that appeared as it did in Slides 1 and 2 during 1946. In the lower right hand corner of Slide 3 was a large hole caused by an uncontrolled well that made a swamp of the lower half of this onion field, and prevented the field from being cultivated in its entirety.

On the property part of which is shown in Slide 4, there formerly were 16 small wells that flowed from around their respective casings, and also, one large "blue spring" in the upper part of the field similar to that shown in Slide 1. For as long as can be remembered, this piece of property ~~remained~~ a poor and swampy pasture. In 1947 these wells were sealed and the land has since dried and been cultivated. Roots and sod of this earlier swamp area are noted in the picture, and a young cabbage patch appears in the background. The entire field of

105 acres of rich soil is now being cultivated. It may be of interest to note that for several years many truck-loads of turkey feathers were hauled from a nearby processing plant to this field to add humus to the heavy clay soil.

Slide 5 shows a large new well drilled near the Geneva-Columbia Steel Mill, in Utah County, as a replacement for two old wells that were permanently sealed and abandoned. Near the fence corner shown at the left of the picture, these two old wells had developed to conditions similar to Slides 1 and 2. This new 8-inch well yields 700 gallons per minute and can be controlled by the clamp device shown at the right of the well. The quantity of water required by this farmer represents approximately one-quarter of the total amount discharged by the two abandoned wells in a year's time. Twenty-three other wells were sealed in the immediate vicinity of this well, with a combined discharge of 3,790 gallons per minute. As a result, ground-water pressures have increased considerably throughout the area, and the new replacement wells yield approximately ~~1/3~~ one-third more water, during the period they are open, than flowed formerly from the 24 wasting wells. The underground reservoir is now storing water during periods of little or no use. Similar results have been experienced in several other parts of the State.

Slide 6 shows a well near Lehi, Utah, that is connected to the mud jack with the usual flexible hose hook-up. This mud jack is powered with a gas engine and is equipped with dual mud pumps. A clay-cement grout is pumped through the hose under pressures of as much as 250 lbs. per square inch. Under such pressures, grout is forced into every crack and crevice in the underground system, and in most instances is forced to the land surface around the casing before the pumping is stopped.

Slide 7 shows a 3-inch well after grouting has been completed. The mud-grout can be seen around the casing where it has come up to the land surface. In some instances, the entire area around a well will be heaved upward by the mud pressures below. In other instances, the grout will break through to the surface along cracks or "gopher holes" - sometimes more than 100 feet from the well.

The majority of wells plugged to date have taken less than 10 cubic yards of clay grout to completely fill the casing and underground cavity. A few wells, however, have taken more than 100 cubic yards of grout, and one well took 134 yards before grout began showing on the surface.

Clean clay is readily available in most areas where well plugging has been done (Bonneville Clays). Frequently cement is added to the clay, and in a few instances where additional weight has been required to hold down the high artesian pressures, bentonite and/or crushed smelter slag has been added.

Slide 8 shows a replacement well in Vineyard, Utah, with a pressure head of nearly 40 feet. This is in an area where formerly a number of leaking wells had kept the artesian pressure much lower.

Not all ground-water leakage in defective wells occurs on the surface of the land where it can be readily detected. All too frequently leaking occurs below the surface, from one aquifer to the next, or as an intermixing of several underground sources of water. This may be caused by the improper drilling of a well, or may result from the casing being perforated in undesirable zones, or from the deterioration of the casing in zones that had originally been cased off. In such situations, the leakage can usually be corrected when recognized, but it is first necessary to determine the nature and the position of the leaks in the well casing. A few remarks regarding the detection of subsurface leakage in a defective well may be of interest here.

Occasionally as one stands near a well in which the water level stands some little distance below land surface, the sound of falling water can be heard in the casing. This suggests that water from one aquifer at a higher level is circulating with the water in a lower aquifer. This intermixing of underground waters would probably not be detected had not the sound been audible at the surface. The same type of intermixing occurs without detection in many other wells. Thus, it may occur in flowing artesian wells, in pumped wells, and perhaps also, in many unused and abandoned wells which appear harmless and inoffensive. Where underground leakage in wells is suspected, special tests must usually be made, often using specially designed equipment, to determine the extent of leakage in the well and the position in the casing that leakage occurs.

In general, two types of measuring equipment are commonly used to determine subsurface leakage in water wells:

(1) Equipment that measures changes in water velocity in the casing, at depth, and

(2) Instruments that determine changes in water quality or temperature at varying depths in the well.

In either type of survey, the size and position of openings in the well casing is suggested from measured changes in water quality or velocity, and the quantity of water either entering or leaving the casing may be estimated by the magnitude of these measured changes. This is especially true if the water is circulating through large, well-defined openings in the casing.

Several reports have been published describing methods of testing wells for underground leakage. A few references are included in a bibliography at the end of this paper.

Velocity Surveys. - The use of a velocity-type meter for finding leaks in water wells dates back to about 1910, when several types of meters were developed, including the Price current meter that is in general use in measuring surface streams (Livingston, 1954, p. 13). It was not until 1925, however, that a satisfactory velocity meter was developed, that could be lowered efficiently in a well. For a detailed ground-water study conducted by the U. S. Geological Survey in the Roswell artesian basin, New Mexico (Fiedler and Nye, 1933, p. 234), a new deep-well current meter was designed and constructed, and has since been used in the exploration of numerous wells in other areas.

Slide 9 shows the three elements of this Au deep-well meter, named after its designer, which when assembled is lowered into the casing on a cable. As the upward moving water rotates the impeller, an armature also turns, and a clicking impulse is transmitted to the earphones of the operator standing over the well.

Slide 10 is the same instrument assembled. In exploring a well, the meter is let down a little at a time, and velocity observations are made at regular intervals to determine points of leakage. In a nonflowing well, no velocity will be noted until a leak is encountered, ~~while~~ in a flowing well a leak is indicated by a change in velocity. If a water-bearing stratum which supplies water to the well is passed, the speed of the impellor wheel will decrease.

A velocity survey is ordinarily started after all flow from the well has been shut off at ground level. The meter is lowered slowly and the ~~revolutions~~ are observed. At intervals of 10 to 50 feet, the meter is held at some known depth for a few minutes while the rpm (if any) are counted. If a change in the rpm is found, intermediate positions are tested until the point of leakage is determined. When an increase in velocity is found between two water-bearing beds, it may be necessary to know the direction of movement. If the rpm are carefully observed while the meter is being lowered at a constant rate through that section, and ~~if compared with the rpm of the meter~~ while it is being raised at an equally constant rate, the direction of flow can easily be determined. Obviously the meter will ~~have the lesser rpm as~~ it moves in the direction of the flowing water. It is important to have information on the sizes of casing in the well, because the velocity of the water in the bore of the well will be in proportion to the cross-sectional area of the casing.

Satisfactory velocity surveys can be made in wells to determine the relative amount of water contributed from each water-bearing bed. This is done by lowering the Au deep-well meter in the open well and then by setting the pump. The pump is started while the meter is at the bottom of the well. The meter is raised, and velocities are determined at the points desired. Care should be taken to provide extra weight on the meter to keep it from being drawn toward the pump by the upward flow of water. Special care should also be taken to protect the cable while the pump is being lowered in or removed from the well.

Very small rates of leakage, as small as a gallon a minute, can be found by placing a packer between the meter tube and the inside of the casing. Thus, the entire flow passes through the meter. The packer should never be lowered below the lower end of the casing in unconsolidated material, because the packer invites caving as it rubs against the unprotected bore of the well.

Quality of water and temperature surveys.- In many areas the waters from different aquifers differ considerably in chemical quality and/or temperature, and variations in these characteristics are frequently used to distinguish one water source from another. Several types of specially designed equipment have been used to measure changes in these characteristics in a well, and to indicate the position of water additions or losses from a well. Especially in areas of high chloride contamination are the "electrode" surveys used to good advantage. The construction of an electrode that has been used by the U. S. Geological Survey is shown in Slide 11.

Slide 12 is a diagram showing the location of salt-water leaks in three wells.

The analyses of a number of bailer samples at various depths in a well would provide similar data from which depth curves could be plotted. This type study would not rely on the properties of conductivity alone, and a curve, based on some key dissolved constituent in the water, might indicate the mixing of two or more waters of varying chemistry.

Slide 13 shows the cross-sections of three devices used in sampling water at depth in wells.

Not all leakage and contamination in water wells occurs through perforations placed in the casing at the time of drilling. Three slides are included here to show the deteriorated condition of well casing after a few years of use. (#14, #15, #16.)

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