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Occurrence of Ground Water in Northwest Kansas

by

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Information concerning the nature and occurrence of ground water throughout Kansas has been gathered for a number of years by geologists and engineers of the State Geological Survey, the Division of Water Resources of the State Board of Agriculture and the Environmental Health Services of the State Department of Health. These agencies joined with the U.S. Geological Survey in 1937 in a cooperative ground-water program to study the ground-water resources of the State.

The objectives of this program include the collection of basic data pertinent to the ground-water resources of the State and to investigate and publish reports on the most pertinent areas. Ground-water investigations have generally been on a county basis, but stream valleys and areas of pollution have also been studied. Slide 1 shows the status of this program.

Investigations currently being made include Trego and Decatur Counties in northwest Kansas, several counties in southwestern Kansas and several in eastern Kansas. A field office is located at Garden City for studies in that area. Tentative plans are now being made to establish a field office in northwest Kansas.

Ground-water conditions throughout Kansas depend to a great extent upon the rock formations that occur both at the surface and underground. Although eastern Kansas receives more rainfall than the western part of the state, much of the State's ground-water reservoirs are in western Kansas where much of the area is underlain by deposits of sand, gravel, and silt several hundred feet in thickness. The lower part of these deposits are saturated with water and contain a considerable quantity of ground water in storage.

Slide 2 shows outcropping rocks in Kansas. In general, the yellow shades are areas where ground water is more abundant. Most of the large ground-water reservoirs are in the western and south-central parts of the State. In the eastern part of Kansas, ground-water reservoirs are largely restricted to the alluvial valleys.

The next slide will show a section along the state line about 15 miles west of Goodland. This is a block diagram of the northern part of the High Plains of Colorado. The front side of the block is cut along the Kansas-Colorado state line and extends from about the northern part of Greeley County, Kansas, northward to the northeast corner of Colorado. The block is cut again in an east-west direction along a line approximately straight west of Goodland.

The short-line pattern in the lower part of the diagram represents thick strata of shale that serves as a relatively impervious layer below which there is no downward percolation of ground water. Deposits of silt, sand, and gravel (called the Ogallala Formation) overlie this shale. The lower part of the Ogallala is saturated with water and constitutes the large ground-water reservoir in this area. The Ogallala becomes progressively thinner eastward and in eastern Graham and Trego Counties only remnants of the Ogallala remain where it caps the hills in the interstream areas. Similarily, the Ogallala also thins to a feather edge to the west in Colorado.

South of Goodland in northern Wallace County, the Smoky Hill River has removed the Ogallala, exposing the underlying shale beds.

Thus, for the most part this large ground-water reservoir is isolated around its edges by outcrops of impervious shale and chalk beds. Underlying the reservoir are great thicknesses of impervious shale and chalk beds. In the vicinity of Goodland, a deep drill test would penetrate below the Ogallala Formation about 800 feet of black and brown shale called the Pierre Shale. Below this would be about 750 feet of chalk and chalky shale called the Niobrara Formation, and below that about 300 feet of the Carlile Shale. Strata below this consists of many hundreds of feet of shale and limestone. Thus we see that these great deposits of sand and gravel which constitutes the ground-water reservoir in this area are surrounded by and underlain by considerable thicknesses of impervious rock formations through which the movement of any appreciable amount of water is impossible.

Thus, it becomes apparent that ground water in this area is derived entirely from local precipitation in the form of rain or snow that has fallen in the area or immediately to the west in Colorado. Part of the precipitation that falls is carried away by streams as surface runoff. Part of the precipitation is returned directly to the atmosphere by evaporation. Part of it is absorbed by vegetation, some of which is later returned to the atmosphere by transpiration. The rest percolates downward toward the water table. Part of the water percolating downward will be held by surface tension to the walls of the open spaces through which the water passes in its decent. However, some of the water will reach a depth, or zone, where all the open spaces are filled with water. This zone is called the zone of saturation, the upper surface of which is known as the water table. The water table does not remain stationary but fluctuates up and down in response to recharge and discharge of ground water to the reservoir. Thus, changes in the water level indicate to what extent the reservoir is being replenished or depleted.

The next slide is a diagrammatic section of a well that is being pumped. As water is withdrawn from a well, the water level in the vicinity of the well is lowered to form what is called the cone of depression, which is deepest at the wall of the well and extends some distance from the well. The lateral extent of the cone of depression is called the area of influence, and the vertical distance that the water level is lowered is called the drawdown. When pumping stops, the cone of depression gradually fills with water moving toward the well from the surrounding vicinity until equilibrium is again reached between the water level in the well and the surrounding water-bearing materials. A greater pumping rate in a well results in a greater drawdown; thus, water moves toward the well under a steeper gradient and at a greater rate. When large quantities of water are withdrawn from a high-capacity well, such as an irrigation well, the water level drops rapidly at first, gradually dropping more slowly until it becomes almost stationary. When pumping stops, the water level rises rapidly at first, gradually rising more slowly until it finally reaches approximately its original position before pumping began.

The next slide illustrates two closely spaced wells being pumped, showing mutual interference between wells, and the resulting cone of depression. If wells are closely spaced, as in a well field or an intensively irrigated area, the cone of depression developed by each well may overlap those of adjacent wells, causing mutual interference. When mutual interference occurs, the drawdown at any point within the radius of influence of the wells is the sum of the drawdown caused by the individual wells at that point. When wells interfere, the pumping lift in each well is increased and the discharge is decreased. Also, to maintain a constant discharge from a pumped well would increase the drawdown and extend the cone of depression. In areas where many wells are pumping from the same aquifer, the large cone of depression resulting from mutual interference may not have sufficient time to recover between pumping periods and the water level may decline persistently.

The northwest Kansas area is not as conducive to recharge as are some areas in Kansas, although it is more conducive to recharge than some. For instance, the alluvial valleys in the state are especially conducive to the infiltration of water because the soil and subsoil are generally sandy and porous and because of the nearness of the water table to the land surface. The terrain of alluvial valleys is relatively flat and runoff is not so rapid, thus giving the water more time to infiltrate into the ground.

Let us look at a few other areas in Kansas and compare them to northwest Kansas. Surface drainage is favorable to the recharge of ground water in several areas in southwest Kansas. Bear Creek rises in Colorado more than 50 miles west of the state line, entering Kansas in northwestern

Stanton County from where it flows northeastward across that county, thence across the northwestern corner of Grant County to within about 10 miles of the Arkansas River where all traces of it gradually disappear. Even during flood stages the flow does not reach the Arkansas River. The water is poured out on the plains in northern Grant County and into the sand hills in southern Kearny County where much of it readily seeps into the ground.

Several streams flow south-easterly across the northern part of Kearny County toward the Arkansas River but these streams gradually disappear in western Finney County before reaching the Arkansas River, even during flood stages. The Finney trough in north-central Finney County has very little surface drainage and consequently little runoff.

White Woman Creek rises in Colorado about 20 miles west of the state line, flows eastward across Greeley County, Kansas and on eastward across the southern part of Wichita County to the central part of Scott County where it terminates at the edge of a large flat depressional area. During periods of heavy precipitation temporary lakes are formed and a considerable amount of water infiltrates into the ground, especially after the growing season when transpiration and evaporation losses are low. Flood waters have caused several square miles to be flooded in this area.

During the drough of the mid-1950's, pumping of water from the Equus beds by irrigators and the city of Wichita lowered the water level more than 30 feet near the center of the area of decline. Because of the shallow water level and the sandy soil and subsoil of the Equus beds area, ample rainfall during the latter part of the 1950's relieved a situation that was considered alarming by some at one time but that is now well under control.

The sand hills area just south of the Arkansas River in southwestern Kansas has no surface drainage and rainfall rapidly infiltrates into the underlying deposits.

Conversely, conditions in northwest Kansas are not so favorable for recharge as are the areas mentioned above. In northwest Kansas, the topography has greater relief and consequently the drainage is better developed which results in more rapid runoff. In general, the soil and subsoil is tighter thus retarding infiltration. In general, the depth to the water table is greater than it is in most of the areas mentioned above.

Although recharge rates vary locally, the average recharge in the Goodland area is believed to be about a quarter to a half inch per year. The runoff of surface water is about half an inch per year. The normal annual amount of precipitation is about 18 inches at Goodland. Thus most of the rainfall leaves the area by means of evaporation and transpiration.

Let us take an area in northwest Kansas, Sherman County for instance, and assume an average rate of recharge of $\frac{1}{2}$ inch per year, and compute the amount of water added to the aquifer by recharge annually. We could compare this amount of recharge to the amount of ground water authorized to be withdrawn annually for irrigation as of January 1964.

$$\frac{1}{2} \text{ inch per sq. mi.} = 1{,}116{,}000 \text{ cubic feet} = \frac{1{,}116{,}000}{43{,}560} = 26.6 \text{ acre-feet per sq. mi.}$$

There are 1,055 square miles in Sherman County.

$1{,}055 \times 26.6 = 28{,}000$ acre feet of recharge annually in Sherman County.

According to records of the Division of Water Resources of the State Board of Agriculture, 70,722 acre-feet of ground water were authorized to be withdrawn annually for irrigation as of January 1964. Thus, against an appropriated 70,000 acre-feet of annual withdrawal, we have 28,000 acre-feet of recharge--a deficiency of 42,000 acre-feet, or 2.5 times more water appropriated than the amount of recharge.

Let us calculate the total amount of ground water in Sherman County available for pumping, compare this to the amount of ground water appropriated for irrigation, and further relate it to years of pumping time.

Assuming a specific yield of 15 percent, water for irrigation is stored in the amount of about 100 acre-feet per square mile per foot of saturated thickness. The average saturated thickness in Sherman County is about 120 feet.

1,055 x 120 x 100 = 12 million acre-feet of ground water in storage. Assume that half of this, or 6 million acre-feet, will be available for irrigation. The deficiency between the amount of water appropriated annually and the amount of annual recharge was 42,000 acre-feet.

$\frac{6,000,000}{42,000}$ = 140 years to pump half the ground water from the aquifer. This is without increased irrigation development. Double the amount of withdrawal and it would more than cut the 140 years in half--only 54 years to pump half the ground water. Quadruple the withdrawal and it would take 24 years. The distressing aspect is that although our assumption of recharge may be wrong by an much as 100 or even 200 percent, recharge rates become relatively less significant as withdrawal rates become higher. Thus, as much as one or two inches of recharge instead of $\frac{1}{4}$ or $\frac{1}{2}$ inch would not change the picture much if the area became overdeveloped to any extent. For instance, using an average rate of recharge of 2 inches per year (instead of $\frac{1}{2}$ inch) in our computation above when the withdrawal was quadrupled would give an answer of only 34 years instead of 23 years. These figures computed, as stated, for a withdrawal 4 times the amount of water appropriated as of January 1964.

A network of about 900 observation wells are measured throughout the State as a part of the cooperative ground-water program by Federal and State agencies. Most of these wells are measured quarterly, but some are measured monthly, and some only once a year. About 12 wells have recorders that give a continuous record of water-level fluctuations. By plotting water-level measurements for a given well, a hydrograph may be made which gives a graphical picture of the water-level fluctuations in that well.

The next slide illustrates several hydrographs of representative wells in southwestern Kansas. The left-hand scale is feet to water level below land surface. The scale at the top is for years of time. The period of record for these hydrographs is from about 1940 through 1962. The 1963 water level measurements have not been plotted on these as yet. The hydrographs at the top are in heavily irrigated areas in Grant and Haskell Counties and reflect a regional decline of water levels. The water level in the Grant County well number 400 (second from the top) declined from about 53 feet below land surface in 1944 to about $71\frac{1}{2}$ feet below land surface at the end of 1962. Let us look at the last part of this hydrograph--

the part since 1960. In January 1961 the water level was approximately 66 feet below land surface from where it steadily declined until the latter part of October (after the irrigation season) when it was 69 feet below land surface. During the following winter the water level rose about a foot to approximately 68 feet. In early spring of 1962 the water level began falling again and by the end of 1962 the water level was about $71\frac{1}{2}$ feet below land surface. The depth to water in this well in December 1963, although not shown on this graph, was 72.73 feet below land surface. The lower hydrographs are wells in Seward and Ford Counties in areas where irrigation is not practiced extensively and because of the shallow depth to water reflect only seasonal fluctuations and drouth conditions.

The next slide shows hydrographs of 4 representative wells in Harvey and Sedgwick counties in south-central Kansas. Again the scale on the left is depth to water level and the scale at the top is time in years. Notice that the water level in these wells started to decline about 1950. There was considerable ground-water pumping in the area but the situation was aggravated by a persistent drouth until the latter part of the 1950's when the water level began to recover. These wells are in the Equus-beds area--an area mentioned earlier as being conducive to recharge. The depth to water in most of the Equus beds is fairly shallow, the land quite flat, and the soil sandy.

Slide 8 shows hydrographs of wells in west-central Kansas, and one (the bottom one) is a hydrograph of a well in Sherman County, about half a mile west of Goodland. The wells are all in areas that are irrigated to some extent and all reflect a general decline of the water level since about 1950. The two middle hydrographs are of wells in which the water table is quite shallow and these wells consequently reflect the high rainfall during 1951 and the subsequent recharge resulting from that wet year. The depth to water illustrated in the top hydrograph ranges from about 60 to 85 feet. In this hydrograph, the rise following 1951 is not nearly so pronounced as it is in the middle 2 hydrographs. The water level illustrated in the bottom hydrograph ranges from about 136 feet to 141 feet below land surface, and in this hydrograph there is very little rise in the water level following 1951. Because of the greater depth to water, there would be a greater lag in a rise in the water level. There does appear to be a small rise during 1953, after which there has been a continuous decline in this well.

Before ground-water pumpage begins an aquifer is in equilibrium with nature. The aquifer is full (actually running over) and recharge equals discharge. Ground water moves from points of recharge to points of discharge. Along the outer edges, water is returned to the atmosphere by evaporation and transpiration. Theoretically, if enough water is withdrawn to lower the water level sufficiently it might be possible to salvage some of the water that now escapes around these edges. Although ground-water levels have lowered locally in northwestern Kansas the last few years, natural discharge of ground water has been affected little. Thus, ground-water pumpage can be considered to have come from storage.

We commonly hear the expression that the country is running out of water. Actually the United States is blessed with abundant water supplies--it's just that the water is not distributed evenly with respect to time and place. In addition many of our streams have become polluted--and in some areas ground water is being pumped much faster than the aquifer is being replenished.

The High Plains south of the Canadian River in Texas and New Mexico is such a place where initial ground water in storage has been estimated at 400 million acre-feet. In this area ground water is being mined at such a pace that the area is rapidly approaching the time when the pumping of water for irrigation will no longer be economically feasable. Because the economy of the area is geared to the irrigation of crops, a considerable adjustment must soon be made.

The Ulysses area in the western part of Grant County and the northeastern part of Stanton County in southwest Kansas has reached a stage of development where the water level is declining locally at an alarming rate. Although the area of greatest decline (about 90 feet) is small, the area of 20 feet or more decline exceeds 400 square miles at this time. In 1960 the greatest decline in the Ulysses area was 40 feet and the area of 20 feet or more of decline was only about 100 square miles.

In Scott County, the water level has declined locally as much as 50 feet in areas of considerable pumping. A decline in the water level of about 15 feet in the Goodland area reflects pumping for irrigation.

With the development of electronics the last few years, new tools have emerged that may help to provide answers to some of the questions we need to know to better evaluate the characteristics of ground-water reservoirs. The most pertinent questions relate to recharge, specific yield of aquifers, and evapotranspiration losses.

We have begun to apply the IBM electronic computer to hydrologic problems. Beyond the analysis of data from the pumping tests are studies involving the statistical significance of the relationships of surface water, ground water,evaporation, transpiration, precipitation, etc.

The flow of water in a ground-water system is analogous to the flow of electricity through an electrical circuit. Scaled electrical models can be built to simulate ground-water systems. The term "analog" is used because of the analogy between the characteristics of electricity in a circuit and the behavior of ground water. More specifically, current in a circuit is analogous to the rate of flow of water, voltage is analogous to head, resistance to the permeability of the aquifer, and capacitance to the storage coefficient of the aquifer. Therefore, resistors and capacitors are used to duplicate either measured or estimated physical conditions of the aquifer, while current and voltage are used to duplicate the movement of water.

The use of the neutron moisture probe to determine the recharge to an aquifer and the specific yield of an aquifer has definite possibilities. The probe has its own radioactive source and indicates the hydrogen ion. We have devised a method of running the probe down the drill hole using the electric logger. Studies are now in progress in southwest Kansas to determine the difference between the moisture content of saturated material and the moisture content of the same material after it has been drained. Another study which involves following a slug of water with the probe as it descends downward toward the water table could give us much needed information on recharge characteristics.

In summary, the northwest Kansas area is fortunate in having an abundant water supply in much of the area. However, physical conditions for recharge do not appear to be as favorable as in some parts of Kansas. Under natural conditions, this reservoir is full, actually running over. Not to use this water when it can be used beneficially would be wasteful. However, the ground-water reservoir can not be developed without a decline of the water level. The higher the rate of withdrawal, the greater the lowering of the water level will be. It is possible to develop the aquifer to an extent that serious problems will result. Overdevelopment in an irrigation area will cause serious lowering of the water level, thereby increasing the pumping lift and the consequent increase in pumping cost. As the number of irrigation wells increase the areas of drawdown would increase in size as the cone of depression deepens. As the deposit became dewatered, the transmissibility of the deposits would become less, and well yields would tend to become less. Increased development could cause critical areas. Of course, it would not be possible to pump the aquifer dry. Long before that it would become economically unfeasable to continue pumping water for irrigation so that water would be left for domestic and municipal use.

There comes the question of whether in the interest of civilization we should reserve some of this water for future generations. The answer has generally been that the present generation will take advantage of the natural resources as it finds them and has need for them. Ideally a reservoir should be developed and operated so that it becomes part of a modified hydrologic cycle, capable of sustaining the developed yield or even an increased withdrawal perennially and not developed so that withdrawals are so great that they can be sustained for only a few years or decades.

ILLUSTRATIONS