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Groundwater Level Survey in Nebraska

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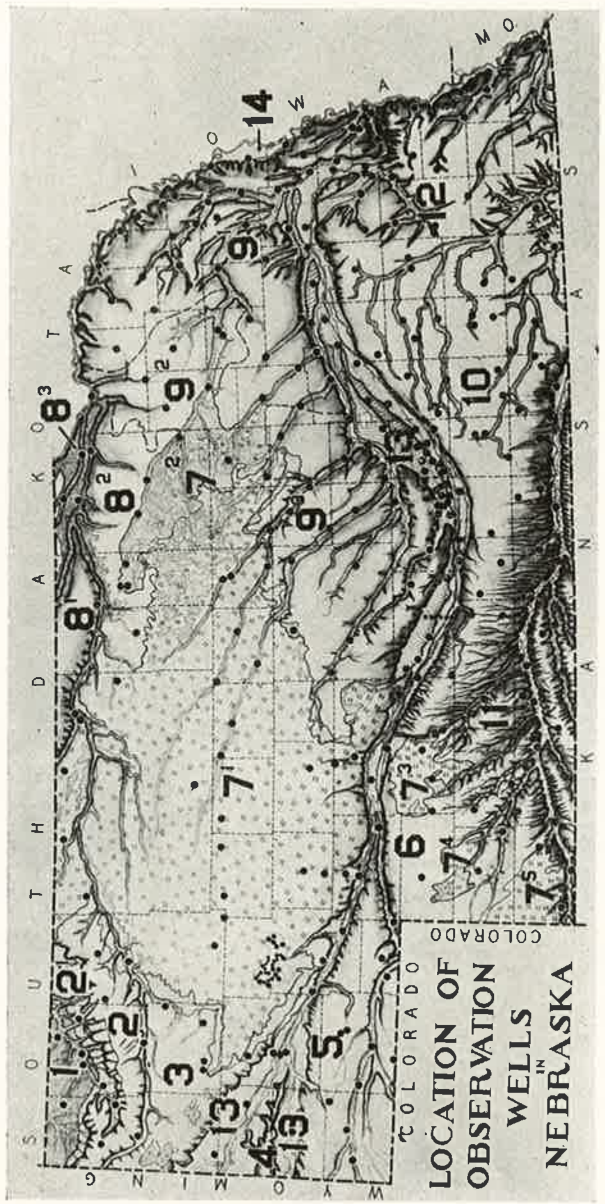

The Topographic Regions of Nebraska: 1, Pierre Plains; 2 and 2[1], Pine Ridge; 3, Box Butte Tableland; 4, Wild Cat Ridge; 5, Cheyenne Tableland; 6, Perkins Tableland; 7[1] and 7[5], Sandhill Region and outliers of which 7[2] is the Prairie Plains area; 8, 8[1], 8[2], and 8[3], Northern Tablelands in which 8[3] is the Boyd Plain developed on Pierre Shale; 9[1], 9[2], and 9[3], Loess Hill Region; 10, Loess Plain Region; 11, Republican Valley Region; 12, Drift Hill Region; 13, Platte Valley Lowlands; 14, Missouri River Lowlands.

GROUNDWATER LEVEL SURVEY IN NEBRASKA

By Herbert A. Waite
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Groundwater is now recognized as a leading natural resource. Its wastage and near exhaustion at places during periods of drouth have caused widespread alarm in regard to the permanence of this water supply. Present conditions call for a close, factual investigation of groundwater and the measures which should be inaugurated for its conservation. The investigation outlined in this paper is intended to be of use in showing the relation of groundwater to rainfall and drouth. It will also serve in the further study of the sources of replenishment and direction of movement of groundwater and in determining the availability of this water for various uses.

An investigation of the groundwater levels in Nebraska has been in progress since 1930 by the United States Geological Survey in cooperation with the Water Survey and Geological Survey departments of the Conservation and Survey Division of the University of Nebraska. This investigation included a study of the groundwater resources of the Platte River Valley in Central Nebraska where periodic measurements of the water levels have been made on approximately 120 irrigation and test wells since August, 1930 to determine their fluctuation in response to precipitation, irrigation, stream flow, and in some cases pumpage. A summary of the four-year period of observation appears in the latter part of this paper. Our present state-wide water level program incorporates a number of these original Platte Valley wells, so that the continuity of these records has not been broken.

At the present time there is a special demand for information concerning the configuration and fluctuation of the water table with reference to the source of the groundwater and the direction in which it is moving. In a state where there are recurring drouths, observations on groundwater levels, as well as surface water levels, become of prime importance. The drouth of the past few years emphasized most vividly the necessity of further definite investigations regarding the lowering of the water table.

Nebraska's comprehensive water level reading program is the first of the kind in the United States. Other states have had many cooperative regional groundwater investigations, but none of these has covered an entire state. Most of the cooperative projects have been special groundwater investigations restricted to small areas, as the one in Sacramento Valley, California; the Roswell Artesian Basin, New Mexico; and the Hartford and other areas in Connecticut.

Groundwater measurements are being made monthly in Nebraska on 325 wells scattered throughout the state. One full time observer covers most of them. Several agencies are cooperating in the program. The Department of Roads and Irrigation furnishes data every month on water-levels in the vicinity of Bridgeport. The Biological Survey is measuring water levels in a group of wells in Garden County in the vicinity of the Crescent Lake Bird Refuge, and these records are also available. Superintendent E. M. Brouse measures certain test wells on the University Experiment Station at Valentine. The City of Lincoln, through its city engineer, Mr. D. L. Erickson, has been making periodic measurements on numerous test wells in the vicinity of Lincoln's new municipal water supply plant near Ashland, and these readings are available. The City of Grand Island is keeping a record of the groundwater level in that vicinity by means of a well equipped with an automatic water stage recorder, and this record is also available.

Explanation of Terms. It is possible that some of the terms used in this paper may not be well understood by all who may read the report. Among these terms or names are the following: *capillary water, percolation, groundwater, water table, impervious platform, aquifer, water gradient, underflow, drawdown, replenishment, recovery,* and *depletion.*

The moisture that is held in the soil, subsoil, and mantle rock, but does not completely saturate them is largely *capillary water.* Its movement (*percolation*) is controlled by the porosity of the materials in which it occurs.

Groundwater proper is that form of moisture accumulation which fills or saturates the spaces in the ground. Its upper limit or surface is known as the *water table,* and in many places its lower limit is an *impervious platform* which prevents the percolation of water to greater depths.

A well-defined water-bearing formation is sometimes designated as an *aquifer* or water horizon in which the movement (*underflow*) of water is in the direction of the slope (*gradient*) of the water table. The groundwater is restored (*replenished*) from rainfall. It is withdrawn from storage by pumpage, by seepage, by evaporation, and by plant growth (*transpiration*). The lowering of the water table by pumpage is called *drawdown.*

The local adjustment and elevation of the water level in a well after pumping is known as *recovery.* The exhaustion or near exhaustion of the groundwater at any place is its *depletion.*

Location of Wells. Most of the wells being measured in Nebraska were located during the summer of 1934 by Mr. L. K. Wenzel of the United States Geological Survey, and the writer. It was the plan to use existing wells, wherever possible. In localities where difficulties were encountered in finding suitable wells upon which measurements might be

made, observation wells were drilled by the state drilling crew. During the fall of 1934 thirty such wells were installed. These wells filled in where control was lacking and thus served to complete the distribution pattern.

In choosing wells for observation, several precautions were necessary to insure a true reflection of the groundwater conditions at any point. It was desirable to keep away from all pumping influence which might tend to create a drawdown condition of the water table, since any well, adjacent to a pumped well, is liable to fall within the zone of influence or cone of depression of that well, and any measurement under such condition would not represent an accurate register of the water table at that point. It was found desirable, therefore, to locate wells at some distance from towns having municipal wells. In several instances, however, irrigation wells have been used as observation wells. The majority of the wells which have been under observation in the central Platte Valley since 1930 are of this type, and several more irrigation wells in other parts of the state are included for regular periodic observation.

An irrigation well is idle approximately nine months of the year, and measurements of it during this period of the year are representative of the normal conditions. One of the things favoring the observation of irrigation wells is the ease with which the measurement can be made. Then, too, wells of this type are more or less permanent, and successive observations may be secured for a long period of time.

Measurements on irrigation wells during the pumping season are of particular value, since they give evidence of the permeability of the gravel bed supplying the well by a reading of the drawdown level at the time of pumping. An approximation of the amount of water the aquifer will yield is also gained from observations of this nature.

From time to time it is found advisable to locate additional wells for observation in order to have them better adapted to our needs than those first located. Likewise, in a few instances, it has been necessary to locate wells similar to those that have been dismantled or otherwise rendered not usable.

Types of Wells. Several types of wells are included in those which have been selected for observation. Some of them are *abandoned or rarely used* wells, but are ideal for observation since their water levels are unaffected by pumping.

In the extreme southeastern corner of the state it was necessary to select a few *used* wells, since the recent drouth has put a premium on every well with any water in it whatsoever. Many of the abandoned wells in this vicinity were found to be dry, while the water bearing wells were equipped with pumps and were in service. It was necessary at places in this area to locate unused wells or to drill new ones for observation.

The procedure followed in using a well that is in service is to measure the depth to water and record a short account of previous water withdrawals, noting the time of withdrawal and the approximate amount of water withdrawn previous to the measurement. Thus, when the records are being interpreted in the office, the short history of the use of the well prior to measurement serves to explain conditions as they were at the time of the measurement.

In some parts of the state abandoned *dug* wells were located and used. These are particularly suitable for the installation of automatic water stage recorders because of their large diameters.

Tubular wells are common in many parts of the state. They are common in the sandhill areas where the water table is fifty feet or more below the surface. They are also the most common wells on the tablelands where the water table is relatively deep. The tubular well usually consists of a two-inch pipe with a sandpoint on the end and a cylinder which is generally placed just above the sandpoint. These wells have proven satisfactory wherever the gravel section which makes up the aquifer is of sufficient thickness and permeability to allow the water to be transmitted readily to the well.

In places where the gravel column is quite thin and where the material is less permeable, the tubular well becomes impractical, and the *cased* well makes its appearance. There are also portions of the state where the impervious bedrock floor lies close to the surface, and the aquifers resting on top of this floor are limited in thickness. Hence it becomes necessary to utilize as much of this narrower gravel column as possible, and a cased well best serves the demands.

Cased wells are typical in a narrow area bordering the Republican River. At places here the shallow bedrock limits the thickness of the water bed, and tubular wells are not entirely satisfactory.

There are areas in northeastern Nebraska, particularly in Knox and Boyd counties, where tubular wells have been tried and have been found to be a failure. The quality of the water is such that the screened portions of tubular wells are readily attacked by it and rendered useless. The life of an ordinary well screen is very short in this area, hence cased wells are more suited to existing conditions.

There are relatively few cased wells in the south-central part of the state, in the vicinities of Holdrege, Minden, Hastings, and in the areas south of these towns. Tubular wells are abundant here because they are best adapted to the conditions. The depth to water in this region ranges from about 80 to 200 feet, increasing westward, and the thickness and permeability of the gravel of the underlying aquifer is of such a nature that sufficient water is transmitted to a tubular well.

Tubular wells, with a few exceptions, are practically worthless for observation, due to the nature of their construction. Although many abandoned tubular wells were encountered throughout the state during the process of locating observation wells, few, if any, could be adapted for our use. In many cases the wells were open and unencumbered with a pump or rods, but in nearly every case a water level measurement was not reliable, due to the nature of the well. Oftentimes the check valve in the bottom of the well was still in place, and unless it were out of working order, the water level in the well would be held above normal, thus registering a false level. In many cases where the rods and the bottom check valve had been removed, the measurements could not be trusted, due to the condition of the sandpoint. After remaining in the ground over a period of years, some sandpoints become corroded, and the circulation through their screened portions becomes sluggish. In some cases the openings become sealed to the point where water can neither leave nor enter the well, and many times tubular wells are abandoned for this very reason. Therefore, no worthwhile use can be made of them for observation because of their questionable condition.

A simple field test to prove the merit of an abandoned tubular well is to measure the water level as it stands originally in the well, and then introduce from five to ten gallons of water in the pipe. If the artificially raised water level recedes to a point near the original reading, there is reason to believe that the well is open and functioning, and any measurement in the future should be an accurate register of the static level. If, however, the subsequent measurements do not indicate a decline in level after introducing the water, the well is not open for one reason or another, and hence, is not suitable for further observation. This test was used on this program to prove the feasibility of using several abandoned tubular wells. In two instances it was found necessary to discard wells of this type after tests had demonstrated that they were not open and not functioning properly.

Selecting Observation Wells. Several precautions were taken in choosing the observation wells that would be representative of normal conditions. In direct contrast to the effect of adjacent pumping, there is the opposite effect, namely the influence of nearby bodies of water, both moving and standing. These might, in turn, build up the water level to a point higher than normal in an observation well located within their range, thus creating another false picture of actual conditions. Therefore, any wells located in close proximity to irrigation canals, ditches, reservoirs, or to rivers backed up by dams are undesirable, and care should be taken to avoid such locations as often as possible. However, if it becomes desirable to locate a well under the circumstances just outlined, a careful description of any adjacent factors of influence should be recorded to aid in the interpretation of measurements of that well.

Several wells were located to show the effects of canal loss on the water table level in locations adjacent to such an influence. Others were chosen adjacent to streams in order to determine what relationship obtains between the fluctuating discharge of these streams and the water level in adjacent areas. A few observation wells were located at points along the upper reaches of the Blue River near the place where it changes from an intermittent to a live stream. The purpose here is to determine the relation of underflow to stream discharge.

Note: The observer should record a short history of all factors which might influence the water level in a well in any way. It has been shown that ponded water in roadside borrow pits, adjacent to a well, sometimes materially affects the water-level in that well. When recent rains or snows fill ditches near observation wells, the observer should record this in his notes to that effect. Every factor that has a bearing on the interpretation of any given measurement of a well should be recorded.

Depths to Water. The entire group of wells presents a varied assortment of depths to water, ranging from about 3 feet in the shallower wells to 275 feet in the deepest well. Some of the shallowest wells are located in valleys, as one would naturally expect, and the wells with water-levels more than 200 feet below ground surface are located on the higher uplands. The maximum depth to water of any of the wells located to date in this project is about 274 feet. This well is located about 15 miles northwest of Curtis, at the highest point in that vicinity.

There are a number of wells with water levels exceeding 100 feet in depth, and several in which the water table occurs at depths of more than 200 feet below the surface. The majority of the wells, however, have water levels ranging in depth from a few feet up to 100 feet below the surface.

Field Methods. Before entering the field, tentative locations were plotted on a map at strategic points. The next step in locating the wells was to travel to these various sites and search the vicinity of the position marked on the map for a well which would be suitable for observation. Considerable leeway was given to the man making locations, and the designated point on the map did not necessarily bind him to that particular locality. At times it was impossible to find a satisfactory well at the point marked on the map, but generally the area within a short radius of the point yielded a well which was satisfactory. If a suitable well was sighted at some point not necessarily indicated on the map, it was included, especially if it filled in the control for a given area.

The next step after locating a well in the field was to fill out a well schedule for it. A standard government form was used for this purpose and included date of location, field number of well, observer's name, owner's name; location by section, township, range, county, and state; elevation, total depth, type of well, size and type of casing, type of pump and power, character of water, etc. Other things pertaining to the well were included in this form. On the back of each sheet was included a description of the reference point, i.e., the point from which all measurements were to be made and a sketch of that point, showing relation to ground surface and its height above or below this surface. Below this sketch appeared a plan of the location of the well, which included roads leading to it and all features which would help in locating the well, such as houses, sheds, barns, fences, nearby drainages, section corners, etc. In tying a well into some known object, such as a house, barn, or fenceline, the approximate distances in feet were indicated. The completed schedule included sufficient information to permit a new observer to locate the well and obtain the kind of data established by the original observer.

It is desirable to have each well located on its respective county map. In placing it on a map, the location should show the position of the well in its proper 40-acre tract of the correct quarter section in which it falls. For convenience in the field, small portions of county maps showing individual well locations are mounted on cardboard placards, and in driving to a well the observer can select the map for the particular well he is to visit next and have it handy to aid him in locating it.

Copies of every well schedule are on file in Washington, D. C., and in the Lincoln office of the Conservation and Survey Division at the University of Nebraska. Likewise, the results of subsequent measurements of each well are again tabulated on an individual Well Measurement Record sheet, so that the well readings for any given well are listed in order, and a glance at the sheet will show the behavior of the water level in that well. From these sheets it is then possible to plot hydrographs for the wells which will show fluctuations in water level. A common practice in drawing up hydrographs is to plot a rainfall graph at the bottom of the sheet, thus showing the relation of precipitation to water level fluctuation.

Aquifers. There are many kinds of aquifers represented in a statewide program such as the one described here. It is desirable to have observations on as many different types of these water horizons as possible. A partial list of some of the principal aquifers in Nebraska would include the Dakota sandstone, Pleistocene sands and gravels, alluvial valley fills, Tertiary sands and gravels (including the Ogallala sandstone), the Fox Hills sandstone and associated formations, certain of the limestones in the Pennsylvanian System in the southeastern part of the state, small aquifers in gravel pockets and lenses in the drift hills, seep water in the Chadron formation on top of bed rock shale, and others.

Some of the wells in southeastern Nebraska tap Pennsylvanian limestone aquifers, while others are dependent on water which has for its source valley fill made up of alluvial sands and gravels. In the northeastern part of the state, glacial gravels and till furnish abundant water to wells. The Dakota sandstone in this area lies close enough to the surface in many instances for wells to penetrate and tap. In the central part of the state, sands and gravels of the Pleistocene age furnish abundant supplies to wells, both irrigation and domestic. In the western part of the state, Tertiary sands and gravels also furnish abundant supplies. The Ogallala formation, consisting of cemented sands and gravels and semi-consolidated sands and silty sands, is the best known Tertiary aquifer and yields good supplies of water. In some parts of northwestern Nebraska, the Chadron formation is the principal aquifer.

Methods of Measuring Wells. Steel tapes graduated in tenths and hundredths of a foot are used in this work. Lead weights are shaped out of ordinary sheet lead for use on the end of the tape and their function is to keep the tape taut inside the well. A hundred-foot tape is used for the majority of the wells, but the observer is also equipped with a 25-, a 50-, and a 300-foot tape. Wells over a hundred feet in depth are measured with the 300-foot tape.

The common practice in measuring a well where the surface of the water is visible to the observer is to chalk the first foot and a half of the tape with ordinary blue carpenter chalk. Next the tape is lowered into the well until some part of the chalked portion of it is cut by the water surface in the well. The observer then holds the nearest even foot mark of the tape on the previously selected permanent measuring point for the well, and hauls up the tape and reads where the water level has cut on the lower end. By subtracting this reading from the number of feet held on the reference point, the exact depth to water below the measuring point is obtained. If average care is taken in measuring, the readings should never be off more than a hundredth of a foot, and such accuracy is neither difficult nor impossible. On wells where the water surface is not visible, some experimenting is necessary before the correct depth to water can be ascertained, but once it is established, subsequent readings are simple and no further experimentation is required.

Types of Measuring Points. In selecting a measuring point, care must be taken to choose the most permanent point about the well. It is desirable to pick one that will not be altered, since all subsequent measurements of the well are to be made from that point, and it is imperative that the elevation of the reference point remain constant.

One of the first things to be carried out in the near future, in connection with measuring points, is the establishment of a permanent benchmark adjacent to each well, to which the reference point of the well will be tied in by instrumental levels. Then, if by some chance, the measuring point on any well is disturbed, a new one can be selected, and the difference in elevation between the new and old reference points can then be computed by tying in the new point to the permanent benchmark nearby.

Probably the most common measuring point chosen, for cased wells at least, is the top edge of the casing. Since the measuring point of each well is already referred to the ground surface, it is not necessary that the reference point be located on an object flush with the ground level. Another common reference point is the top edge of the concrete curb; still another might be the top edge of a wooden plank in the pump platform. Other reference points may also be established. The observer uses his own discretion in picking suitable measuring points on new wells.

Results. To date there have not been sufficient measurements on all of the wells to draw any reliable conclusions regarding the fluctuations of water levels, and any interpretation of the results will have to be deferred until more facts have been secured by subsequent measurements. However, the following are a few generalized deductions made at this time:

1. Little change in water level has occurred in the wells in which the water table is at a depth greater than 100 feet. In the majority of instances there have been raises or declines of a few hundredths of a foot, and in a few cases up to several tenths of a foot. In other words, the levels in this depth class seemed to be more or less constant. The wells falling in this depth range are unaffected by local recharge, and their water-levels are governed by broad regional recharge.

2. Wells in which the water table is comparatively close to the surface show considerable fluctuation. They responded to local precipitation, and show evidence of local recharge.

3. The shallow water table in the valleys and basins of the sandhill areas fluctuates considerably more than does the deeper water table in the sandhills proper.

4. During the drouth, the water table lowered markedly alongside the deep drainage canals.

5. There has been little fluctuation in the water level in the high table lands and in the Loess Plain Region during the past four or five years.

6. Some of the wells in the Platte Valley demonstrated very clearly the influence of extensive fall irrigation. The water level in the vicinity of Lexington has risen from 2 to 4 feet as a result of such irrigation, due to the recharge from ditches, laterals, and from fields flooded for irrigation.

Future Plans for the Work. It has been found advisable in a few instances to take steps to protect the open observation wells, because it is not uncommon for certain individuals to drop objects into open casings, and tampering of this nature is harmful, not only to future measurement, but it also spoils the well for possible further use. Therefore, there is a mutual interest between the well owner and the observer in keeping the wells protected from vandals. In several cases, wells which were originally chosen for observation have been filled by careless persons, making subsequent measurements of water levels impossible. It is planned to seal and lock with padlocks all isolated wells which might be subject to tampering.

Metal signs have been placed at each well with notices that it is being measured monthly by the state and the United States Geological Survey, and with the additional warning not to disturb it. Those signs will serve to protect the wells and make their use known to the public.

The establishment of sea level elevations at each of the wells in the near future is contemplated. The datum to be used in this work will be taken from the United States Coast and Geodetic Survey's precise level network. Much of the control can be gathered from permanent benchmarks located at advantageous points throughout the state. By using sea level datum for all of the state it will be possible to determine the altitude and contour of the water table.

It is also planned to extend the water level program to include a study of municipal water supplies for the entire state. The observer reading the wells has an excellent opportunity to become acquainted with conditions involving municipal supplies in Nebraska cities and towns. All of these studies should make it possible to predict a reliable estimate of groundwater available in the future for wells in Nebraska.

SUMMARY OF A FOUR-YEAR PERIOD OF OBSERVATION OF GROUNDWATER LEVEL IN THE PLATTE RIVER VALLEY IN CENTRAL NEBRASKA [1]

A resumé of the periodic observations since 1930 on the water levels in about 100 wells located in the Platte River Valley in central Nebraska, between Grand Island and Cozad, has shown that in October, 1934, the water levels in these wells stood from 1 to 8 feet lower than in October, 1930, thus indicating a general decline of the groundwater table throughout this part of the Platte Valley.

The greatest decline of the groundwater table has occurred in parts of the valley between Cozad and Kearney. In this area, the principal cause for this decline has been subnormal precipitation, combined with the fact that there has been a relatively small amount of surface water available for irrigation in the last four years. The decline has ranged from 4 to 8 feet in an area north of Cozad and Lexington and from 3 to 4 feet in an area on the north side of the valley from Lexington to beyond Kearney.

East of Kearney the decline of the water table has in general been less than the decline west of Kearney. In the area east of Kearney, the water table had not been built up prior to 1930 to any great extent by surface water irrigation, hence the decline was smaller. Such decline as occurred was due chiefly to subnormal precipitation, also in part to the considerable quantity of groundwater that was pumped for irrigation.

A comparison of the fluctuation of the water levels in 20 observation wells between Grand Island and Kearney and their relation to precipitation has shown the following: Water levels in wells in which the water table stands more than 10 feet below the surface in general rise and fall less than the water levels in wells where the depth to water is less than 10 feet below the surface. The wells are in the same stretch of the Platte Valley, but those of the latter group are located nearer the river where the water table is not far below the surface.

The more active fluctuation in the shallower wells is due to the following causes: Recharge from precipitation occurs more frequently where the water table is shallow, and thus more pronounced rises of the water level result. On the other hand, the roots of more plants draw water directly from the zone of saturation where the water table is shallow, and consequently larger declines of the water level occur in the growing season. In the winter and spring periods of 1931, 1933, and 1934, the average rise was less than one inch in the deeper but more than one foot in the shallow wells. Consequently, in the last four years the net decline was nearly the same in each group.

In the first half of 1932 there were rather large rises of the water levels in all of the wells in the Platte Valley due to an increase above normal precipitation at that time. From October, 1931, to April, 1932, the average precipitation recorded at Grand Island and Kearney was slightly above normal, and consequently considerable water percolated into the ground and was added to the groundwater reservoir in this recharge period. As a result, the water level did not reach as low a level in 1932 as it did in 1931. Since July, 1932, the precipitation has been about 22 inches below normal—almost one year's normal precipitation—and the water level in the valley has suffered annual declines. However, it may reasonably be expected that future years of greater precipitation will again raise the groundwater levels.

[1] Taken from Memorandum for the Press, "Four-Year Decline of the Ground-Water Level in the Platte River Valley, in Central Nebraska, Caused by Subnormal Precipitation." Cooperative investigation of State and Federal Geological Surveys by Leland K. Wenzel.

CONCLUSIONS

1. It is imperative that the water level readings be made for record over a long period of time, which is in line with the purpose of the Federal Government.

2. Studies of the water levels are fundamental in interpreting the fluctuation and contour of the water table.

3. The drouth of the past few years has emphasized most vividly the necessity of further definite investigations regarding the lowering of the water table.

4. Our present state-wide water level reading program incorporates a number of the original Platte Valley wells so that the continuity of the records has not been broken.

5. Observations are being made on 325 wells scattered over the entire state. Periodic measurements are to be made on these wells throughout the year.

6. There is an increasing amount of interest being shown on the part of the owners of the wells now being measured. The majority of them react very favorably to the work being done and are willing to cooperate in every possible way.

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