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GROUND WATER IN KEITH COUNTY, NEBRASKA

BY

LELAND K. WENZEL AND HERBERT A. WAITE

WITH SECTIONS ON

PLATTE VALLEY PUBLIC POWER AND IRRIGATION DISTRICT, SUTHERLAND PROJECT

BY

E. E. HALMOS

AND

CENTRAL NEBRASKA PUBLIC POWER AND IRRIGATION DISTRICT, TRI-COUNTY PROJECT

BY

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Prepared in cooperation with the
CONSERVATION AND SURVEY DIVISION,
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GROUND WATER IN KEITH COUNTY, NEBR.

By Leland K. Wenzel and Herbert A. Waite

ABSTRACT

This report presents the results of a cooperative investigation of the ground-water resources of Keith County, Nebr., by the Geological Survey, United States Department of the Interior, and the conservation and survey division of the University of Nebraska. The investigation, which constitutes a part of a State-wide program of ground-water studies in Nebraska, was made in the summer of 1935.

The North Platte and South Platte Rivers flow eastward across Keith County in moderately flat valleys and divide the county into three areas—an upland plain south of the South Platte River, an upland plain between the two rivers, and an area of sand hills north of the North Platte River. The south and middle uplands are underlain by the Ogallala formation, of Tertiary age, and are capped in places by accumulations of loess. The north upland also is underlain by the Ogallala formation, but it is capped almost everywhere by fine, incoherent, wind-blown sand that probably has been derived from the Ogallala and other Tertiary formations.

Abundant supplies of water are obtained from wells in all parts of the county. The water is derived chiefly from alluvial sand and gravel in the valleys of the rivers and from sand and gravel in the basal part of the Ogallala formation. A large amount of water also is stored in the wind-blown sand in the sand-hill area, but, as this area is sparsely settled, it contains only a few wells. The water in Keith County is hard but otherwise does not have objectionable properties.

The ground-water level, or water table, in Keith County ranges from the land surface to nearly 500 feet below the surface. It stands about 200 feet below the surface in most of the south upland and from 200 to 500 feet below in the middle upland. The water table is not far below the surface near the rivers and in depressions between sand hills on the north upland, but it stands 100 feet or more below the surface near the edge of valleys and below the higher land in the sand hills. Approximately 350 wells, about half of the wells in the county, were visited during this investigation and their depth ascertained. The depths ranged from 8 to about 500 feet and averaged about 147 feet. The average depth of water in the wells was about 21 feet.

The general movement of ground water beneath the south and middle uplands is from southwest to northeast or east. The water level near the south county line slopes toward the South Platte River, with a gradient of about 10 feet to the mile. Ground water east of Ogallala apparently moves out of the South Platte Valley under the middle upland to the North Platte Valley, but the amount of this underflow probably is small. Beneath the north upland the movement of ground water is to the south or southeast. This area of sand hills constitutes a large underground reservoir that furnishes considerable water to the North Platte River by direct percolation and also by seepage into tributaries of the river. The drainage of the area is poorly developed, and the wind-blown sand readily absorbs large quantities of the rainfall; thus there is plentiful recharge to the zone of saturation. The water table beneath a large part of the area stands 150 to 300 feet above the level of the North Platte River, and the slope to the stream is as much as 75 feet to the mile.

Most of the water pumped from wells is used for domestic purposes and for stock. In size and capacity most of the wells are small. Of 323 wells visited, 239 were 3 to 4 inches in diameter, 13 were less than 3 inches, and 71 were larger than 4 inches. About 36 wells are pumped for irrigation, but it was reported that less than 800 acres of crops were irrigated by ground water in 1934.

The fluctuations of water level in wells in the county are mostly small. Ground-water discharge apparently is adjusted closely to the rather small recharge, and seasonal fluctuations are small, except in some of the wells in areas where the water level is very near the surface. The water level in most of the wells on the uplands fluctuates from day to day in response to changes in atmospheric pressure, but in 2 years of observation on these wells and on the wells in the areas of shallow water level, no long-time trends could be discerned.

INTRODUCTION

COOPERATIVE GROUND-WATER INVESTIGATIONS IN NEBRASKA

A cooperative investigation of the geology and ground-water resources of south-central Nebraska was undertaken in 1930 by the Geological Survey of the United States Department of the Interior and the conservation and survey division of the University of Nebraska. The results of this work have since been published.[1] In 1934 a State-wide program of water-level measurements in wells was begun.[2] At the end of 1936 this program included about 60 wells in the Platte River Valley in which periodic measurements have been made since 1930 and about 350 other wells throughout the State that were established as observation wells in 1934, 1935, or 1936.

In 1935 the scope of the cooperative investigation was enlarged to cover a general program of ground-water work throughout the State, and an investigation of the ground-water resources of Keith County was made. It is planned to conduct investigations in other parts of Nebraska where ground-water problems exist and also to continue the program of water-level measurements for an indefinite period. This report presents the results of the work done in Keith County by L. K. Wenzel, of the Federal Geological Survey, and H. A. Waite, of the State Geological Survey.

METHODS USED IN THIS INVESTIGATION

The surface geology of Keith County was mapped, use being made of the soil map of the county prepared by the United States Depart-

[1] Wenzel, L. K., The Thiem method for determining permeability of water-bearing formations and its application to the determination of specific yield: U. S. Geol. Survey Water-Supply Paper 679-A, 1936. Lugn, A. L., and Wenzel, L. K., Geology and ground-water resources of south-central Nebraska, with special reference to the Platte Valley between Chapman and Gothenburg: U. S. Geol. Survey Water-Supply Paper 779, 1938.

[2] Waite, H. A., Ground-water level survey in Nebraska: Nebraska Geol. Survey Paper 7, 14 pp., 1935. Wenzel, L. K., A State-wide program of periodic measurements of ground-water level in Nebraska: Am. Geophys. Union Trans., 1935, pp. 495–498; The recovery of ground-water levels in Nebraska in 1935: Am. Geophys. Union Trans., 1936, pp. 370–371. Water levels and artesian pressure in observation wells in the United States in 1935: U. S. Geol Survey Water-Supply Paper 777, pp. 86–94. Water levels and artesian pressure in observation wells in the United States in 1936: U. S. Geol. Survey Water-Supply Paper 817, pp. 89–167, 1937.

ment of Agriculture [3] because it was found that the soils closely reflect the nature of the underlying materials. (See pl. 1.) The logs of test holes drilled by the conservation and survey division of the University of Nebraska and by the Platte Valley Public Power and Irrigation District were studied. Information was obtained on about 350 water wells in the county with respect to their diameter and depth, depth to the water-level, use, and, in a few of the wells, the quality of the water. (See pl. 2 and table of well records.)

A map showing the contours on the water table in the county was prepared from data obtained by measuring the depth to water level in the wells. A definite point at the top of the well, usually the top of the casing, was used as a mark from which to measure. The altitudes of the measuring points were determined approximately by the use of altimeters, and the altitude of the water level in each well was obtained by subtracting the depth to the water level from the altitude of the measuring point. After the locations of the wells and the altitude of the water level in each were plotted on a base map, contour lines, or lines showing equal altitudes of water level, were drawn. From this map the altitude at which the water level will be encountered or the altitude to which the water level will rise if wells are drilled in any part of the area can be estimated. (See pl. 2.)

A map showing the range in depth of the water table below the land surface (pl. 5) was prepared from the map showing contours on the water table and from the topographic maps of the Federal Geological Survey, which show the altitude of the land surface.

Weekly measurements of water level were made in several wells in Keith County while field work was in progress in the summer of 1935, and measurements have been continued at about monthly intervals in some of these wells as a part of the State-wide program of water-level measurements. The water levels in two wells in Keith County and one well in Deuel County, about a mile west of the Keith County line, have been measured periodically since the summer of 1934.

ACKNOWLEDGMENTS

The investigation in Keith County was carried on under the general supervision of G. E. Condra, director of the conservation and survey division of the University of Nebraska, and O. E. Meinzer, geologist in charge of the division of ground water of the Federal Geological Survey, to whom the writers are indebted for constructive criticism and suggestions during the investigation and for review of the manuscript of the report. E. C. Reed, assistant State geologist, also reviewed the manuscript and gave many helpful suggestions, especially relating to the geology of the county. Howard Haworth, O. J. Scherer, and C. S. Osborne, of the conservation and survey division,

[3] Layton, M. H., and Buckhannan, W. H., Soil Survey of Keith County, Nebr.: U. S. Dept. Agr., Bur. Chem. and Soils, (Soil Survey Rept.) ser. 1926, No. 14, 52 pp., 1930.

drilled test holes at several locations in the area to ascertain the thickness of the water-bearing deposits. Mr. Scherer and R. R. Bennett, also of the conservation and survey division, have made measurements of water levels in observation wells in Keith County since 1935, and Mr. Scherer located and obtained information in 1935 on several wells in the sand-hill area. A. L. Lugn, geologist, University of Nebraska, assisted the writers by furnishing information relating to the geology of the area, and E. E. Halmos, consulting engineer of the Platte Valley Public Power and Irrigation District, furnished logs of several test holes. Chemical analyses of samples of water collected from wells in the county were made by E. W. Lohr of the Federal Geological Survey. The writers are much indebted to the residents of the area for freely furnishing information regarding their wells and for allowing their wells to be measured, sometimes at an inconvenience to themselves.

PREVIOUS INVESTIGATIONS

The principal earlier reports that include some discussion of the Keith County area and that have been drawn upon to some extent in this report are listed below:

Hay, Robert, Water resources of a portion of the Great Plains: U. S. Geol. Survey 16th Ann. Rept., pt. 2, 1895.

Johnson, W. D., The High Plains and their utilization: U. S. Geol. Survey 21st Ann. Rept., pt. 4, 1901, and 22d Ann. Rept., pt. 4, 1902.

Darton, N. H., Preliminary report on the geology and underground water resources of the central Great Plains: U. S. Geol. Survey Prof. Paper 32, 1905.

Slichter, C. S., and Wolff, H. C., The underflow of the South Platte Valley: U. S. Geol. Survey Water-Supply Paper 184, 1906.

Layton, M. H., and Buckhannan, W. H., Soil Survey of Keith County, Nebr., U. S. Dept. Agr., Bur. Chem. and Soils (Soil Survey Rept.), ser. 1926, No. 14, 52 pp., 1930.

Condra, G. E., The conservation of Nebraska's water resources: Nebraska Univ., Conservation Dept. Bull. 3, 1930.

Condra, G. E., Schramm, E. F., and Lugn, A. L., Deep wells of Nebraska: Nebraska Geol. Survey, 2d ser., Bull. 4, 1931.

Condra, G. E., The relation of drought to water-use in Nebraska: Nebraska Univ., Conservation Dept. Bull. 6, 1934.

Condra, G. E., and Reed, E. C., Water-bearing formations of Nebraska: Nebraska Geol. Survey Paper 10, 1936.

Lugn, A. L., Pleistocene geology of Nebraska: Nebraska Geol. Survey, 2d ser., Bull. 10, 1935.

GEOGRAPHY

LOCATION, EXTENT, AND POPULATION

Keith County lies in the southwestern part of Nebraska. (See fig. 1.) The southwest corner of the county touches the northeast corner of Colorado. Ogallala, the county seat, is 332 miles by rail west of Omaha and 228 miles northeast of Denver. The county has an area

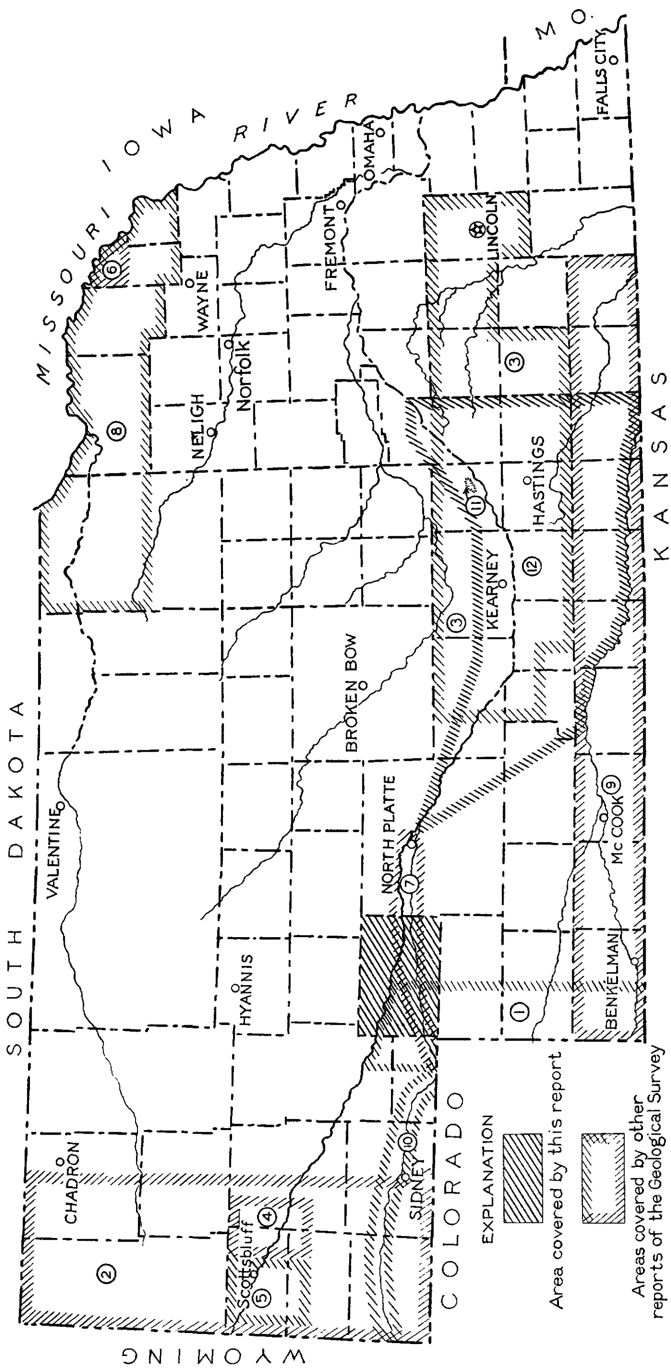

FIGURE 1—Map of Nebraska showing location of Keith County and other areas in Nebraska covered by reports of the Geological Survey.

1. 16th Ann. Report, pt. 2, pp. 535–588.
2. Professional Paper 17.
3. Water-Supply Paper 12.
4. Geologic Folio 87.
5. Geologic Folio 88.
6. Geologic Folio 156.
7. Water-Supply Paper 184.
8. Water-Supply Paper 215.
9. Water-Supply Paper 216.
10. Water-Supply Paper 425–B.
11. Water-Supply Paper 679–A.
12. Water-Supply Paper 779.

of 1,085 square miles and extends approximately 42 miles east and west and 27 miles north and south.

Keith County was organized from a part of Lincoln County in 1873. Its present boundaries were established in 1887, when a part of it was taken to form Perkins County. The population of the county grew from 194 in 1884 to 6,721 in 1930. According to the census of 1930, a little more than half of the population of the county is classed as rural. The sand-hill area is sparsely settled and the population is densest in the river valleys and on upland plains. In 1930 Ogallala, the largest town in the county, had a population of 1,631; the village of Paxton, 507; and the village of Brule, 329.

TRANSPORTATION

The county is crossed by the main line of the Union Pacific Railroad, which follows the north side of the South Platte Valley. A branch of this system traverses the North Platte Valley. United States Highway No. 30 follows the South Platte River across the county, paralleling the railroad most of the way. It is hard-surfaced across the entire county. County roads follow section lines, except in the sand hills and in the severely eroded parts of the tablelands, where the surface relief controls their location.

AGRICULTURE AND INDUSTRIES

At the present time much of the land on the north and south tablelands and throughout the North Platte and South Platte Valleys is held in comparatively small farms and is used for the production of grain and livestock. The sand hills are included in large stock ranches, on which sufficient hay is cut for feeding purposes.

Corn is the leading crop in the county. Wheat ranks second among the grain crops. Oats rank third and are often grown as an intermediate crop between corn and wheat. Barley ranks next, followed by rye. Sugar beets are grown by a few farmers, entirely on irrigated land. Potatoes are grown in a small way throughout the terraces and uplands. Wild hay occupies the largest acreage of the hay crops. Some alfalfa is also raised. Among the minor crops sorgo (sweet sorghum), millet, Sudan grass, and sweet clover are the most important. They are grown chiefly for feed.

Under average prevailing conditions the hard lands are thought to be better suited to the small-grain and forage crops and the sandy soils to such crops as rye, corn, and potatoes. The eroded slopes of the canyons and the less stable parts of the sand hills are suitable only for grazing.

As throughout most of western Nebraska, the livestock industry holds an important place in the agriculture of Keith County. The raising of cattle is the most important branch of this industry. Sheep raising receives little attention, and hog raising is only moderately important. Very few hogs are raised in the sand-hill area. Practically no manufacturing is carried on.

CLIMATE

Keith County has a clear, dry, stimulating climate characteristic of moderately high plateaus. The seasons are rather widely variable, with somewhat long, cold winters and short, warm summers. The falls are usually long and mild. The rainfall is moderate, the humidity relatively low, and the rate of evaporation high. Most of the precipitation occurs in the spring and early summer, although there are occasional periods of rainy weather in the fall. There are no pronounced differences in climatic conditions within the county.

The heaviest rainfall occurs during the growing season, from May to August, for the most part as local thundershowers. In early summer the rainfall is, in general, fairly well distributed, but from July on the distribution is less and less favorable, until conditions bordering on drought sometimes occur during August and September. The recorded average annual rainfall at Paxton is 19.79 inches and at Ogallala, 19.16 inches. The following tables give the mean monthly, seasonal, and annual precipitation and the precipitation in the wettest and dryest years of record at Paxton and the annual precipitation at Paxton and Ogallala.

Mean monthly, seasonal, and annual precipitation and precipitation in wettest and driest years of record, in inches, at Paxton, Keith County

[From U. S. Weather Bureau]

Month	Mean [1]	Total amount for the driest year (1934)	Total amount for the wettest year (1915)
December	0.62	0.34	0.59
January	.38	.08	.48
February	.67	.58	.59
Winter	1.67	1.00	1.66
March	.87	.30	1.98
April	2.22	(2)	9.06
May	3.08	1.51	9.13
Spring	6.17	1.81	20.17
June	3.08	1.99	4.01
July	2.70	1.05	2.52
August	2.82	.96	6.87
Summer	8.60	4.00	13.40
September	1.63	2.00	1.38
October	1.22	(2)	1.20
November	.50	.52	.01
Fall	3.35	2.52	2.59
Year	19.79	9.33	37.82

[1] Based on precipitation averages obtained from the U. S. Weather Bureau station at Lincoln, Nebr., for the 35-year period, 1898–1932 inclusive, part of which were supplied by interpolation.
[2] Trace.

Annual precipitation, in inches, at Paxton and Ogallala, Keith County

[From U. S. Weather Bureau]

Year	Paxton	Ogallala	Year	Paxton	Ogallala
1894		6.65	1923	25.19	
1910	11.57		1924	13.03	
1911	16.72		1925	15.99	18.66
1912	21.78		1926	17.44	15.69
1913	19.98		1927	20.84	22.41
1914	16.59	15.79	1928	22.54	21.37
1915	37.82	38.77	1929	17.18	14.58
1916	13.87	15.79	1930	23.25	22.36
1917	21.33	16.12	1931	16.05	14.16
1918	24.52	18.62	1932	20.42	17.13
1919	27.42		1933	22.64	25.35
1920	17.62		1934	9.33	
1921	14.03	19.61	1935	24.62	22.72
1922	16.24				

SURFACE FEATURES

Keith County is in the western part of the Great Plains region. It includes about equal parts of the high-plains and sand-hill divisions, which together comprise the uplands and occupy about 85 percent of the total area. The entire area north of the North Platte River, the north upland, which constitutes about 40 percent of the total area, is mantled with deposits of fine sand of eolian origin. The area south of the North Platte River is made up of almost level to undulating tablelands, which are remnants of the original high plains. The broad valley of the South Platte River separates this division into two triangular tableland areas, a middle upland and a south upland, the middle upland being slightly larger.

Except where modified by rather broad and shallow stream valleys, the surface features of the high-plains division are those of a gently eastward-sloping constructional plain. This plain was uplifted in early Pleistocene time, and the rivers extending across it excavated valleys of greater or less width and depth, the process of erosion soon giving rise to the local features of the present topography. The surface slopes so gently in many places that drainage would be deficient if it were not for the low regional rainfall and underlying permeable rocks. Long and gradual slopes are typical of the south upland, where, in places, shallow basin-like depressions and gravelly and sandy knolls occur. Where the Ogallala formation disintegrates in place, an accumulation of sand and scattered pebbles remains. The surface is exceptionally rough along the bluffs of the South Platte Valley, where the tributary streams have carved the edge of the tableland and produced narrow strips of sharply dissected land.

Similar areas of rough land occur on the middle upland in belts averaging less than 3 miles in width. In the eastern part of the county, the converging rivers and their tributaries have carved the intervening upland into an intricate system of deep, steep-sided ravines separated by narrow, crest-like divides. Bedrock is exposed as escarpments at a number of places in the sides of the valleys. In the western part of the county the tableland is hilly, and the surface is broken by steep-sided drainageways, which in their lower courses tend to break into gullied ravines with gravel-strewn floors. Steplike benches, which have been caused by slumping of the land along the slopes, are prominent features in this area.

The area north of the North Platte River is a part of the great sandhill region of western Nebraska. The surface has been modified by wind and is a succession of sandy hills and ridges alternating with narrow valleys and depressions, some of which are marshy. These dunes and ridges range in height from 20 feet to 60 feet or more.

Belts of alluvial land 1 to 4½ miles wide lie along the North Platte and South Platte Rivers and along many of their short tributaries. Terrace gravels are extensively developed higher on the sides of the valleys. Lying about 200 feet below the general level of the uplands and 30 to 50 feet above the normal level of the streams, these flat to gently undulating terraces, or second bottoms, are well drained. Terrace lands are most fully developed along the South Platte River. The bottom lands, or flood plains, occupy the lowest positions in the county. With a few modifications, they are prevailingly flat and in places are subject to inundation during high stages of the rivers.

The average altitude of the sand-hill area of the county is about 3,450 feet; of the upland plains, 3,400 feet; and of the alluvial lands, 3,150 feet. The general slope is toward the east, the altitude of United States Coast and Geodetic Survey bench marks at Brule being 3,288 feet; at Ogallala, 3,214 feet; and at Paxton, 3,057 feet.

DRAINAGE

Keith County is drained by the North Platte and South Platte Rivers and their tributaries. The South Platte River traverses the county with a gradient much steeper than that of the North Platte. At the west county line the South Platte River is about 90 feet higher than the North Platte; at Ogallala the South Platte is 60 feet higher, and at Paxton 35 feet higher than the North Platte directly north of these points. During most of the year the water in both the North Platte and South Platte Rivers flows in a network of shallow, meandering channels. The flow of the North Platte generally is sustained throughout the year, whereas the South Platte often becomes dry, except for scattered water holes.

Numerous perennial streams, most of them less than 6 miles in length, flow out of the sand hills to the North Platte River. These streams have relatively constant flows because they carry chiefly ground water that is discharged from the large underground reservoir of the sand-hill area. Whitetail Creek is the largest of these streams (pl. 4).

The drainage on the middle upland is in general southeast to the South Platte River and north to the North Platte. At many places the headward projections of the two sets of tributaries, all of which are ephemeral, meet at an obtuse angle. Canyons that drain to the South Platte River appear to have their counterpart in canyons that head on the same divide but drain to the North Platte River. For example, Ogallala Gulch, northwest of Ogallala, appears to connect with Bryan Canyon, which drains northward; Chase Canyon, which slopes southeastward, is in line across the divide with the head of Eagle Gulch, which slopes northward; and the head of Brule Canyon, which drains southeastward, is nearly coincident with the head of Dankworth Canyon, which breaks out of the northern edge of the tableland and drains northward.

The drainage on the south upland is north to the South Platte River. None of the streams are perennial, and most of the drainage lines are short and rather steep. Shallow undrained depressions in which the rainfall collects and stands for long periods, occur a few miles south of the South Platte Valley. These depressions are probably the result of wind erosion.

PUBLIC POWER AND IRRIGATION PROJECTS

Two public power and irrigation projects are under construction in Keith County. The Platte Valley Public Power and Irrigation District, known as the Sutherland project, plans to divert water from the North Platte River and to carry it through a system of canals to the vicinity of North Platte, Lincoln County, where it will be utilized for power production and irrigation. The Central Nebraska Public Power and Irrigation District, known as the tri-county project, plans to construct a dam on the North Platte River in Keith County where water can be stored and released down the river for power production and irrigation in the south-central part of the State. Descriptions of the two projects by E. E. Halmos and G. E. Johnson are given below.

PLATTE VALLEY PUBLIC POWER AND IRRIGATION DISTRICT, SUTHERLAND PROJECT

By E. E. Halmos, Resident Engineer in Charge

The Platte Valley Public Power and Irrigation District, organized under the laws of the State of Nebraska, senate file 310, comprises Keith, Lincoln, Dawson, Buffalo, and Hall Counties and extends for a distance of about 200 miles along the North Platte and Platte Rivers between Ruthton and Grand Island. The district owns a water-storage and hydroelectric development, known as the Sutherland project, the construction of which was begun in 1934 and is now (1935) in the process of completion.

The Sutherland project was conceived primarily to provide much-needed supplemental irrigation to lands in the Platte Valley between North Platte and Kearney, which lands are under canals that have been constructed and operated by eight different companies during a period of about 50 years. The continuously decreasing flow in the Platte River, which was due to increased use of water west of North Platte, pointed to the need of storing the winter flow of the river for release during the late spring and the summer. Economic studies indicated that in order to make the project self-supporting, electrical power of a salable character must be produced and must be sold at a price high enough to provide for about four-fifths of the fixed and operating charges.

It was found economically possible to construct a reservoir having a capacity of approximately 175,000 acre-feet at a place about 3 miles south of the village of Sutherland, in Lincoln County. This capacity was considered necessary for the successful operation of a hydroelectric power plant and for the delivery of supplemental water to irrigators. The full reservoir has a water surface 3,084 feet above sea level. Complete utilization of the water necessitates drawing this down 65 feet.

The source of the water for storage in the reservoir and for the operation of the power plant is the North Platte River, and a point had to be located along this river that was sufficiently high above the level of the Sutherland Reservoir to permit the conveyance of a part of the flow of the river into the reservoir. Such a point was found near Keystone, in Keith County, where the diversion dam and canal intake were located.

From the intake the water is carried eastward in an open canal on the south slope of the North Platte Valley in Keith County for a distance of about 17 miles and thence southward in a huge cut through the divide between the North Platte and South Platte Rivers. At the south end of this cut, at Paxton, the water enters a pressure conduit called the South Platte siphon, which is 1½ miles long. This conduit crosses the South Platte Valley underneath the South Platte River and emerges on the south slope of the valley, whence the water again flows in a general easterly direction in an open canal for approximately 12 miles to the Sutherland Reservoir. The conduit from the diversion dam to the Sutherland Reservoir is called the supply canal.

The water issuing at the low level of the Sutherland Reservoir is conducted in an easterly direction through the outlet canal, approximately 19 miles long, into the regulating reservoir, which is about 6 miles south of the city of North Platte. From the regulating reservoir the water flows northward through a 3-mile power canal, forebay, and pen stocks to the powerhouse. The turbines discharge the water into a tailrace approximately 2 miles long, which terminates at the South Platte River about 3 miles west of the point where the North Platte and South Platte Rivers unite to form the Platte River.

The altitude of the spillway crest at the diversion dam is 3,123.25 feet, and the altitude of the South Platte River at the mouth of the tailrace is 2,795 feet. The maximum altitude of the regulating reservoir at the head of the power canal is 3,006 feet, which gives a gross head of 211 feet on the power plant, or 117 feet less than the total difference in altitude of the points of intake and return. The Sutherland Reservoir has a normal maximum draw-down of 60 feet, and approximately 57 feet of head is lost in friction in as many miles of conduit. All canals and structures are designed to accommodate a flow of 2,000 cubic feet per second.

In the powerhouse, two hydroelectric generating units are installed, each of which has a capacity of 12,500 kilowatts. Provision is made for the future installation of two additional units of the same capacity. All water to be delivered to the irrigation companies must pass through the turbines.

The electric current generated in the powerhouse is transformed to higher voltages at the switchyard, located near the powerhouse, and is thence transmitted to the east and to the south.

At present a 115-kilovolt 3-phase line connects the North Platte powerhouse with the generating station of the Loup River Public Power District at Columbus, Nebr.; a 66-kilovolt line is constructed to McCook; and the city of North Platte is supplied on generating voltage at 13.8 kilovolts. Future plans involve interconnection with the hydroelectric generating stations to be built by the Central Nebraska Public Power and Irrigation District.

CENTRAL NEBRASKA PUBLIC POWER AND IRRIGATION DISTRICT, TRI-COUNTY PROJECT

By G. E. Johnson, Chief Engineer and General Manager

The tri-county project is a realization of the ambitions of a large number of residents of south-central Nebraska to supplement the rainfall in that part of the State with water diverted from the Platte River. Some of the men who pioneered the promotion of the project 25 years ago are gone, but many are still living and are very much interested in the conservation of water, one of the natural resources of the State.

The project includes storage, irrigation, and hydroelectric plants with their transmission lines.

An on-river reservoir will be created on the North Platte River north of Ogallala, Keith County, by the construction of the Kingsley (Keystone) Dam.

Water leaving the Kingsley Dam will flow about 1¾ miles down the North Platte River to the diversion dam of the Platte Valley Public Power and Irrigation District, known as the Sutherland project. Here it may pass on down the river or be diverted as needed through their canal system, the Sutherland Reservoir, and the power plant near the city of North Platte, where it will be delivered to the South Platte River just above its junction with the North Platte.

The upper diversion dam of the tri-county project is to be built across the North Platte River about 1 mile downstream from the eastern boundary of the present North Platte Airport, which is east of the city. At this location it will control the combined flow of the North Platte and South Platte Rivers, including the water passing the power plant of the Sutherland project. The diversion dam is designed to deliver down the river the water that the senior appropriators downstream are entitled to have pass this point and at the same time to divert into the supply canal of the tri-county project the water that belongs to them by virtue of direct flow appropriations and stored water released at the Kingsley Dam.

The supply canal follows a southeasterly course across the valley south of the river. It enters the hills at Cottonwood Canyon and delivers water into the Jeffrey Canyon regulating reservoir, which is 21.5 miles below the upper diversion dam. The Jeffrey Canyon powerhouse is just below this regulating reservoir at the foot of the hills opposite the town of Brady and about 1½ miles west of it.

The tailrace from the Jeffrey plant continues eastward as the supply canal for about 3 miles to a wasteway, or control structure. At this point the water can be divided, in order to return to the river any surplus water, any water required to be turned into the river for senior appropriators downstream, or any stored water sold to these appropriators or others. The water to be retained by the tri-county project will continue to flow in the supply canal in a southeasterly direction and will discharge into the Johnson regulating reservoir, due north of Elwood.

Johnson Plant No. 1 is located about 1 mile east of its regulating reservoir. Water from this plant is carried eastward about 3½ miles to Johnson Plant No. 2, which is almost due south of Lexington. The tailrace of Johnson Plant No. 2 continues eastward as the supply canal for almost 4 miles, until it is within about 1,500 feet of the south channel of the Platte River. At this point another wasteway, or control structure, will be built, which will be similar to the one below the Jeffrey plant and will be used for the same purposes.

Tri-county water retained at this wasteway will be turned into the Phelps County canal, in the valley 2 miles west of the Gosper-Phelps County line. The Phelps County canal follows a general southeasterly direction until it reaches a point about 6 miles north of Holdrege,

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where it takes a course more to the east. It passes north of Funk, Axtell, and Minden. Northeast of Minden it empties into the Adams County canal, which follows a general northeasterly direction to within about 1 mile of Prosser.

Main irrigation laterals will take water from the Johnson regulating reservoir, Phelps County canal, and Adams County canal and deliver water to smaller laterals for irrigation lands between Elwood and Hastings.

The supply canal from the upper diversion dam to the Phelps County canal is 75.74 miles long, the Phelps County canal is 56.48 miles long, and the Adams County canal is 21.43 miles long, making a total of 153.65 miles of main canal.

Transmission lines have been laid out to serve the territory south of the Platte River from the Central Nebraska Public Power and Irrigation District's most westerly power plant to Lincoln, with convenient tie-ins with the Platte Valley Public Power and Irrigation District lines out of North Platte and the Loup River Public Power District lines out of Columbus. The main transmission system will carry 115,000 volts, and the secondary system will carry 34,500 volts.

KINGSLEY (KEYSTONE) DAM

The Kingsley Dam, also called the Keystone Dam, will be of the hydraulic fill type. It will be 1,100 feet wide at the base, 28 feet wide at the top, and 162 feet high. The top of the dam will carry a roadway bordered on each side by wave walls of concrete. The main dam will be about 2 miles long and will be joined by a dike 1 mile long. This dike will range in height from 60 feet at the point where it joins the dam down to a mere roadway embankment. Below the surface of the water the side slopes range from 3:1 to 5:1.

The shell of the dam will be composed of pervious sand and gravel pumped from borrow pits located in the valley above and below the dam. The finer materials will be sluiced into a core pool on the axis of the dam. Fines not supplied from the borrow pits will come from the loess-capped hills south of the dam. The impervious core thus formed will have a width equal to its depth from the top of the dam.

A 24-inch layer of selected gravel will serve as a bed for riprap surfacing on the upstream face of the dam.

A line of steel sheet piling with top extending into the impervious core will have its points embedded in Brule clay. This line of piling will connect with a concrete cut-off wall around the conduits at the south end of the dam and will extend northward across the valley for 9,700 feet. The piling ranges in length from 40 feet to about 165 feet.

The plans for the dam have been checked and approved by the Power Division of the Public Works Administration, the Federal Power Commission, the United States Army Engineers, and the Nebraska Department of Roads and Irrigation.

The present contracts include the building of the control structure and the Morning Glory Spillway, including equipment, the conduits and their stilling basin, and the steel sheet piling cut-off.

DISTRICT-OWNED LABORATORIES

Early in 1936 the District established at Ogallala a laboratory fully equipped to run any of the fundamental tests made at the laboratories of the United States Army engineers or the United States Reclamation Service.

Thirty-six model dams have been built in this laboratory. Most of them have contained actual materials available for construction, but a few have been constructed of synthetic materials for the purpose of checking model tests run with actual materials. All models have included a model subgrade equal to the actual subgrade to be encountered in the construction of the dam being studied.

Extensive field investigations have been made of quality and quantity of materials required for the embankment section of the Kingsley Dam.

UPPER DIVERSION DAM

The upper diversion dam is of the conventional type that experience of other engineers has shown to be very satisfactory for diversion dams on the North Platte and South Platte Rivers.

SUPPLY CANAL

The term "supply canal" applies to all of the canal system from the upper diversion dam to the Phelps County canal, a distance of 75.74 miles. The normal hydraulic section at the diversion dam has a capacity of 2,000 cubic feet per second, a velocity of 2.67 feet per second, a base width of 55 feet, and a water depth of 10 feet.

All the canals are located with the water surface as near the natural land surface as possible. In order to shorten the canal and otherwise obtain alinement it has been necessary at some places to have the water surface above the natural land surface. In all places on the supply canal where the water surface will be 2 feet or more above the natural land surface, a compacted embankment will be constructed 1 foot above the normal water surface and then finished to the top with cast-in material, with an allowance of 25 percent for shrinkage of the cast-in material.

Cross drainage is handled by pipe or flume inlets and by pipe or reinforced concrete box inverted siphon cross drains under the canal. Inverted siphons carry the canal under three of the largest drainage channels, and at three other large channels there will be a combination of a flume for the canal and a box culvert cross drain under the flume for the cross drainage. These are now under construction.

Run-off has been computed on the basis of 4 inches of rain falling in 2 hours with run-off completed in 4 hours. The percentage of run-off has been varied in accordance with the slopes of the drainage area.

POWERHOUSES

The substructure of the powerhouses will be reinforced concrete and the superstructure will have a structural steel frame. The walls are to be of face brick with stone trim.

The water wheels of the Jeffrey Plant will be of the Francis type for 116 feet head.

Each of the two generators will have a rated capacity of 10,000 kilovolt-amperes, 0.9 power factor, 6,900 volts, 3-phase, 60 cycles, 180 revolutions per minute.

The turbines of the Johnson Plant No. 1 will be of the same type as those at the Jeffrey Plant and for the same head.

Johnson Plant No. 1 will take water through a power canal about eight-tenths of a mile long leading from the Johnson regulating reservoir, which has a water-surface area of 2,800 acres and a capacity of 55,000 acre-feet when full.

At Johnson Plant No. 2 each turbine will take approximately 1,900 cubic feet per second at full load under a head of 146 feet. The first construction will include one generator rated at 20,000 kilovolt-amperes, 0.9 power factor, 6,900 volts, 3-phase, 60 cycles, 164 revolutions per minute, and provision for 1 additional unit. The electrical features, in general, are similar to the Jeffrey Plant and Johnson Plant No. 1.

All plants will be provided with water rheostats in order to maintain maximum flow of water for irrigation regardless of power requirem ents.

IRRIGATION

Water is essential to profitable agriculture. A profitable agricultural business is essential to the prosperity of a community that has no other means of making a living. In the tri-county area the problem is not irrigation and overproduction but how to obtain sufficient production with the aid of irrigation to enable the people to pay interest on their investments, to pay taxes, and to have enough left over to maintain an average American standard of living.

The lands within the tricounty district, even in years of normal rainfall, do not receive the amount of rain required to make agriculture a profitable business. The United States Census Reports covering the past 30 years show a steady decline in rural population. Pioneer settlers of the area tell of a general decline in the production of agricultural crops per acre during the same period. The need for irrigation in this area was recognized as early as 25 years ago, and the first promoters of the tri-county project felt the need for supplemental water for this use.

The first application for water made by the tri-county district listed 547,000 acres of land to which it wished to apply water. The granting of this application was challenged in the Nebraska Supreme Court by certain senior appropriators, and the court ruled that in Nebraska water could not be applied to lands outside of the watershed of the river from which diversion was being made. An amendment to this application resulted in the granting of a water right from direct flow, limited to 1 cubic foot per second for 140 acres of land, for 194,000 acres within the watershed and within the area covered by the first application. The total acreage to be irrigated from direct flow and storage is 298,000 acres.

Topographic maps having contour intervals of 2 feet were made before the lateral systems were laid out. Bench marks were set at half-mile intervals on each section line, in one direction only, as vertical control and section lines were used as horizontal control. Each map sheet showed the topography of 160 acres on a scale of 200 feet to the inch. In the office these were transferred to tracings, each tracing showing a square mile. The original sheets were plotted in the field by the protractor method from observations taken with a transit and stadia board. By the use of this method the district has been able to map the topography of more than 500,000 acres at an average cost of 12.9 cents per acre.

Land owners using water will be required to pay $2.50 per acre per year. The contract provides for an average annual delivery of 1 acre-foot per acre. The payment is to cover principal and interest on the Public Works Administration loan that was used for construction and to cover maintenance charges. After the loan is paid off the payment will be reduced to cover maintenance.

ROCK FORMATIONS AND THEIR WATER-BEARING PROPERTIES

GENERAL FEATURES OF ROCK FORMATIONS

The formations exposed in Keith County are of Tertiary age and younger. The oldest formation exposed is the Brule clay, the upper member of the White River group of Oligocene age, which is known to crop out in only one locality. A well in the North Platte Valley 4 miles west of Keystone was the only one in the county that passed through the Brule clay. This well also passed through the Chadron formation, the lower member of the White River group, and reached the Pierre shale, of Cretaceous age. The Ogallala formation, of late Miocene and Pliocene age, which constitutes the main part of the uplands in Keith County, unconformably overlies the Brule clay. The

Arikaree and Gering formations, which in the western part of the State lie above the Brule clay and below the Ogallala, are here absent.

Most of the middle upland, the high divide between the North and South Platte Rivers, is made up of sediments of the Ogallala formation. The western part of this upland, however, is capped by a deposit of loess that lies unconformably on the eroded surface of the Ogallala formation. (See pl. 1.) A smaller area of loess occurs in the central part of the middle upland, northeast of the town of Ogallala, and a still smaller deposit in the eastern part. A deposit of unconsolidated sand and gravel lies on part of the middle upland north of Paxton. This deposit is probably Pleistocene in age, but because sufficient information is not available to classify it definitely it was not mapped separately from the Ogallala formation.

On the north upland the Ogallala formation has been covered by extensive deposits of incoherent fine or medium-grained eolian sand, but it is exposed at the surface along tributaries near the North Platte River. Other isolated outcrops of the Ogallala formation may be found throughout the north upland, but these exposures are too small to show on the map.

Over the major part of the south upland the Ogallala formation is exposed at the surface. Areas of sand dunes are scattered throughout the eastern third of this upland, and thin deposits of loess cover the easternmost part.

The North Platte and South Platte Valleys in Keith County are partly filled with terrace and flood-plain deposits of Pleistocene and Recent age. The valleys of the larger tributaries to these rivers also contain valley fill. In this report no attempt is made to differentiate the older and younger alluvial deposits of the valleys and terraces.

The sandstone, sand, and gravel of the Ogallala formation and the alluvial material of the river valleys constitute the chief sources of water for the county. Adequate supplies of water usually are obtained from these materials at comparatively shallow depths, and hence it has not yet been necessary to prospect for deep aquifers. Channel sands in the Chadron formation may be present locally below the Brule clay, and, if present, they probably will furnish potable water. Deeper aquifers include the basal beds of the Niobrara formation, which are of doubtful value, and beds of the Dakota sandstone, which lie far below the surface and probably contain water that is highly mineralized.

LOGS OF TEST HOLES

Although numerous wells have been drilled in the county for water supply, few, if any, records were kept of the earlier drilling. Several test holes were drilled recently, and the thickness and kind of material encountered were recorded. In 1934 the equipment of the Nebraska Conservation and Survey Division was made available for drilling several holes in the North Platte Valley near Keystone, in connection with the construction of the diversion dam for the Platte Valley Public Power and Irrigation District. In 1935 several test holes were drilled specifically for this investigation. In March 1937, the Central Nebraska Public Power and Irrigation District drilled a test hole 4 miles west of Keystone that passed through the Brule clay and Chadron formation and reached the Pierre shale. The logs of 13 of the test holes are given on the following pages, and the locations of the holes are shown on plate 2.

Log of test hole 1, in sec. 2, T. 14 N., R. 38 W.

[Near north bank of North Platte River. Altitude 3,114.4 feet]

	Thickness (feet)	Depth (feet)
Sand, fine, grades to medium downward. No sharp change to next sample	5.8	5.8
Sand, medium to coarse, well-rounded, some medium-sized gravel, a few medium-sized pebbles, water-worn Brule	11.4	17.2
Sand, fine	2.9	20.1
Gravel, coarse to medium, some medium sand, water-worn pebbles of Ogallala and Brule	4.1	24.2
Sand, very fine, even textured	8.5	32.7
Sand, fine to medium, a slight amount of gravel	5.0	37.7
Gravel, medium, some sand, all subangular, water-worn pebbles of Brule and Ogallala, grades somewhat finer with depth	13.5	51.2
Clay (Brule)	4.6	55.8

Log of test hole 2, in sec. 2, T. 14 N., R. 38 W.

[Near midpoint of North Platte River, approximately 700 feet south of north bank. Altitude 3,115.1 feet]

	Thickness (feet)	Depth (feet)
Sand, fine to medium, grades coarser as depth increases	5.8	5.8
Gravel, medium, coarser, at 6.5 feet, a few broken-up pieces of Ogallala	.7	6.5
Sand, coarse to fine, gravel	9.1	15.6
Limy sandstone (Ogallala), large pieces of broken-up Ogallala in fine sand	.8	16.4
Sand, fine, with some small gravel	1.6	18.0
Sand, coarse, with pebbles at 18.4 feet, some large pieces of broken-up Ogallala at 21.0 feet	4.0	22.0
Sand, very fine	9.0	31.0
Sand, medium to coarse, with a few water-worn pebbles of Brule in lower part	2.6	33.6
Gravel, coarse, with large pieces of water-worn Brule fragments and a few pieces of broken-up Ogallala	5.4	39.0
Gravel, medium to coarse	3.9	42.9
Sand, medium, some fine, well-rounded, predominantly pink in color	3.0	45.9
Gravel, sand—gravel coarse, sand fine	2.2	48.1
Clay (Brule)	6.7	54.8

Log of test hole 3, in sec. 2, T. 14 N., R. 38 W.

[Approximately 550 feet north of south bank of North Platte River. Altitude 3,114.6 feet]

	Thickness (feet)	Depth (feet)
Sand, fine, grades coarser as depth increases, some small gravel in sample	6.5	6.5
Gravel, fine in upper few inches, medium to coarse below, some water-worn Brule fragments and some broken Ogallala material	6.3	12.8
Sand, coarse, some fine gravel, with large pieces of water-worn Brule fragments, a small amount of angular material (broken Ogallala)	6.8	19.6
Sand, coarse, some coarse gravel, all well-rounded	10.2	29.8
Gravel, coarse, some small pebbles, some coarse sand well-rounded to subangular, water-worn Brule fragments	11.7	41.5
Sand, coarse, with some fine gravel, mostly fairly well-rounded grains	2.3	43.8
Sand, coarser than that above with some subrounded large pebbles	2.8	46.6
Sand, medium to coarse, no pebbles, largely quartz, some hornblende and feldspar grains, some rather angular fragments of Brule clay	4.2	50.8
Clay (Brule)	5.3	56.1

Log of test hole 4, in the W½SE¼ sec. 26, T. 15 N., R. 38 W.

[Approximately 2.5 miles west and 2 miles north of Keystone]

	Thickness (feet)	Depth (feet)
Sand, wind-blown	32.5	32.5
Clay, black, loam	1.5	34
Clay, carbonaceous	4	38
Clay, bluish-green	4	42
Sand and fine gravel	4	36
Gravel	7	53
Clay, greenish	2	55
Gravel	4	59
Clay, brownish, hard	2	61
Sand, green, and fine green gravel with some clay chunks, hard drilling	9	70
Clay, greenish	2	72
Clay, chiefly greenish and brownish, grades into brown at 85 feet	15	87
Clay, sandy, brownish (Brule?)	21	108
Clay (Brule)	----------	108

Log of test hole 5 in the NE¼ sec. 35, T. 15 N., R. 38 W.

[Approximately 2.5 miles west of Keystone. Depth to water level, 9.2 feet]

	Thickness (feet)	Depth (feet)
Loam, sandy	0.5	0.5
Sand	3.5	4
Loam, sandy	5	9
Clay, bluish	1.5	10.5
Clay, black	1.5	12
Sand, green, coarse	1.5	13.5
Clay, black	3.5	17
Sand, green, coarse, and fine	11	28
Clay, greenish-yellow	.5	28.5
Gravel, fine	33.5	62
Clay, greenish-yellow	1.5	63.5
Sand, coarse and fine	49.5	113

Log of test hole 6 in the SE¼ sec. 35, T. 15, N., R. 38 W.

[Approximately 2.5 miles west of Keystone. Depth to water level, 7.5 feet]

	Thickness (feet)	Depth (feet)
Loam, sandy	0.5	0.5
Sand	5	5.5
Clay, black and bluish, contains vegetation; thin gravel layers at 14 feet	8.5	14
Clay, blue	1	15
Gravel, medium coarse with hard brown clay particles	8.5	23.5
Sand	8.5	32
Sand, coarser	2.5	34.5
Gravel, coarser	.5	35
Clay (Brule)	----------	35

Log of test hole 7 on the south line of sec. 35, T. 15 N., R. 38 W.

[Approximately 2.5 miles west of Keystone. Depth to water level, 7.0 feet]

	Thickness (feet)	Depth (feet)
Loam, sandy	0.5	0.5
Sand	3	3.5
Clay, bluish and black	6.5	10
Sand and fine gravel	11	21
Sand, finer	4	25
Sand and gravel, water-worn Brule and Ogallala fragments	29	54
Clay (Brule)	----------	54

Log of test hole 8 in the SE¼SE¼ sec. 5, T. 12 N., R. 41 W.

[On south side of South Platte River, 4 miles south and 6½ miles west of Brule, along west side of road, just south of irrigation canal]

	Thickness (feet)	Depth (feet)
Topsoil	5.5	5.5
Gravel, with sandy clay	2.5	8
Loess, yellow	3.5	12.5
Sand and fine gravel	9.5	22
Gravel, medium to coarse with sandy clay at 28½ feet	13	35
Gravel, with limy concretions	3	38
Clay, white, sandy, very compact, gravel lense at 58 feet (Ogallala)	44	82
Gravel, fine to medium	12	94
Clay, brown, sandy	11	105
Gravel, with some sandy clay	5	110
Gravel, coarse	17	127
Clay, light, sandy, very hard	11	138
Clay (Brule ?)	77.5	215.5

Log of test hole 9, on north line of sec. 35, T. 13 N., R. 41 W.

[On south sideof South Platte River, 2 miles south and 5½ miles west of Brule. Depth to water level 6.5 feet]

	Thickness (feet)	Depth (feet)
Topsoil	3	3
Clay, very rusty, sandy	2.5	5.5
Sand, gray, very micaceous	5.5	11
Clay, black, gummy	3.5	14.5
Gravel, coarse, very slow drilling	9.5	24
Clay, pinkish-white, sandy, with gravelly lenses at 39 feet and 47 feet (Ogallala)	29	53
Gravel, fine, cemented at 53 feet and 71 feet	20	73
Gravel, with some clay	3	76
Clay, consolidated, sandy	20	96
Clay, sandy, well-cemented, compact	8	104
Clay (Brule)	11	115

Log of test hole 10, in the SE¼NE¼ sec. 6, T. 12 N., R. 40 W.

[On south side of South Platte River, 3 miles south and 1½ miles west of Brule, just south of irrigation canal. Depth to water level about 55 feet]

	Thickness (feet)	Depth (feet)
Topsoil	3	3
Loess, yellow	2	5
Clay, sandy, sandier as depth increases	5	10
Gravel, fine	12	22
Clay, sandy	11	33
Gravel, fine	3	36
Limy sandstone, gravel (Ogallala)	3	39
Gravel, consolidated, hard drilling, sandy clay layer at 47½ feet	14	53
Clay, sandy, with fine gravel lense at 58 feet	16	69
Clay, brown, sandy, with thin sandstone layers	12	81
Clay, light, sandy, with thin sandstone layers, fossil roots at 96 feet	40	121
Clay, sandy, same as above	28	149
Gravel, fine to medium	11	160
Clay, sandy compact	3	163
Gravel, medium coarse at 175 feet, from 184 to 187 very hard drilling, cemented gravel	44	207
Clay, buff, sandy	20	227
Gravel, medium	1	228
Clay (Brule ?)	7	235

Log of test hole 11, in the SW¼NW¼ sec. 17, T. 13 N., R. 39 W.

[On north side of South Platte River, 5 miles west of Ogallala, just north of U. S. Highway 30 and east of county road intersection. Depth to water level 7 feet]

	Thickness (feet)	Depth (feet)
Loess, yellow	6	6
Clay, gray, sandy	2	8
Clay, black, gummy	2.5	10.5
Gravel, coarse below 14 feet	15.5	26
Gravel, coarse with sandy clay and sandstone particles	4	30
Sand, coarse, with fine gravel	11.5	41.5
Sandstone	1.5	43
Sand, coarse, with fine gravel	2	45
Gravel, coarse	16	61
Gravel, fine	7	68
Sand, coarse	5	73
Clay, brown, sandy, very tough and compact (Ogallala)	12	85
Clay, buff to white, sandy	8	93
Limestone	1	94
Clay, brown, sandy	15	109
Gravel	1	110
Limestone (?)	1	111

Log of test hole 12, in the NE¼NE¼sec. 36, T. 13 N., R. 39 W.

[On south upland, 4½ miles south and half a mile west of Ogallala, along south side of road about 250 feet west of section corner]

	Thickness (feet)	Depth (feet)
Topsoil	3	3
Loess	5	8
Gravel (Ogallala)	36	44
Clay, brown, sandy	29	73
Gravel, medium	5	78
Clay, light, sandy, containing some gravel	8	86
Gravel, medium to coarse	7	93
Clay, brown, sandy	2	95
Gravel, coarse	3	98
Clay, brown, sandy, with coarse sand and gravel	12	110
Gravel, fine to medium	3	113
Rock	----------	113

Log of test hole 13, in the SE¼SE¼ sec. 3, T. 14 N., R. 38 W.

[On bottom land south of North Platte River, 4 miles west of Keystone. Altitude, about 3,135 feet. Drilled by Central Nebraska Public Power and Irrigation District]

	Thickness (feet)	Depth (feet)
Soil, clay, and sand	8	8
Alluvium	5	13
Clay (Brule)	2.4	15.4
Clay, medium hard (Brule)	69.6	85
Clay, hard (Brule)	2	87
Clay, medium hard (Brule)	8	95
Clay, hard (Brule)	1	96
Clay, medium hard (Brule)	4	100
Clay, hard, fragments of fossilized bone (Brule)	3	103
Clay, medium hard (Brule)	47	150
Clay, hard (Brule)	33	183
Clay, hard, with pieces of white limestone and some fine sandstone (Brule)	27	210
Clay, moderately soft (Brule)	5	215
Clay, hard (Brule)	66	281
Clay, medium hard (Brule)	6	287
Clay, very hard, light colored (probably Chadron)	31	318
Clay, very hard, light blue (Chadron)	1.5	319.5
Clay, very hard (Chadron)	4.5	324
Clay, hard (Chadron)	4	328
Clay, light blue, soft, sticky (Chadron)	25	353
Shale, yellow, rusty, soft (weathered Pierre)	14	367
Shale, medium hard (Pierre)	4	371
Shale, very hard (Pierre)	.5	371.5
Shale, dark gray, medium hard, slightly sandy (Pierre)	3.5	375

QUATERNARY SYSTEM

PLEISTOCENE AND RECENT SERIES

ALLUVIUM

On the lower slopes adjacent to the North and South Platte Rivers and along some of the smaller streams of the county sandy loam, some of which contains coarse constituents, has been deposited by the streams from the higher lands. Some of this material is found on a wide zone of bottom lands bordering the rivers, and the rest is found on the adjoining terraces that in places extend back from the river bottom for several miles. The terrace and flood-plain deposits in Keith County are of Pleistocene and Recent age and were laid down in broad, deep valleys carved in the Tertiary formations by the North Platte and South Platte Rivers and their larger tributaries. The successive terraces and the present flood plain record a period of alternate filling and cutting in the valleys. The alluvium in the South Platte Valley overlies the Ogallala formation, whereas the alluvium in the North Platte Valley lies directly on the Brule clay. Seven of the eight test holes drilled in the North Platte Valley (Nos. 1, 2, 3, 4, 6, 7, and 13) encountered Brule clay directly beneath alluvium. Test hole 5 did not reach the Brule and ended in alluvium. All test holes drilled in the South Platte Valley (Nos. 8, 9, 10, and 11) encountered the Ogallala formation above the Brule clay.

The Pleistocene and Recent alluvium in Keith County consists of unconsolidated sand and gravel with some silt and clay. It includes much fine to coarse sand in varying mixtures, and unassorted fragments of the reworked Ogallala formation and Brule clay. The character, degree of assortment, thickness, areal extent, and distribution are extremely variable from place to place.

The Pleistocene and Recent alluvium differs from the Ogallala and older formations in that it does not represent a continuous stratigraphic horizon over a broad area. It is confined entirely to the North Platte and South Platte River Valleys and to their tributary valleys. The valleys of the two rivers are underlain by alluvium for distances ranging from about 1 to 3 miles from the streams, whereas the tributary valleys are underlain by only narrow strips of alluvium, which in many of the valleys are but a few hundred feet wide. The alluvium in the North Platte and South Platte Valleys is derived in part from the erosion of the mountains to the west and in part from the disintegration of the formations within the county, chiefly the Ogallala. The alluvium in the tributary valleys is largely inwash from the disintegrating Ogallala formation that has been carried down from higher levels by streams during freshets.

The alluvium that forms valley fill ranges in thickness from a few feet to about 150 feet. Test hole 5, which was drilled in the bed of the North Platte River, was still in alluvium at its total depth of 113 feet. The log of test hole 11, on the north side of the South Platte River 5 miles west of Ogallala, records a thickness of 110 feet of alluvium. Well 269, an irrigation well in the SW¼NW¼ sec. 32, T. 13 N., R. 40 W., is reported to have reached the Ogallala formation about 57 feet below the surface. In most places the alluvium probably is less than 150 feet thick. The variations in thickness are due largely to irregularities in the surfaces of the Ogallala formation and the Brule clay upon which it was deposited.

Much of the alluvium in the North Platte and South Platte Valleys is water bearing, and a large number of wells pumped by windmills and a few irrigation wells are supplied from it. Several of the irrigation wells are reported to yield as much as 1,000 gallons a minute. The alluvium in many of the tributary valleys occurs above the general water table and is not saturated. In such places wells must be sunk to the basal part of the Ogallala formation, which generally contains ample water for domestic wells. Recharge of the ground water in the alluvium from precipitation, especially where the water table is shallow, usually occurs in the spring, and thus moderate withdrawals of water do not permanently deplete the supply. There also is some recharge to the alluvium by underflow down the North Platte and South Platte Valleys and from the dune sand and Ogallala formation where these materials occur upgradient from the alluvium.

DUNE SAND

A vast deposit of dune sand, which reaches a thickness of more than 100 feet, mantles the Ogallala formation north of the North Platte River. The deposition of the sand probably began in Pleistocene time, while loess was being deposited in other areas, and has continued intermittently to the present time. The sand was probably derived from Tertiary formations and was deposited near its points of origin by the wind, the silt and clay being carried to more distant points. Strong winds assisted in disintegrating the Tertiary rocks and carried and rolled the residual sand into dunes that migrated in the direction of the prevailing winds until a vegetative cover was formed. This resulted in a rolling topography of gently sloping hills and wide valleys. These hills and valleys are still in process of formation and are still subject to modification through eolian influence. Although these sands were largely derived from the Tertiary formations, it is probable that they are in part the remains of formations of early Pleistocene age.

The sand-hill area is important hydrologically because it represents a large area of ground-water recharge. The mantle of sand that caps this area readily transmits a large part of the precipitation to the underground reservoir. The ground-water recharge is greater here than in any other part of the county. The area is sparsely settled and hence there are only a few wells, but these wells furnish abundant supplies of water. Although water occurs in many places at shallow depths, most of the wells are comparatively deep. The fine sand composing the sand hills does not yield water freely to wells, hence drilling generally is carried to a depth at which coarse sand or gravel is encountered. It is probable that a large proportion of the lateral flow of water in the sand hills is carried through the coarse sand and gravel that occur at depth beneath most of the area, although these materials apparently are thin in comparison with the dune sand. This sand and gravel may be part of the Ogallala formation or may be Pleistocene in age.

LOESS

Loess caps a large part of the middle upland in Keith County. (See pl. 1.) In many places it lies unconformably over the eroded surface of the Ogallala formation and was probably deposited chiefly in the Peorian stage of the Pleistocene epoch. It is believed to be the equivalent of at least a part of the sand hills in age.[4] The loess represents an outlying remnant of a former smooth plain that at one time extended west beyond its present limits. It is brownish-yellow, or almost white calcareous, loose, floury silt that contains little material coarser than very fine sand. The deposit is very uniform in texture and is compact but relatively soft. In many places accumulations of particles of white carbonate of lime give the material a splotched appearance. Occasional streaks of sand and old soil are found. Although it is known locally as yellow clay, the percentage of clay is comparatively small. A characteristic of loess is the manner in which it stands in the vertical plane, producing perpendicular bluffs along streams and in road cuts. Most of the loess in the county is thought to have been deposited by wind, although streams have played a contributing part in its origin.

Loess is limited, for the most part, to the middle upland. Where present on the south upland, notably south of Paxton, the deposits are relatively thin and in some places are intermixed with gravel. The formation probably does not exceed 50 feet in thickness. The loess is essentially not water-bearing in Keith County, as is shown by the fact that no wells are known to end in it.

TERTIARY SYSTEM

OGALLALA FORMATION

CHARACTER, DISTRIBUTION, AND THICKNESS

The Ogallala formation, of late Miocene and Pliocene age, lies unconformably on the eroded surface of the Brule clay. It consists of a series of hard and soft layers of sandstone, in part cemented with lime,

[4] Lugn, A. L., personal communication.

with some interbedded and intermixed buff to gray or pinkish structureless clay, silt, and fine sand. Pebbles of various kinds occur erratically throughout, and coarse gravels and conglomerates are found in the lower part. In places the Ogallala formation merges into a light-colored sandy clay that generally contains much carbonate of lime in the form of streaks or nodules. The harder calcareous beds are light gray. Quartz and feldspars usually make up about 95 percent of the mineral content of the sediments, but micas, garnet, magnetite, tourmaline, zircon, hornblende, olivine, epidote, sillimanite, and other minerals are found also.

The Ogallala formation dips gently southeastward, apparently conforming more or less to the general inclination of the original surface of the plains.

The dip is probably in part depositional and in part deformational.

This formation is well shown in the cliffs along the valleys of the North Platte and South Platte Rivers and in the walls of the canyons of the tributary streams. The caliche beds in it become very hard on being exposed and thus are resistant to erosion, whereas the interbedded silt, sand, and gravel disintegrate readily. Typical exposures of the Ogallala formation are characterized by ledgelike beds of caliche that project out over the slumping deposits of silt, sand, and gravel. (See pl. 3, *A*.) The formation gives rise to low, rounded knobs on the upland. Its maximum thickness in Keith County is about 500 feet. Well 274, on the middle upland plain in the SE¼SE¼ sec. 4, T. 14 N., R. 40 W., penetrated about 500 feet of the Ogallala formation. Water was encountered about 460 feet below the surface of the land, presumably in the basal part of the formation. As previously stated, the Ogallala formation was not encountered in the test holes drilled in the North Platte Valley, Brule clay being struck directly beneath the alluvium. However, all test holes drilled in the South Platte Valley and also the hole drilled on the south upland (No. 12) penetrated the Ogallala. Test hole 8, about 2½ miles south of the South Platte River, penetrated about 100 feet of the Ogallala formation before striking the Brule clay. (See pl. 2.) Test hole 9, about half a mile south of the South Platte, passed through about 80 feet of Ogallala before reaching the Brule. Test hole 10, 2½ miles south of the South Platte River and 5 miles east of hole 8, apparently penetrated 192 feet of Ogallala. Test hole 11, about a quarter of a mile north of the South Platte River, struck the Ogallala formation at about 85 feet below the surface and apparently was still in the formation when drilling was stopped at 111 feet. Test hole 12, 4 miles south of the South Platte, struck the Ogallala at about 8 feet below the surface after penetrating 3 feet of top soil and 5 feet of loess and apparently was still in the Ogallala when drilling stopped at 113 feet. Slichter and Wolff,[5] in connection with investigations of the underflow of the South Platte Valley, drove 9 wells in the valley south of Ogallala. Hard pan, probably caliche beds in the Ogallala, was encountered in 5 of the wells at depths ranging from about 35 feet to 60 feet. Hard pan was not encountered in 2 wells driven to about 80 feet below the surface and in 2 shallow wells. The diagram on page 10 of their report shows a V-shaped valley in the Ogallala that is filled with alluvium to a depth of more than 80 feet.

The Ogallala formation has the greatest areal extent of any of the bedrock formations exposed in the county. It occurs in much of the area south of the North Platte River, and scattered outcrops are found on the north side of the river.

ORIGIN

All the upland areas in Keith County are remnants of the original surface of the High Plains, which was laid down in Ogallala time. In Oligocene time, after the rivers had deposited the Brule clay, the regimen of the ancestral Platte River changed from a depositional cycle to an erosional one, perhaps in response to a gradual increase in humidity accompanied possibly by tilting. As a result, the surface of the Brule clay was dissected into wide, shallow troughs and broad intervening ridges. During this interval fluviatile sediments of early Miocene age were being deposited in western and northwestern Nebraska. At the beginning of Ogallala time (late Miocene) the topographic features on the Brule surface in Keith County were buried under a cover of smoothly spread alluvium.

The beginning of the Ogallala cycle of deposition represents a different set of physical conditions, possibly climatic, possibly diastrophic. The Platte River in Ogallala time was a desert type of stream. It had a more or less continuous flow, was widely variable in volume, and was always heavily loaded. A stream of this type normally overruns its banks and spreads upon the surface, which it either has built up or is engaged in building up, and by seepage losses it contributes to the ground water. Desert streams work vigorously, but sporadically. They not only overrun and modify their flood plains at intervals, but they also subtract from the arable area of the flood plain by maintaining sand-wash belts that mark the lateral limits of their shiftings. The active water courses of these streams shift laterally in considerable sections, flowing around or subdividing upon the obstructions created by their temporary deposits. According to Johnson:[6]

> The High Plains exhibit in the main in their sections, both artificial and natural, unmistakable evidence that they were built upon dry land by streams. They are

[5] Slichter, C. S., and Wolff, H. C., The underflow of the South Platte Valley: U. S. Geol. Survey Water-Supply Paper 184, 1906.

[6] Johnson, W. D., The High Plains and their utilization: U. S. Geol. Survey 21st Ann. Rept., pt. 4, pp. 626–627, 1901.

remnants of an old debris apron. Their surfaces are residual patches of a former vastly extended gradation plane. That this is so—that the deep silt, sand, and gravel accumulation is of fluvial origin—unmistakably appears upon detailed examination of its composition and structure. * * * In short, the source of the material was the Rocky Mountains; the agency in its transportation running water—that is, streams from the mountains—and these, extending into a desert climate, had the desert habit of branching and lacing flow, and built up the desert surface with their burden of debris from the mountains to a delicately adjusted slope of equilibrium.

The original smooth plain was spread in substantially its present form by these widely shifting, heavily loaded, and depositing streams from the mountains and was completed late in Pliocene time.

A change of climate may have been sufficient to terminate the Ogallala cycle of deposition; at least there is evidence that the climate during the glacial epochs of the Pleistocene was considerably more humid. Virtually the same mountain streams that formerly built up the broad fanlike deposits of the plains are at present cutting away and degrading them. They are running in fixed courses and have excavated valleys. The present North Platte and South Platte Rivers are examples of such streams. Not only have these rivers entrenched themselves in the plains in Keith County but their shorter tributaries have further dissected them. This degradation has caused isolated areas to stand out in relief. They are conspicuously uplands of survival. They have survived because they are resistant to erosion. In some places, however, their survival is due more to their covering of sod than to the resistance of the unconsolidated deposits that underlie them. Sod is very effective not only in arresting erosion but also in preventing the formation of drainage channels. In some places layers of hard caliche retard erosion.

Some geologists believe that the Tertiary sediments are chiefly lacustrine in origin. Among those who have offered evidence in support of the theory of lacustrine deposition are Williston [7] and Hay. [8] There is, however, unmistakable evidence that the Tertiary sediments were deposited by desert streams upon substantially the same slope that exists at the present time. In support of his theory of fluviatile origin Johnson [9] says:

Among these evidences are the patchy character, the overlapping and the rapid thinning and thickening of the beds of the finer materials, and the prevailing coarseness and channel-form occurrence of the gravel at all levels. With lake deposits, gravel of any size is a phenomenon only of the shore line, and its distribution there will be in symmetrical lines. In the case of the Plains the source of derivation having been wholly or at least mainly from the one side—that of the Rocky Mountains—gravel should be disposed in long curving bands, parallel in general to that side. Instead, it occurs unmistakably in irregular west-east courses, and at all depths within the mass.

[7] Williston, S. W., Semiarid Kansas: Kansas Univ. Quart., vol. 3, no. 4, pp. 213–214, 1895.
[8] Hay, Robert, U. S. Geol. Survey 16th Ann. Rept., pt. 2, p. 569, 1895.
[9] Johnson, W. D., U. S. Geol. Survey, 22d Ann. Rept., pt. 4, p. 638, 1902.

A. OGALLALA FORMATION IN WALL OF TRIBUTARY TO NORTH PLATTE RIVER.

B. DEEP WELL EQUIPPED WITH A WINDMILL.

A. HEAD OF EAST BRANCH OF WHITETAIL CREEK.

B. SEEPAGE FROM GRAVEL AT HEAD OF EAST BRANCH OF WHITETAIL CREEK.

The evidence in favor of the theory of essentially fluviatile origin of the tablelands as opposed to the theory of lacustrine origin appears to be conclusive. However, it is probable that lenses of algal limestone in the Ogallala formation may have been deposited in local ponds. Likewise, material of eolian origin may be locally interbedded. The theory of fluviatile origin is generally believed to explain best the conditions that existed during the formation of the uplands.

WATER-BEARING PROPERTIES

The basal part of the Ogallala formation consists of more or less unconsolidated sand and gravel that yield water freely to wells throughout most of the county. Almost all the farm wells on the plains and some of the wells in the South Platte Valley obtain water from the lower part of the formation. However, this part of the Ogallala appears to be absent at places beneath the north bluff of the middle upland plain where the upper surface of the Brule clay is high. The northward pinching out of this permeable bed between the comparatively impermeable underlying Brule clay and the overlying caliche beds doubtless creates a rather effective underground dam that impedes the normal movement of water in this area.

Other beds of sand and gravel occur at higher levels in the Ogallala formation in Keith County, but only one rather persistent deposit has been noted. This bed lies near the top of the section and is exposed at many places in the area, both on the upland surface and along the sides of valleys where tributaries to the North Platte and South Platte Rivers have cut back into the upland. The bottoms of most of the tributary canyons consist of sand and gravel that probably has been derived from this deposit. The upper bed of sand and gravel is not usually water-bearing.

Thin scattered deposits of sand and gravel occur in the Ogallala formation between the upper and lower gravel beds. In some places they are underlain by relatively impermeable caliche beds and may contain water. Only a few wells in Keith County are known to derive their supply of water from such perched horizons, although drillers report that many of them have been encountered. Well 245, on the south upland plain about 6 miles south of Ogallala, obtains its supply from perched water. The water level in this well apparently is about 30 feet above the general water table of the area. The quantity of perched water in these beds is usually not sufficient to furnish wells with an adequate supply.

Several small springs rise in the tributary valleys in the western part of the south upland. The springs probably result from seepage of perched water at exposed contacts between thin deposits of gravel and underlying caliche beds. Several of the springs supply water for domestic purposes and for stock. Nowhere does the flow of a spring persist on the surface for more than a few hundred yards, because the water seeps into the permeable sand and gravel of the stream beds and probably is added eventually to the main body of ground water.

TYPICAL SECTIONS

Three sections of the Ogallala formation in Keith County furnished by A. L. Lugn, University of Nebraska, are given below.

Section east of Ogallala, north and south through E½ sec. 33, T. 14 N., R. 38 W.

	Feet
Pleistocene	
Loess and gravel occur in this vicinity but were not present in measurable amounts at the locations where the beds below were studied.	
Tertiary (Ogallala)	
Silt and silty, fine sand, brownish-buff, mostly unconsolidated, some harder thin zones	15
Sandstone, light grayish, hard, mostly fine-textured sand, contains some yucca-like structures	7–8
Sandstone and volcanic ash, the ash weathered and altered; siliceous yucca structures throughout at some places, absent at other nearby outcrops	2½–3
Sand, gray and greenish yellow, brownish in some places, fine; some silt, massive, unconsolidated; thin, harder zones in some outcrops	9–10
Sandstone and sand, whitish, very hard, irregular, weathering at top in some places, becomes smooth calcareous ledge in some outcrops; upper hard ledge (2 feet) grades downward into marly bed (3 feet) in some places, and into unconsolidated fine, pinkish, silty fine sand at other places; some yucca-like nodular structures in the upper part	6–10
Sand, brownish, silty and fine; some stem and rootlet structures; fragments of fossil bones in this horizon and in bed next above [10]	6–7
Gravel and sand, sand medium to coarse, clean, some pebbles 2 to 3 inches in diameter; a channel deposit, bedded and cross-bedded	15
Sandstone, whitish and pinkish to brownish, mostly calcareous and hard with some softer zones, some chalcedony nodules; fine texture with some silt admixture; forms ledge low in the valley at some places	14
Sand and silt, brownish-red, soft; rootlet structures; contains fossil seeds (*Stipidium*)	11–12
Marl, whitish, silty, soft, massive	9½
Sandstone, reddish-brown, blocky structure	10–11
Sand and silt, grayish, soft, fine-textured; stems and rootlets	6
Sand, red-brown, silty, calcareous; stems and rootlets	3¼
Sand and silt, gray, soft; stems and rootlets	9
Sandstone, whitish and gray, fairly hard, calcareous, fine-textured; exposed only in creek bed	3–3½
Sand and clay, reddish-brown, fine	2

[10] Hesse, C. J., A vertebrate fauna from the type locality of the Ogallala formation: Kansas Univ. Science Bull., vol. 22, pp. 79-117, 1935.

Section at Cedar Point in SE¼ sec. 2, T. 14 N., R. 38 W.

	Feet
Pleistocene	
Loess, fine sandy silt; more or less covered slope	10–30
Gravel and sand, mostly coarse terrace gravels	0–20
Tertiary (Ogallala)	
Sandstone, whitish hard ledge, calcareous, fine texture. A pinkish, hard silty clay ledge 3 to 5 feet thick occurs 20 feet above this bed at some places	4
Sand, pinkish, fine with silt, 2 or 3 harder zones	16–17
Sandstone, hard, whitish to pinkish, smooth ledge at top (2 feet); soft, pinkish, fine sand, somewhat mineralized below	15
Sandstone, yucca bed, hard, smooth; contains yucca concretionary structures, also some volcanic ash; forms ledge	2
Silt and sandy clay, brownish-buff, unconsolidated; a few thin harder zones	16
Sandstone, whitish, calcareous, fine-textured; a ledge in some places	2
Silt, pinkish to reddish-brown, soft	7
Sandstone and conglomerate, whitish, smooth, calcareous; crystalline sand grains and small pebbles; lower 2 to 3 feet softer	10
Sandstone, whitish, calcareous, hard; contains yucca structures in lower 6 feet. This bed and the one next above form main escarpment ledge in this exposure	9½
Sand and gravel, light brownish, contains some silt in certain zones, some secondary mineralization; silicified stem and rootlet structures; pebbles ½ to 1 inch in diameter in gravel zones; finer at top, much covered	15
Sandstone, whitish and pinkish, hard, calcareous; massive ledge for the most part; sand and pebbles up to ½ inch in diameter; some yucca structures in upper 2 feet	10–11
Silt and fine sand, soft, calcareous	5
Silt, pinkish, heavily loaded with secondary calcium carbonate, more or less vertical secondary structures, very hard	5–7
Silt and clay, pinkish, Brulelike, more or less vertical, secondary, knobby concretionary structures; contains fossilized Ogallala seeds of genus *Biorbia*	40–45
Tertiary (Brule clay)	
Clay and silt, pinkish, massive, compact, hard	35

Section south of Belmar Station in SE¼ sec. 13, T. 15 N., R. 41 W., in SW¼ sec. 18, and in W½ sec. 19, T. 5 N., R. 40 W.

	Feet
Pleistocene	
Some sand and gravel, mostly a weathering residue, from disintegrated Ogallala material only slightly reworked	1–3
Tertiary (Ogallala)	
Sandstone, gray to brownish, weathers rough and irregular, hard, crystalline coarse and medium sand, calcareous	2–3
Sandy silt, brownish, fine, soft; some secondary mineralization; lower part less brownish and more calcareous, harder	16
Sandstone, brownish, irregular, fine-textured sand, hard	2–3

Section south of Belmar Station in SE¼ sec. 13, T. 15 N., R. 41 W., in SW¼ sec. 18, and in W½ sec. 19, T. 5 N., R. 40 W.—Continued

	Feet
Silt and clay, light-gray to white, upper 1 to 2 feet very marly with hard clay; thickness very irregular, probably a lake or bayou deposit; full of fossil bone, mostly fragments	5–12
Sandstone, gray, fine, sandy, calcareous	2
Sandstone, brownish-gray; contains siliceous yucca structures	3
Sandstone, grayish and white; hard, yucca structures	3
Sand, pinkish, fine, harder and softer zones	9
Silt and clay, reddish-brown; upper 2 feet a clay marl that is nearly white in some places; some brown fine sandstone zones in lower softer part	12
Sandstone and conglomerate, grayish and pinkish; upper 3 feet very hard and conglomeratic, pebbles up to 1½ inches in diameter; a 2-inch layer of whitish "algal" limestone occurs below the conglomerate ledge; lower part of fine, calcareous sandstone, forms good ledge	9
Sandstone, grayish and pink, softer and harder layers, *Biorbia* present	5
Sand and clay, fine sand, bedded and massive, in part laminated; a 3-inch hard calcareous fine, micaceous sandstone layer near the middle; *Biorbia* present	13
Sandstone, grayish and pinkish, hard, massive, calcareous, medium to coarse-textured sand; forms ledge	7
Sand and clay, pinkish-brown, upper 5 feet fine-textured with thin zones of blocky sandstone; lower 17 feet much covered but mostly soft sand and gravel	22
Sandstone, conglomerate, and sand; crystalline sand and pebbles, calcareous, hard for the most part with softer zones; forms the main escarpment ledge in this outcrop; contains *Biorbia rugosa* seeds throughout	20
Sandstone, whitish, hard, calcareous, conglomeratic; siliceous concretionary structures, pipy to massive — 7	
Sand, soft, calcareous, some mineralization — 3	
Sandstone, whitish-gray, hard, calcareous siliceous structures — 5½	
Sandstone, gray, soft, medium sand — 2	
Sandstone, gray, soft, in part hard and whitish — 2½	
Sand, silt, and clay, gray and whitish, unconsolidated, with one hard zone 5 or 6 feet from the bottom and a few other very thin hard zones higher	32
Sandstone, whitish, and grayish, calcareous; upper 3 feet very hard and massive, fine-textured; next 2 to 3 feet white, calcareous, softer fine sand; 3 to 4 feet next below very hard, massive gray fine sandstone; lowest 10 to 12 feet soft, whitish, fine sand. This entire bed contains *Krynitzkia coroniformis* seeds	18–23
Marl, whitish, impure and sandy, with some silt and clay	12
Base of exposed section at about 3,268 feet above sea level.	

Celtis seeds occur more or less throughout the beds exposed south of Belmar Station, and *Panicum* and *Berriochloa* seeds are associated in the highest beds. In other outcrops, *Biorbia* seeds also occur in the highest beds.

BRULE CLAY

The Brule clay, of Oligocene age, is the oldest formation exposed in Keith County, and it probably is present at some depth in all of the county. It is exposed in at least one locality, and numerous wells have been drilled into it. It is gray to pink in color, usually silty, generally massive, and includes some thin sandy zones. This formation may have been deposited as a water-laid loess that was subsequently compacted by the weight of overlying sediments. Where it is well exposed, as in the western part of the State, the presence of stream channels, a terrestrial vertebrate fauna, and aqueous bedding, particularly in its lower part, indicate that it is primarily a stream-laid deposit. It is about 330 feet thick 4 miles west of Keystone, where test hole 13 penetrated a thickness of 287 feet, and deposits 45 feet or more in thickness occur above the portal of the well. Most of the test holes in the North Platte Valley encountered the Brule clay, but generally no attempt was made to penetrate it. Test hole 8 passed through about 77 feet of the Brule.

The upper zone of the Brule is characterized by "potato-like" concretions of calcium carbonate scattered throughout the mass. Vertical weathering causes these concretions to stand out as knobs on exposed surfaces of this upper zone.

The Brule clay is exposed in the vicinity of Cedar Point on the south side of the North Platte, in sec. 2, T. 14 N., R. 38 W. (See pl. 1.) At this point the top of the Brule is about 60 feet above the surface of the river.

Where the upper zone of the Brule clay is more or less jointed and fissured, it may yield small quantities of water to wells, but otherwise the formation is relatively impermeable. In most places it constitutes an impervious bedrock floor and forms a more or less tight seal for the water in the overlying Ogallala formation. No wells are definitely known to tap water in the Brule in Keith County.

CHADRON FORMATION

Inasmuch as only one test hole is known to have been drilled through the Brule clay in Keith County, the character of most of the formations underlying the Brule has not been definitely ascertained. However, the older formations are well known in other parts of the State, and if present at depth in Keith County they are likely to possess about the same stratigraphic, lithologic, and water-bearing characteristics. Most of these older formations crop out in eastern Nebraska and along the Rocky Mountain front, and many of them are doubtless continuous under Keith County. They have also been encountered between their eastern and western limits in deep wells in other counties.

The Chadron formation, the lower member of the White River group of Oligocene age, crops out in western Nebraska and is present at depth in Keith County. In western Nebraska it consists of sandy clay of light greenish color, which is usually underlain by coarser beds containing deposits of gravel.[11] It is believed that about 76 feet of

[11] Darton, N. H., Preliminary report on the geology and water resources of Nebraska west of the one hundred and third meridian: U. S. Geol. Survey 19th Ann. Rept., p. 759, 1898.

Chadron was drilled through in test hole 13, 4 miles west of Keystone, where the underlying Pierre shale was penetrated to a depth of about 20 feet. The 76 feet of material referred to as the Chadron formation consists of light-gray and bluish shale, with some hard calcareous zones. It is fine-grained throughout, and no sandy zones were found.

FORMATIONS OLDER THAN THE TERTIARY

The Pierre shale is present in Keith County and was encountered at a depth of about 353 feet in test hole 13. This extensive formation occurs beneath most of central and western Nebraska and has been encountered in many deep wells. It is a dark, very sticky, plastic shale that ranges in thickness from 100 feet in eastern outcrops to as much as 3,000 feet in Banner County.[12] The Pierre shale is in general impermeable and where it has been penetrated in other parts of the State yields practically no water, except small amounts in joints and fissures. The water generally is of poor quality, and much of it is unfit for consumption.

The Niobrara formation, consisting principally of a chalky shale, is found beneath the Pierre shale. In places it reaches a thickness of 600 feet and yields small amounts of water to wells. The basal part may be rather productive, but the water generally contains large amounts of lime and sulphates.

Rocks of Benton age, including the Carlile shale, Greenhorn limestone, and Graneros shale, underlie the Niobrara formation across western, central, and part of eastern Nebraska and are probably present below Keith County. In places the total thickness of these rocks is as much as 1,000 feet. The Carlile and Graneros shales usually are barren of water. The Greenhorn limestone yields some water to wells near its outcrop area in the eastern part of the State, but it probably will be of little value in Keith County.

Typical Dakota sandstone, the basal formation of the Upper Cretaceous series, underlies the rocks of Benton age and is exposed in places in the eastern and southeastern parts of the State. The group consists of sandstone and shale members, the sandstone furnishing water to wells in eastern Nebraska. It is estimated that the rocks of this group will be encountered in Keith County at a depth of more than 2,000 feet, and that they will yield moderate supplies of water, probably under artesian head, but the water may be highly mineralized. The artesian head in this group probably is sufficient to bring the water near the surface, but it is doubtful whether the wells will flow.

Other water-bearing formations occur beneath the Dakota sandstone, but it is believed that these rocks lie at a prohibitive depth and

[12] Condra, G. E., and Reed, E. C., Water-bearing formations of Nebraska: Nebraska Geol. Survey Paper 10, p. 10, 1936.

that the water in them is likely to be too highly mineralized to be suitable for use. In eastern Nebraska and in Iowa these older formations, such as some of the Carboniferous limestones and sandstones, the dolomites of Niagaran age (Silurian), Galena dolomite (Ordovician), St. Peter sandstone (Ordovician), and the Jordan and Dresbach sandstones (Cambrian), yield water to wells, but they are important mostly where they lie not more than a few hundred feet below the surface and where adequate supplies of water are not available at shallower depths.

HISTORY OF THE PRESENT TOPOGRAPHY

At the end of the great Tertiary cycle of deposition the Pleistocene ushered in a period of dissection of the High Plains, which, except for minor interruptions, has continued down to the present. In Keith County the unbroken surface of the Ogallala depositional plain was soon trenched by the North Platte and South Platte Rivers and their tributaries. The excavation of these valleys probably began in early Pleistocene times, but the only evidence as to their age near Keith County is the presence of Peorian loess within their margins.[13] That this downcutting was not continuous is evidenced by the presence of a series of terrace levels. This would indicate that there were periods when the rivers and tributaries were flowing at grade, followed by new uplifts in the west and increased erosive activity. In the North Platte Valley west of Keith County three distinct terrace levels are clearly discernible.[14] These levels indicate that there were three periods when valley cutting in the North Platte Valley was temporarily retarded, each of which was ended by a rejuvenation of the river. The terraces converge eastward, so that in Keith County their identity is obscure. Within the county their multiple character is clearest in the South Platte Valley.

This downstream convergence of terrace levels is taken to mean that the rejuvenation of the river was primarily caused by differential uplift toward the Rocky Mountain region. However, at least four other factors are capable of changing the regimen of these major streams: (1) The eustatic fluctuation of the sea level in response to the locking up and release of water in the ice sheets; (2) the presence of ice sheets and meltwater in the Mississippi Basin; (3) the wide variation in the climate of glacial or interglacial epochs, with a resulting disturbance of the longitudinal profiles of the major rivers; (4) crustal movements effected by the accumulation and disappearance of the great ice sheets, which movements would be different in direction from crustal movements assigned to the Rocky Mountain diastrophism.

[13] Lugn, A. L. Pleistocene geology of Nebraska: Nebraska Geol. Survey, 2d ser., Bull. 10, p. 158, 1935.
[14] Dow, C. L., quoted by Lugn, A. L., op. cit., pp. 168–171.

Any efforts to segregate the controlling factors responsible for the intermittent activity of these rivers would require evidence that apparently does not exist in Keith County.

MOVEMENT OF GROUND WATER

The underground reservoir in Keith County receives water by percolation from areas outside the county and from precipitation and stream flow in the county. The water moves from areas of relatively high altitude or pressure to areas of low altitude or pressure in the direction of the hydraulic gradient, which is at right angles to lines of equal altitude on the water surface. Such lines have been drawn for Keith County from data obtained in this investigation and are shown on plate 2. The lines of equal altitude were drawn on the map after the altitude of the static water level in about 350 wells had been computed by subtracting the depth to water level in each well from the altitude of the measuring point. The depth to water level was measured with a steel tape, and the altitude of the measuring point was determined by altimeters—instruments designed to measure air pressure in feet above sea level. The determination of differences in altitude by means of altimeters is not a precise method, and hence the altitudes so determined are only approximate. Inaccuracies are caused by changes in barometric pressure and temperature and by difficulties in reading the instrument. Errors caused by changes in barometric pressure were reduced by making readings of air pressure with two altimeters, one of which was maintained at a bench mark of known altitude and was read about every 5 minutes while the other was taken from well to well. The instrument readings made at the wells were then corrected for changes in air pressure observed during the 5-minute intervals at the bench mark. A correction for air temperature was applied to all measurements, and at least 3 readings were taken at each observation. The altitude of many of the wells was determined from more than one bench mark of known altitude, and thus it was possible to check the accuracy of the method. Most of the readings checked within 1 or 2 feet, and only a very few were as much as 5 feet in error. Although not precise, it is believed that the altitudes so determined are reasonably accurate and that the contour lines shown on plate 2 indicate rather closely the direction of movement of the ground water.

The general direction of movement of ground water south of the North Platte River in Keith County is slightly north of east. The contour lines on plate 2 indicate that water percolates into the area from the south and west, part of it probably originating in Colorado. The slope of the water table under the south upland plain averages about 9 or 10 feet to the mile. The direction of movement of the water is nearly parallel to the South Platte Valley; hence the ground-water level several miles south of the river is in most places not far above river level. The altitude of the water table 8 miles south of the North Platte River, at Ogallala, is about 25 feet above river level.

The form of the water table under the south upland apparently is affected only slightly by differences in the topography, because the direction of movement of the ground water and the rate of slope of the water table are rather uniform. In a few localities, such as that south of Roscoe, the contour lines are somewhat irregular, probably as the result of local differences in the thickness or permeability of the Ogallala formation. There probably is more recharge from precipitation in some of the valleys of the larger northward-trending tributaries than on the south upland plain, but this is not clearly shown by the contour lines.

The contour lines on the middle upland east of Ogallala show that there is some movement of water from the South Platte Valley toward the North Platte Valley. The gradient of the South Platte River is steeper than that of the North Platte, and the South Platte flows across the county at a higher altitude, being about 90 feet higher than the North Platte at the west county line and about 30 feet higher at the east county line. As previously stated, the Brule clay is apparently high in the north bluffs of the middle upland, and as a result the movement of ground water to the northeast is impeded. This damming up of the water doubtless causes the apparent steep slope of the water table from the middle upland toward the North Platte Valley. Although the Brule clay probably forms a rather effective dam, it is believed that there is some movement of water, as indicated by the contour lines, through cracks and fissures in the Brule and in some places through the basal gravel bed of the Ogallala formation.

The water table stands at shallow depths in the North Platte and South Platte Valleys. Doubtless considerable recharge from precipitation takes place in these valleys, and some of the water that moves out of the South Platte Valley to the northeast is derived from this source. Recharge also occurs in some of the tributary valleys on the middle upland, as is indicated by the contour lines in the vicinity of Brule canyon, northwest of Brule. The water table stands relatively high beneath the lower part of the canyon, forming a ground-water ridge from which the water moves both to the south and to the east. An eastward-trending ground-water ridge exists between the two rivers near the west county line, and water percolates from this ridge toward both rivers.

Although it is believed that water-table conditions exist beneath most of the upland area of Keith County, it is likely that in isolated areas the ground water is confined under pressure and rises in wells above the depth at which it is encountered. The pinching-out of the permeable basal gravel in the Ogallala formation between the relatively impermeable Brule clay and caliche beds beneath the north plain may create some artesian pressure.

The form of the water table and the movement of ground water beneath the north upland are very different from the conditions in the middle and south uplands. Large amounts of rainfall are absorbed by the dune sand in the north upland, and as a result the water table has been built up to a comparatively high level, being about 300 feet higher in some places than it is under the plains at points directly south. The water table in this sand-hill area is comparatively flat near the north county line but is very steep near the North Platte River, sloping southward as much as 75 feet a mile. The area is sparsely inhabited, and it was possible to measure the depth to water level in only a few scattered wells; thus the contours in this part of the county are probably less accurate in detail than those in the southern part. Several holes were bored in localities where the water table was near the surface, and the altitude of the water level as measured in them was used in the construction of plate 2.

Numerous small perennial streams flow from the sand hills to the North Platte River. Most of these streams are less than 6 miles long and have rather narrow valleys that have been cut back into the hills, exposing high bluffs of sand in some places. The largest stream of this kind in Keith County is Whitetail Creek, which enters the North Platte River about 1½ miles west of Keystone. The discharge of the creek is very constant throughout the year, because practically all of its flow is seepage from the ground-water reservoir in the sand-hills area. In 1933 the discharge of Whitetail Creek, in sec. 36, T. 15 N., R. 38 W., ranged from 16 to 61 cubic feet a second, and in 1934 from 18 to 42 cubic feet a second.[15] The discharge for most of the time, however, was about 30 cubic feet a second. The total run-off for the year ending September 30, 1933, was 22,700 acre-feet, and for the year ending September 30, 1934, it was 20,856 acre-feet.

A large part of the flow of Whitetail Creek enters the stream near the source of its three branches, each of which heads in a cirquelike depression in the hills. (See pl. 4, A.) In many places, especially at the head of the east branch, the streams have cut through dune sand to underlying gravel, and most of the seepage enters through this gravel. (See pl. 4, B.) The narrow valley floor of the east branch is a bog containing numerous springs, many of which rise near the edges of the valley at points 10 feet or more above stream level. The water table slopes very steeply toward the creek, as is shown by the contour lines on plate 2. The creek is 50 to 100 feet below the general water table of the area. A well drilled in the

[15] Nebraska Bur. Irrigation, Water Power, and Drainage, 20th Bienn. Rept., 1933-34, pp. 674, 713.

valley of Whitetail Creek might encounter water under sufficient pressure to create a flow, as is the case in the valley of Birdwood Creek, a similar stream that enters the North Platte River a few miles east of Keith County.[16] The head of the west branch of Birdwood Creek is in the extreme northeast part of Keith County, and the influence of the stream on ground-water movement is indicated by the contour lines.

For the year ending September 30, 1933, the run-off from Clear Creek was 6,357 acre-feet; from Lonergan Creek, 4,794 acre-feet; from Skunk Creek, 2,049 acre-feet; and from Cedar Creek, 1,741 acre-feet. The run-off from these creeks and from Whitetail Creek totals about 37,600 acre-feet. This run-off, most of which is ground water, is equivalent to about 14 percent of the precipitation on the sand-hill area in Keith County. The total ground-water run-off from the sand-hill area in the county doubtless is considerably larger.

The velocity of the ground water and the quantity of underflow beneath the uplands is not known. The permeability and thickness of the saturated material ranges between wide limits, and the hydraulic gradient varies from place to place; hence both the rate of movement and quantity of flow are extremely variable. Slichter and Wolff[17] measured the velocity of the underflow of the South Platte Valley near Ogallala and found that the ground water moved downstream at rates of 2.3 to 13.6 feet a day. As all of the velocities measured were above "hard pan," it appears likely that the measurements were made entirely in alluvium and not in the Ogallala formation. Slichter and Wolff concluded that the underflow of the South Platte Valley did not exceed 10 cubic feet a second.

The rate of movement of ground water is generally very slow, and under normal conditions the time required for the water to move comparatively short distances is very great. Ground water in the South Platte Valley moving at a rate of 13.6 feet a day will cross Keith County in about 43 years, and at a rate of 2.6 feet a day it will cross the county in about 260 years.

DEPTH TO GROUND WATER

The depth to ground water in Keith County ranges from the land surface in some places in the valleys of the North and South Platte Rivers and in parts of the sand-hill area to about 500 feet beneath the middle upland plain. The water table lies deepest about 3 miles south of the North Platte Valley, in sec. 33, T. 15 N., R. 41 W.

A map showing the depth to the water table in Keith County was prepared by superimposing contours on the water table upon a map showing surface topography and then drawing lines with 50-foot

[16] Slichter, C. S., and Wolff, H. C., The underflow of the South Platte Valley: U. S. Geol. Survey Water-Supply Paper 184, pp. 26–28, 1906.

[17] Slichter, C. S., and Wolff, H. C., op. cit., pp. 9–12.

vertical intervals between points having the same depth to water level. (See pl. 5.)

The water table stands less than 50 feet below the land surface in the valleys of the North Platte and South Platte Rivers, where the width of these shallow-water areas ranges from about 1 to 4 miles; in the narrow valleys of some of the tributaries to the two rivers; and in the depressions between the sand hills. Over most of the plain south of the South Platte River the depth to the water table is 150 to 250 feet, but there are small areas where the water table stands 50 to 150 feet below the surface, and two isolated areas where it stands 250 to 300 feet below the surface. The south bluffs rise rather steeply, and as a result there is only a narrow strip of land roughly paralleling the South Platte Valley where the water table stands 50 to 150 feet below the surface. This strip broadens in the eastern part of the county so that it extends about 5 miles south of the river.

The depth to the water table on the middle upland plain ranges from 200 to about 500 feet. The depth gradually increases from east to west across this V-shaped area and reaches its maximum in the northwestern part, where over large areas northwest of Brule the water table lies more than 350 feet below the surface. The land surface rises abruptly from both rivers, and only beneath narrow strips of land bordering the larger valleys or extending up tributary valleys does the water table stand less than 200 feet below the surface.

In most of the sand-hill area the water table stands less than 100 feet below the surface and in many localities less than 50 feet. In a few isolated areas, such as that north of Paxton, the depth to water is as much as 300 feet, but only beneath the higher hills.

The variation in depth to the water table in Keith County is shown in the profiles of plate 6. Two profiles (*A–A′* and *B–B′*) extend across the county from east to west; the third profile (*C–C′*) extends from north to south through Ogallala. The surface topography for these profiles was taken from topographic maps, and the altitude of the water table is based on the contour lines shown on plate 2.

RECHARGE AND DISCHARGE OF GROUND WATER AS RECORDED BY FLUCTUATIONS OF THE WATER TABLE

The water table in Keith County fluctuates almost continually. This fluctuation is due to many causes of two main kinds—(1) recharge from precipitation, seepage from streams, and seepage from irrigated fields; (2) discharge by plants, seepage into streams, pumpage from wells, and evaporation.

Measurements of the water level in 21 wells in Keith and Deuel Counties have been made at intervals since 1934. All the observation wells were measured several times while field work was in progress, and periodic measurements have been continued since then on 13 of the wells. The records on 3 wells extend back to 1934. The hydrographs of the wells are shown on plate 7.

Where the water table stands only a few feet below the land surface in Keith County recharge from precipitation probably occurs at various times throughout the year, but where the water table lies deep recharge occurs only infrequently. The hydrographs of most of the shallow observation wells on plate 7 show a seasonal fluctuation, whereas the hydrographs of the deep observation wells do not. Definite rises in May and June 1935 that resulted from rather heavy rains are shown by the hydrographs of wells 17 and 348. Both of these wells are in the South Platte Valley. The water level in well 186, in the sand-hill area north of the North Platte River, did not rise appreciably in these months.

Some of the water diverted from streams for irrigation in the county seeps into the ground and is added to the zone of saturation. Well 295 is a few hundred feet south of an irrigation canal in the South Platte Valley on the south side of the river, and the water-level fluctuations in this well indicate ground-water recharge that probably is due to seepage from the canal. Water was maintained in the canal during most of the summer of 1935, and as a result the water level in the well rose in July and August and declined only a small amount in subsequent months. Water was not maintained in the canal in the winter of 1935–36, and the water level in the well declined. As a result of this artificial recharge, the water level in the well reaches high levels in the summer and low levels in the winter or spring, whereas the water levels in most wells unaffected by such seepage reach low stages in the summer and high stages in the winter or spring. The type of water-level fluctuation observed in well 295 has been observed in several wells in the North Platte Valley, where irrigation with water diverted from streams is extensively practiced.

The water level in well 210 rose about 0.15 foot in the first part of August 1935, during which time practically no rain fell. This well was in a field of corn that was irrigated during this period, and the rise of the water level in the well doubtless was caused by some of this water seeping down to the zone of saturation. The very great rise of water level in this well that occurred in October when there was no rain probably was also due to irrigation.

During 1935 construction was completed on a project of the Platte Valley Public Power and Irrigation District that included a diversion dam near Keystone, an irrigation canal across the divide between the North Platte and South Platte Rivers north of Paxton, an inverted syphon beneath the bed of the South Platte at Paxton, and a canal from the south side of the South Platte to a storage reservoir south of Sutherland (see pp. 10–12). Water was first diverted from the North Platte River to the storage reservoir in the winter. Well 22 is on the south side of the South Platte River a few hundred yards north of the canal, and the water-level fluctuations in the well indicate that there probably has been seepage from the canal in this locality. The water level in the well rose rather persistently from the fall of 1935 to the spring of 1937 (see pl. 7), even though the precipitation in 1936 was below normal.

The rather rapid decline of water level in the shallow wells in the summer probably is caused chiefly by the use of water by plants. Where the water table is only a few feet below the land surface the roots of many plants extend down to the zone of saturation, and a large part of the water needed in the growth of the plants is derived from this source. Most of the trees and other plants along the North Platte and South Platte Rivers and their tributaries and also in parts of the sand-hills area draw heavily on the zone of saturation during the summer months. This transpiration demand decreases greatly in the fall and winter, and the water levels in wells in these areas usually stage a marked recovery that lasts until the next growing season begins.

Wells 203 and 329 are pumped for irrigation. The decline of the water level in these wells during the pumping season of 1935 was not severe, and the hydrograph of well 203 does not indicate an appreciable depletion of ground water in 1936. (See pl. 7.) A longer record of water levels will be needed before the effect of the pumping can be ascertained. There probably is sufficient water in the alluvium and the underlying Ogallala formation in the South Platte Valley and in the alluvium in the North Platte Valley to supply many more irrigation wells than the few that are now in use in the county without seriously depleting the supply. In the South Platte Valley as much as 1,000 gallons of water a minute is now pumped from wells 24 to 36 inches in diameter and 40 to 60 feet deep, and most of it comes from the alluvium. Deeper wells that penetrate both the alluvium and the Ogallala formation probably will yield more water. At present the water pumped from wells in Keith County is used to irrigate only about 800 acres of crops (see p. 51), and probably less than 1,000 acre-feet of water is pumped annually. At this rate of pumping it does not seem likely that the ground water in the area will be materially decreased. It is not known whether wells on the uplands drawing from the Ogallala formation would have sufficient yields for irrigation. Yields as high as 50 gallons a minute probably can be obtained, but because the lift is great the practicability of irrigating with water pumped from such depths is questionable.

Fluctuations of the water level in observation wells in Keith County are small in comparison with fluctuations that occur in eastern Nebraska, where the annual precipitation is much greater. In Keith County discharge from the ground-water reservoir has become approximately adjusted to the recharge over a long period of years. This adjustment has resulted in a deep-lying water table in many places and has left only narrow strips of land where the water table is high and where trees and vegetation are abundant.

Complete records of water level in 13 wells on which measurements were continued from October 1935 to January 1, 1937, are included in Water-Supply Paper 817.[18] Subsequent records will be published in other volumes of this series. The numbers assigned to the Keith County wells in Water-Supply Paper 817 are given in the following table:

Well number in this report	Well number in Water Supply Paper 817	Well number in this report	Well number in Water Supply Paper 817
17	Keith County 93.	210	Keith County 358.
22	Keith County 348.	221	Keith County 360.
53	Keith County 349.	261	Keith County 357.
99	Keith County 350.	295	Keith County 355.
107	Keith County 351.	301	Keith County 356.
186	Keith County 255.	348	Deuel County 94.
203	Keith County 359.		

FLUCTUATIONS OF GROUND-WATER LEVEL CAUSED BY CHANGES IN ATMOSPHERIC PRESSURE

The water levels in all the deep wells in the county that were measured fluctuated in response to changes in atmospheric pressure. Where relatively impermeable layers, such as caliche beds, occur between the land surface and the water table, the transmission of changes in atmospheric pressure through the ground to the water table may be greatly impeded. However, changes in air pressure usually may be transmitted directly down to the water level inside the well casing, and thus a differential pressure sometimes is created between the water inside and outside of the well casing that forces water either out of or into the well. When the atmospheric pressure decreases the water level in the well rises, and, conversely, when the atmospheric pressure increases the water level in the well declines. The water table outside of the well may, however, remain practically stationary while these fluctuations are occurring in the well. Measurements of the water levels in wells 225 and 221 were made at about 15-minute intervals on October 8, 1935, and changes in atmospheric pressure were determined by simultaneous readings of altimeters at the wells. The data so obtained show that there is a close correlation between the fluctuations in barometric pressure and the fluctuations in water level. (See pl. 8.) On October 8 the air pressure declined during most of the day, as shown by the rise in altitude readings, and consequently the water levels in the wells rose. The air pressure

[18] Meinzer, O. E., and Wenzel, L. K., Water levels and artesian pressure in observation wells in the United States in 1936, with statements concerning previous work and results: U. S. Geol. Survey Water-Supply Paper 817, pp. 141–143, 1937.

began to increase at about 5:00 p. m., and at about the same time the water levels in the wells began to decline.

Where there is an impermeable layer at some distance above the water table and where the well casing is perforated only below the water table (see fig. 2, A), the atmospheric pressure acts on the water level in the well, and the water level may fluctuate with changes in

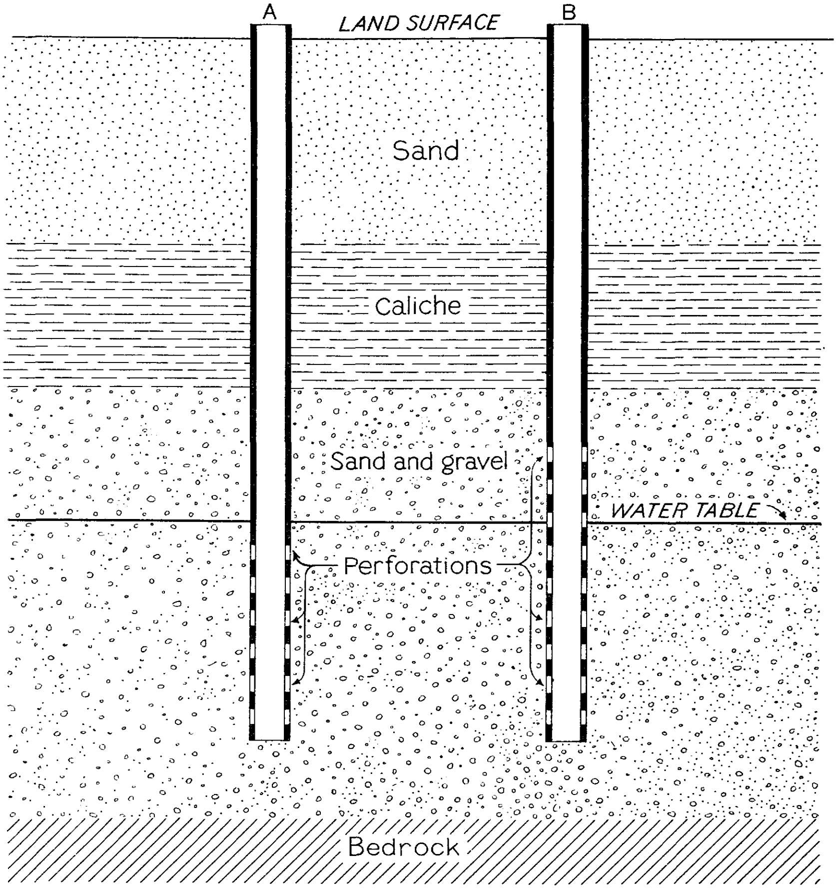
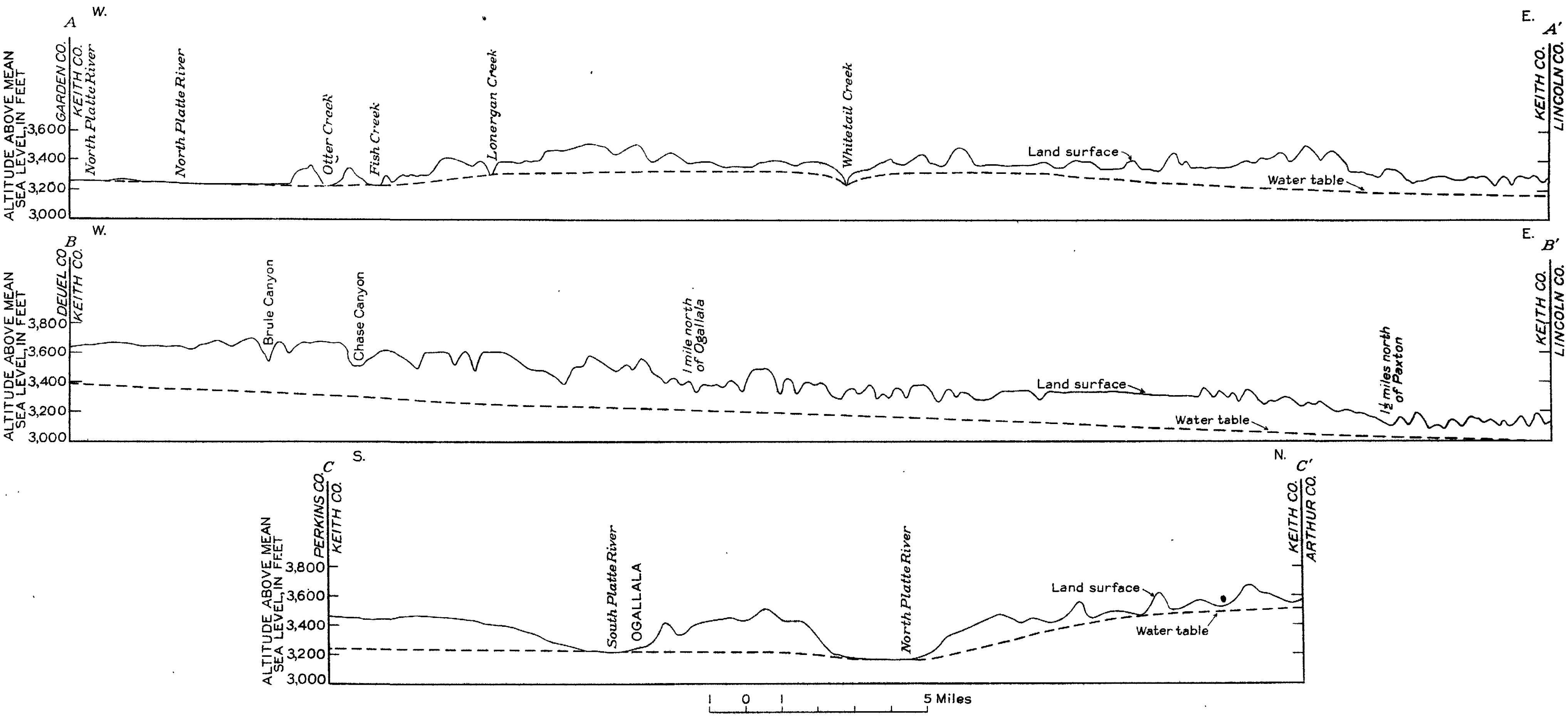
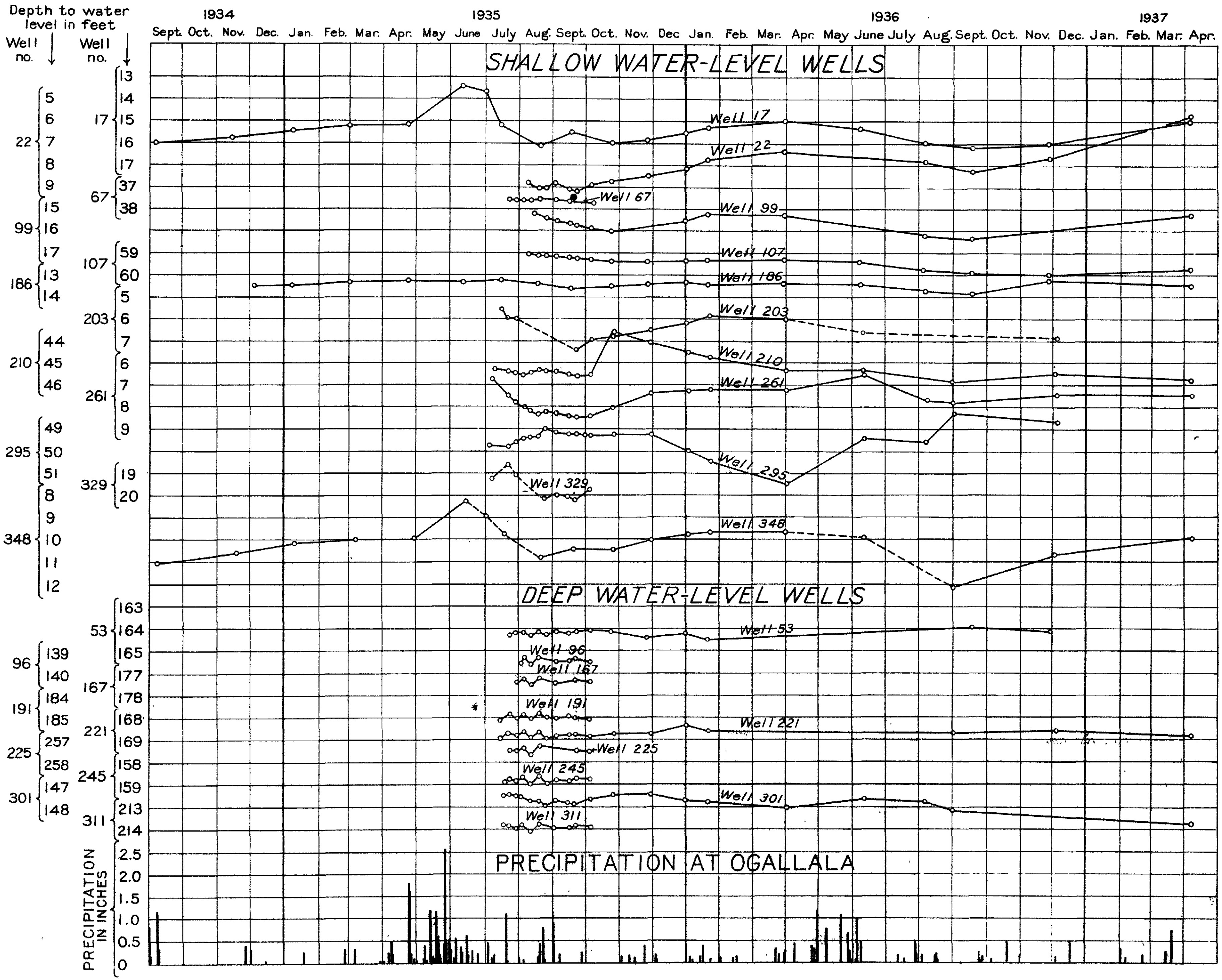


FIGURE 2.—Diagrammatic section showing conditions that cause water-level fluctuations due to (A) changes in atmospheric pressure and (B) "blowing" and "sucking" wells.

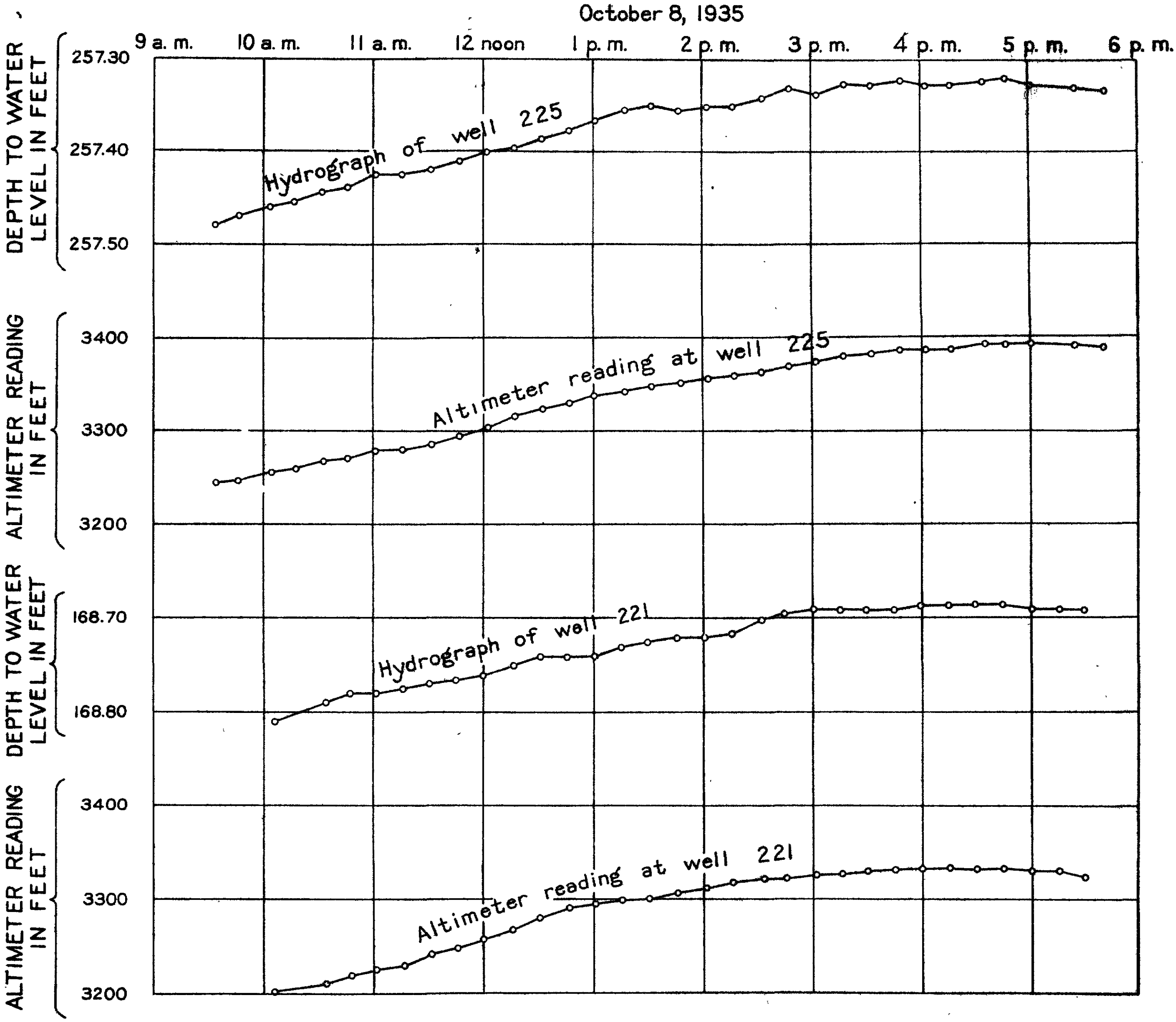
barometric pressure much as it would if all the material below the impermeable layer were filled with artesian water. However, if perforations occur between the water table and the impermeable layer (see fig. 2, B), air may be forced through the well into the interstices of the unsaturated material below the impermeable layer when the atmospheric pressure increases, and out through the well when the atmospheric pressure decreases. This may cause an appreciable movement of air into or out of the well at its top, which in some wells is of sufficient



PROFILES ACROSS KEITH COUNTY SHOWING LAND SURFACE AND WATER TABLE.



GRAPHS SHOWING FLUCTUATIONS OF WATER LEVELS IN WELLS.



GRAPHS SHOWING FLUCTUATIONS OF WATER LEVELS IN WELLS 225 AND 221 CAUSED BY CHANGES IN ATMOSPHERIC PRESSURE.

velocity to cause a whistling or roaring sound. The water level in such wells fluctuates only slightly, if at all, in response to changes in atmospheric pressure. Locally these wells are known as "blowing" and "sucking" wells, and because major changes in atmospheric pressure usually are followed by changes of weather, the wells occasionally are used to predict the weather.

Because the water levels in many of the deep wells in Keith County and also in other counties in western Nebraska fluctuate in response to changes in atmospheric pressure, scattered measurements on the wells may show very erratic changes in water levels. The weekly measurements made in 1935 in the deep wells in Keith County vary considerably from week to week. (See pl. 7.) However, the atmospheric pressure fluctuates within fairly definite limits, and therefore fluctuations in water level caused by changes in air pressure are confined to definite limits—in Keith County to fractions of a foot. For this reason major trends in water level can be determined from the records of occasional measurements if the records extend over a long period. The water level in well 301 appears to have had a definite downward trend since 1935, the beginning of the period for which records were kept. This well is in a gravelly area south of the South Platte River, near the head of a dry tributary to the river. Considerable recharge probably occurs in the vicinity of the well in certain periods of high precipitation, and thus at times the water level in the area surrounding the well may be built up locally to a stage higher than that in other areas where facilities of recharge are less favorable. Such a condition would cause the water level near the well to decline slowly in succeeding periods when there is little or no recharge.

CHEMICAL CHARACTER OF THE GROUND WATER

Samples of water from 29 wells in Keith County were sent to the Geological Survey at Washington, D. C., for chemical analyses together with samples from the North and South Platte Rivers. The samples of ground water were taken from wells in the North Platte and South Platte Valleys, most of which tapped the alluvium, and from wells on the uplands that tapped the Ogallala formation. The samples taken from wells 34 and 347 may be water from either the Ogallala formation or the Pleistocene and Recent material above it. Determinations of hardness, and of bicarbonate, sulphate, and chloride were made on the water from 18 of the wells and that from the two rivers. More complete analyses were made on the water from 11 wells, which included the municipal supplies of Ogallala and Paxton. The analyses are given in the following table.

Analyses of water from Keith County

[Parts per million. Well numbers correspond to numbers in table of well records. Analyses by E. W. Lohr]

Well No.	Location	Total dissolved solids	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulphate (SO_4)	Chloride (Cl)	Nitrate (NO_3)	Fluoride (F)	Total hardness ($CaCO_3$)	Date of collection (1935)	Temperature (°F.)
29	4 miles south of Paxton	201		0.60	53	12		6	196	14	6	13	0.0	182	Oct. 9	54
34	2 miles north of Sarbon	351		.01	82	17		14	197	42	33	66	.3	275	Oct. 10	54
37	1 mile southeast of Sarbon								155	100	12			195	do	56
41	2 miles north of Paxton								142	120	16			237	do	56
125	3 miles northeast of Roscoe	187		3.87	47	10		10	184	18	5	4.8	.2	158	Oct. 12	56
167	5 miles southeast of Ogallala	171		.13	40	9.9		13	177	12	4	4.6	.5	141	Oct. 10	57
213	6 miles southwest of Ogallala								226	200	43			429	Oct. 7	54
214	5 miles southwest of Ogallala								195	260	41			450	Oct. 9	54
218	4 miles southeast of Brule								180	120	55			540	do	54
220	5 miles southeast of Brule								207	120	17			338	do	55
225	4½ miles northwest of Ogallala	291		.04	52	12		41	230	50	15	7.2	.3	179	Oct. 12	58
240	3½ miles south of Brule								183	60	30			106	Oct. 7	56
245	7 miles south of Brule	136		4.97	38	8.7		2	142	10	4	2.8	.5	131	Oct. 9	54
246	6 miles south of Brule	130		9.09	33	8.2		6	135	8	4	3.4	.4	116	do	54
253	1 mile northwest of Brule								166	10	3			135	Oct. 10	57
261	1 mile south of Brule								277	400	45			324	Oct. 7	56
263	2½ miles southeast of Brule								337	520	54			638	Oct. 9	53
268	3 miles southwest of Brule								304	440	55			622	Oct. 7	56
272	3 miles south of Brule								253	260	52			570	Oct. 9	56
273	2 miles south of Brule								283	500	54			630	do	54
274	7 miles north of Brule	243		2.31	65	13		7	220	25	7	18	.0	216	Oct. 10	60
294	6 miles southwest of Brule								173	12	6			153	Oct. 7	56
297	9 miles southwest of Brule								251	240	42			488	Oct. 9	56
298	8½ miles southwest of Brule								177	80	48			292	do	56
320	8 miles southwest of Brule								170	50	8			172	do	56
329	7 miles southwest of Brule								278	560	52			570	do	56
347	2½ miles northwest of Belmar								76	3	1	5.2	.2	52	Oct. 12	58
	Paxton public supply [1] (tap water)	848	26	.01	158	30	44	4.3	150	406	42	2.5	.2	518	Oct. 11	58
	Ogallala public supply [1] (tap water)	343	53	.01	62	12	22	10	220	52	9.8	11	.5	204	do	56
	South Platte River at Brule								214	2,000	46			354	Oct. 10	54
	North Platte River north of Paxton								215	120	22			248	do	60

[1] Not treated.

During the course of the investigation in Keith County, residents in the South Platte Valley southwest of Brule reported that in the past few years the water pumped from their wells gradually had become hard. As irrigation with water diverted from the South Platte River is practiced in this area, it was thought that this hardening of the water in the wells probably was caused by the seepage of the hard water of the river from the irrigation canals and irrigated fields. With this in mind, samples of water were collected for analysis from several wells situated where the ground water probably is augmented by seepage from irrigation water, and samples were also collected from nearby areas where there is no recharge of this kind. The hardness of samples of water from 10 wells in the area affected by seepage ranged from 277 to 638 parts per million and averaged 521 parts per million. The water from these wells may be classed as very hard. The hardness of water from 6 wells immediately adjoining the area of seepage ranged from 106 to 328 and averaged 214. The average hardness of water from all wells in the county, except those in the area of seepage, was 192. Therefore, it appears likely that seepage from irrigation canals and from surface water spread on fields has increased the hardness of the water in the South Platte Valley southwest of Brule. A sample of water from the South Platte River had a hardness of 354 and a sample from the North Platte had a hardness of 204. The hardness of river water fluctuates greatly from time to time, but as the flow of the South Platte River is small in summer and consists almost entirely of return flow from irrigated lands in Colorado, whereas the flow of the North Platte River is greater than that of the South Platte, and the proportion of return flow is less, it might be expected that the water of the South Platte would be somewhat harder than that of the North Platte most of the time.

The sulphate content of the samples of water collected from wells in the area irrigated with surface water was as high as 600 parts per million, and it is inferred that the hardness of the water is due chiefly to calcium sulphate. Most of the samples of water collected outside the area irrigated with surface water had less than 100 parts per million of sulphate. Doubtless the hardness of this water is due chiefly to the presence of calcium bicarbonate.

Well 320, situated south of the South Platte River, near the west county line, is within the area of seepage, but it is in a locality where the water table over several square miles stands only 1 to 5 feet below the land surface. The hardness of the water in this well was 172. Doubtless the ground water in this locality is freshened considerably by frequent recharge from precipitation.

The softest water found in the county was obtained from well 347, in the sand hills northwest of Belmar. The hardness of the water was only 52.

The hardness of samples of tap water in Ogallala was 204, whereas the hardness of tap water in Paxton was 518. Neither supply is chemically treated. A part of the water pumped at Paxton is derived from seepage from the South Platte River, because the water from the river moves northeastward, as indicated by the contour lines on plate 2. As previously stated, the flow of the South Platte River during a large part of the year consists chiefly of seepage from irrigated areas, and this water generally is hard. On the other hand, the water pumped from wells in Ogallala percolates from the west; therefore, very little if any of it is seepage from the river.

None of the eleven samples of water tested for fluoride contained more than 0.5 part per million. It is generally recognized that water containing more than about 1 part per million of fluoride may cause mottled teeth.[19]

None of the waters contained objectionable amounts of chloride. The water from wells in the area irrigated with surface water, southwest of Brule, generally had the highest chloride content, but in no sample did the content exceed 55 parts per million.

The temperature of the ground water in the wells is recorded in the last column of the table of water analyses. The lowest temperature recorded was 53° F. and the highest 60° F. The temperature of the water in most of the wells was 56° F.

UTILIZATION OF GROUND WATER

Information was obtained in regard to about 350 wells, about half of the wells in the county. (See table, pp. 54–65.) Of the wells listed 41 are abandoned, either temporarily or permanently. The water supplies of the others are as follows: Entirely domestic, 20; domestic and stock, 173; entirely stock, 66; irrigation, 36; and stock and irrigation, 1. Information in regard to use was not obtained for 12 wells.

DOMESTIC AND STOCK SUPPLIES

Most of the water pumped from wells in Keith County is used for domestic purposes and for stock. The wells in the North Platte and South Platte Valleys generally tap the alluvium, although a few of the deep wells penetrate to the Ogallala formation. The wells on the south and middle uplands draw water from the Ogallala formation, and the wells on the north upland tap water in either the Ogallala formation or the Pleistocene material above it. Most of the wells, especially the deeper ones, are equipped with windmills. (See pl. 3, *B*.)

[19] Dean, H. T., Chronic endemic dental fluorosis: Jour. Am. Med. Assoc., Oct. 17, 1936, pp. 1269–1272.

A few are pumped by hand. Although the wells generally are pumped only when water is needed, some of the stock wells that are equipped with windmills are allowed to pump whenever the wind is sufficient to operate them, and considerable water is wasted in this manner. Many of the wells pump water into tanks where it is stored for use during periods when the wind velocity is too low to operate the windmills. However, the average velocity of the wind in the county is rather high, and periods of calm are infrequent.

The yields of 23 wells equipped with windmills were measured during the investigation. The pumps were operated by the prevailing wind, which fluctuated, and thus the discharge of the wells varied considerably. However, it is believed that the average of the measurements gives about the normal results, because the tests were made over a period of days on wells throughout the county and represent a considerable range in wind velocity. More than one measurement was made on most of the wells in order to determine the yields at different pumping rates. From the information collected, the number of strokes of the pump per minute, the discharge per 100 pump strokes in gallons, and the discharge of the pump in gallons a minute were computed. These data are given in the following table.

Yield of wells pumped by windmills in Keith County

[Well numbers correspond to those in table of well records]

Well No.	Depth to static water level (feet)	Pump strokes per minute	Discharge per 100 pump strokes (gallons)	Discharge (gallons a minute)	Well No.	Depth to static water level (feet)	Pump strokes per minute	Discharge per 100 pump strokes (gallons)	Discharge (gallons a minute)
7	174	34.8	2.3	0.81	194	168	20.7	4.7	0.98
15	77	18.1	5.3	.95			19.9	4.7	.93
		25.4	5.3	1.33	225	257	24.9	6.2	1.55
18	23	26.3	20.1	5.27			25.9	6.9	1.79
		10.6	20.1	2.13			18.6	6.9	1.28
29	163	34.8	6.1	2.11	227	416	18.7	7.1	1.33
		23.7	5.7	1.35			21.4	7.4	1.59
34	47	49.1	12.5	6.14			22.6	6.9	1.56
		36.8	12.5	4.61	246	214	18.0	7.4	1.33
36	12	17.7	8.3	1.47			18.8	7.4	1.39
		13.7	7.4	1.02	253	79	23.5	7.7	1.81
37	44	21.7	8.7	1.89			23.3	6.9	1.60
		27.9	10.0	2.79			22.9	6.9	1.58
54	174	36.7	4.4	1.60	272	70	35.6	7.1	2.54
		37.1	4.7	1.68			35.0	7.1	2.50
57	29	29.0	5.6	1.61	273	44	31.9	8.3	2.65
		21.0	6.7	1.40			52.3	12.5	6.55
		19.7	5.3	1.04			40.8	9.1	3.71
118	99	20.6	1.9	.40	274	461	19.3	5.0	.96
125	235	10.6	9.1	.96			22.6	5.0	1.13
		9.1	7.7	.70			24.5	5.5	1.36
		11.3	8.7	.98			24.7	5.4	1.33
		21.0	8.7	1.82	276	438	20.8	4.3	.89
155	21	27.9	15.4	4.29			21.4	4.3	.91
		29.5	15.4	4.55	347	94	46.6	3.6	1.67
167	177	16.3	8.7	1.42					
		23.5	10.0	2.35	Average	153	25.0	7.7	1.94
		16.1	9.1	1.47					

The pumping rate ranged from about 9 strokes to about 52 strokes a minute, this variation representing largely differences in wind velocity, and the yield of the wells ranged from 0.40 gallon to 6.55

gallons a minute. The discharge of most of the pumps at high pumping rates was proportionately greater than at low rates, which indicated that the efficiency of the pumps generally was higher at higher pumping rates. In the tests that were made, the discharge per 100 pump strokes ranged from 1.9 to 20.1 gallons and averaged 7.7 gallons. The pumps were operated at an average rate of 25 strokes per minute, and the average discharge was 1.94 gallons a minute. The depth to static water level in the wells ranged from 12 to 461 feet and averaged 153 feet.

The pumps on shallow wells, in general, ran at a higher average rate, pumped more water per minute, and yielded more water per stroke than did the pumps on deeper wells. A summary of the yields of wells, grouped by depth to water level, is given in the following table:

Summary of yields of wells equipped with windmills

Range in depth to water level (feet)	Number of wells	Average depth to water level (feet)	Average pump strokes per minute	Average discharge per 100 pump strokes (gallons)	Average discharge (gallons a minute)
12-50	7	31	28.5	11.1	3.20
50-200	10	128	27.1	5.9	1.53
200-461	6	337	19.7	6.7	1.27

MUNICIPAL SUPPLIES

Ogallala and Paxton are the only towns in Keith County that have public water supplies. The other towns are supplied from private wells, each family generally having a well of its own.

Ogallala derives its supply from 3 wells in the north part of the town. Two of the wells, each 18 inches in diameter and 67 and 77 feet deep, respectively, are in the valley and draw water from alluvium. The third well, 14 inches in diameter and 145 feet deep, is on the north bluffs and taps water in the Ogallala formation. The depth to the static water level in the wells in the valley is about 35 feet and in the well on the bluffs about 105 feet. The wells in the valley are equipped with turbine pumps, and the well on the bluffs with a double-acting plunger pump. The well on the bluffs is used only infrequently. Water is pumped into two steel tanks and also directly into the mains, thereby providing a satisfactory and adequate system with a capacity of more than 1,000,000 gallons a day. The maximum daily consumption is about 375,000 gallons, and the average about 200,000 gallons a day. The water is not chemically treated.

Paxton obtains its water supply from two wells in the north part of the town. Both wells tap water in alluvium. One well, 6 inches in diameter and about 107 feet deep, is used only infrequently; the other well, 12 inches in diameter and about 107 feet deep, usually supplies the demand. The 6-inch well is equipped with a double-acting plunger pump that discharges 110 to 125 gallons a minute, and the 12-inch well is equipped with a turbine pump that discharges from 400 to 750 gallons a minute. The depth to static water level in the wells is about 32 feet. Water is pumped into an elevated steel tank and also directly into the mains. The water is not chemically treated. No figures on consumption are available.

IRRIGATION SUPPLIES

Of the 36 irrigation wells in the county, 19 were used to water field crops, 5 to water small gardens, 2 to water grass and flowers in cemeteries, 5 wells were not in use, and information was not obtained in regard to the specific use of the other 5. It was reported that 783 acres of field crops was irrigated in 1934 by water pumped from wells, of which 300 acres was devoted to sugar beets, 133 acres to corn, 133 acres to alfalfa, 77 acres to potatoes, and 140 acres to miscellaneous crops.

Irrigation with water pumped from wells is practiced chiefly in the South Platte Valley, and most of the wells are west of Brule. Irrigation with water diverted from the North Platte and South Platte Rivers and their tributaries is practiced to some extent in the valleys of both of the rivers.

The depth of irrigation wells in Keith County ranged from about 12 to 175 feet and averaged about 45 feet. The depth to water level ranged from about 3 to 54 feet and averaged about 16 feet. The average depth of water in these wells was about 29 feet, in comparison with an average depth of 20.8 feet for all the wells in the county. Of the 36 wells, 19 were 24 inches in diameter, 9 ranged from 10 to 18 inches in diameter, 1 was 36 inches in diameter, and 7 were 6 inches or less in diameter. Twenty wells were equipped with centrifugal pumps, 9 with deep-well turbines, 5 with cylinder lift pumps, 1 with a rotary pump, and 1 was not equipped with a pump. Fourteen of the pumps were operated by electric motors, 10 by tractors, 5 by stationary gasoline or oil engines, 3 by hand, 1 by wind, and for 3 the means of operation was not apparent.

The yield of water from irrigation wells in Keith County ranges from about 2 to 6 gallons a minute for 3- and 4-inch wells pumped by hand or by windmill to about 1,000 gallons a minute for 24-inch wells equipped with centrifugal and turbine pumps. The alluvium is permeable, and thus rather high yields can be obtained from it. The estimated yield of well 269, in the SW¼NW¼ sec. 32, T. 13 N., R. 40 W., owned by H. F. Einspahr, is 1,000 gallons a minute. The water level in this well was 45.64 feet below the top of the casing while pumping was in progress on July 20, 1935. On September 18, when the pump was not operating, the water level stood 30.48 feet below the top of the casing. The drawdown while pumping was thus 15 feet, which indicates a specific capacity, or discharge per foot of drawdown, of about 65 gallons a minute. The well is 24 inches in diameter, and 57 feet deep and is equipped with a deep-well turbine.

The water level in well 329, in the SE¼SW¼ sec. 34, T. 13 N., R. 41 W., was 24.3 feet below the top of the well curb on July 5, 1935, at which time the pump was discharging about 450 gallons a minute. The static water level in this well on July 8 was 19.27 feet below the top of the well curb, thus the drawdown was about 5 feet, and the discharge per foot of drawdown was about 90 gallons a minute. The well is 24 inches in diameter and 43 feet deep and is equipped with a deep-well turbine.

Well 270, in the SE¼NW¼ sec. 32, T. 13. N., R. 40 W., H. F. Einspahr owner, probably is the most productive well in the county. This well, which was completed in 1935, yields about 1,100 gallons of water a minute with a drawdown of about 8 feet, thus the specific capacity of the well is about 137. The well is 24 inches in diameter and 57.5 feet deep and is equipped with a deep-well turbine. Power is furnished by a 30-horsepower stationery Diesel engine. The depth to static water level was 31.94 feet on July 20, 1935.

Several other irrigation wells, including wells 170, 266, 267, 296, 321, and 325, report yields of 900 to 1,000 gallons a minute. With the exception of well 266, which consists of two 12-inch casings, the wells are all 24 inches in diameter. Their depth ranges from 30 to 62 feet.

Most of the irrigation wells in the South Platte Valley are relatively shallow and do not penetrate through the water-bearing gravel of the valley fill. Test drilling in the valley indicates that the Ogallala formation underlies the alluvium and that the basal gravels in the Ogallala probably will yield considerable water. If deeper wells are drilled in the valley through the caliche beds to the underlying basal gravel, both the quaternary alluvium and the Ogallala formation can be utilized, and the yields of such wells probably will be greater than the yields of present wells. Moreover, the drawdown of the water level while pumping probably will be decreased.

WELL CONSTRUCTION

Most of the wells in the county are drilled by the solid-tool or hydraulic rotary methods. A few of the shallow, small-diameter wells have been driven by hand. The wells generally are cased to the bottom with iron pipe or galvanized iron casing. Iron pipe is the most substantial and is most used.

The deepest wells are drilled into the Ogallala formation, and in some places, such as on the middle upland, the wells are as much as 500 feet deep. Although the exposed caliche beds in the county generally are very hard, the unexposed caliche usually is much softer, and well drillers have very little trouble in penetrating it.

The wells are not usually drilled far below the water level because the water-bearing materials are rather permeable and the fluctuations of the water level are comparatively small. Thus satisfactory yields are obtained from most wells without a large drawdown of the water level, and as the normal seasonal fluctuations are small there is little danger of the wells going dry. The depth of water in the wells that were visited in this investigation ranged from a few inches to about 160 feet. Of 278 wells, 71 had a depth of water of less than 10 feet; 85, from 10 to 20 feet; 67, from 20 to 30 feet; 30, from 30 to 40 feet; 13, from 40 to 50 feet; 9, from 50 to 70 feet; 2 had 86 feet; and 1 had a reported depth of water of 157 feet. The average depth of water in these wells was 20.8 feet.

The depth of 282 wells on which information was obtained ranged from 8 to about 500 feet and averaged 146.8 feet. Of these wells, 76 were less than 50 feet deep; 44 were between 50 and 100 feet deep; 28 were between 100 and 150 feet deep; 29 were between 150 and 200 feet deep; 62 were between 200 and 250 feet deep; 22 were between 250 and 300 feet deep; 9 were between 300 and 350 feet deep; 7 were between 350 and 400 feet deep; and 5 were between 400 and 500 feet deep.

Most of the deep wells are 3 to 4 inches in diameter and are equipped with a pump cylinder within the casing and below the water level. Rods extend down from the surface to the pump cylinder through the discharge pipe, which generally is 1 to 2 inches in diameter. The raising of the rods in turn raises the plunger in the pump, which forces water up the discharge pipe. Where the water table is 300 to 500 feet below the surface, the pressure of the water held in the discharge pipe on the check valve in the pump cylinder is very great, and the valve wears out rapidly and must be replaced frequently. This entails considerable effort and expense. It is likely that this condition could be alleviated to some extent if more than one pump cylinder were used—that is, if other cylinders were installed at various depths in the casing in order to reduce the pressure on the bottom check valve.

The diameter of the wells ranged from 1¼ to 36 inches. Of 323 wells, 239 were 3, 3½, or 4 inches in diameter; 13 were less than 3 inches in diameter; and 71 were more than 4 inches in diameter.

WELL RECORDS

Records of wells in Keith County

Well no.	Location	Owner or name	Type [1]	Depth (feet) [2]	Diameter (inches)	Type of casing [3]	Type of pump [4]	Method of lift [5]	Depth to water level below measuring point (feet)	Date (1935)	Measuring point	Use of water [6]	Distance of measuring point above or below land surface (feet)
	T. 13 N., R. 34 W.												
1	NW¼NW¼ sec. 30 [7]	B. Powell	Dr.	139.2	3½	I	L	W	95.33	Aug. 8	Top of casing	DS	1.2
	T. 14 N., R. 34 W.												
2	NE¼NW¼ sec. 30 [7]	E. Binegar	Dr.	102.5	4	G	L	W	90.15	Aug. 17	Top of casing	DS	0.7
	T. 12 N., R. 35 W.												
3	NW¼NW¼ sec. 2	J. Pochop	Dr.	198.1	3½	I	L	W	166.12	Aug. 7	Top of casing	DS	1.6
4	SE¼NW¼ sec. 6	E. Dafler	Dr.	222.4	3½	I	L	W	176.54	Aug. 6	Top of whole in concrete base.	A	.3
5	NW¼NE¼ sec. 8	A. Dafler	Dr.	196.4	3	I	L	W	180.99	Aug. 7	do	DS	.0
6	NW¼NW¼ sec. 10	H. Spurgin	Dr.	197.1	3½	I	L	W	187.37	do	Top of 5-inch casing	DS	.6
7	NE¼NE¼ sec. 11	C. Wisner	Dr.	195.7	3½	I	L	W	174.40	do	Top of casing	A	.8
8	NE¼NE¼ sec. 13	E. Roberts	Dr.	231.9	3½	I	L	W	171.62	do	Top of tile pipe	DS	1.1
9	NE¼NE¼ sec. 18	H. Drager	Dr.	172.5	3½	I	L	W	160.15	Aug. 6	Top of 4 by 4 clamp	DS	1.7
10	NE¼NW¼ sec. 19 [8]	L. Lehl	Dr.	169.5	3½	I	L	W	159.38	do	Top of casing	DS	1.8
11	NE¼NW¼ sec. 22 [8]	C. Schaefer	Dr.	211.9	4	G	L	W	196.71	Aug. 7	do	A	1.2
12	NW¼NE¼ sec. 23 [8]	G. Burton	Dr.	222.7	3½	I	L	W	201.51	do	Top of casing coupling	DS	1.1
13	NW¼NE¼ sec. 24 [8]	P. Allison	Dr.	204.8	3	G	L	W	180.35	do	Top of casing	DS	.6

T. 13 N., R. 35 W.													
14	NE¼SE¼ sec. 2	A. Fisher	Dr.	14.8	5	G	L	H	6.83	Aug. 16	Top of casing	D	0.8
15	SW¼NW¼ sec. 3		Dr.	92.1	3½	I	L	W	76.88	do	Top of wood platform	S	1.5
16	SW¼NW¼ sec. 4	M. Pease	Dr.	67.6	3½	I	L	WG	56.06	do	Top of casing	DS	1.0
17	SW¼SW¼ sec. 5	D. Thiessen	Dr.	18.1	6	G	N		13.65	July 2	do	A	1.0
18	SE¼SE¼ sec. 8	P. Anderson	Dr.	[9] 23.9	6	G	L	W	23.19	Aug. 9	do	DS	.3
19	SE¼SW¼ sec 8	Paxton Cemetery	Dr.	[9] 34.3	4	I	L	H	30.53	do	do	I	.9
20	NW¼SE¼ sec. 10	L. Anderson	Dr.	35.8	12	G	L	W	20.63	do	do	I	1.1
21	SW¼SW¼ sec. 11	R. Jorgensen	Dr.	33.7	6	G	L	W	21.80	do	do	S	.3
22	NW¼SE¼ sec. 12	E. Pueppke	Dr.	21.7	6	G	C	G	8.77	do	do	SI	.2
23	SW¼SE¼ sec. 13	C. Grunden	Dr.	102.4	3½	I	L	W	93.51	Aug. 8	do	DS	1.1
24	NE¼NE¼ sec. 19	H. Lawhead	Dr.	75.4	3½	I	L	W	69.75	Aug. 9	do	DS	.4
25	SW¼NW¼ sec. 21	A. Otto	Dr.	99.3	4	I	L	W	89.52	Aug. 7	do	DS	.8
26	NW¼NW¼ sec. 22	L. Anderson	Dr.	[9] 75.8	3	I	L	W	72.49	Aug. 9	do	DS	1.0
27	NE¼NE¼ sec. 26	G. Woodrow	Dr.	88.4	4	G	L	W	81.82	Aug. 8	do	A	.2
28	NE¼NW¼ sec. 27	R. Baltzell	Dr.	141.7	4	G	L	W	123.56	do	do	DS	.7
29	SE¼SE¼ sec. 30	C. Larly	Dr.	212.2	3½	I	L	W	162.90	Aug. 6	Top of galvanized iron casing.	S	.4
30	NW¼NW¼ sec. 30	S. Munson	Dr.	142.0	3½	I	L	W	106.66	Aug. 8	Top of steel plate	DS	1.0
31	NE¼NE¼ sec. 33	W. Myers	Dr.	192.9	3	I	L	W	184.42	do	Top of galvanized iron casing.	DS	.6
32	SW¼SE¼ sec. 34	H. Lawler	Dr.	215.9	3½	I	L	W	187.24	do	Top of casing	S	.6
T. 14 N., R. 35 W.													
33	NE¼NE¼ sec. 14	W. Knight	Dn.	22.4	2	I	N		4.20	Aug. 17	Top of lower cylinder coupling.	A	−1.3
34	NE¼NE¼ sec. 15	J. Stafford	Dr.	[9] 53.3	3½	I	L	W	46.52	do	Top of casing	DS	2.8
35	SW¼SE¼ sec. 22	L. Quinby	Dn.	26.3	1¼	I	P	H	7.27	do	Top of pipe	A	2.6
36	SE¼SW¼ sec. 24		Dn.	21.4	1¼	I	P	H	12.31	do	Top of pump head	A	2.7
37	NE¼SE¼ sec. 26	C. Gries	Dr.	[9] 45.0	3½	I	L	WG	44.25	do	Top of casing	DS	2.1
38	NW¼SW¼ sec. 27	W. Mars	Dr.	29.9	4	I	L	H	23.82	Aug. 16	do	D	.9
39	NW¼NE¼ sec. 28	H. Hartman	Dn.	16.3	1¼	I	P	H	7.07	Aug. 17	Top of pipe	A	1.7
40	SE¼NE¼ sec. 29	T. Wilcox	Dr.	[9] 27.3	3	G	L	W	26.62	do	Top of casing	S	.5
41	NW¼SW¼ sec. 29	C. Reitz	Dr.	75.4	3½	G	L	W	53.36	Aug. 16	do	DS	2.0
42	NW¼SW¼ sec. 30	J. Hugs	Dr.	63.1	3½	I	L	W	53.21	Aug. 19	do	S	1.0
43	SE¼SW¼ sec. 32	H. Brown	Dr.	160.6	3	I	L	W	148.06	Aug. 16	do	DS	.1
44	NE¼SE¼ sec. 36	H. Killder	Dr.	[9] 74.1	3½	I	L	W	68.23	do	do	S	2.5
T. 16 N., R. 35 W.													
45	SE¼SE¼ sec. 26	Colman	Dr.	74.0	4	I			52.78	Sept. 24	Top of casing		3.2

See footnotes at end of table.

Records of wells in Keith County—Continued

T. 12 N., R. 36 W.

Well no.	Location	Owner or name	Type	Depth (feet)	Diameter (inches)	Type casing	of Type of pump	Method of lift	Depth to water level below measuring point (feet)	Date (1935)	Measuring point	Use of water	Distance of measuring point above or below land surface (feet)
46	NE¼SE¼ sec. 2	E. Meyers	Dr.	201.6	3	I	L	W	183.37	Aug. 6	Top of casing	S	0.6
47	NE¼NE¼ sec. 3	P. Ageton	Dr.	220.3	3½	I	L	WG	212.50	do	do	DS	.3
48	SE¼NE¼ sec. 7	F. Jantzen	Dr.	221.3	3½	I	L	W	194.03	Aug. 3	do	DS	.8
49	NE¼NE¼ sec. 8	H. Miles	Dr.	202.5	3	I	L	W	183.81	Aug. 5	Top of 5-inch casing	DS	1.2
50	SW¼SW¼ sec. 9	L. Laflin	Dr.	200.2	3	I	L	W	181.35	do	Top of galvanized iron casing.	DS	.8
51	NE¼SE¼ sec. 10	A. Hahn	Dr.	228.5	3½	I	L	W	204.95	do	do	DS	1.3
52	NE¼SE¼ sec. 12	H. Mathers	Dr.	208.7	3½	I	L	W	193.44	Aug. 6	Top of casing	DS	1.1
53	NE¼NE¼ sec. 14		Dr.	175.8	3½	I	N		164.33	July 23	Top of 1 by 6 base	A	.0
54	SW¼NW¼ sec. 15	S. Monson	Dr.	204.2	3½	I	L	W	174.30	Aug. 3	Top of galvanized iron casing.	DS	1.5

T. 13 N., R. 36 W.

Well no.	Location	Owner or name	Type	Depth (feet)	Diameter (inches)	Type casing	of Type of pump	Method of lift	Depth to water level below measuring point (feet)	Date (1935)	Measuring point	Use of water	Distance of measuring point above or below land surface (feet)
55	NE¼SE¼ sec. 2	G. Sampson	Dr.	61.0	5	G	L	W	57.75	Aug. 16	Top of casing	DS	0.5
56	SE¼NW¼ sec. 3	G. Hanson	Dr.	112.4	3½	I	L	W	76.24	do	Top of galvanized iron casing.	DS	1.1
57	SW¼NW¼ sec. 4		Dr.	32.6	4	G	L	W	28.54	do	do	S	2.1
58	SW¼NE¼ sec. 5	R. McConughy	Dr.	[9] 25.2	6	I	L	W	23.07	Aug. 15	Top of casing	S	1.4
59	SW¼NW¼ sec. 6	L. Mogelson	Dr.	64.3	3½	I	N		47.04	do	do	A	1.2
60	NE¼NE¼ sec. 12	W. Wilson	Dn.	13.5	1¼	I	P	H	7.36	Aug. 16	Top of pipe	D	2.2
61	NE¼NE¼ sec. 13	J. Monson	Dr.	89.5	6	I	L	W	83.30	Aug. 9	Top of casing	S	.2
62	NE¼NE¼ sec. 15	F. Goertzen	Dr.	34.6	6	G	L	W	30.08	do	do	DS	.5
63	SE¼NE¼ sec. 18	E. Hoog	Dr.	[9] 38.1	3½	I	L	W	35.31	Aug. 10	do	DS	1.8
64	NE¼SE¼ sec. 19	P. Egington	Dr.	126.6	3½	I	L	W	114.39	do	do	DS	.6
65	SW¼NW¼ sec. 21	School District No. 8	Dr.	107.3	4	G	L	H	93.85	Aug. 9	do	D	.5
66	NE¼NW¼ sec. 22	E. Creek	Dr.	75.7	6	G	L	W	63.82	Aug. 10	do	DS	.8
67	NE¼NE¼ sec. 24	do	Dr.	45.1	3½	I	L	W	37.59	July 23	do	S	1.3
68	NE¼NE¼ sec. 27	M. Kearney	Dr.	138.7	3	G	L	W	120.93	Aug. 9	do	DS	.3
69	NE¼NE¼ sec. 28	G. McGee	Dr.	132.3	4	I	L	W	110.70	do	Top of casing coupling	DS	
70	NW¼SW¼ sec. 30	F. Harder	Dr.	227.5			L	W	196.91	Aug. 10	Top of casing	DS	1.4
71	NE¼NW¼ sec. 32	S. Myers	Dr.	213.7	4	I	L	WG	183.66	do	Top of galvanized iron form.	DS	.7
72	SE¼SW¼ sec. 32	J. Monson	Dr.	221.7	3½	I	L	W	202.61	Aug. 3	Top of casing	DS	.8
73	SE¼SE¼ sec. 33	G. Friesen	Dr.	246.2	3½		L	W	217.60	do	do	DS	1.3
74	NE¼NW¼ sec. 34	G. Kraus	Dr.	173.8	4	I	L	W	165.82	Aug. 8	do	DS	1.2
75	NE¼NW¼ sec. 36	R. Lawler	Dr.	183.4	3½	I	L	W	178.26	Aug. 9	do	DS	.8

T. 14 N., R. 36 W.

76	NE¼SE¼ sec. 19	Dolzal estate	Dr.	[9] 44.2	3½	I	L	W	36.87	Aug. 20	Top of casing	S	1.8
77	NE¼NE¼ sec. 19	do	Dr	33.6	6	I	L	W	19.32	do	do	DS	2.7
78	NW¼SW¼ sec. 21	B. Snyder	Dr.	40.9	4	I	L	WG	22.86	do	Top of 2 by 8 plank	DS	.3
79	NW¼SE¼ sec. 22	Z. Snyder	Dr.	28.9	4	I	L	WG	17.35	do	Top of casing	DS	−3.7
80	SE¼SW¼ sec. 24	W. Sadle	Dr.	31.3	4	I	L	W	18.24	Aug. 19	do	DS	.9
81	SE¼NE¼ sec. 26	H. Snyder	Dr.	125.2	3½	I	L	W	110.25	do	Top of wood curb	DS	1.9
82	SE¼NE¼ sec. 27	G. Andrews	Dr.	87.9	4	I	L	W	69.76	do	Top of casing	DS	2.5
83	NE¼NE¼ sec. 28	J. Bassett	Dr.	70.5	3	I	L	W	55.98	Aug. 20	do	DS	1.1
84	NW¼SW¼ sec. 33	E. Bassett	Dr.	190.7	3½	I	L	W	163.27	Aug. 16	do	DS	.6
85	SW¼SE¼ sec. 34		Dr.	113.5	5	G	L	W	109.90	do	do	S	.8

T. 16 N., R. 36 W.

86	NE¼NE¼ sec. 5								11.45	Sept. 24	Top of casing		
87	NE¼NE¼ sec. 20	J. Scollin							8.70	do	do		

T. 12 N., R. 37 W.

88	NE¼NE¼ sec. 3		Dr.	285.6	3½	I	L	W	222.36	Aug. 3	Top of casing	DS	0.9
89	NW¼SE¼ sec. 5	J. Riedel	Dr.	152.2	3½	I	L	W	143.32	Aug. 2	do	S	2.9
90	SW¼NW¼ sec. 6	W. Most	Dr.	197.2	3½	I	L	W	183.20	Aug. 1	do	DS	1.7
91	SE¼NE¼ sec. 7	A. Hansmeier	Dr.	209.8	3½	I	L	W	186.36	Aug. 2	do	DS	1.8
92	SW¼SW¼ sec. 9	P. Linquist	Dr.	135.8	3½	I	L	W	112.70	do	do	S	2.0
93	NW¼NE¼ sec. 12	G. Jansen	Dr.	249.7	3	I	L	W	241.25	Aug. 3	do	DS	.8
94	NE¼NE¼ sec. 15	A. Koch	Dr.	255.2	3½	I	L	WG	237.07	do	do	DS	.6
95	SW¼NW¼ sec. 20 [8]	M. Apolius	Dr.	[9] 168.0	3	I	L	W	167.78	Aug. 2	do	DS	1.4
96	NW¼SW¼ sec. 22 [8]	S. Cressem	Dr.	171.9	3½	I	L	W	139.55	Aug. 3	do	A	1.0
97	NE¼SE¼ sec. 24 [8]	P. Janzen	Dr.	[9] 269.2	3	I	L	W	253.89	do	do	DS	.6

T. 13 N., R. 37 W.

98	SW¼NW¼ sec. 1	L. Elliott	Dr.	49.2	3½	I	L	W	40.26	Aug. 15	Top of galvanized iron form.	DS	0.0
99	NW¼NE¼ sec. 3		Dr.	21.6	6	G	L	W	15.20	do	Top of casing	S	1.4
100	SW¼NE¼ sec. 4	F. Thalken	Dr.	38.7	24	G	C	T	11.64	do	Top of curb	I	2.0
101	NE¼NE¼ sec. 4	do	Dr.	[9] 88.2	6	I	L	W	85.25	do	Top of casing	S	3.7
102	SE¼NW¼ sec. 5	H. Bove	Dn.	24.8	1¼	I	P	H	18.88	do	Top of pipe	D	1.5
103	NE¼NW¼ sec. 6	G. Buckwalter	Dr.	54.6	3½	I	L	W	39.57	do	Top of casing	DS	1.5
104	NW¼SW¼ sec. 8	R. Walker	Dr.	45.6	3	I	L	W	41.36	Aug. 10	do	DS	1.2
105	SW¼NE¼ sec. 9	J. Apolius	Dr.		4	I	L	W	6.05	do	do	DS	.5
106	NW¼NE¼ sec. 15	School District No. 42	Dr.	34.9	3½	I	L	W	26.22	do	do	D	.5
107	NW¼NE¼ sec. 16	S. Hilliard	Dr.	71.0	6	G	N		59.07	do	do	A	.7

See footnotes at end of table.

Records of wells in Keith County—Continued

T. 13 N., R. 37 W.—Continued

Well no.	Location	Owner or name	Type	Depth (feet)	Diameter (inches)	Type of casing	Type of pump	Method of lift	Depth to water level below measuring point (feet)	Date (1935)	Measuring point	Use of water	Distance of measuring point above or below land surface (feet)
108	NW¼SW¼ sec. 18	Pounds estate	Dr.	105.7			L	G	97.74	Aug. 13	Top of 1 by 12 plank	A	1.5
109	NE¼NW¼ sec. 20	Allen estate	Dr.	155.5	3½	I	L	W	120.30	Aug. 12	Top of casing	DS	.2
110	NE¼NW¼ sec. 22	J. Apolius	Dr.	55.4	3½	I	L	W	52.32	Aug. 10	Top of manhole base	DS	.0
111	NW¼NW¼ sec. 23	P. Peters	Dr.	113.2	3	I	L	W	90.24	do	Top of casing	DS	.4
112	SW¼SE¼ sec. 24	H. Logan	Dr.	73.5	4	I	L	W	69.39	do	do	D	1.1
113	SE¼SW¼ sec. 27	R. Geisert	Dr.	79.6	3½	I	L	W	26.59	Aug. 1	do	DS	.8
114	SE¼NW¼ sec. 28	do	Dr.	[9] 154.9	3	I	L	W	145.61	Aug. 2	do	DS	2.0
115	NW¼NW¼ sec. 30	E. Geisert	Dr.	229.7	3½	I	L	W	186.55	Aug. 12	do	DS	1.7
116	NE¼NE¼ sec. 31	St. Johns Church	Dr.	261.1	3½	I	L	W	201.86	Aug. 1	do	DS	1.6
117	SW¼SW¼ sec. 32	B. Sthum	Dr.	228.6	3	I	L	W	185.81	do	do	DS	.4
118	NW¼NW¼ sec. 34	R. Geisert	Dr.	116.2	3	I	L	W	99.18	do	do	S	.6
119	SE¼SE¼ sec. 36		Dr.	260.8	3	I	L	W	218.43	Aug. 3	do	DS	1.2

T. 14 N., R. 37 W.

Well no.	Location	Owner or name	Type	Depth (feet)	Diameter (inches)	Type of casing	Type of pump	Method of lift	Depth to water level below measuring point (feet)	Date (1935)	Measuring point	Use of water	Distance of measuring point above or below land surface (feet)
120	NW¼NW¼ sec. 8	G. Feltz	Dn.	22.2	1¼	I	P	H	14.56	Aug. 26	Top of check valve seat	D	2.3
121	SE¼NE¼ sec. 15	C. Thalken	Dr.	[9] 25.3	3½	I	L	W	24.40	do	Top of casing	D	2.2
122	SW¼NW¼ sec. 17	H. Beckuis	Dr.	234.5	3½	I	L	W	224.25	Aug. 22	do	S	.7
123	SW¼NW¼ sec. 20	M. Madsen	Dr.	289.9	3½	I	L	W	272.08	do	do	S	2.8
124	NW¼SW¼ sec. 21	G. Stuehm	Dr.	251.3	3½	I	L	W	240.80	do	do	DS	1.6
125	SE¼SW¼ sec. 23	H. Jensen	Dr.	249.4	3½	I	L	WG	235.36	Aug. 20	do	DS	2.7
126	SE¼NE¼ sec. 24		Dr.	63.3	3½	I	N		58.70	do	do	A	1.6
127	NE¼SE¼ sec. 25	J. Frosh	Dr.	235.4	3½	I	L	W	226.88	do	do	DS	.8
128	SW¼SE¼ sec. 28	H. Madison	Dr.	239.7	3½	I	L	W	230.33	Aug. 22	do	DS	2.2
129	SW¼NW¼ sec. 29	W. Hahn	Dr.	[9] 236.4	3½	I	L	W	232.57	do	do	DS	2.7
130	SE¼SE¼ sec. 32	E. Kohler	Dr.	97.7	3½	I	L	W	75.40	Aug. 15	do	S	1.7
131	SW¼NE¼ sec. 34	C. Thalken	Dr.	184.2	3	I	L	W	166.50	do	do	S	.1
132	SE¼NE¼ sec. 35	F. Thalken	Dr.	[9] 214.1	3½	I	L	W	208.44	Aug. 20	do	DS	1.0

T. 15 N., R. 37 W.

Well no.	Location	Owner or name	Type	Depth (feet)	Diameter (inches)	Type of casing	Type of pump	Method of lift	Depth to water level below measuring point (feet)	Date (1935)	Measuring point	Use of water	Distance of measuring point above or below land surface (feet)
133	NW¼SE¼ sec. 4		B.[10]						11.00	Sept. 23	Top of lath		0.0

					T. 16 N., R. 37 W.							
134	NW¼SE¼ sec. 3	R. Rice	B.[10]						11.87	Sept. 23	Top of lath		0.0
135	SE¼SE¼ sec. 20	W. Mannon	Dr.	72.3	4	I	N		26.69	do	Top of casing	A	−4.0
					T. 12 N., R. 38 W.							
136	NE¼NW¼ sec. 2	W. Holscher, Sr	Dr.	221.0	3	I	L	W	197.58	July 30	Top of casing	DS	1.0
137	NW¼NE¼ sec. 5	J. Badberd	Dr.	233.6	3½	I	L	W	194.71	July 29	do	DS	2.5
138	SE¼SE¼ sec. 6	C. Moline	Dr.	207.6	3	I	L	W	199.20	do	do	DS	−2.0
139	NW¼NE¼ sec. 8	E. Walker	Dr.	203.4	3	I	L	W	182.05	do	do	DS	−3.2
140	NE¼NW¼ sec. 10	E. Haessler	Dr.	249.8	3½	I	L	W	192.03	July 30	do	DS	.8
141	SW¼SW¼ sec. 10	A. Linquist	Dr.	201.5	3½	I	L	W	182.48	do	do	DS	−.2
142	NW¼NE¼ sec. 11	E. Most	Dr.	239.4	3½	I	L	W	197.18	Aug. 2	Top of pump pipe support.	DS	2.4
143	NE¼NE¼ sec. 13		Dr.	226.2	3½	I	L	W	188.31	Aug. 5	Top of casing	DS	
144	NW¼NW¼ sec. 14	Lundgren estate	Dr.	237.3	3½	I	L	W	205.95	July 30	do	DS	1.8
145	SE¼SW¼ sec. 14	O. Johnson	Dr.	198.8	3½	I	L	W	190.35	do	do	DS	3.0
146	NW¼NW¼ sec. 17	H. Walker	Dr.	226.7	3½	I	L	W	200.85	do	do	DS	.2
147	NE¼SW¼ sec. 18	M. Rasdal	Dr.	229.5	3½	I	L		203.72	July 13	do	A	.3
148	NW¼NW¼ sec. 21 [8]	H. Wiseman	Dr.	223.4	3½	I	L	W	188.61	July 29	do	DS	3.6
					T. 13 N., R. 38 W.							
149	NE¼NE¼ sec. 2	F. Lute	Dr.	24.5	6	I	L	W	19.09	Aug. 15	Top of casing	S	1.3
150	NE¼NW¼ sec. 4	J. Feltz	Dr.	37.5	3	I	L	WG	28.94	do	do	S	1.7
151	NW¼NE¼ sec. 5	G. Welch	Dr.	95.3	3½	I	L	W	67.53	do	do	DS	2.6
152	NW¼SW¼ sec. 8	H. Brown	Dr.	176.0	3	I	R	G	19.02	Aug. 13	do	I	.7
153	SW¼NW¼ sec. 9	C. Hollingsworth	Dr.	56.1	24	G	T	E	20.95	do	do	I	.0
154	SE¼NE¼ sec. 10	Goold Ranch	Dr.	[9] 19.4	6	I	L	G	6.48	do	do	S	.0
155	SW¼SW¼ sec. 10	W. Tepley	Dr.	31.2	6	G	L	WG	20.97	do	Top of concrete base	DS	.5
156	NE¼SE¼ sec. 14	A. Cook	Dr.	99.8	3	I	L	W	90.71	do	Top of casing	S	1.7
157	NW¼SW¼ sec. 14	J. Meyers	Dr.	119.9	3	I	L	W	105.96	do	do	DS	1.8
158	NW¼NW¼ sec. 16	T. Goold	Dr.	55.1	3½	G	L	W	48.77	do	do	DS	1.1
159	NE¼NW¼ sec. 18	W. Koenig	Dr.	60.4	6	I	L	W	44.07	July 12	do	DS	1.6
160	NE¼SW¼ sec. 19	do	Dr.	187.6	6	I	L	W	174.87	do	do	S	1.1
161	NE¼SE¼ sec. 20	T. Goold	Dr.	161.9	3½	I	N		141.61	Aug. 12	do	A	.7
162	SE¼NW¼ sec. 22	F. Holscher	Dr.	[9] 177.8	3½	I	L	W	174.80	do	do	S	.5
163	NE¼NE¼ sec. 26	F. Hahn	Dr.	240.6	3½	I	L	W	211.30	do	do	DS	.8
164	NW¼NW¼ sec. 27	C. Worden	Dr.	[9] 215.9	3½	I	L	W	215.25	do	do	DS	2.3
165	SW¼SE¼ sec. 29	J. Krajewski	Dr.	234.4	3½	I	L	W	213.89	do	do	DS	.9
166	SW¼SW¼ sec. 31	J. Frerichs, Jr	Dr.	241.9	3½	I	L	W	202.53	July 12	do	DS	2.1
167	NW¼NE¼ sec. 34	F. Taylor	Dr.	216.8	3½	I	L	W	177.45	July 30	do	DS	1.6
168	NW¼SW¼ sec. 35	W. Holscher, Jr	Dr.	222.9	3	I	L	W	187.53	Aug. 1	do	S	1.5

See footnotes at end of table.

Records of wells in Keith County—Continued

Well no.	Location	Owner or name	Type	Depth (feet)	Diameter (inches)	Type of casing	Type of pump	Method of lift	Depth to water level below measuring point (feet)	Date (1935)	Measuring point	Use of water	Distance of measuring point above or below land surface (feet)
					T. 14 N., R. 38 W.								
169	NW¼SW¼ sec. 2	S. Gainsforth	Dr.	104.3	8	I	L	W	18.26	Aug. 26	Top of casing	D	3.3
170	SW¼NE¼ sec. 4	J. Heinemann	Dr.	43.2	24	S	T	T	19.15	do	do	I	-.2
171	NW¼NW¼ sec. 8	G. Pinkston	Dr.	[9] 59.4	3½	I	L	W	56.63	do	do	DS	1.0
172	NW¼NE¼ sec. 12	J. Bannon	Dr.	35.4	6	G	L	W	26.08	do	do	D	.0
173	SW¼SE¼ sec. 13	R. Curry	Dr.	241.1	3½	I	L	W	216.28	Aug. 22	do	S	2.1
174	NW¼NW¼ sec. 13	R. Ruser	Dr.	252.9	4	I	L	W	242.67	do	do	DS	2.8
175	SW¼SW¼ sec. 15	F. Taylor	Dr.	349.8	3½	I	L	W	321.96	Sept. 12	do	DS	2.8
176	NW¼SW¼ sec. 17	J. Eichner	Dr.	250.5	3½	I	L	W	237.85	Aug. 22	do	S	2.9
177	SW¼SW¼ sec. 21	W. Rapp	Dr.	277.4	3½	I	L	W	270.55	Aug. 21	do	DS	2.7
178	NW¼NE¼ sec. 25	J. Luenenburg	Dr.	286.9	3½	I	L	W	272.64	Aug. 27	do	DS	3.3
179	NW¼NW¼ sec. 26	H. Suhr	Dr.	335.5	3	I	L	WG	322.31	do	do	DS	.8
180	SW¼SE¼ sec. 29	M. Sievers	Dr.	233.6	4	G	L	W	219.36	Aug. 21	do	S	3.4
181	SE¼SW¼ sec. 30	D. Martens	Dr.	204.8	3½	I	L	W	177.27	do	do	DS	1.3
182	SW¼SE¼ sec. 36	F. Lute	Dr.	61.6	3	I	L	W	50.09	Aug. 15	do	DS	1.1
					T. 15 N., R. 38 W.								
183	SE¼SW¼ sec. 25		B.[10]						6.58	Sept. 23	Top of lath		0.0
184	SW¼SW¼ sec. 30	A. Thies	Dr.	30		G	N		5.46	Sept. 21	Top of casing	I	.0
					T. 16 N., R. 38 W.								
185	SW¼SW¼ sec. 22	G. McGinley	B [10]						8.62	Sept. 23	Top of lath		0.0
186	NW¼NE¼ sec. 30	Univ. of Nebraska	Dr.	42.3	2								
					T. 12 N., R. 39 W.								
187	SW¼SE¼ sec. 2	B. Blakeney	Dr.	212.3	3	I	L	W	190.26	July 13	Top of casing	DS	1.2
						I	N		13.26	July 17	do	A	2.5
188	NW¼ SW¼ sec. 4	H. Nelson	Dr.	[9] 207.7	3	I	L	W	201.28	July 15	do	A	1.0
189	NW¼ SW¼ sec. 6	C. Wiest	B.	24.4	12	N	P	H	11.84	July 16	Top of tank curb	A	1.7

190	SE¼NE¼ sec. 12	C. Binder	Dr.	217.9	3	I	L	W	170.31	July 29	Top of concrete base	DS	.5
191	NW¼SW¼ sec. 12	H. Armknecht	Dr	212.7	3	I	L	W	185.14	July 13	Top of casing	A	1.0
192	NE¼NE¼ sec. 15	F. Taylor	Dr.	207.6	3½	I	L	W	180.15	July 15	Top of iron pipe collar	DS	.9
193	NW¼NE¼ sec. 16	C. Nichols	Dr.	217.8	3½	I	L	W	189.11	do	Top of casing	DS	1.6
194	NW¼NE¼ sec. 18	Spikes	Dr.	191.3	3½	I	L	W	167.51	July 16	do	S	1.8
					T. 13 N., R. 39 W.								
195	SW¼NW¼ sec. 1	Ogallala Cemetery	Dr.	40.7	3½	I	L	H	32.99	July 18	Top of casing	I	0.1
196	SE¼SE¼ sec. 3	F. Belton	Dr.	48.0	3½	I	L	W	32.80	Aug. 14	do	S	1.8
197	SW¼NE¼ sec. 4	R. Searle	Dr.	110.6	3½	I	L	W	106.11	Aug. 13	do	S	2.7
198	SW¼SW¼ sec. 4	School District No. 14	Dr.	[9] 52.5	3½	I	L	W	47.15	do	do	D	.8
199	NE¼NE¼ sec. 5	F. Leibert	Dr.	135.8	3½	I	L	W	130.15	do	do	S	.9
200	SE¼NW¼ sec. 7	H. Frerichs	Dr.	74.4	3½	I	N		69.98	do	do	A	3.5
201	SW¼SW¼ sec. 7	do	Dr.	34.6	6	G	L	W	30.21	do	do	S	1.0
202	NE¼SW¼ sec. 8	A. Skidmore	Dr.	49.9	6	G	L	G	37.06	do	do	I	.2
203	SW¼SW¼ sec. 9		Dr.	30.7	24	G	T	E	5.59	July 17	do	I	1.0
204	NW¼SW¼ sec. 10		Dr.	23.1	6	G	L	W	19.91	do	Top of casing collar	S	1.8
205	SE¼SE¼ sec. 11	D. Spangler	Dr.	44	24	G	C	T	16.66	July 12	Top of 4 by 6 sill	I	1.0
206	SW¼SW¼ sec. 12	M. Tressler	Dr.	38.3	24	G	T		16.34	do	Top of casing	I	.2
207	SE¼NE¼ sec. 15	J. Ryan	Dr.	17.3	6	G	L	H	7.84	July 11	Top of concrete base	D	.3
208	SW¼SE¼ sec. 16	J. Annable	Dr.	37.1	6	G	L	W	31.30	do	Top of casing	DS	1.4
209	NE¼NW¼ sec. 17	E. Smith	Dg.	8.3	36	W	L	W	8.05	Aug. 13	Top of 1 by 12 cover	S	1.8
210	SE¼SW¼ sec. 19	G. McGinley	Dr.	[9] 53.7	4	I	L	W	45.32	July 10	Top of casing	A	3.7
211	SE¼SE¼ sec. 20	A. Harrison	Dr.	97.2	4	I	L	W	70.76	July 11	do	DS	1.4
212	NE¼NE¼ sec. 20	W. Shireman	Dr.	40.6	8	G	L	W	34.49	do	Top of 2 by 12 plank	D	1.5
213	SE¼SW¼ sec. 20	J. Cunningham	Dr.	102.5	3	I	L	W	66.35	do	Top of casing	DS	.0
214	SW¼SE¼ sec. 21	S. Sherman	Dr.	[9] 96.2	3½	I	L	W	84.28	do	do	DS	1.1
215	NW¼NW¼ sec. 22	M. Cannon	Dr.	52.9	3	I	L	H	43.12	do	do	D	.6
216	NE¼NW¼ sec. 23	A. Ehlers	Dr.	79.2	3½	I	L	W	56.86	July 22	do	DS	−3.7
217	NW¼NE¼ sec. 26	P. Eggers	Dr.		3	I	L	W	207.76	July 12	do	DS	.9
218	NE¼SE¼ sec. 30	B. Hull	Dr.	[9] 92.2	3	I	L	W	84.08	July 11	Top of 3 by 12 plank	DS	.5
219	NW¼NW¼ sec. 30	B. Duncan	Dr.	44.0	6	G	N		42.71	July 10	Top of casing	A	1.4
220	SW¼NW¼ sec. 33	H. Shelburne	Dr.	229.5	6	I	L	W	209.64	July 16	Top of galvanized iron form.	DS	1.2
221	SE¼SE¼ sec. 34	Peters estate	Dr.	199.3	3½	I	L	W	168.95	July 15	Top of casing	A	1.6
					T. 14 N., R. 39 W.								
222	NE¼NE¼ sec. 6	V. Ohrlund	Dr.	193.0	3½	I	L	W	161.72	Aug. 23	Top of casing	S	1.7
223	NW¼NE¼ sec. 8	M. Kelly	Dr.	[9] 178.0	3	I	L	W	177.77	do	do	S	.6
224	NE¼SW¼ sec. 13	A. Ivers	Dr.	310	3½	I	L	W	283.12	Aug. 21	do	DS	1.8
225	SE¼SE¼ sec. 15	M. Kelly	Dr.	283.9	3½	I	L	W	257.49	July 23	Top of pipe clamp	A	2.3
226	SW¼NW¼ sec. 18	H. Fenwick	Dr.	384.9	3½	I	L	W	298.32	Sept. 6	Top of casing	DS	1.1
227	NE¼SE¼ sec. 21	H. Sass	Dr.	490.5	4	I	L	W	415.55	Sept. 12	do	DS	2.7
228	SE¼SW¼ sec. 23	C. Kleber	Dr.	238.3	3½	I	L	W	229.09	Aug. 21	do	DS	2.4
229	SE¼SE¼ sec. 24	Percy estate	Dr.	211.3	3	I	L	W	201.48	do	do	DS	2.7
230	NW¼SW¼ sec. 28	W. Davison	Dr.	224.1	3½	I	L	W	212.04	Sept. 5	do	DS	.3
231	NW¼NW¼ sec. 32	C. Nichols	Dr.	323.4	3½	I	L	W	319.47	do	do	DS	2.5
232	NE¼SW¼ sec. 36	P. Viola	Dr.	132.7	3½	I	L	W	116.10	Aug. 14	do	DS	.2

See footnotes at end of table.

Records of wells in Keith County—Continued

Well no.	Location	Owner or name	Type	Depth (feet)	Diameter (inches)	Type of casing	Type of pump	Method of lift	Depth to water level below measuring point (feet)	Date (1935)	Measuring point	Use of water	Distance of measuring point above or below land surface (feet)
T. 15 N., R. 39 W.													
233	NE¼SE¼ sec. 21		B.[10]						5.36	Sept. 21	Top of lath		0.0
234	NW¼NE¼ sec. 32	M. O'Bryan	Dr.	40.5	4	I	N		29.32	Aug. 23	Top of casing	A	3.0
T. 16 N., R. 39 W.													
235	NW¼SW¼ sec. 20		B.[10]						7.29	Sept. 21	Top of lath		0.0
236	NW¼NW¼ sec. 32		B.[10]						8.53	do	do		.0
T. 12 N., R. 40 W.													
237	NW¼SE¼ sec. 1	F. Taylor	Dr.	230.7	3½	I	L	W	208.19	July 17	Top of casing	DS	2.1
238	NE¼NW¼ sec. 2	G. Schulz	Dr.	242.3	3½	I	L	W	200.10	do	do	DS	2.3
239	SE¼SE¼ sec. 3	P. Johnson	Dr.		3½	I	L	W	206.75	July 20	do	DS	1.5
240	NE¼NE¼ sec. 6	A. Muldoon	Dr.	100+	3	I	L	H	66.24	July 6	do	A	1.3
241	NE¼NE¼ sec. 8	F. Struckman	Dr.	160.4	3½	I	L	W	147.54	July 22	do	DS	1.3
242	SW¼SE¼ sec. 10	E. Blair	Dr.	226.1	3	I	L	W	198.61	July 16	Top of concrete curb	DS	.5
243	SE¼SE¼ sec. 14	M. Weist	Dr.	200.1	3	I	L	W	184.48	do	Top of casing flange	DS	−2.5
244	NE¼NE¼ sec. 17	F. Struckman	Dr.	249.1	3½	I	L	W	220.85	July 18	Top of casing	S	1.7
245	NE¼NW¼ sec. 19 [8]	A. Moore	Dr.	174.1	3	I	L	H	158.89	do	do	S	3.1
246	NW¼NW¼ sec. 21 [8]	H. Osborn	Dr.	234.7	3½	I	L	W	214.15	July 17	do	DS	2.6
T. 13 N., R. 40 W.													
247	NE¼NE¼ sec. 1	J. Campbell	Dr.	192.9	3½	I	L	WG	169.04	July 27	Top of casing	S	2.3
248	SW¼ SE¼ sec. 2	Omaha National Bank	Dr.	167.4	3½	I	L	W	150.07	do	do	S	2.3
249	SE¼SW¼ sec. 4	E. Harms	Dr.	130.7	3	I	L	W	119.06	July 26	do	DS	2.8
250	SE¼SE¼ sec. 6	do	Dr.	171.5	3½	I	L	W	143.08	do	do	S	1.0
251	NW¼SW¼ sec. 7		Dr.	267.3	3½	I	L	W	249.18	July 24	do	DS	1.4
252	SW¼SE¼ sec. 8	T. Austin	Dr.	86.2	3½	I	L	W	75.74	July 26	do	DS	1.0
253	SE¼SE¼ sec. 9	R. Harms	Dr.	107.9	4	I	L	W	78.87	do	do	S	1.9
254	SW¼SW¼ sec. 11	Brule Cemetery	Dr	59.5	3½	I	L	H	53.99	July 27	do	I	.8

255	SW¼SW¼ sec. 12	Truttner estate	Dr.	[9] 49.4	4	G	L	W	47.62	July 17	do	S	.7
256	NE¼NE¼ sec. 13	A. Schmidt	Dr.		18	G	C	G	22.29	Aug. 13	Top of 3 by 12 plank	I	.3
257	NE¼SW¼ sec. 14	H. Meyers	Dr.	24.2	10	N	N		23.67	do	Top of wood cover	A	.0
258	NW¼SE¼ sec. 15	B. Kuskie	Dr.	23.6	6	G	C	E	12.62	Aug. 14	Top of casing	I	1.1
259	SE¼SE¼ sec. 16	Berryman estate	Dr.	30.2	3½	I	L	G	18.45	do	do	S	2.0
260	SE¼SE¼ sec. 17	O. Hays	Dr.	[9] 22.9	3	I	L	WG	21.92	July 25	do	DS	−4.4
261	SE¼SW¼ sec. 22	O. Beal	Dr.	13.0	6	G	L	H	6.75	July 8	Top of concrete base	A	.3
262	SW¼SE¼ sec. 23	J. Sims	Dr.	22.3	12	G	C	G	12.55	July 10	Top of 2 by 4 sill	S	.5
263	SE¼NE¼ sec. 24	G. McGinley	Dr.	31.0	8	I	L	W	25.13	do	Top of casing	S	.5
264	SW¼SW¼ sec. 25	C. Schulz	Dr.	51.6	8	G	L	W	36.95	do	do	S	1.1
265	NW¼SE¼ sec. 27	H. Rewerts	Dr.	11.6	16	G	C	O	4.82	July 8	Top of wood curb	I	1.3
266	SE¼SW¼ sec. 29	J. Brown	Dr.	44	12	G	C	E	[11] 9	July 6		I	
267	SW¼NW¼ sec. 31	O. Hardessen	Dr.	61.9	24	G	T	E	12.63	do	Top of casing	I	1.0
268	SE¼NE¼ sec. 32	E. Harrach	Dr.	51.8	6	G	L	H	40.41	July 9	Top of concrete base	S	1.1
269	SW¼NW¼ sec. 32	H. Einspahr	Dr.	57.4	24	G	T	E	[12] 45.64	July 20	Top of casing	I	.5
270	SE¼NW¼ sec. 32	do	Dr.	57.5	24	G	T	O	31.94	do	do	I	.5
271	NW¼NW¼ sec. 34	S. Sneddeker	Dr.	33.4	3	I	L	H	21.16	July 8	Top of 2 by 10 plank	A	.5
272	SW¼SW¼ sec. 34	O. Beal	Dr.	[9] 90.4	3	I	L	W	69.62	July 9	Top of casing	D	.4
273	NW¼NW¼ sec. 35	do	Dr.	[9] 51.8	3½	I	L	W	43.51	July 10	do	S	.6

T. 14 N., R. 40 W.

274	SE¼SE¼ sec. 4	W. McDonald	Dr.	[9] 483.1	3½	I	L	W	460.61	Sept. 11	Top of casing	DS	1.9
275	SE¼SW¼ sec. 8	C. Spoeneman	Dr.	401.8	3½	I	L	W	397.77	Sept. 7	do	DS	2.6
276	SE¼NE¼ sec. 10	C. Taylor	Dr.	466.8	4	I	L	W	438.01	Sept. 6	do	DS	2.0
277	NE¼NE¼ sec. 22	F. Taylor	Dr.	388.9	4	I	L	W	382.56	do	do	DS	3.0
278	NW¼NW¼ sec. 25	H. Schultz, Jr	Dr.	370.1	3½	I	L	W	359.39	Sept. 5	do	DS	−3.7
279	NE¼NE¼ sec. 29	E. Meredith	Dr.	342.9	3½	I	L	W	313.14	Sept. 9	do	A	2.4
280	SW¼SW¼ sec. 30	S. Grimes	Dr.	291.7	3½	I	L	W	269.94	Sept. 6	do	DS	.5
281	SW¼NE¼ sec. 31	C. Sautter	Dr.	203.7	3½	I	L	W	182.82	July 26	do	S	1.4
282	SW¼SW¼ sec. 32	W. Harris	Dr.	182.9	3	I	L	W	150.33	do	do	S	−3.6
283	SE¼SE¼ sec. 33	M. Hickstein	Dr.	338.9	3½	I	L	W	317.71	Sept. 9	do	DS	.5

T. 15 N., R. 40 W.

284	SW¼SE¼ sec. 11		B [10]						8.57	Sept. 21	Top of lath		0.0
285	NW¼NW¼ sec. 18	C. Harman	Dr.	15.6	4	I	L	WG	10.90	Sept. 13	Top of casing	S	−4.7
286	SW¼SW¼ sec. 19	do	Dr.	141.4	4	G	N		94.45	do	do	A	2.5
287	NE¼NE¼ sec. 20	Samuelson estate	Dr.	[9] 59.3	3	I	L	W	59.27	do	do	A	.2
288	SE¼NE¼ sec. 22	C. Samuelson	Dr.	10.2	2	I	L	H	8.09	do	Top of 2 by 12 plank	D	.2
289	SE¼SW¼ sec. 24	School District No. 32	Dr.	42.7	3½	I	L	W	32.46	do	Top of casing	D	.5
290	SW¼NE¼ sec. 34	A. Copley	Dr.	280.7	3½	I	L	W	253.43	Sept. 14	do	S	.5

See footnotes at end of table.

Records of wells in Keith County—Continued

Well no.	Location	Owner or name	Type	Depth (feet)	Diameter (inches)	Type of casing	Type of pump	Method of lift	Depth to water level below measuring point (feet)	Date (1935)	Measuring point	Use of water	Distance of measuring point above or below land surface (feet)
T. 16 N., R. 40 W.													
291	SE¼NE¼ sec. 2	D. McQueen	Dr.	53.4	3	I	L	W	24.30	Sept. 21	Top of casing	S	2.4
292	NE¼NE¼ sec. 6	Adams	Dr.	36.9	5	G	N		20.09	Sept. 20	do	A	0
T. 12 N., R. 41 W.													
293	NE¼SE¼ sec. 1	T. Reimers	Dr.	136.3	3½	I	L	W	96.82	July 22	Top of casing	S	1.4
294	NW¼SE¼ sec. 2	E. Reimers	Dr.	100+	3	I	L	W	57.64	July 5	do		.8
295	NW¼SW¼ sec. 3	L. Anderson	Dr.	59.0	8	G	L	W	49.78	do	do	A	.8
296	SE¼NE¼ sec. 6	Dorn estate	Dr.	29.6	24	G	C	T	7.03	July 3	Top of hand primer	I	−6.0
297	SW¼ SW¼ sec. 6	A. Eiker	Dr.	45.1	24	G	C	T	17.25	July 6	Top of casing	I	.0
298	NW¼NW¼ sec. 8	D. Hothan	Dr.	80.0	3	I	L	H	51.56	July 9	do	D	.8
299	SW¼SE¼ sec. 8	M. Mauplin	Dr.	184.5	3	I	L	W	166.53	July 20	do	DS	.8
300	NW¼NW¼ sec. 9	A. Eiker	Dr.	100+	3	I	L	W	82.85	July 9	do	S	.8
301	SE¼NW¼ sec. 11		Dr.	181.3	3½	I	N		147.54	July 19	do	A	1.2
302	NW¼SW¼ sec. 13	L. Barton	Dr.	298.6	3½	I	L	W	228.85	July 18	do	DS	.9
303	SW¼NE¼ sec. 14	F. Westerbuhr	Dr.	232.8	3	I	L	W	226.68	do	do	DS	1.2
304	SW¼NW¼ sec. 15	G. Schulz	Dr.	142.5	4	I	L	W	123.69	July 19	do	S	1.1
T. 13 N., R. 41 W.													
305	NW¼SE¼ sec. 1	C. Sautter	Dr.	269.9	3½	I	L	W	230.79	July 24	Top of casing	DS	2.1
306	SW¼SE¼ sec. 2	J. Lintz	Dr.	180.5	3	I	L	W	168.55	do	do	DS	1.5
307	SW¼NW¼ sec. 3	W. Ward	Dr.	304	3½	I	L	W	282.14	do	do	DS	1.8
308	NE¼NE¼ sec. 5	J. Perrell	Dr.	257.1	2½	I	L	W	234.96	do	do	DS	.8
309	NW¼SW¼ sec. 5	O. Hill	Dr.	229.4	4	I	L	W	206.14	July 22	Top of concrete base	DS	.6
310	SE¼SE¼ sec. 8	C. Peary	Dr.	188.0	3	I	L	W	163.37	do	Top of casing	DS	−5.8
311	SE¼SE¼ sec. 10	D. Cruickshank	Dr.	217.7	3	I	L	W	213.86	July 17	do	S	1.2
312	SE¼SW¼ sec. 12	M. McDonald	Dr.	144.7	3½	I	L	W	134.89	July 25	do	DS	1.0
313	SE¼NE¼ sec. 14	C. Sautter	Dr.	239.9	3	I	L	W	175.75	July 15	do	DS	.5
314	SW¼NW¼ sec. 17	J. Fox	Dr.	217.1	3½	I	L	W	181.94	July 23	do	DS	1.5
315	SE¼SE¼ sec. 20	V. Hein	Dr.	88.4	3	I	L	W	79.29	Aug. 14	do	DS	.1
316	SW¼NE¼ sec. 22	C. Linch	Dr.	150.9	3	I	L	WG	91.77	July 25	do	DS	1.0
317	NE¼NE¼ sec. 24	School District No. 31	Dr.	74.9	3	I	L	H	61.18	do	do	D	.6
318	SW¼NW¼ sec. 24	D. Cruickshank	Dr.	50.9	8	I	L	W	33.61	do	Top of concrete base	DS	2.6
319	NW¼ SW¼ sec. 25	McClain estate	Dn.	12.3	1¼	I	N		10.88	July 6	Top of 2 by 10 plank	A	.7
320	SW¼SE¼ sec. 32	J. Zabel	Dr.	31.3	15	G	C	E	3.38	Oct. 9	Top of casing	I	−2.4
321	SE¼SE¼ sec. 32	do	Dr.	45	24	G	C	E	6.14	July 3	Top of wood tie	I	.5
322	SW¼NE¼ sec. 32	F. Junge	Dr.	48.5	24	G	C	E	3.78	do	do	I	.0
323	NW¼NW¼ sec. 32	Kjeldgaard Bros	Dr.	18.9	10	G	C	E	4.90	do	Top of concrete floor	I	.0

324	SW¼NW¼ sec. 32	do	Dr.	37.6	12	G	T	E	4.30	do		Top of pump base	I	.3
325	SE¼SE¼ sec. 33	G. Eiker	Dr.	44.8	24	G	C	T	11.35	do		Top of wood tie	I	.9
326	NW¼SW¼ sec. 33	E. Olsson	Dr.		24	G	C	E					I	
327	NW¼NE¼ sec. 34	Kjeldgaard Bros	Dn.	20.0	1¼	I	N		4.58	July	6	Top of pipe	A	1.6
328	NW¼NW¼ sec. 34	P. Winter	Dr.		24	G	C						I	
329	SE¼SW¼ sec. 34	E. Bostrom	Dr.	43.1	24	G	T	T	19.27	July	5	Top of steel curb	I	.5
330	SW¼SE¼ sec. 35	P. Peterson	Dr.	41.9	36	G	N		21.25	do		Top of casing	I	−.5
331	NW¼SE¼ sec. 35	do	Dr.		16	G	C	T	15.32	do		Top of steel channel	I	.7
332	SE¼NE¼ sec. 36	D. Santero	Dr.		16	G	C	T	11.01	July	6	Top of concrete curb	I	.4
333	NE¼SW¼ sec. 36	E. Reimers	Dr.	49.2	24	G	C	E	14.91	July	5	Top of steel channel	I	.3
						T. 14 N., R. 41 W.								
334	SW¼SE¼ sec. 2	G. Macy	Dr.	382.2	3½	I	L	W	362.35	Sept.	10	Top of casing	DS	0.5
335	NW¼SW¼ sec. 9	W. Brockmoller	Dr.	376.5	3½	I	L	W	313.39	do		do	DS	−4.8
336	SE¼NE¼ sec. 13	W. Mueller	Dr.	416.1	3½	I	L	W	409.36	Sept.	9	do	DS	.7
337	SW¼SW¼ sec. 20	O. Bittinger	Dr.	328	4	I	L	W	298.09	July	23	do	DS	1.2
338	NW¼SW¼ sec. 22	M. Remington	Dr.	300+	3	I	L	W	295.23	July	18	do	A	1.1
339	SW¼ SW¼ sec. 26	F. Rallens	Dr.	[9] 274.3	4	I	L	W	267.70	Sept.	10	do	DS	2.5
340	SW¼SE¼ sec. 28	G. Bundy	Dr.	300+	3	I	L	W	283.94	July	23	do	DS	2.1
341	NW¼NW¼ sec. 32	V. Fisher	Dr.	267.8	3½	I	L	W	252.69	July	22	do	DS	1.2
						T. 15 N., R. 41 W.								
342	NE¼NE¼ sec. 4			13					10.92	Sept.	21	Top of casing		0.0
343	SW¼SE¼ sec. 10	H. Orr	Dn.	8.5	1¼	I	L	H	2.12	Sept.	14	Top of pipe	S	−1.6
344	SW¼SW¼ sec. 14	J. Burnett	Dr.	[9] 67.3	3½	I	L	W	53.39	do		Top of casing	S	2.5
345	SW¼ SE¼ sec. 33	B. Barnica	Dr.	355.4	3½	I	L	W	319.94	Sept.	12	do	DS	.8
						T. 16 N., R. 41 W.								
346	NW¼NW¼ sec. 8	J. Honegger	Dr.	[9] 73.7	3½	I	L	WG	69.37	Oct.	3	Bottom of tee	DS	4.0
347	NE¼SW¼ sec. 25	H. Peterson	Dr.	107	4	I	L	W	93.91	Sept.	20	Top of casing	DS	2.0
						T. 12 N., R. 42 W.								
348	NW¼NW¼ sec. 1 [13]	W. Kimball	Dr.	42.4	24	G	C	T	8.97	July	3	Top of 4 by 6 base	I	2.6
349	NE¼NE¼ sec. 24 [13]	F. Judiesch	Dr.	265.5	3½	I	L	W	225.54	July	19	do	DS	1.9

[1] B, bored; Dn, driven; Dr, drilled; Dg, dug.
[2] Depths given to tenths of a foot are measured; depths given to even feet are reported.
[3] G, Galvanized iron; I, iron; N, none; S, steel; W, wood.
[4] C, Centrifugal; L, lift; N, none; P, pitcher; R, rotary; T, turbine.
[5] E, Electric; G, gasoline engine; H, hand; O, stationary oil engine; T, tractor; W, wind; WG, wind and gasoline engine.
[6] A, Abandoned; D, domestic; DS, domestic and stock; I, irrigation; S, stock; SI, stock and irrigation.
[7] In Lincoln County.
[8] In Perkins County.
[9] To top of pump cylinder
[10] Test hole.
[11] Reported.
[12] Pumping.
[13] In Deuel County.

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