Ground-Water Resources of Republic County and Northern Cloud County, Kansas

By

V. C. FISHEL

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BULLETIN 73

GROUND-WATER RESOURCES OF REPUBLIC COUNTY AND NORTHERN CLOUD COUNTY, KANSAS

By V. C. FISHEL

with chapters on the Quaternary geology and Cenozoic geologic history

By S. W. LOHMAN

and analyses by

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Prepared by the State Geological Survey of Kansas and the United States Geological Survey, with the coöperation of the Division of Sanitation of the Kansas State Board of Health and the Division of Water Resources of the Kansas State Board of Agriculture

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By V. C. Fishel

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ABSTRACT

This report describes the geography, geology, and ground-water resources of Republic County and northern Cloud County in north-central Kansas. The area embraces a total of 25 townships, or 899 square miles. The area is drained by the Republican River and its tributaries. The climate is subhumid, the average annual precipitation being about 26 inches. Wheat farming, cattle raising, and general farming are the principal occupations in the area.

The rocks exposed in Republic County and northern Cloud County are of Cretaceous and Quaternary age. The areal distribution of the formations is shown in Plate 1. The oldest formation cropping out in the area is the Dakota formation of Cretaceous age, which is exposed in the southeastern part of Republic County and in northern Cloud County. The overlying Graneros shale and Greenhorn limestone of Cretaceous age are best exposed in the eastern and southern parts of Republic County along the edges of the streams where the overlying Carlile shale has been eroded away. The Carlile shale mantles the upland areas in the west-central, central, and eastern parts of Republic County. The Pleistocene deposits, which include the Belleville formation, and the loess deposits, comprise the surface materials in a large area in northern Republic County. The soils and alluvium are the youngest deposits in the area.

Test drilling revealed that the ancestral Republican River channel entered Republic County 5 miles south of the Nebraska State line, crossed the present channel near Republic City, and entered Nebraska near Chester.

The report contains a map showing by contours the shape and slope of the water table in the Republican River Valley and in the ancestral Republican River Valley. The map shows that ground water moves into the Republican Valley from both sides. The depth to the water table ranges from less than 10 feet in the Republican Valley to more than 100 feet in the upland in northern Republic County.

The ground-water reservoir is recharged principally by precipitation that falls within the area, by the addition of water from Republican River, and by underflow from adjacent areas. Water is discharged from the ground-water reservoir by seepage into Republican River, by underflow eastward and southward into adjacent areas, by transpiration and evaporation in areas of shallow water table, and by wells. All of the domestic, stock, and public water supplies and a part of the irrigation water supplies are obtained from wells.

Most of the domestic and stock wells in the Republican Valley are driven. Most of the wells on the upland are drilled or bored. The use of ground water

for irrigation has barely started. At the time of the field investigation there were only four active irrigation wells in the Republican River Valley in Cloud and Republic Counties. Five other wells formerly were used for irrigation.

The ground water in the alluvium and the Belleville formation is hard but it is generally suitable for most ordinary uses. In local areas in northern Cloud County it is highly mineralized. Waters from the Dakota formation in the outcrop areas are relatively soft but they are generally highly mineralized in other areas.

The field data upon which most of this report is based are given in tables, and include records of 291 wells and chemical analyses of the water from 58 wells. Logs of 126 test holes are also given.

INTRODUCTION

Purpose and Scope of the Investigation.—The investigation upon which this report is based is part of an extended program of ground-water investigations in Kansas begun in July, 1937, by the United States Geological Survey and the State Geological Survey of Kansas in coöperation with the Division of Sanitation of the Kansas State Board of Health and the Division of Water Resources of the Kansas State Board of Agriculture. Similar investigations are being conducted in several other counties in Kansas.

The Bureau of Reclamation has been making a survey of the Republican River Valley primarily to determine the potential irrigation development of the basin. In its investigation of the valley between the Nebraska State line and Concordia, Kansas, the Bureau has been interested in the relative desirability of irrigating valley lands with ground water or by a system of canals diverting water from Republican River or by a combination of both. Some of the arable land is situated so as to be irrigable more feasibly using ground water than surface water.

A. W. Redman, engineer of the Bureau of Reclamation, made a reconnaissance of the area during the summer of 1941. He obtained information regarding the existing irrigation wells, measured the water levels in several domestic wells, and selected some sites for test drilling. Five test holes were drilled by William Steele, well driller employed by the Bureau of Reclamation, in August 1941. The Bureau of Reclamation concluded from these preliminary surveys that ground-water irrigation was feasible in a part of the area but that a more intensive investigation of the ground-water resources of the area should be made. They proposed that the investigation should be made in coöperation with other interested Federal and State agencies in Kansas. In December 1941, C. T. Judah, engineer in charge of the Bureau's hydrologic investigations in the Republican

River Valley, conferred in regard to this proposed study with R. C. Moore, State Geologist, George S. Knapp, Chief Engineer, Division of Water Resources, State Board of Agriculture, and S. W. Lohman, Federal Geologist in Charge of ground-water investigations in Kansas, and plans were laid for the coöperative investigation that was made during the summer of 1942. It was agreed that the investigation should include all of Republic County and the Republican River Valley down to Concordia and that the investigation of the groundwater resources of the Republican River Valley would be in coöperation with the Bureau of Reclamation. The investigation was made under the general administration of R. C. Moore, State Geologist, and J. C. Frye, Executive Director, State Geological Survey of Kansas and O. E. Meinzer, Geologist in Charge, Division of Ground Water, Federal Geological Survey, and under the direct supervision of S. W. Lohman, Federal Geologist in Charge of ground-water investigations in Kansas.

Location and Extent of the Area.—The area considered in this report includes Republic County and part of Cloud County that lies in the Republican River Valley. Republic and Cloud Counties lie in the first and second tiers of counties respectively from the north border of the State and a short distance east of its center. Republic County has a total of 20 townships or an area of 719 square miles. Its location with respect to adjoining counties is shown in Figure 1.

Previous Investigations.—The more important studies dealing with the geology and ground-water resources of north-central Kansas that

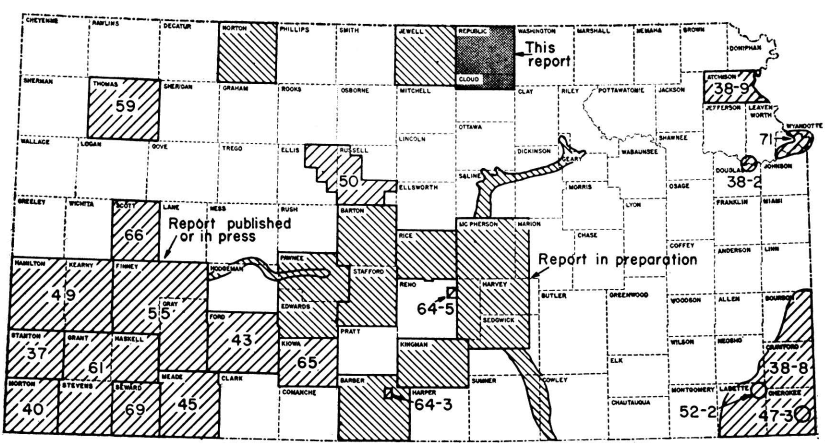


FIG. 1. Area covered by this report and other areas in Kansas for which coöperative ground-water reports have been published or are in preparation.

have a bearing on Republic County are cited below. Specific references are cited at appropriate places in the text by author and date and are listed in the references at the end of the report.

The geology of the Upper Cretaceous in Kansas was described by Logan in 1897. Darton (1905, pp. 289, 292, 313) made reference to a few wells in this area in a preliminary report on the geology and ground-water resources of the central Great Plains. Because of the severe drought culminating in 1913 that resulted in water shortages in a large part of the State Haworth (1913, pp. 40-43) prepared a special report on well waters in Kansas in which he discussed the availability of ground water in the Republican River Valley. A report by Wing (1930) on the geology of Cloud and Republic Counties was the first detailed report on the area. Wing's report included a very brief discussion of the availability of ground water. The Dakota formation in adjacent areas was described by Tester in 1931. In 1940, Moore and others prepared a generalized report on the ground-water resources of Kansas. A very detailed study of the outcrop area of the Dakota formation was made by Plummer and Romary (1942). An investigation was made by Cady (In press) of the ground-water resources of the Republican River Valley in Nebraska adjacent to Republic County.

Methods of Investigation.—Three months were spent in Republic and northern Cloud Counties during the summer of 1942, of which about two months were spent in the Republican River Valley obtaining data for this report. S. W. Lohman spent a few days in the field during the summer of 1942 and in the summer of 1944 I was accompanied in the field for three days by Mr. Lohman and C. C. Williams of the Federal Geological Survey and C. W. Hibbard, vertebrate paleontologist of Dyche Museum of Natural History, University of Kansas. Approximately 275 wells were visited and the total depth of the well and depth to water level below land surface were measured using a steel tape. Well owners and drillers were interviewed regarding the nature and thickness of the water-bearing formations penetrated by the wells, and all available logs were collected. Records of wells that furnish public, domestic, and irrigation supplies were collected. Information regarding the yield and drawdown of wells, and the temperature, chemical character, and use of ground water was obtained.

Samples of water from 51 wells were collected; they were analyzed by H. A. Stoltenberg, Chemist, in the Water and Sewage Laboratory of the Kansas State Board of Health at Lawrence. In addition anal-

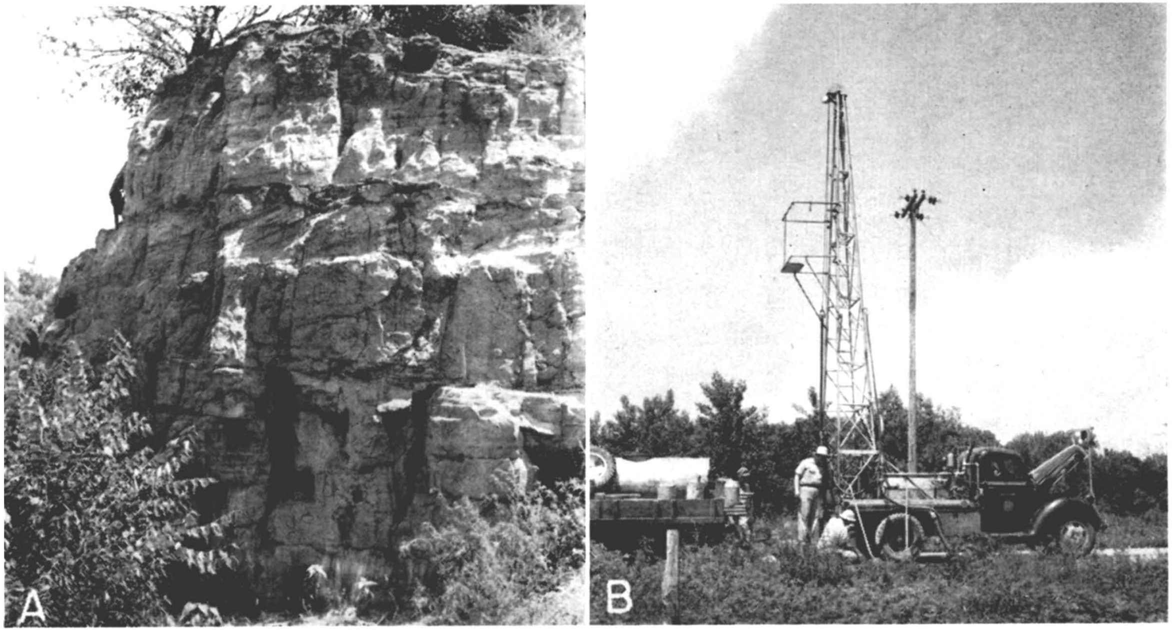


PLATE 3. *A,* Sandstone of the Dakota formation in Concordia on east side of U. S. Highway 81. *B,* Portable drilling machine owned by the State Geological Survey, used in drilling test holes in Cloud and Republic Counties.

yses of water from 6 public supplies in Republic County were furnished by the Kansas State Board of Health.

During the investigation 113 test holes (Pl. 2) were put down in the area by Ellis D. Gordon, James B. Cooper, Oscar S. Fent, Milford Klingaman, and John J. Conard using a portable hydraulic-rotary drilling rig owned by the State Geological Survey (Pl. 3B). Samples from the test holes were collected and studied in the field by Cooper or Fent and were again studied in the office by me. Logs of 4 test holes in the Republican River Valley were furnished by the Bureau of Reclamation. Logs of 22 test holes near Scandia, 7 test holes near Concordia, and 13 test holes north of Belleville were kindly supplied by the Layne-Western Company, Kansas City, Missouri. Logs of 7 test holes near Concordia were furnished by the Air-Made Well Company.

The altitudes of the measuring points of the wells and the test holes in the Republican River Valley were determined by Fred A. Maynard, engineer of the Bureau of Reclamation, using a spirit level. Mr. Maynard also assisted me in an inventory of the wells in the Republican River Valley. The altitudes of the measuring points of the wells and test holes in northern Republic County were determined by C. K. Bayne, S. C. Brown, and R. N. Tripp of the State Geological Survey, using a spirit level.

Pumping tests on two irrigation wells (245 and 254) were made by Kenneth D. McCall, engineer of the State Division of Water Resources, and Woodrow W. Wilson, engineer of the Federal Geological Survey. These tests were made to determine the yield of the wells and the permeability of the water-bearing materials.

The base map for Plates 1 and 2 was prepared from county maps compiled by the State Highway Department. The locations of the roads were corrected from observations in the field and the drainage pattern was corrected from observations in the field and from aerial photographs obtained from the United States Department of Agriculture, Agricultural Adjustment Administration. Plate 1 shows the locations of all the wells visited during the course of the investigation. The wells are numbered in order by townships from north to south and by ranges from east to west. Within a township they are numbered in the same order as the sections.

Fossil teeth collected from the Pleistocene sand and gravel deposits in northern Republic County were identified by Mr. Hibbard.

Acknowledgments.—I am indebted to the many residents of the area who readily gave permission to measure their wells, and who supplied helpful information regarding them. Much helpful information was supplied by Dr. E. P. Ahrens of Scandia, Kansas, Director, National Reclamation Association; Glenn B. Snapp, President, North Central Kansas Electric Coöperative, Inc., and Benton Bachelor and John Umberger, members of the Water Conservation Committee of the Belleville Chamber of Commerce.

Logs of test holes put down by the Layne-Western Company were kindly furnished by R. O. Joslyn, president of that company.

The manuscript for this report has been critically reviewed by several members of the Federal Geological Survey; R. C. Moore, Director of Research, and John C. Frye, Executive Director, State Geological Survey of Kansas; George S. Knapp, Chief Engineer, Division of Water Resources, Kansas State Board of Agriculture; Paul D. Haney, Director and Chief Engineer, and Ogden S. Jones, Geologist, Division of Sanitation, Kansas State Board of Health. This report has been edited by Betty J. Hagerman of the State Geological Survey and the illustrations were drafted by Robyn Ashby and Robert White of the State Survey.

GEOGRAPHY

Topography and Drainage

Republic County lies in the Pliocene-Cretaceous ground-water province of the Great Plains (Meinzer, 1923, p. 310). It has three types of topography: (1) the loess-covered gently sloping plain in the north-central part of the county; (2) the numerous alluvial valleys; and (3) the deeply dissected uplands which are typical of Cretaceous areas and which cover the eastern, southeastern, and southwestern parts of the county.

The highest part of Republic County is along the Nebraska line and has an altitude of about 1,640 feet. The lowest point in the county has an altitude of about 1,320 feet and is about 2.5 miles west of the southeast corner of the county. The maximum relief, therefore, is about 320 feet.

All but the northeastern corner of Republic County is drained by Republican River and its tributaries. The northeastern corner of the county is at the headwaters of Little Blue River which flows into Big Blue River and is a tributary of Kansas River. Republican River enters the county at the northwest corner and after following a southerly course crosses the southern border of the county about 8 miles from the southwest corner of the county. After entering Cloud County its course is to the southeast as far as Concordia and then follows an easterly direction until it leaves the county.

Salt marshes are found northwest of Jamestown in Salt Marsh Creek and in the valley south of Wayne and Talmo. In these localities the valley is exceptionally wide, the valley flat is marshy, and the water is salty, leaving a white coating on the surface during dry periods. The marsh near Jamestown occurs in the Graneros shale, and the one near Wayne is in the Dakota formation.

The marsh near Wayne and Talmo is known as the Tuthill Marsh and for a time it was one of the principal sources of common salt in Kansas. In fact, the first salt manufactured in Kansas was made from the incrustation and from the brine of this marsh (Darton, 1905, p. 389). That this marsh has changed considerably within the last 80 years is shown by a comparison of its present appearance with published descriptions given in earlier years. Mudge (1864, pp. 33-35) described this marsh as follows:

The valley here is wide, gradually rising to the high prairies, so common in that part of the state. The marsh covers nearly one thousand acres, more or less impregnated with saline matter. About one-third is entirely void of vegetation, which the brine will not allow to grow. It is perfectly level, and at the time of our first visit was as white as a wintry snow-field, with a crust of crystallized salt. The marsh is of recent Alluvial formation, composed of sand and loam, from twenty to thirty feet in thickness, brought down by the wash from the high prairies, which rise gradually from three sides. In this alluvium, at various depths, are found the bones of buffalo, deer and antelope, which have probably made this a resort for salt for long ages past, as they are seen to do at the present time.

The incrustation of salt is frequently three-eighths of an inch in thickness. This is scraped up and used in its natural state for salting cattle, etc.; but for domestic purposes it is melted by being mixed with about twenty gallons of water to a bushel of salt, when the mechanical impurities, sand, etc., readily settle. The salt is then returned to a solid state by evaporation. The marsh after scraping, produces a second crop of salt, in from five to seven days of dry weather, and after repeated scrapings during the past three years, yields as full a supply as at first. The brine exists in nearly equal quantities and strength in all parts of the marsh, and can be obtained by boring a few feet, or digging pits. No definite salt spring shows itself at the surface, but the supply must come from numerous points below, though coming from one great central reservoir or salt bed.

According to the observations of Mr. J. G. Tuthill, who lives near, and has made borings in over one-hundred different places to a depth of twenty or thirty feet, there is a very uniform supply and strength of brine. The water preserved for analysis was obtained by me by a boring made at random. It was found at four feet from the surface. The density, by the salometer, was 24° (6.6 Baume or specific gravity of 1.0421), with the thermometer at 60.° This should give a bushel of salt for one hundred and thirty gallons of the water (not counting impurities), which is three times the strength of the ocean. It was taken at our second visit, immediately after a heavy rain, which must have diluted the brine.

Hay inspected this marsh about 25 years later and found that it had changed considerably during the intervening period as indicated by the following account (Hay, 1891, pp. 88-89):

There can be no question as to the accuracy of the description given by Mudge, but in important respects it differs from a description that would be made today. When Professor Mudge was there, there were probably not fifty acres of plowed land within miles of the marsh; now there are hundreds of acres on all its borders. The result is that much of what was salt marsh is now covered with recent alluvia from the cultivated slopes, and areas where the incrusting was probably great are now covered with cat-tails and other marsh plants. Still, several hundred acres are yet sufficiently saline as to be without vegetation, but nowhere was the saline efflorescence at the time of our visit (September, 1890), so much as one-eighth of an inch in thickness. We digged six feet to get water, though it should be remarked that this is a dry year, and when found the strength by the salometer was 13° with the thermometer at 70°. This would, when corrected to 60° Fahrenheit, give a somewhat higher strength, but still much below that found by Professor Mudge. In the quarter of a century that has elapsed since our old friend visited this marsh, it is safe to say that as a marsh it has diminished in area and its brine is weaker.

There was a well bored some years ago on a piece of land higher than the common level of the marsh, and though this mound is entirely surrounded by the lower level of the marsh, yet the brine in the well always stands at the top, and sometimes flows over the mound. The strength of this by the salometer was 14° with temperature at 66° Fahrenheit. A spring of water at the old Tuthill or Tuttle farm on the east side of the marsh, rises to the same level as the well on the mound. A well bored on the north side of the marsh some twelve years ago, gave stronger brine at sixty feet, but it is now filled up.

Prior to 1942, the lower part of the marsh had been dammed forming a shallow lake which had been stocked with fish. A sample of water collected along the edge of the lake in 1942 had a chloride content of only 690 parts per million. However, this water was greatly diluted by surface inflow.

Population

According to the census of 1940, Republic County had a population of 13,124 and an average density of population of 18.3 inhabitants to the square mile, as compared with 21.9 for the entire state. The census records show a gradual reduction in the population since 1890 of about 100 persons a year. The population of Republic County in 1890 was 19,002; in 1900, 18,248; 1910, 17,447; 1920, 15,855; and in 1930, 14,745.

The chief cities and their populations, as reported by the census for 1940, are as follows: Belleville, 2,580; Scandia, 614; Courtland, 383; Republic, 376; Munden, 193; Narka, 193; and Agenda, 179.

Transportation

Republic County and northern Cloud County have exceptionally good transportation facilities. One of the main lines of the Chicago, Rock Island and Pacific Railroad passes through Republic County. The Rock Island Railroad passes through Courtland and Scandia and then divides at Belleville, the northern branch going northeast through Munden and Narka and through Omaha to Chicago, and the southern branch going to Kansas City through Cuba and Clyde. The Missouri Pacific Railroad connects this area with St. Joseph and Kansas City. It passes through Clyde and Concordia and branches at Yuma. The northern branch from Yuma passes through Norway, Scandia, Republic, Warwick, and Superior. The Union Pacific Railroad has a spur line extending from Junction City to Concordia. The Atchison, Topeka and Santa Fe Railway from Emporia to Superior passes through Concordia, Kackley, Courtland, and Lovewell. The Burlington Railroad from Denver to Kansas City passes through Superior, Hardy, and Chester which are on the boundary line between Kansas and Nebraska. A spur from this line passes through Cuba, Wayne, and Concordia.

In addition to the railroads, state and national highways cross Republic County and northern Cloud County from north to south and from east to west and offer easy access to the area by automobile from all directions. U. S. Highway 81 through Concordia and Belleville is one of the important north-south routes across the country, connecting Winnipeg, Canada, with Laredo, Texas on the Mexican border. U. S. Highway 36 runs through Belleville, Scandia, and Courtland. State Highways 9 and 28 connect Concordia with Clyde and other cities to the east and with Jamestown, Beloit, and other cities to the west. Many of the county roads are graveled and are kept in good condition throughout the year and most of the township roads have been graded.

Agriculture

Agriculture is the chief occupation in Republic County. Wheat, corn, sorghums, and oats are the principal crops grown. A considerable number of cattle and hogs are raised. In the Republican Valley the principal crops are corn, alfalfa, and sorghums. Some irrigation from wells and from the river is practiced in the valley.

Republic County has a total of 460,160 acres. In 1939 the average size of the 2,209 farms in the county was 199.0 acres. The principal crops or usage of farmed land in 1939 in percentage of the total farmed acreage are given in Table 1.

TABLE 1.—*Crops and usage of land in Republic County in 1939, in percentage of total acreage*

USAGE OF LAND	Percentage	Crop	Percentage
Cropland harvested	64	Wheat	27
Cropland failure	3	Corn	19
Cropland idle or fallow	2	Sorghums	4
Plowable pasture	5	Oats	4
Woodland	1	Alfalfa	1
All other land	25	All other crops	9

The soils of Republic County have been described by Throckmorton and others (1937, p. 172) as follows:

The soils of Republic County have been formed from a variety of materials. Most of those in the northern part have been formed from the weathering of wind-deposited materials which formed a mantle or covering over the underlying soils in that part of the county. Those in the extreme southeastern corner have been formed from the weathering of Dakota sandstone, while most of the soils in the remainder of the county have been formed from the weathering of soft limestone and calcareous shales. The soils as a group are dark brown to almost black silt loams to silty clay loams underlain by relatively heavy silty clay loam to clay subsoils and become lighter in color with increase in depth. On the more level areas the upper subsoils are of the consistency of claypan. The soils along the streams vary from sands to clays and from light gray to almost black in color. The soils of Republic County contain sufficient quantities of nutrients to meet the requirements of farm crops.

NATURAL RESOURCES AND INDUSTRIES

The mineral resources of economic importance in Republic County are gravel and sand, building stone, coal, and clay. Sand and gravel deposits are abundant along Republican River, both in the present stream bed and in low terraces near the margin of the present flood plain. These materials are also abundant in the Pleistocene deposits in the north-central part of the county (Pl. 4A). Sand and gravel are excavated extensively by shovels or by centrifugal pumps at many different points.

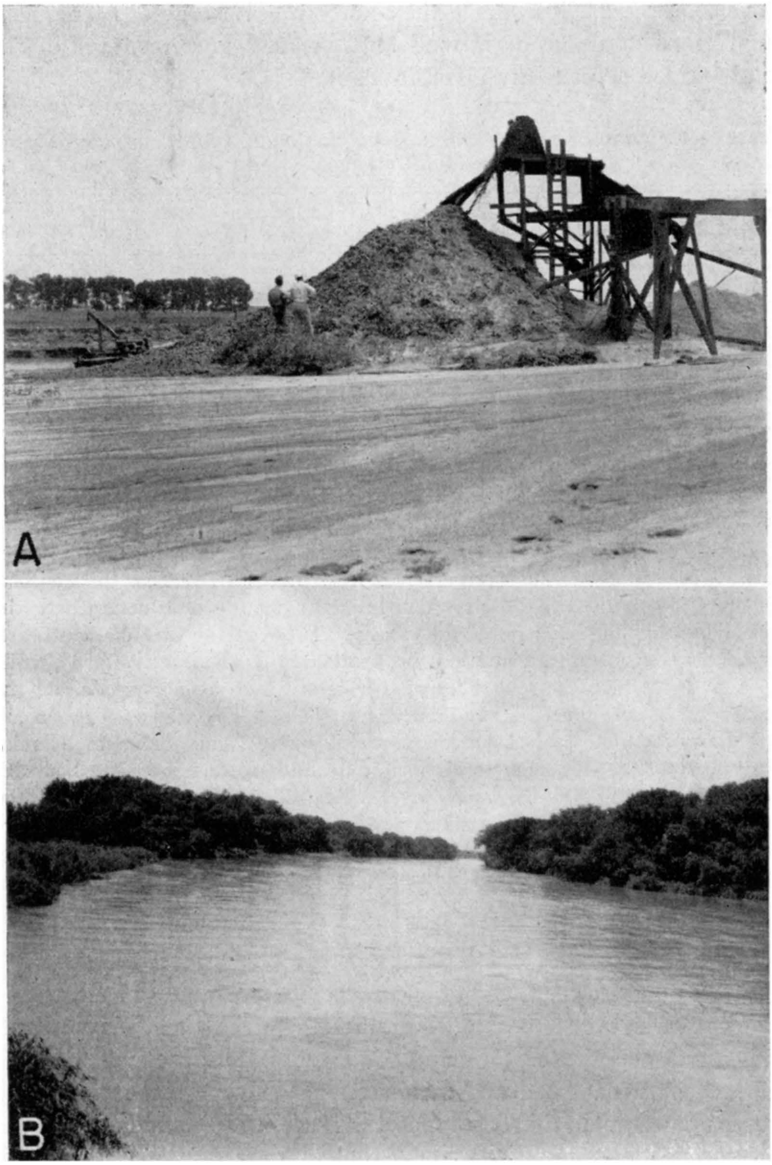


PLATE 4. *A,* Sand and gravel pit in Belleville formation northeast of Republic City in sec. 20, T. 1 S., R. 4 W. *B,* Republican River at relatively high stage on June 14, 1942. View looking north from bridge west of Norway.

The Greenhorn limestone, which crops out extensively in Republic County, is used as building stone. The "Fencepost limestone," which is at the top of the Greenhorn, is quarried at many places in the county. Quarrying is commonly done along the line of outcrop, where the overburden is thin and the rock not badly weathered. The bed ranges in thickness from 6 to 9 inches and is moderately fine and chalky in texture. It is soft enough to permit considerable ease in quarrying, but hardens on exposure. It can always be identified at its outcrop or in a building or fence by its light creamy buff color, which grades into a darker buff band near the center.

Production of coal was begun at Minersville on the border between Republic and Cloud Counties as early as 1855 and was continued until relatively recent times when cheaper transportation brought insurmountable competition from eastern Kansas fields. The peak of production was reached in 1894 and 1895 when at least eight companies were operating in the field. Production for Cloud County reached 5,000 tons in 1895 and 8,242 tons for Republic County in 1894 (Wing, 1930, pp. 43-44).

The mines ranged in depth from 30 to 110 feet. The deeper mines began near the base of the Jetmore chalk member of the Greenhorn limestone and passed through approximately 90 feet of blue shale belonging to the lower part of the Greenhorn and to the Graneros shale. The coal occurs approximately 12 feet below the top of the upper sandstone of the Dakota formation (Wing, 1930, p. 44).

Samples of clays in the Dakota formation in the southeastern part of Republic County were collected in 1939 and 1940 by Plummer and Romary (1942) in connection with an extensive study of the ceramic possibilities of Kansas clays. The ceramic properties of the clay will be given in a subsequent bulletin of the Kansas Geological Survey.

CLIMATE

The U. S. Weather Bureau maintained a precipitation gage at the City of Republic from 1902 to 1934 and has maintained a precipitation gage at Belleville since 1934. The distribution of the normal annual precipitation at Belleville, which is 26.52 inches, by months is given in Table 2.

TABLE 2.—*Average monthly precipitation at Belleville*

MONTH	Precipitation, inches	MONTH	Precipitation, inches
January	0.53	July	3.26
February	0.94	August	3.20
March	1.16	September	2.85
April	2.40	October	1.77
May	4.00	November	1.20
June	4.22	December	0.75
		Annual	26.52

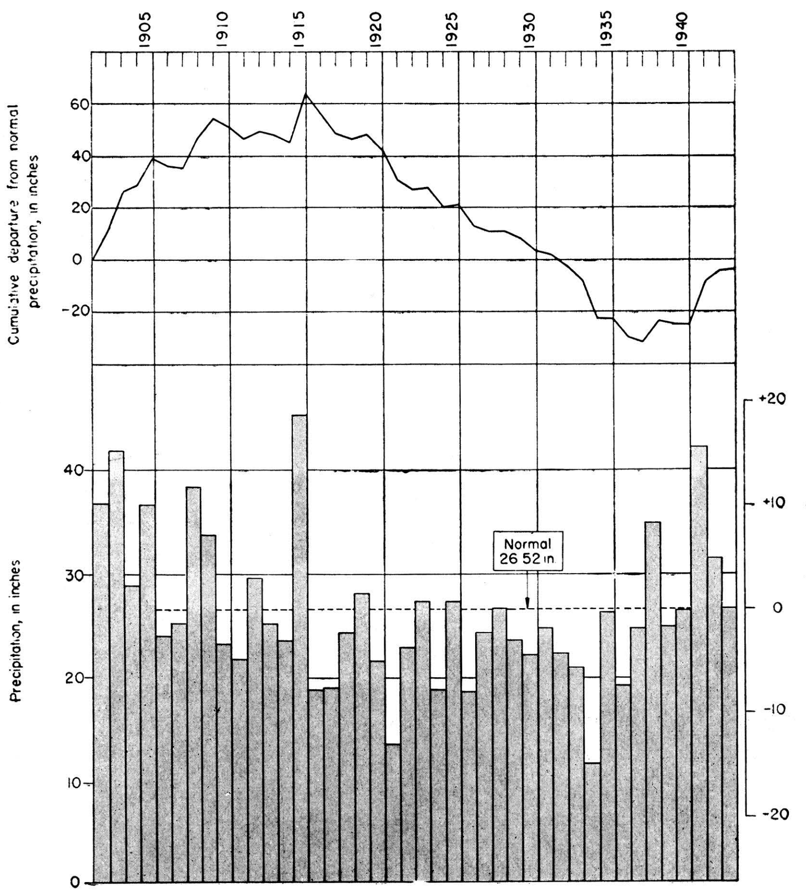


FIG. 2. Annual precipitation and cumulative departure from normal precipitation at Republic and Belleville, Kansas. (Data from U. S. Weather Bureau.)

About 78 percent of the precipitation falls during the six-month period from April 1 through September 30, which is favorable for growing crops. The annual precipitation and the cumulative departure from normal precipitation for the stations at Republic and Belleville for the period of record beginning in 1902 are shown graphically in Figure 2. The precipitation has ranged from 11.79 inches in 1934 to 45.20 inches in 1915.

The U. S. Weather Bureau has maintained a precipitation gage at Concordia since 1885. The normal annual precipitation recorded at Concordia is 25.24 inches. The annual precipitation and the cumulative departure from normal precipitation at Concordia for the period of record beginning in 1885 are shown graphically in Figure 3. The precipitation has ranged from 15.28 inches in 1934

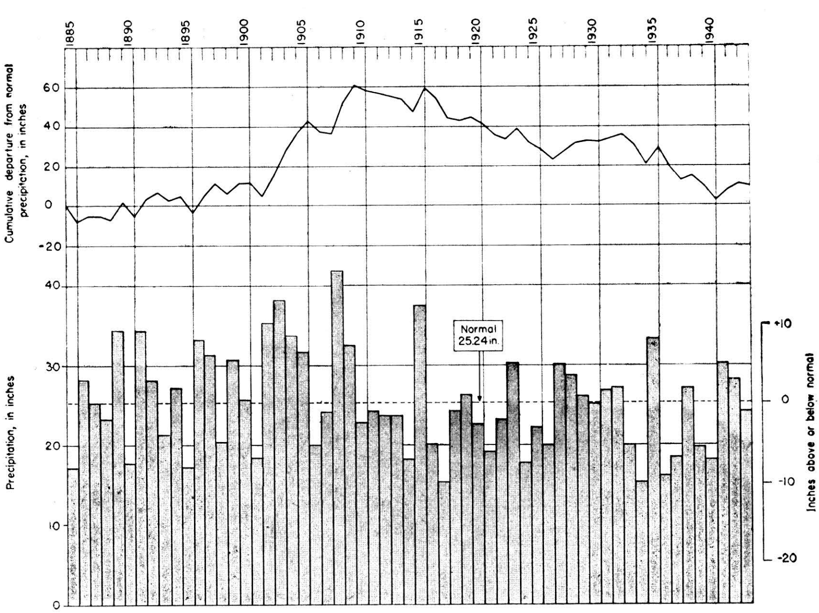


FIG. 3. Annual precipitation and cumulative departure from normal precipitation at Concordia, Kansas. (Data from U. S. Weather Bureau.)

to 41.88 inches in 1908. The average precipitation and average departure from normal precipitation for 10-year periods are given in Table 3.

TABLE 3.—*Average annual precipitation and average annual departure from normal for 10-year periods from 1885 to 1942 at Concordia, Kansas*

PERIOD	Average annual precipitation, inches	Average annual departure from normal, inches
1885–1894	25.73	+ .49
1895–1904	28.40	+3.16
1905–1914	26.30	+1.06
1915–1924	23.65	—1.59
1925–1934	24.16	—1.08
1935–1944	25.51	+ .27

The mean temperatures at Belleville and Concordia are 53.1° and 53.8° F., respectively. The growing season in Republic County has ranged from 128 to 197 days and averages 163 days. The latest date of a killing frost in the spring is May 24 while the earliest date of a killing frost in the fall is September 20.

GEOLOGY

SUMMARY OF STRATIGRAPHY

The rocks exposed in Republic County and northern Cloud County are of Cretaceous and Quaternary age. The areal distribution of the formations is shown in Plate 1. The oldest formation cropping out in the area is the Dakota formation of Cretaceous age, which is exposed in the southeastern part of Republic County and in northern Cloud County. The overlying Graneros shale and Greenhorn limestone of Cretaceous age are best exposed in the eastern and southern parts of Republic County along the edges of the streams where the overlying Carlile shale, also of Cretaceous age, has been eroded away. The Carlile shale mantles the upland areas in the west-central, central, and eastern parts of Republic County. The Pleistocene deposits, which include the Belleville formation and the loess deposits, comprise the surface materials in a large area in northern Republic County. Loess covers much of the area underlain by the Belleville formation and also mantles the Cretaceous rocks in parts of the area to the south. The soils and alluvium are the most recent deposits in the area.

The character and ground-water supply of the geologic formations in Republic County and northern Cloud County are described briefly in the generalized section (Table 4) and in more detail under "Water-bearing formations."

Pre-Cenozoic Geologic History

Although the oldest rocks exposed at the surface in Republic County and northern Cloud County belong to the Dakota formation, it is known from the records of several deep tests for oil and gas in the area that the exposed rocks are underlain by older sedimentary rocks of Paleozoic age, which in turn rest upon crystalline rocks of pre-Cambrian age. The geologic history during the Paleozoic and Mesozoic eras discussed on the pages that follow is based largely on reports by Wing (1930) and Landes and Ockerman (1930, pp. 39-40).

PALEOZOIC ERA

Just as the Dakota formation underlies the stratigraphically higher and younger formations which occur at the surface toward the west, it in turn is underlain by older formations which crop out successively at the surface to the east. These older formations may be studied by examining records and drill cuttings of deep wells and by examining the outcrops to the east. Many deep wells have been drilled in Republic and Cloud Counties but only the Murdock well (sec. 6, T. 6 S., R. 4 W.) is known to have penetrated rocks older than the Pennsylvanian. Hence, much of the geologic history of this area during the Paleozoic Era is surmised from the logs of deep wells in near-by counties and the outcrops of the rocks to the east. According to Landes and Ockerman (1930, p. 39) the region at the beginning of the Cambrian period probably was a broad undulating plain underlain by granite and other crystalline rocks. Erosion of the pre-Cambrian surface was brought to an end in Late Cambrian or Early Ordovician times by submergence beneath the sea. Deposition of limestone and shale occurred during the Ordovician and Silurian, and continued on into the Devonian period when the land rose above the sea and erosion began. As a result of his study of the log of the Murdock well, Wing (1930, p. 36) believes that rocks of Mississippian age are absent in Republic and Cloud Counties. If ever deposited, these rocks seemingly were all removed by erosion during the emergence of the land at the end of Mississippian time. After Mississippian time the area was again inundated by the Pennsylvanian sea advancing from the southeast.

TABLE 4.—*Generalized section of the geologic formations in Republic and Cloud Counties, Kansas*

System	Series	Subdivision	Thickness (feet)	Physical character	Water supply
Quaternary	Recent and Pleistocene	Alluvium and Terrace deposits	0–125	Sand, gravel, and silt, comprising stream deposits in the Arkansas Valley and in the valleys of many smaller streams. Coarse gravels occur as terrace deposits bordering the present flood plain of Republican River at levels of 10 to 20 feet above the flood plain.	The alluvium yields large supplies of water to wells in the Republican Valley and lesser amounts in the smaller stream valleys; supports some irrigation wells in the Republican Valley. Some waters from the alluvium are very hard, having from 160 to 1,198 parts per million of hardness. Locally in Cloud County the waters contain up to 13,000 parts per million of chloride.
		unconformable on older formations			
	Pleistocene	Loess	0–40	Buff silt at top ("Peorian"), underlain by thin dark soil zone, underlain in turn by reddish-brown silt ("Loveland") containing some fine sand and clay and, locally near the base, some coarse sand and fine gravel.	Does not yield water to wells in Republic and Cloud Counties.
		unconformable on older formations			
		Belleville formation	0–235	Sand, gravel, and silt comprising stream deposits in and near the ancestral Republican River Valley.	Yields abundant supplies of good water to wells. The hardness of the water generally ranges from 250 to 500 parts per million.
		unconformable on older formations			
		Carlile shale: Blue Hill shale member; Fairport chalky shale member	280±	Shale, blue-gray, massive to thin bedded.	Yields little or no water to wells in Republic and Cloud Counties except the weathered zone which yields only meager supplies.

TABLE 4.—*Generalized section of the geologic formations in Republic and Cloud Counties, Kansas—Concluded*

System	Series	Subdivision		Thickness (feet)	Physical character	Water supply
Cretaceous	Gulfians*	Greenhorn limestone	Pfeifer shale member	15–16	Chalky shale with beds of thin chalky limestone, discoided concretions, and thin beds of bentonite. "Fencepost limestone" at top.	Very few wells obtain water supplies from the Greenhorn limestone in Republic and Cloud Counties. Only very limited supplies of comparatively hard water may be expected from wells penetrating this formation.
			Jetmore chalk member	13–14	Alternating beds of chalky shale and chalky limestone, "shell" limestone at top.	
			Hartland shale member	45–53	Chalky shale with a few thin beds of chalky limestone and bentonite.	
			Lincoln limestone member		Yellowish chalky shale with hard, thin-bedded, finely-laminated, crystalline limestone at top and bottom and a few thin beds of chalky limestone.	
		Graneros shale		20–30	Dark bluish-black, fissile, noncalcareous clay shale with numerous thin lenses of sandy shale, sandstone, and interbedded ironstone concretions.	No wells are known to derive water supplies from this formation in Republic and Cloud Counties.
		Dakota formation		300 ±	Fine-grained, gray to white to yellow-brown sandstone, irregularly bedded, and varicolored clay and sandy shale.	Sandstone yields abundant supplies of water having wide range in quality. Generally shallow wells yield water of good quality and deep wells yield water of poor quality.

* This term which is employed by the State Geological Survey of Kansas has not been adopted by the Federal Geological Survey. Cretaceous stratigraphy after Wing (1930).

The Pennsylvanian was predominantly a time of deposition of shale and limestone. The rocks laid down during the Pennsylvanian include in ascending order the Cherokee, Marmaton, Kansas City, Lansing, Douglas, Shawnee, and Wabaunsee groups and comprise about 1,300 feet of alternating beds of limestone and shale. Although no evidence of unconformity at the base of Permian rocks is known from study of wells in the Republic-Cloud-County area, deep channels were eroded in the uppermost Pennsylvanian deposits farther east near Missouri River and these valleys were filled with basal Permian sand. Probably there was a corresponding interruption of sedimentation in the area treated in this report. The first deposits of Permian age in Republic and Cloud Counties were gray shale, anhydrite, gypsum, salt, and a few beds of limestone. Later in the Permian, thick deposits of red beds were laid down under nonmarine conditions.

MESOZOIC ERA

Deposition evidently was terminated by an uplift that brought the region above water at the close of the Paleozoic Era. Probably this condition extended through the latter part, if not all, of Triassic time and through Jurassic time, during which there was no deposition and probably considerable erosion. According to Wing (1930, p. 12) rocks representing the Triassic and Jurassic are not known to occur in Republic and Cloud Counties. Also the Early Cretaceous deposits are absent in this area. In Late Cretaceous time the deposits of the Dakota formation were laid down in fresh water on beaches and near the shore during an uplift in which the sea retreated far to the south. Further submergence permitted the marine water to cover the land again and the Graneros shale and the limestones and limy shale of the Greenhorn limestone were deposited. There followed a time when the sea received large amounts of clay and silt from the streams emptying into it, and the Carlile shale was deposited. Still younger Cretaceous rocks crop out just to the west of these counties and probably also covered these counties but were later removed by erosion, as described below. At the close of the Cretaceous Period movements of the earth crust produced the Rocky Mountains and affected at least in part the rocks in north-central Kansas. During this time the Cretaceous and older rocks in the area probably were tilted to produce their present regional dip to the northwest (Wing, 1930, Pl. 16).

Cenozoic Geologic History

By S. W. Lohman

TERTIARY PERIOD

After the tilting of Cretaceous and older rocks at the close of the Mesozoic Era, there was a long period of erosion that persisted throughout most, if not all, of the Tertiary Period, truncating the Cretaceous sediments. Toward the close of Tertiary time, during the Pliocene Epoch, aggrading and laterally shifting streams deposited the silts, sands, and gravels comprising the Ogallala formation over large areas in western Kansas. No deposits of Tertiary age are now found in Cloud and Republic Counties, and if any such materials were deposited they were removed by post-Pliocene erosion.

QUATERNARY PERIOD

Pleistocene Epoch

The major events of the Pleistocene Epoch in this area are downcutting and aggradation of the major streams, important drainage changes, and deposition of loess.

During early Pleistocene time or possibly late Pliocene time the ancestral Republican River channel was cut, not where the present stream flows, but along the east-trending buried channel in northwestern Republic County revealed by test drilling (Pls. 2 and 5). Upstream from this area in Nebraska, where the channel has been traced also by test drilling (Cady, in press), the old channel trends generally west-east parallel to the present channel in a course mainly north of it. Turning southeast the old channel meets the modern stream near Bostwick, Nebraska. Cady concluded that the ancient channel entered Kansas where the modern channel enters, but evidence (Pl. 2) has been obtained to show that it crossed the state line somewhat west of this point and passing through northeastern Jewell County, Kansas, entered Republic County at a point 5 miles south of the Nebraska line; it crossed the present channel near the City of Republic and again entered Nebraska near Chester. Its course northeastward into Nebraska has been traced by subsequent test drilling by the Nebraska and Federal Geological Surveys, the results of which are to be published later.

The approximate shape and gradient of the ancient channel in Republic County and suggestions of several tributary channels are shown on Plate 2. The cutting of this channel may have begun before the close of Tertiary time or may have followed a pre-existing

Tertiary drainageway, but probably it took place early in the Pleistocene—possibly in early Nebraskan time, as held by Cady (In press).

It is believed that Marsh Creek, which now heads just south of a "wind gap" at the NW cor. sec. 27, T. 2 S., R. 6 W., in Jewell County, just 2 miles west of the Republic County line, formerly carried most of the drainage of what is now White Rock Creek, and that the ancestral Marsh Creek was beheaded by a small tributary of the deepening ancestral Republican River, or that possibly this piracy occurred during the cutting of the present channel described below. White Rock Creek now flows about 1.5 miles north of this "wind gap" and less than 20 feet below the highest point in the saddle of the gap, which is between hills capped by the Niobrara formation. Moreover, the gradient of the present White Rock Creek is considerably steeper downstream from the vicinity of the abandoned gap.

That the ancestral Republican River entered Kansas, flowed across part of Republic County, and re-entered Nebraska near Chester is clearly demonstrated by the records of test holes as described above (Pls. 2 and 5). The remaining question is what later caused this stream to abandon its former well-established course and turn abruptly south past Scandia to Concordia and thence eastward and southeastward to join Kansas River near Junction City. A review of the available evidence indicates that this major change in drainage and the filling of the old channel may have taken place somewhat as follows.

Filling of the ancestral channel by the coarse sand and gravel forming the lower part of the Belleville formation may have begun during the Nebraskan Stage of glaciation, if Lugn (1935, p. 92) is correct in contending that the equivalent Holdrege formation of Nebraska was formed as an "inwash-outwash fluvio-glacial deposit" in Nebraskan time. According to Cady (in press) valley filling may have ceased temporarily and perhaps some deposited material may have been excavated. According to Lugn (1935, p. 98) the Fullerton formation was deposited in parts of Nebraska during the Aftonian interglacial stage.

Todd (1909, pp. 108-110) presented evidence that as the glacier advanced westward during the Kansan Stage it successively dammed streams draining what is now the Missouri River Basin, forcing the waters from a vast area to find new southward courses along the western border of the glacier. Todd (1919) concluded that during this stage the glacier extended only as far westward as the present Big Blue River in Marshall County, Kansas, and suggested that at the time of maximum ice advance the major drainage was carried by the ancestral Big Blue River to a point in Nebraska where that stream was blocked by the ice, thence across to the ancestral Little Blue River at Fairbury, Nebraska, down that stream into Marshall County, Kansas, where it rejoined the ancestral Big Blue River and was carried to the ancestral Kansas River. Later evidence (Lugn, 1934, fig. 186; Schoewe, 1939), however, indicates that during the Kansan Stage the glacier extended farther west, blocking not only the ancestral Big Blue but also the ancestral Little Blue River, so that still another outlet must be found that might have carried the large volume of water from parts of Montana, Wyoming, Colorado, North Dakota, South Dakota, and Nebraska. The evidence presented below indicates that the outlet for this drainage during the maximum advance of the glacier was by way of the new and present course of Republican River southward through Republic County to Concordia and thence eastward and southeastward to the ancestral Kansas River.

After the ancestral Republican River Valley was cut and partly filled with early Pleistocene sand and gravel, and after the temporary cessation of valley filling as described above, there is evidence (Cady, in press) of a second alluviation in the Republican Valley area during which time the upper part of the Belleville formation was deposited in Republic County. This corresponds to the deposition of Lugn's (1935, pp. 103-104) Grand Island formation in central Nebraska, which he interpreted as Kansan in age. This deposit covered a wide area in central Nebraska (Lugn, 1934, fig. 186), including not only the stream valleys but also large interstream areas, and in Republic County the filling seems to have extended to about the crest of the old divide south of the ancestral Republican River (Pls. 1 and 2). At this time the lowest point along the old divide seemingly lay between Republic and Scandia, and an important tributary of the ancestral Kansas River probably headed just south of this low point and drained southward and eastward past the site of Concordia. At the time of maximum advance of the glacier during the Kansan Stage, the eastward-flowing ancestral Republican River was effectively dammed, forcing the ponded waters to spill over this low divide and be captured permanently by the southward flowing tributary—part of the present Republican River.

Some water may have spilled over at other points along the old divide, but it seems reasonable to assume that the maximum flow took place between Republic City and Scandia, for the new channel was formed there and has remained there. Supporting evidence is afforded by the bedrock-contour map of the present Republican River Valley (Pl. 2) and successive cross sections B-B′, H-H′, J-J′, K-K′, and L-L′, of the valley between Republic City and Concordia (Pl. 5). Thus, the steepest gradient along the base of the bedrock channel occurs at or just north of Scandia between sections H-H′ and J-J′; the narrowest part of the spillway occurs at or north of section J-J′; and, as shown on the topographic map of the Concordia quadrangle, the narrowest and steepest-sided part of the Republican River Valley in the area occurs along this stretch. Also, the bedrock contours and the successively thicker valley fill shown in sections southward from line H-H′ indicate a concave-upward stream profile such as is characteristic of the headwater region of a stream—here the old tributary leading southward, modified only by downcutting of the spillway through the nonresistant Carlile shale. The cutting of the new channel left the ancestral channel and valley filled with sand, gravel, and some clay of the Belleville formation.

After the downcutting of the channel a change in conditions caused the Republican River to fill the channel with alluvium, as shown in the cross sections. The alluvium differs in composition from the Belleville formation (p. 91) and hence probably came in part from different sources. As stated by Cady (in press):

> It [the alluvium] is gray, coarse, well sorted sand, composed partly of crystalline rock particles from the mountains to the west, and partly of local rock particles. Of the latter material the glistening green "quartzite" from the Ogallala formation in the (western) Republican Valley area is most conspicuous. There is also gravel in the alluvium. Part of the pebbles are crystalline, derived no doubt from earlier deposits in the valley, but ultimately derived from regions far to the west. Local rocks, particularly the Niobrara formation, are represented in the gravel, especially in the lower zones.

After deposition of the Belleville formation and before the overlying "loess" was laid down some of the sand and gravel was reworked by rain and small streams into thin deposits of stratified sand and pebbles that generally are not crossbedded as are those of the Belleville formation. Then followed the widespread deposition of a reddish-brown silt and clay, containing some grains of sand and some organic material, which is about 100 feet thick over the filled channel of the ancestral Republican River. This material is widespread in Nebraska where it has been called the Loveland formation or Loveland loess by Lugn (1935, p. 128) who correlated it with similar material in Iowa described earlier by Shimek (1909). Kay (1928) established the age of the Loveland in Iowa as probably Sangamon, or post-Illinoian. Lugn (1935, pp. 131-132) regarded the Loveland loess of eolian origin and thought that the color of the Loveland was originally red, concluding that the material making up the deposit was blown in from regions to the southwest where redbeds are exposed. Cady (in press) presents evidence that the loess probably is chiefly of local eolian origin and that the red color is secondary and was derived from the oxidation of an iron-rich deposit whose original color probably was gray or greenish gray. A recent study of loess in Louisiana by Russell (1944) indicates that at least in some places loess may have been formed from streamlaid deposits that have undergone a secondary process described by him as loessification.

After the deposition of the "loess," correlated with the Loveland loess of Nebraska, the material was subjected to erosion and weathering. This old weathered surface is well preserved by a fossil soil zone (Pl. 6B) as much as 2 to 3 feet thick (p. 93). In some places this soil zone and part or all of the underlying "Loveland loess" was eroded away before deposition of the overlying younger loess.

After the formation and erosion of the soil formed on the "Loveland loess," a deposit of light grayish-buff or yellow silt which Lugn (1935, p. 158) called the "Peorian loess" was laid down as a thin blanket on the older materials (Pls. 6B and 7A), and generally overlies the soil zone described above, to which an eolian origin has been ascribed by most geologists. Leighton (1931) states that this material was deposited during the Iowan and early Wisconsin glacial stages and Kay (1939) associates it with the Iowan and Tazewell drifts.

Late Pleistocene and Recent Events

After the alluviation of the present Republican River Valley, subsequent changes caused at least two renewals of downcutting which produced two stream-graded levels. The lower one comprises the present flood plain of the river; the higher is preserved as a terrace at a few places and is shown in sections H-H′ and K-K′ (Pl. 5). The terrace generally is underlain principally by silt resembling somewhat the "loess" described above, but is probably composed of reworked material carried in by streams or by early floods of the main river.

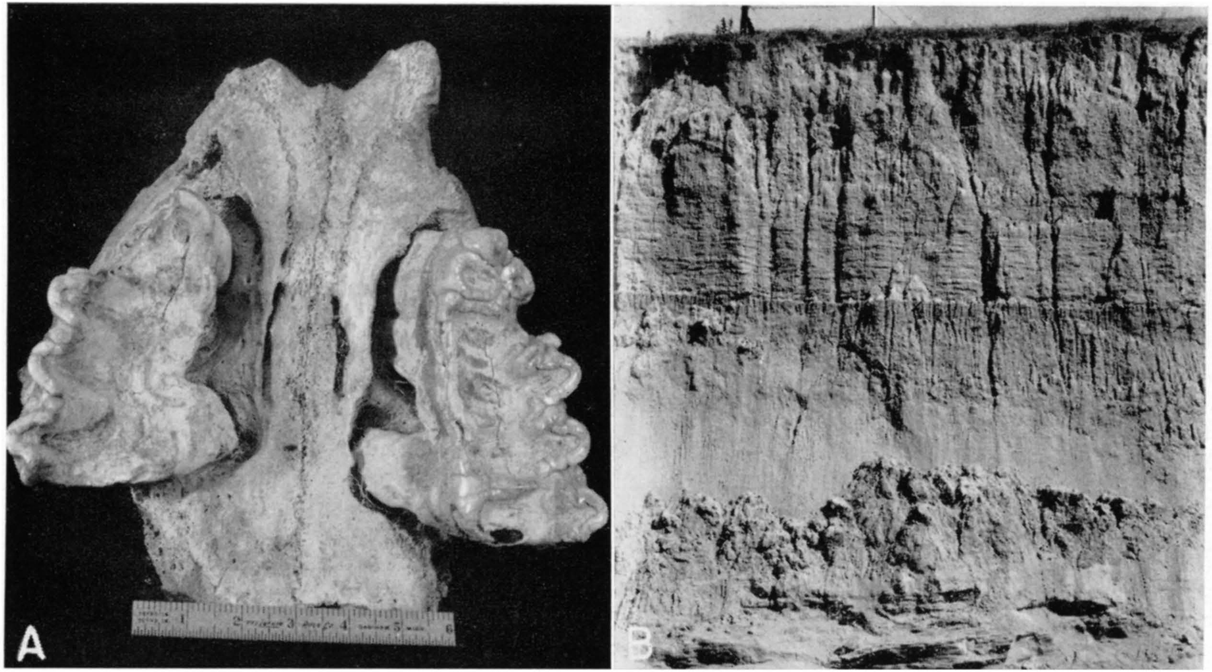


PLATE 6. *A,* Palate of *Stegomastodon,* taken from graval pit shown in plate 7B. *B,* Exposure of loess along small stream in the NE¼ SE¼ NE¼ sec. 13, T. 1 S., R. 5 W. Top to bottom: Recent soil, buff "Peorian loess," dark soil zone (marked by geology pick), reddish-brown "Loveland loess," and at bottom—cross-bedded sand of Belleville formation. (Photograph by S. W. Lohman.)

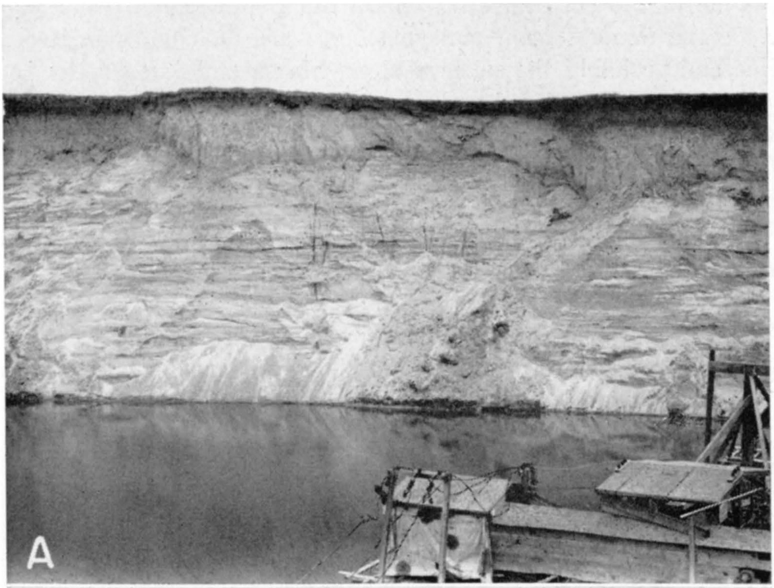


PLATE 7. *A,* Sand and gravel pit just south of Cowles, Webster County, Nebraska, in sec. 9, T. 2 N., R. 10 W. Section at extreme left, top to bottom: Recent soil, brownish Loveland loess, sand and gravel of Grand Island formation, below water line is at least 55 feet of sand and gravel belonging to Grand Island and Holdrege formations. Section at middle and right: Recent soil, Peorian loess resting on uneven erosion surface from which Loveland loess has been removed, rest of section same as at left. (Photograph by S. W. Lohman.) *B,* Gravel pit in sec. 15, T. 2 S., R. 2 W., Republic County, Kansas, in Belleville formation from which the fossil shown in Plate 6A was obtained.

Some of the surficial alluvium in the Republican River Valley and along minor stream valleys (p. 95) was laid down in Recent time and probably the swamps along Marsh and Salt Creeks (pp. 16-17) also were formed rather recently. Post-Pleistocene erosion which has modified the landscape in many parts of the area was accompanied by the formation of sand dunes in the area northeast of the City of Republic.

GROUND WATER

Source

Ground water is the water that supplies springs and wells. In Republic County and northern Cloud County ground water is derived entirely from precipitation (rain or snow). Part of the water that falls as rain or snow is carried away by surface runoff and is lost to streams, part of it may evaporate or be absorbed by vegetation and transpired into the atmosphere. The part that escapes runoff, evaporation, and transpiration percolates slowly downward through the soil and underlying strata until it reaches the water table where it joins the body of ground water in what is known as the zone of saturation.

The ground water percolates slowly through the rocks in directions determined by the topography and geologic structure until it is discharged eventually through springs or wells, through seepage into streams, or by evaporation and transpiration in bottom lands adjacent to the streams. Most of the water obtained from shallow wells and springs in this area is obtained largely from precipitation in the general vicinity.

Occurrence

The rocks and surficial deposits that form the crust of the earth are, in general, not solid throughout, but contain numerous open spaces, called voids or interstices, and it is in these spaces that water is found below the surface of the land and from which it is recovered in part through springs and wells. There are many kinds of rocks and they differ greatly in the number, size, shape, and arrangement of their interstices and hence, in their water-bearing properties. The mode of occurrence of ground water in any region, therefore, is determined by the geology of the region.

The interstices of rocks range in size from minute pores of microscopic dimensions to openings several inches in width and they can be divided into two classes—primary and secondary. The primary or original interstices were formed contemporaneously with the formation of the rock; the secondary interstices were developed by processes that affected the rock after it had been formed. In Republic County the water-bearing rocks are all of sedimentary origin, and the openings that hold the water are (1) the open spaces between the grains of the rocks (primary interstices) and (2) the joints, crevices, and open bedding planes which have resulted from fracturing of the rocks (secondary interstices).

The amount of water that can be stored in any rock depends upon the porosity of the rock. Porosity is expressed quantitatively as the percentage of the total volume of rock that is occupied by interstices. When all its interstices are filled with water, a rock is said to be saturated. The amount of water that a rock will yield when saturated is known as the specific yield. The specific yield of a water-bearing formation is defined by Meinzer (1923a, p. 28) as the ratio of (1) the volume of water which, after being saturated, it will yield by gravity to (2) its own volume. This ratio is generally stated as a percentage.

The amount of water a given rock can hold is determined by its porosity, but the rate at which it will yield water to wells is determined by its permeability. The permeability of a rock is its capacity for transmitting water under a hydraulic gradient and is measured by the rate at which it will transmit water through a given cross section under a given loss of head per unit of distance. Certain beds of dense clay and shale may have higher porosities than beds of coarse sand; but, because of the small size of their interstices, they may transmit no water under ordinary differences of head and may be considered as impervious. Rocks differ greatly in their degree of permeability, according to the number and size of their interstices and the extent to which these interstices open into one another.

Artesian Conditions

Ground water may be said to have normal pressure, subnormal pressure, or artesian pressure. The static level of ground water under normal pressure coincides with the water table or the upper surface of the zone of saturation. Under subnormal pressure the static level is below this surface and under artesian pressure, above it. Artesian water is ordinarily under sufficient pressure to rise appreciably above the point at which it is encountered. A well that flows at the land surface is known as a flowing artesian well.

Artesian or confined conditions are said to exist where a water-bearing bed is overlain by an impermeable or relatively impermeable bed that dips from its outcrop to the discharge area. Water enters the water-bearing bed at the outcrop and percolates slowly downward to be held in the water-bearing bed by the overlying confining bed. Down the dip from the outcrop area the water exerts considerable pressure against the confining bed, so that when a well is drilled through the confining bed into the water-bearing bed the pressure is released and the water rises in the well. If the water is under sufficient pressure, and if the altitude of the land surface at the well is lower than the altitude of the outcrop of the water-bearing bed, the water may rise high enough to flow at the surface. In places where there are lenses or beds of relatively impermeable clay or silt at the level of the water table, the water encountered below such lenses or beds will rise to the level of the surrounding water table, but such water is under normal pressure and is not artesian.

Although there are no known flowing wells in Republic County at the present time, the water in the Dakota formation at many places in the southern and western parts of the county seems to have been under slight artesian head. Logan (1897, p. 213) reported that—

> In some places on account of the local dip of the underlying sandstone, the water is forced through the shales and comes to the surface in the form of salt springs. In one of the Republic County salt marshes an artesian flow was obtained with sufficient pressure to lift the water 12 feet high.

The Water Table and Movement of Ground Water

The permeable rocks that lie below a certain level in Republic County, and elsewhere generally, are saturated with water under hydrostatic pressure. These saturated rocks are said to be in the zone of saturation, the upper surface of which is called the water table. The permeable rocks that lie above the water table may be said to be in the zone of aeration. The water that enters the soil at the surface moves slowly down through the zone of aeration to the zone of saturation, except that which is retained in the zone of aeration by capillary action. In fine-grained material the earth is always moist several feet above the water table due to capillarity, and this moist belt is called the capillary fringe. Water in the capillary fringe or in transit in the zone of aeration is not available to wells, hence wells must reach the water table before water enters them.

SHAPE AND SLOPE

The water table is not a static, level surface, but rather it is generally a sloping surface that shows many irregularities caused by differences in permeability and thickness of the water-bearing material and by unequal additions of water to or removal from the ground-water reservoir at different places.

Irregularities in the water table may be caused in several ways. In places where conditions are exceptionally good for recharge, the water table may be built up to form a mound or low ridge from which the water spreads out, but this spreading takes place very slowly because of the frictional resistance offered by the small interstices through which the water must move. In material of low permeability these mounds or ridges may be very sharp, but in very permeable material, the slopes generally are gentle. Depressions in the water table indicate places where ground water is being discharged and may occur along streams that are below the normal level of the water table or in places where water is withdrawn by wells or plants.

The permeability of the water-bearing material affects the slope of the water table. If the water is moving through fine-grained sediments the frictional resistance to the movement of the water is great, requiring a steeper slope than when the same quantity of water moves through a more permeable material. A steeply sloping water table is observed on the west side of Republican River south of the City of Republic where the alluvium contains almost no permeable gravel and sand.

The shape and slope of the water table in the Republican Valley between the Nebraska state line and Concordia and in part of the Belleville formation in the northern part of Republic County are shown on the map (Pl. 8) by contours drawn on the water table. Each contour line has been drawn through points on the water table having approximately the same altitude. Collectively they show the configuration of the upper surface of the ground-water body in much the same manner as contours on topographic maps show the general shape of the land surface. The altitude of the water surface in each of the wells that were used in compiling the map has been referred to sea-level datum. Ground water moves in the direction of maximum slope, which is at right angles to the contours.

The contour map indicates that the water table slopes toward Republican River from both sides and that ground water is discharging into the river. Near the middle of the valley, the contours trend almost at right angles to the axis of the valley, and the spacing of the contours indicates an average hydraulic gradient or slope of about 5 feet to the mile.

The contour map also indicates that in the ancestral Republican River Valley between the City of Republic and Chester, Nebraska, the water table slopes toward the old channel from both sides. Thus, the water moves toward the old channel from both sides and then moves down the old valley to the northeast, crossing into Nebraska near Chester. The flatness of the water table in the ancestral Republican River Valley is caused by an increase in the permeability and thickness of the water-bearing materials from the edges toward the middle of the valley and from the southwest to the northeast. The thickness of the saturated gravel and sand deposits ranges from less than 5 feet along the edges to about 100 feet in the deeper parts of the channel and from about 40 feet near test hole 36 northeast of the City of Republic to more than 100 feet near Chester.

A ground-water mound or divide occurs about 3 miles northeast of the City of Republic. It is caused by the slope of the bedrock floor formed by the underlying Cretaceous rocks and by the excellent opportunity for ground-water recharge in a large area of sand dunes, there being little or no intervening loess between the capping sand dunes and the underlying Pleistocene gravel and sand.

In the rest of the county the water table in general follows the configuration of the land surface but data are not available in the outcrop area of the Dakota formation on which definite conclusions may be based. However, the water levels in a few scattered wells indicate that in general the ground water in the Dakota formation in Republic County is moving to the southeast toward the outcrop area.

RELATION TO TOPOGRAPHY

Except in the Belleville formation the water table in Republic County follows in a general way the configuration of the surface; it rises under the hills and sinks under the valleys but its slope is nearly everywhere less than that of the land. In the Belleville formation, however, the depth to the water table is largely controlled by the slope of the bedrock floor formed on the underlying Cretaceous rocks and the water table is practically independent of the surface drainage. A 1,600-foot contour on the land surface roughly parallels Republican River about 3 miles northeast of the City of Republic. The depth to the water table at test hole 26 (Pl. 2) which is near the deepest part of the ancestral Republican River Valley is 37.5 feet. Following a circuitous route the 1,600-foot contour crosses U. S. Highway 81 at about the deepest part of the channel which is not far from the Nebraska state line. The water level is 123.6 feet below the land surface in test hole 4 in the NE cor. of sec. 3, T. 1 S., R. 3 W. Between test holes 4 and 26 the land surface rises in places to an altitude of about 1,680 feet. At test hole 22 the water level is 166.7 feet below the land surface.

The relation of the water table to topography is affected and often obscured by variations in the permeability of the underlying rocks. An impervious layer may bring the water table to the surface on a hillside, resulting in a spring. This condition can be observed in places where the Jetmore chalk member of the Greenhorn limestone crops out on a hillside. During periods of heavy precipitation water percolates downward through fractures and other openings until it reaches an impervious layer of limestone or shale. Moving horizontally along the impervious layer, it emerges or seeps out on hillsides and road cuts.

FLUCTUATIONS IN WATER LEVEL

The water table in Republic County is not a stationary surface, but a surface that fluctuates up and down much like the water level in a lake or reservoir. However, over a long period of time a condition of approximate equilibrium exists between the amount of water that is added annually to ground-water storage and the amount that is discharged annually by both artificial and natural means. In general, the water table rises when the amount of recharge exceeds the amount of discharge and declines when the discharge is greater than the recharge. Thus, changes in the water levels in wells indicate to what extent the ground-water reservoir is being depleted or replenished.

The factors controlling the rise of the water table in Republic County are (1) the amount of precipitation within the county that passes through the soil and descends to the water table; (2) the amount of water entering the county beneath the surface from areas farther west; and (3) the amount of influent seepage that reaches the underground reservoir from Republican River and some of the creeks at times when the water level in the river or creeks is higher than the adjoining water table. All these factors depend upon precipitation either in the county or in the Republican River Basin. The relation between the amount of precipitation and the level at which the water stands in wells is complicated by several factors. After a long dry spell the soil moisture becomes depleted through evaporation and transpiration and when a rain does occur the soil moisture must be replenished before any water can descend to the water table. During the winter when the ground is frozen the water falling on the surface is hindered from reaching the water table, and during the hot summer some of the water that falls as rain is lost directly into the air by evaporation. Where the water table stands comparatively far below the surface it fluctuates less in response to precipitation than it does where it is comparatively shallow.

The factors controlling the decline of the water table are (1) the amount of water pumped from wells; (2) the amount of water absorbed directly from the water table by plants; (3) the amount lost from the ground-water reservoir by evaporation; (4) the amount lost through springs; (5) the amount of ground water passing beneath the surface into adjacent areas; (6) and the amount discharged as effluent seepage into the streams.

Fluctuations of ground-water levels in Republic County are related primarily to the amount of recharge received from precipitation and to the amount of discharge of ground water by transpiration and effluent seepage. The fluctuations caused by precipitation are considered under the section on recharge; the fluctuations caused by transpiration and effluent seepage are considered under the section on discharge.

Recharge

The addition of water to the zone of saturation is known as ground-water recharge. Ground-water recharge in Republic County is derived from precipitation within the county, from influent streams, and from subsurface inflow from areas to the north and west of the county.

RECHARGE FROM LOCAL PRECIPITATION

Most of the ground-water recharge in Republic County is derived from precipitation, which averages about 26 inches annually in Republic County. Part of the precipitation runs off through surface channels, part is evaporated, part is transpired by plants, and part seeps downward to the the zone of saturation and recharges the ground-water reservoir. When the amount of water absorbed in the soil zone is greater than can be held up by capillary forces opposing the pull of gravity, the balance will move downward to the zone of saturation. Usually the belt of soil moisture is largely depleted by the end of the growing season, owing to the removal of much of the available water in this belt by evaporation and transpiration. This deficiency must first be satisfied before recharge takes place.

Other things being equal, the fraction of water that is absorbed by the soil and becomes available as recharge depends upon the character of the soil and of the underlying material through which the water must pass enroute to the zone of saturation. Thus, the soils in the loess-covered areas in north-central Republic County, being compact, absorb water very slowly, whereas the sandy soils in the dune-sand area northeast of the City of Republic, being porous, absorb considerable water and transmit it downward to the water table.

In the summer of 1942, nine observation wells (40, 95, 158, 172, 188, 202, 204, 209, and 230) were selected in Republic County, and periodic measurements of water level in them were begun in order to obtain information concerning the fluctuations of storage in the ground-water reservoir. The descriptions of the wells and the water-level measurements for 1942 are given in the annual water-level report of the Federal Geological Survey for that year (Meinzer and Wenzel, 1944, pp. 147-149). Subsequent water-level measurements will be published in ensuing annual water-level reports. The descriptions of the wells are included in Table 22 of this report.

Of the nine wells, two (172 and 230) are in the alluvium in the Republican River Valley, two (202 and 204) are in the Dakota formation, three (40, 95, and 209) are in Pleistocene deposits of sand and gravel, and the other two (158 and 188) are in the soil mantle and weathered zone of the Carlile shale. Measurements were discontinued in well 204 in 1943 and in wells 172 and 95 in 1945. The hydrographs of the water levels in these wells except 204 and the cumulative departure of the precipitation at Belleville from normal are shown in Figure 4.

In Figure 4 correlation between the cumulative departure from normal precipitation and some of the hydrographs is suggested. Others show very little correlation. The correlation depends much on the source of the water. The hydrographs of wells in the alluvium of the Republican River Valley (172 and 188) correlate in a measure with the cumulative departure from normal precipitation, but there is practically no correlation between the cumulative

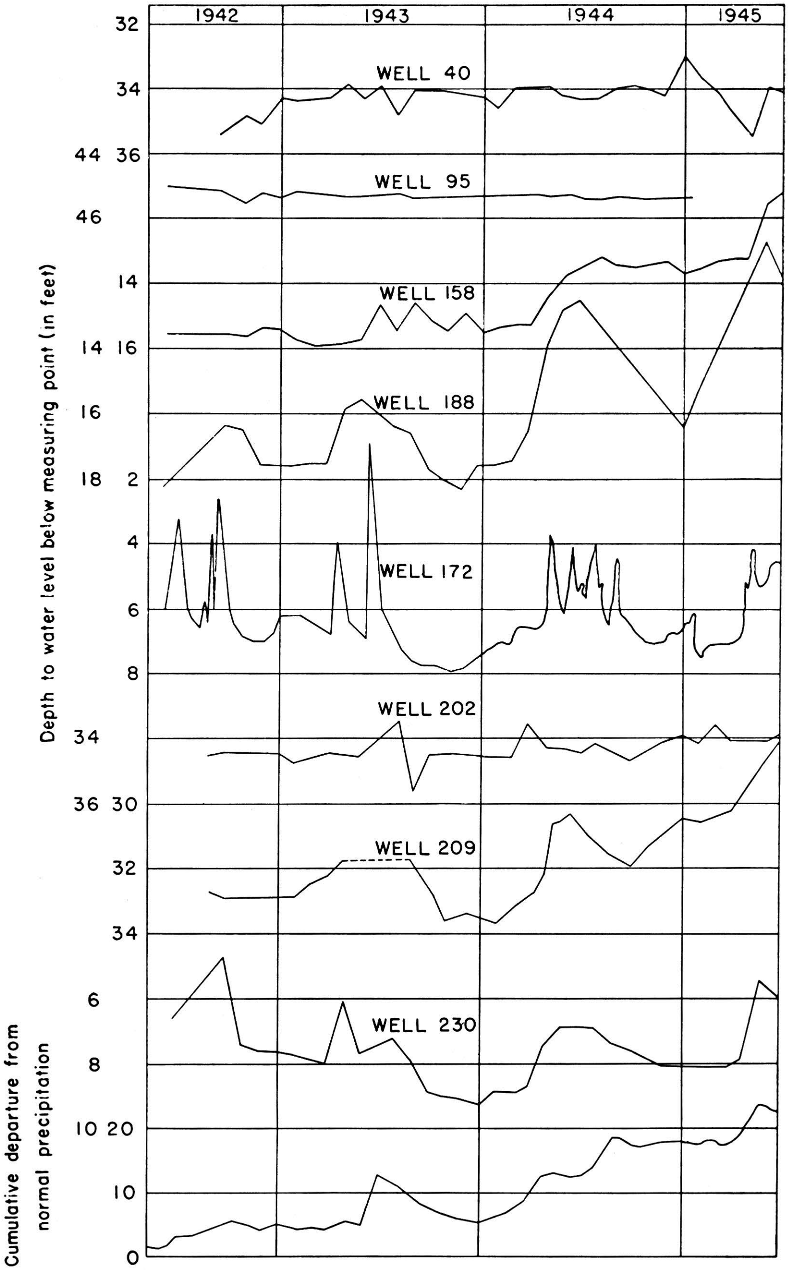


FIG. 4. Hydrographs showing the relation between the monthly fluctuations of the water levels in eight wells in Republic County and the cumulative departure from normal precipitation at Belleville.

departure from normal precipitation and the hydrographs of wells in the Dakota formation (202 and 204) and in the Pleistocene deposits of sand and gravel (40 and 95). The peaks on the hydrograph for well 172 are caused by recharge from the river. If the peaks are eliminated the hydrograph is very similar to the hydrograph for well 230 and in general it follows the seasonal cumulative departures from normal precipitation.

The logs of test holes in the Republican River Valley and the cross sections in Plate 5 indicate that the material above the water table is not as permeable as that at greater depths. Most of the surficial material is silty or sandy, however, and very little of it is clay. Throughout most of the valley, conditions for recharge from precipitation seem to be good. That recharge to the water table in the alluvium is high is shown by the hydrographs of wells 172 and 230 in Figure 4. The peaks on the hydrograph of well 172 are caused by flood stages of the river as it is located about 100 feet from the river. The water table in the vicinity of well 230 is recharged by local precipitation and it has had an annual fluctuation of more than 2 feet during the period of record.

In an area of several square miles that lies northeast of the City of Republic, the conditions for recharge from precipitation are excellent. Part of the area is underlain by dune sand that has a very high infiltration capacity. From Plate 5 it can be seen that the gravel and sand deposits of the Belleville formation are near the surface in this area. To the northeast the gravel and sand deposits dip below thick deposits of loess. Near the intersection of U. S. Highway 81 with the Nebraska state line the overlying loess deposits have a thickness of about 100 feet. The amount of groundwater recharge through these thick deposits of loess must be very low, as indicated by the hydrographs of wells 40 and 95 (Fig. 4). The ground water supplying the wells in this area is derived from recharge along the south edge of the channel, where the loess is thin or absent, from the recharge area northeast of the City of Republic, as shown on Plate 8, and from the movement of ground water in a southeasterly direction from a recharge area in Nebraska.

Conditions for ground-water recharge in the rest of the county are only fair. The water levels in the surficial deposits overlying the Carlile shale have a wide range in fluctuation but the specific yield of the material is low (see hydrographs of wells 158 and 188 in Fig. 4). The amount of recharge depends on the topography, soil cover, and vegetation. Intensity of ground-water recharge in the southeastern part of the county where the Dakota formation crops out depends on whether the exposed material is sandstone or clay. Clay and shale in the Dakota are nearly impervious and permit practically no ground-water recharge but if the sandstone is exposed at the surface as it is in many places or if it is mantled by a thin permeable layer of soil there will be an appreciable amount of ground-water recharge (see hydrograph of well 202 in Fig. 4).

Conditions are not favorable for ground-water recharge in the outcrop area of the Greenhorn limestone. Some members of the Greenhorn are practically impervious. Moreover, the land surface generally has a steep slope, resulting in high surface runoff. Most of the recharge in the Greenhorn limestone occurs where upturned permeable layers are exposed, permitting ground-water to move down the dip from the exposure.

PERCOLATION FROM OUTSIDE OF AREA

The ground water moves easterly and southeasterly from Jewell County into Republic County and, as shown by the water-table contours on Plate 8, in a southeasterly direction into a part of Republic County from Nebraska. The amount of water moving in from Jewell County is small for the saturated water-bearing material at the county line averages less than 15 feet in thickness and is not very permeable. As indicated by the logs of the test holes near the Nebraska state line (Pl. 5), the saturated gravel and sand deposits there range in thickness from 50 to 100 feet and are very permeable.

Although the Dakota formation is exposed at several places in Republic County, much of the water that it contains undoubtedly enters the formation from outcrop areas outside the county. The regional dip of the Dakota is northwestward and it might at first be assumed that the ground water is percolating down dip to the northwest from the outcrop area in the southeastern part of the county. Limited data based on the water levels in 12 wells (9, 99, 151, 152, 154, 193, 194, 202, 208, 215, 218, and 243) indicate, however, that the ground water in the Dakota formation is moving in a southeasterly direction toward the outcrop area. There are local irregularities in the water table in the Dakota caused by creeks that have cut below the water table. The water levels in some of the wells do not necessarily represent the static water level in the Dakota formation for, unless the ground water in the overlying formations is tightly cased off, the measured water level will be an equilibrium level between the water level in the Dakota formation and water levels in the overlying formations. Also, in many places the static water level varies with the depth of penetration into the Dakota formation.

SEEPAGE FROM STREAMS AND PONDS

Two factors determine whether or not a stream is capable of supplying water to the underground reservoir: (1) the water surface of the stream must be above the water table and (2) the material between the stream channel and the water table must be sufficiently permeable to permit water to percolate downward and outward from the stream. It seems unlikely that much ground-water recharge is derived from the intermittent streams in Republic County. With the exception of Republican River, which carries runoff the year around from other areas upstream, the perennial streams of the area are those toward which ground water is moving and along which it is discharging as effluent seepage. Along the small streams that carry only surface discharge the opportunity for ground-water recharge occurs only for short periods during and following storms that produce surface runoff. However, many small streams and gullies are dammed, forming ponds or surface reservoirs which undoubtedly contribute some ground-water recharge.

The water-table contours in Plate 8 indicate that in the Republican River Valley the water table is higher than the stream surface and hence that the ground water is moving toward the river. Under normal conditions there would be no ground-water recharge from the river. Under conditions of heavy withdrawal of ground water resulting in a lowering of the water table below the stream surface, or during flood stages of the river, however, the direction of movement of the ground water with respect to the river would be reversed and there would then be recharge from the river. An inspection of the cross sections of the valley given in Plate 5 shows that the bed of the river rests in permeable sand and gravel. The bed of the river may be silted over at different times and at different places but at other times and places the bed is composed of sand and gravel. There are many sand bars along the river that can be seen at times of low stage. Conditions seem to be favorable for recharge from the river if the water table declines below the stream surface or below the bed of the river.

The infiltration capacities of 68 soils were determined by Free, Browning, and Musgrave (1940, pp. 12-14). Five of these soils permitted essentially no infiltration; the other 63 soils had infiltration capacities ranging from 0.1 inch to 5 inches an hour. The 68 soils had an average infiltration capacity of 0.88 inch an hour. Babcock and Cushing (1942, p. 54) found that the bed of Queen Creek in Pinal County, Arizona, had an average infiltration capacity of 0.54 inch an hour. At times when the bed of Republican River is stilted over the infiltration capacity probably is low and may be comparable to that of the soils noted above. At other times when the bed of the river is composed of sand and gravel, however, the infiltration capacity is much higher than that of most soils. It seems unlikely that the infiltration capacity of the bed of the river would ever be as low as 0.1 inch an hour, which was the value obtained for tight clay soils. Rough computations indicate that if the bed of Republican River should have an infiltration capacity equal to the bed of Queen Creek in Arizona, or even equal to the minimum of the 63 soils given above (0.1 inch an hour), that the potential amount of influent seepage from Republican River would depend not so much on the infiltration capacity of the bed of the river as on the availability of stream flow. Although the recharge from the river might at times be limited by the amount of available stream flow, past records indicate that the amount of stream flow would be more than adequate to supply the needs of probable near-future ground-water developments in the valley.

The rate of infiltration from the river would be governed somewhat by the temperature of the water. The viscosity of water increases with a decrease in temperature, resulting in a decrease in infiltration. In some areas where a large part of water pumped from wells is derived directly from stream flow, the yields of wells have been observed to decline during the winter when the viscosity of the water becomes appreciably higher (Thompson, 1942, p. 467). The relation between water temperature and rate of seepage from canals has been studied by Stearns, Crandall, and Steward (1938, Fig. 14).

Discharge

Ground water is discharged in Republic County by transpiration and evaporation, seepage into streams, ground-water outflow from the county, and discharge by springs and wells. The rate at which it is discharged by natural processes varies with many factors, but especially with the stage of the water table and with the season of the year. Local differences in conditions cause more ground water to be discharged in some parts of the county than in others. More water is withdrawn from the zone of saturation by transpiration from plants in areas adjacent to Republican River and other perennial streams than in areas where the water table lies at great depth. Natural discharge of ground water also takes place by slow movement of ground water out of the county toward the south and east. The amount of water that moves out of the county is approximately the amount that enters from the west plus additions to or subtractions from the ground-water reservoir within the county.

It is probable that before any water was pumped from wells in Republic County the average annual discharge of ground water by natural processes was approximately equal to the average annual recharge. Artificial discharge by pumping represents an additional amount of water taken from the underground reservoir without any increase in the amount of replenishment. The development of large ground-water resources in the county necessarily will cause some lowering of the water table until the natural discharge by evapotranspiration, by the flow of springs and seeps, or by underground movement of water out of the county is decreased by an amount equal to the withdrawal by pumping.

DISCHARGE BY EVAPORATION AND TRANSPIRATION

The roots of plants may draw water directly from the zone of saturation and discharge the water into the atmosphere by the process of transpiration. The rate at which water is withdrawn from the zone of saturation varies with the type of plant, the depth to the water table, the climate, the season of the year, the character of the soil, and possibly other factors.

The water table fluctuates in response to plant transpiration generally only in areas where the water table is relatively near the land surface. It depends on the type of vegetation and the character of the material in the zone of aeration, however. The roots of some types of vegetation, especially alfalfa and some trees, are known to penetrate to great depths. In Jewell County a well in which the water level was 40 feet below the land surface showed transpiration effects. In Republic County the greatest amount of transpiration takes place in the Republican River Valley where the water table is near the surface and where the soil is fertile and supports a vigorous vegetal growth. In parts of the county, along the margins of valleys and on the uplands, where the water table is considerably below the reach of the roots of most plants, water is withdrawn from the belt of soil moisture and hence the zone of saturation is only indirectly affected.

SEEPAGE INTO STREAMS

A stream that stands lower than the water table receives water from the zone of saturation, but streams that stand above the water table cannot receive water from the zone of saturation. During periods of stream flow, streams of the latter type contribute water to the zone of saturation.

Republican River is a perennial stream. White Rock Creek in Republic County is also a perennial stream except during years of very low precipitation. The other streams in the county are ephemeral. The water-table contours in Plate 2 show that ground water is moving toward the river and in places is discharging as effluent seepage into the river. The measurements on which the contours are based were made during the growing season. Those contours differ from water-table contours for the nongrowing season.

DISCHARGE FROM SPRINGS

In Republic County some water is discharged through springs. Most of the springs observed are in the eastern part of the county where the Greenhorn limestone and the Dakota formation crop out. Numerous seeps from the Greenhorn limestone have been observed after periods of heavy precipitation. Percolating ground water in the Jetmore chalk member of the Greenhorn limestone encounters the less permeable shale in the lower part of the Greenhorn or the Graneros shale and as it cannot continue to move downward, it moves laterally and seeps out on the hillsides. Some creeks in the southeastern part of the county have cut their channels down into the Dakota formation and receive water from numerous springs, some of which are reported to be salty.

The total quantity of water discharged by springs in Republic County is not definitely known, but it is small compared to the discharge by other means.

DISCHARGE FROM WELLS

The above discussion treats of the natural discharge of ground water which seems to account for most of the discharge in the county. The rest of the ground-water discharge within the county is by pumping from wells. The recovery of ground water from wells is discussed below.

Recovery

GENERAL FEATURES

When water is withdrawn from a well there is a difference in head between the water inside the well and the water in the surrounding material at some distance from the well. The water table in the vicinity of a well that is discharging water has a depression crudely resembling in form an inverted cone, the apex of which is at the well. This depression of the water table is known as the cone of influence or cone of depression and the corresponding surface area is known as the area of influence. In any given well the greater the pumping rate the greater will be the drawdown (lowering of the water level, commonly expressed in feet) and the greater will be the diameter of the area of measurable influence.

The capacity of a well is the rate at which it will yield water after the water stored in the well has been removed. The capacity depends upon the quantity of water available, the thickness and permeability of the water-bearing bed, the time elapsed since pumping began, and the construction and condition of the well itself. The capacity of a well is generally expressed in gallons per minute. The known or tested capacity of a strong well is generally less than its total capacity, but some weak wells are pumped at their total capacity.

The specific capacity of a well is its rate of yield per unit of drawdown and is determined by dividing the tested capacity in gallons per minute by the drawdown in feet. Well 245, located east of Concordia, had a yield of 730 gallons per minute with a drawdown of 12.27 feet. The specific capacity of that well, therefore, is 59.6 gallons per minute per foot.

When a well is pumped the water level drops rapidly at first and then more slowly, but it may continue to drop for several hours or days, or even months. In testing the specific capacity of a well, therefore, it is important to continue pumping until the water level remains approximately stationary. When the pump is stopped the water level rises rapidly at first, then more slowly, and may continue to rise long after pumping has ceased.

In Republic County and northern Cloud County ground water is recovered from dug, drilled, driven, and bored wells. The type of well depends to a large extent on the character of the water-bearing materials and on the amount of water required.

WELLS

Dug wells

Dug wells are wells that have been excavated by hand, generally with pick and shovel. They are walled with wood, rock, concrete, brick, or metal. They are generally less than 60 feet in depth and are from about 3 to 18 feet in diameter. As a rule dug wells are more subject to surface contamination than are properly constructed drilled wells but in parts of Republic County dug wells are generally preferable for farm wells. Some of the water-bearing materials have a low permeability and hence the wells have a low specific capacity. For intermittent pumping a large dug well acts as a storage reservoir for collecting water during a nonpumping period and it will then furnish moderate quantities of water for short periods of pumping.

Many of the wells that receive their water from the surficial deposits overlying the Carlile shale are dug wells. The specific capacity of these wells is very low unless the wells penetrate sand and gravel in alluvium of the small valleys or old buried valleys. Shallow dug wells are numerous where the Jetmore chalk member of the Greenhorn limestone crops out along small gullies or valleys and where the alluvium does not furnish an adequate water supply. Dug wells are also found in the outcrop area of the Dakota formation and along the fringe of the Belleville formation where the underlying saturated sand and gravel is very thin. Former municipal wells 169 at Scandia and 187 and 188 at Courtland are dug wells of large diameter.

Bored Wells

Many wells in some of the unconsolidated surficial deposits in Republic County were bored and cased with tile but in general the water-bearing materials in Republic County are not suited for the use of bored wells. The bored wells are made by hand augers, post-hole diggers, or by a horse- or power-driven auger. They range in diameter from about 6 inches to 22 inches but commonly are about 12 inches.

Bored wells are found in areas where the Carlile shale is overlain with semipermeable surficial deposits and along the fringe of the Belleville formation.

Driven Wells

Driven wells can be put down only where the materials are sufficiently permeable and soft enough to permit a pipe being driven and where the depth to water level is within 20 or 25 feet of the surface. Driven wells are used quite extensively for domestic and stock supplies in the alluvium in the Republican River Valley. They range in diameter from 1¼ to 1½ inches and are equipped at the bottom with a screened drivepoint. Some of them are equipped with hand-operated pitcher pumps but most of the stock wells are equipped with windmills. In the wells equipped with windmills the cylinder generally is in a pit about 3 or 4 feet deep.

The driven wells in the Republican River Valley are inexpensive to construct and yield adequate water for stock and domestic use. They require considerable servicing as the screens become clogged easily but it is a comparatively easy job to pull the sand point and either clean the screen or replace it with a new one.

Drilled Wells

Many of the domestic and all of the public supplies in Republic and northern Cloud Counties are obtained from drilled wells. Many of the drilled wells used for domestic and stock purposes on the uplands and some of the municipal wells were drilled by portable cable-tool (or solid-tool) rigs. These wells are cased with galvanized-iron or wrought-iron casing, generally about 6 inches in diameter. The municipal and most of the irrigation wells in the Republican River Valley were drilled by the orange-peel-bucket method and are cased with concrete, bronze, or galvanized-iron casing. Those drilled for municipal use range in diameter from 6 to 18 inches.

Wells in consolidated rocks.—Many wells in Republic and northern Cloud Counties obtain water from the consolidated sedimentary deposits (Dakota and Greenhorn formations) and are cased through the overlying unconsolidated deposits and several feet into the bedrock. In most wells of this type the water enters only at the lower end of the casing, hence they are called open-end wells. In some wells, however, the casing extends to the bottom of the hole and the water enters the well through a section of screen or slotted casing placed opposite the water-bearing material. This type of well generally is cased only a short distance into the rock, the lower part of the hole being left uncased.

Wells in unconsolidated deposits.—Most of the wells in north-central Republic County obtain their water supply from the unconsolidated deposits of the Belleville formation. They are cased to the bottom to prevent caving of the walls. In some wells the casing has been perforated in the lower part; in other wells the casing is open only at the bottom. Perforating the casing greatly increases the area of intake, and thus the specific capacity of the well is increased and the entrance velocity of the water is reduced. Well screens are used in some wells to prevent fine sand from entering the well and to increase the intake area.

The municipal wells at Republic, Scandia, and Concordia, the wells at the Concordia Prisoner of War Camp, and some of the irrigation wells were drilled by the orange-peel-bucket method (Pl. 9B) and are gravel packed. In constructing this type of well, a hole of large diameter (48 to 60 inches) is first excavated using an orange-peel-bucket and is temporarily cased. A well screen or perforated casing of a smaller diameter than the hole (12 to 25 inches) is then lowered into place and centered opposite the water-bearing beds. Blank casing extends from the screen to the surface. The annular space between the inner and outer casings then is filled with carefully sorted gravel—preferably of a grain size just slightly larger than the openings in the screen or perforated casing, and also just slightly larger than that of the water-bearing material. The outer casing is then partly withdrawn in order to uncover the screen and allow the water to flow through the gravel packing from the water-bearing material.

The logs of some of the test holes drilled during the investigation reveal that in some places the water-bearing materials are sufficiently coarse and well sorted that gravel-packed wells are not required in order to obtain large yields. In such places less expensive wells employing well screens or slotted casings, but without gravel packing, may be used satisfactorily. In places where the water-bearing materials are fine-grained, however, the gravel-packed wells have several advantages that offset the greater initial cost. The envelope of selected gravel that surrounds the screen increases considerably the effective diameter of the well and decreases the velocity of the water leaving the formation. This reduction in velocity prevents the movement of fine sand into the well and increases the production of sand-free water. Owing to the increased effective area offered by this type of construction, the entrance friction of the water is reduced and hence the drawdown may be reduced appreciably. As stated above, a reduction in drawdown, at a given yield, increases the specific capacity and reduces the cost of pumping.

Assuming that a well of the best possible construction is employed, then the maximum amount of water that can be withdrawn

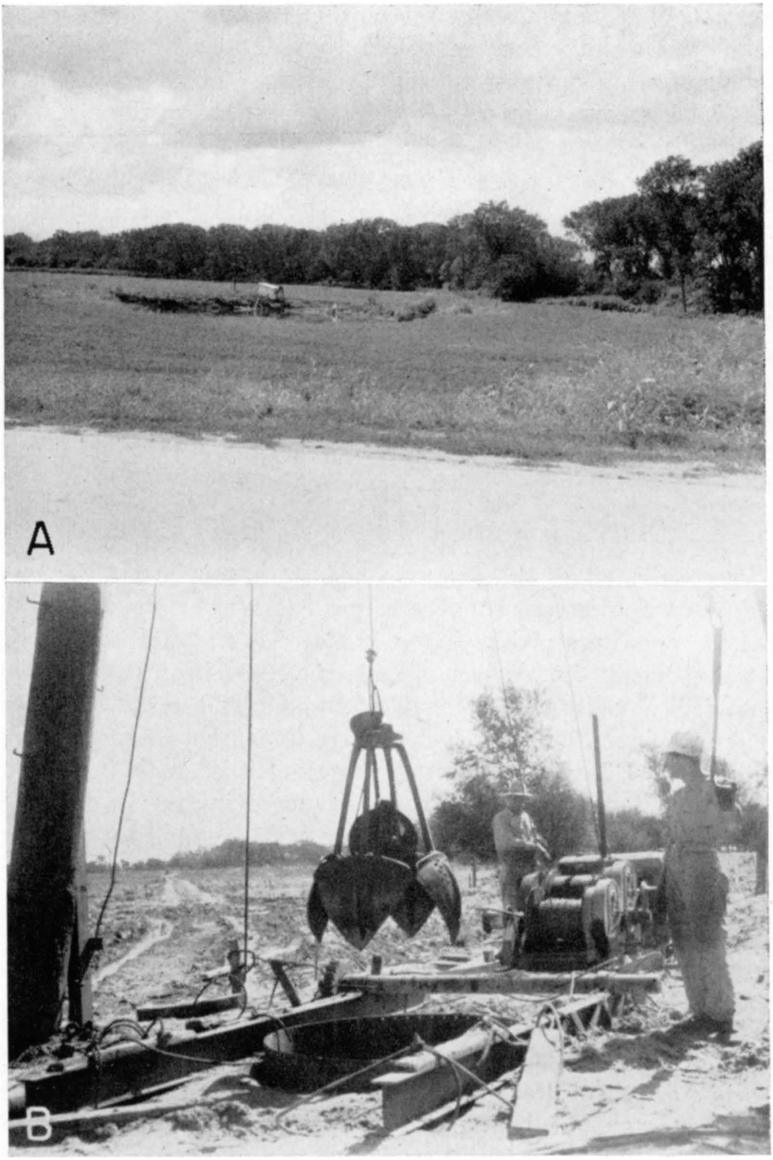


PLATE 9. *A*, Sand pit used as irrigation plant in Republican River Valley, SW¼ sec. 28, T. 5 S., R. 3 W. *B*, Orange-peel bucket used for drilling wells in the Republican River Valley.

from the well is fixed by nature and nothing more can be done to make the well yield more than the water-bearing material will provide. The problem for the driller, then, is to construct each individual well in such a manner as to obtain the greatest yield with the smallest amount of drawdown that is possible under the existing conditions.

Utilization

Ground water in Republic and northern Cloud Counties is used chiefly for domestic and stock purposes and for public supplies. Some ground water is being used in the Republican River Valley for irrigation. Some water is used by the railroads and industrial plants but it is obtained from the public supplies and the amount used is very small. Considerable water was used at the Prisoner of War Camp near Concordia. Records of 291 wells in the area were obtained and are tabulated in Table 15; the principal uses of the water are described below.

DOMESTIC AND STOCK SUPPLIES

Practically all of the domestic and stock supplies in the rural areas and the domestic supplies in small towns that have no public water supplies are obtained from wells. These water supplies are obtained largely from driven wells in the Republican River Valley, from drilled wells in the Belleville formation and in the Greenhorn limestone, from dug and bored wells in the surficial deposits overlying the Carlile shale, and from dug and drilled wells in the Dakota formation. The surficial deposits overlying the Carlile shale have a low permeability and yield only meager quantities of water; hence in areas underlain by these materials dug wells are preferred for supplying stock as they are pumped intermittently and between pumping periods they serve as storage reservoirs.

IRRIGATION SUPPLIES

Interest in irrigation has increased among the farmers in the Republican River Valley during the last several years as a result of nearly a decade of drought. A few attempts have been made to use surface water for irrigating land along the river. Horton Johnson irrigates a part of the SW¼ sec. 31, T. 2 S., R. 4 W. by pumping water from Republican River. The cost of operating this plant is low as the pump is operated with a steam engine using as fuel wood which is obtained by cutting trees along the river. Mr. Johnson reported that the silt in the river water increased the fertility of his land. C. H. Blosser irrigates an alfalfa field in the SW¼ sec. 28, T. 5 S., R. 3 W. by pumping water from an abandoned sand pit that was washed out during the flood in 1935 (Pl. 9A).

The use of ground water for irrigation has barely started. At the present time there are only four active irrigation wells in the Republican River Valley in Cloud and Republic Counties and five other wells that were formerly used for irrigation. The descriptions of these wells are given in the well tables and in more detail in the following paragraphs.

Gillilan well.—The unused irrigation well (50) of Joe Gillilan is about one-half mile southeast of Warwick in the SE¼ NE¼ sec. 5, T. 1 S., R. 5 W. It is 26.3 feet deep and 18 inches in diameter and is cased with galvanized iron. The static water level is about 6.5 feet below the land surface. The well was reported to have a yield of 200 gallons a minute, but was not equipped with a pump at the time of the investigation in 1942.

Bjorling well.—The unused irrigation well (52) of E. W. Bjorling is about one-half mile south of Warwick in the NE¼ NE¼ sec. 6, T. 1 S., R. 5 W. It is 20.8 feet deep, 36 inches in diameter, and is cased with brick. The static water level is about 7.5 feet below the land surface. The well was reported by the owner to have hit gravel at a depth of 18 feet and shale at a depth of 21 feet. The well had a reported yield of 150 gallons a minute. It was equipped with a 2-inch centrifugal pump and when used it was operated by a tractor. This well was not in use in 1942.

Aurnd well.—The irrigation well (64) of Henry Aurnd is about 5 miles northwest of the City of Republic in the SW¼ NW¼ sec. 21, T. 1 S., R. 5 W. It is a dug well, 26 feet deep, 72 inches in diameter, and is cased with concrete tile. It is equipped with a 3-inch centrifugal pump driven by a tractor and was reported to have a yield of about 250 gallons a minute. The well is also equipped with a pump and windmill for stock use. This was the only active irrigation well in Republic County in 1942.

Rickel well.—The former irrigation well (67) of D. A. Rickel is about 2 miles northwest of the City of Republic in the SW¼ SE¼ sec. 23, T. 1 S., R. 5 W. It is a dug well, 16 feet deep, 18 inches in diameter, and is cased with galvanized iron. The water level is about 5 feet below the land surface. The bottom of the well is in shale. When used as an irrigation well it was equipped with a 4-inch centrifugal pump powered by a tractor, and was reported to yield from 100 to 300 gallons a minute. It is now equipped with a cylinder pump and windmill for stock use.

Blosser well.—The inactive irrigation well (230) of Lloyd Blosser is about one-half mile south of Norway in the NE¼ SW¼ sec. 21, T. 4 S., R. 4 W. It is a drilled well, 48 feet deep, 24 inches in diameter, and is cased with galvanized iron. The water level is about 7.0 feet below the land surface. This well was completed in 1931 and was reported to have a yield of 1,200 gallons a minute, which was the largest reported yield of any well in the Republican River Valley in Republic County. It was damaged by the flood in 1935 and has not been used since that time, but it is still equipped with an 8-inch turbine pump and a 25-horsepower diesel engine.

McGreggor well.—The inactive irrigation well (238) of Morris McGreggor is 3 miles south of Norway in the SW¼ SE¼ sec. 33, T. 4 S., R. 4 W. It is a dug well, 19.3 feet deep, 72 inches in diameter, and is cased with rock. The water level is about 11.0 feet below the land surface. The well was abondoned as an irrigation well and was later equipped with a cylinder pump and windmill for stock use. The windmill tower was still standing but the pump had been removed in 1942.

Hannum well.—The irrigation well (276) of Frank J. Hannum is about 3 miles west of Concordia in the SW¼ NE¼ sec. 25, T. 5 S., R. 4 W. It was drilled in 1939. It is 78 feet deep and 4 inches in diameter. The water level is about 7.5 feet below the land surface. The well is reported to have penetrated gravel from 50 to 55 feet and sandstone of the Dakota formation from 55 to 78 feet. It is equipped with a 6-inch centrifugal pump placed in a pit and is operated by a tractor.

Ward well.—The irrigation well (260) of Roy Ward is about 2 miles west of Concordia in the SW¼ NW¼ sec. 31, T. 5 S., R. 3 W. It is a dug and drilled well and is 51 feet deep. The upper 23 feet of the well is 54 inches in diameter and is cased with brick. The lower 28 feet is 8 inches in diameter and is cased with iron pipe, the lower 5 feet of which is perforated. A pumping test made on this well is described on page 105. The well yielded about 50 gallons a minute with a drawdown of 24 feet. It is equipped with a 3-inch centrifugal pump operated by a 4-horsepower gasoline engine.

Wright well.—The irrigation well (245) of W. T. Wright is about 8 miles east of Concordia in the NW¼ SW¼ sec. 25, T. 5 S., R. 2 W. (Pl. 10A). It was drilled in 1942 by Carl Thoman, driller at

Concordia. It is 65.6 feet in depth, 18 inches in diameter, and is cased with galvanized iron. The water level is about 18 feet below the land surface. It is equipped with a turbine pump and operated by a 10-horsepower electric motor. A pumping test made on this well is described on page 104. The well yielded about 730 gallons a minute with a drawdown of about 12 feet.

Public Supplies

Seven cities in Republic County have public water systems—Belleville, Courtland, Cuba, Munden, Narka, Republic, and Scandia, all of which are supplied from wells. Some of the cities have had difficulty in obtaining adequate water supplies but now they all have abundant water. The water supply for Concordia, which is also obtained from wells, is the only public supply in Cloud County that is considered in this report. The water supply for the Prisoner of War Camp located northeast of Concordia in sec. 15, T. 5 S., R. 3 W. is obtained from 2 wells (255 and 256) in the NW¼ sec. 28, T. 5 S., R. 3 W. These wells are about 50 feet deep and 18 inches in diameter. They yield 350 gallons a minute with a drawdown of 2.0 to 2.5 feet.

The water is untreated for municipal use at Belleville, Courtland, Cuba, Munden, Narka, Republic, and Scandia. The City of Concordia chlorinates the water obtained from shallow wells.

Belleville.—Prior to 1927 Belleville obtained its water supply from several municipal wells in the northern part of the city. These wells ranged in depth from 160 to 350 feet and obtained water from the Dakota formation. The water had an objectionable salty taste, especially to visitors. The quality of this water threatened the success of the North-Central Kansas Fair, which is held annually at Belleville. A search for a better water supply resulted in the drilling of two wells (21 and 22) about 10 miles north of the city in the SW¼ sec. 2, T. 1 S., R. 3 W. These wells receive their water supply from gravel and sand of the Belleville formation in the ancestral Republican River Valley (Pl. 5, section G-G′). They are 215 feet deep and 18 inches in diameter. They were drilled by the Layne-Western Company and were gravel packed according to standard procedure. They are equipped with turbine pumps driven by 30-horsepower electric motors. According to Charles J. Klaumann, water superintendent, each well yields 425 gallons a minute with a drawdown of 4.5 feet.

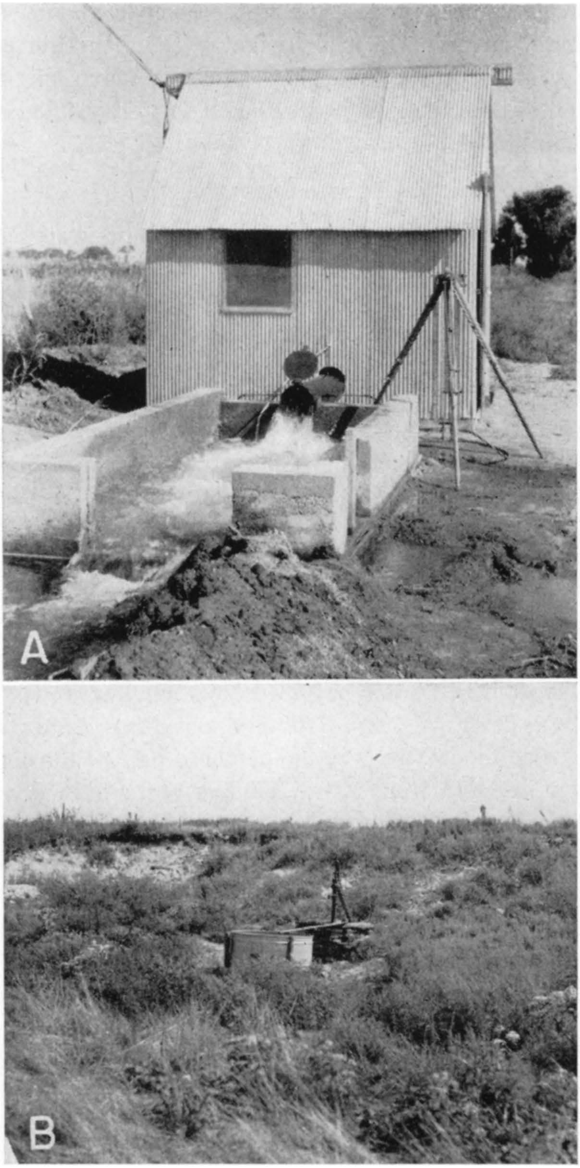


PLATE 10. *A,* Pumping test on irrigation well 245 in the Republican River Valley east of Concordia in sec. 25, T. 5 S., R. 2 W. *B,* A typical stock well (82) in the Greenhorn limestone south of Narka.

The water is pumped by a booster pump to Belleville through a 10-inch cast-iron pipe. The city has a stand pipe and a concrete reservoir having a total capacity of 500,000 gallons. The average daily consumption is about 300,000 gallons.

An analysis of the water (Table 6) indicates a total hardness of 244 parts per million and a fluoride content of only 0.1 part per million.

Courtland.—Prior to 1937 Courtland obtained its water supply from two dug wells (187 and 188) in the northeastern part of the city in the SW cor. sec. 16. These wells are about 50 feet deep and penetrate thin alluvium in a small draw and the soil mantle overlying the Carlile shale. The amount of water yielded by these wells was inadequate for the water requirements of the city especially during the dry years. In 1937 a well was drilled about one-half mile east of town in the SW cor. SE¼ SE¼ sec. 16 (well 189). This well had a reported depth of 67 feet and a diameter of 16 inches. It penetrated several feet of gravel and sand in the alluvium along a branch of Beaver Creek. The well is equipped with a turbine pump having a capacity of about 75 gallons a minute. The pump is driven by a 5-horsepower electric motor.

The water level was reported to be 27 feet below the land surface. Mr. A. E. Haney, water superintendent, reported that after pumping 109 hours at the maximum capacity of the pump the well still had 18 feet of water in it.

The water is pumped to Courtland through a 4-inch pipe. Storage is provided by a standpipe holding 50,000 gallons. The average daily consumption is about 8,000 gallons.

An analysis of the water (Table 6) indicates a total hardness of 720 parts per million and a fluoride content of 0.7 part per million.

Cuba.—The water supply for Cuba is obtained from two wells (141 and 142) drilled into sandstone of the Dakota formation. The wells were reported by Max Nutter, water superintendent, to have a depth of 217 feet and a diameter of 10 inches. The west well (141) was reported to have been drilled in 1925; the east well was drilled prior to 1925.

The wells are equipped with electrically driven cylinder pumps, and each has a reported yield of 30 gallons a minute. The city has two reservoirs—a surface reservoir having a capacity of 25,000 gallons and a standpipe holding 50,000 gallons. The water is pumped from the surface reservoir into the standpipe by a cylinder pump having a capacity of 200 gallons per minute and driven by a 15-

horsepower electric motor. The maximum monthly consumption is about 300,000 gallons. The city has 115 service taps and 18 fire hydrants.

An analysis of the water (Table 6) indicates a total hardness of 158 parts per million and a fluoride content of 0.5 part per million. The water has a bicarbonate content of 427 parts per million.

Munden.—The water supply for Munden is obtained from one dug well (19) in the SW¼ SE¼ sec. 33. The well was reported by C. J. Scala, water superintendent, to have a depth of 62 feet. It is located near the fringe of the Belleville formation and obtains its supply from this formation.

The well is equipped with a turbine pump driven by an electric motor. The pump is operated twice a day for a period of about 2½ hours, and the well is pumped dry at each pumping period. Storage is provided by a standpipe having a capacity of 50,000 gallons. The average daily consumption is about 15,000 gallons. There are 56 service taps and 15 fire hydrants.

An analysis of the water (Table 6) indicates a total hardness of 407 parts per million and a fluoride content of 0.2 part per million.

Narka.—The water supply for Narka is obtained from one drilled well (5) in the northeast part of town in the SW¼ SW¼ sec. 15. The well was drilled by Albert Veach of Mahaska and was reported by Leonard Roubinek, water superintendent, to have a depth of 253 feet and a diameter of 10 inches. The well obtains its water supply from a sandstone in the Dakota formation.

The well is equipped with a turbine pump operated by a 7½-horsepower electric motor. The city has a standpipe having a capacity of 50,000 gallons. The average daily consumption is about 3,000 gallons. The system has 50 service taps and 9 fire hydrants.

An analysis of the water (Table 6) indicates a total hardness of 88 parts per million and a fluoride content of 1.1 parts per million. The fluoride content is on the border line of the safe limit discussed under Quality of Water. The water contains 1,031 parts per million of total dissolved solids including 444 parts per million of bicarbonates.

City of Republic.—The water supply for the City of Republic is obtained from one drilled well (40) located in the eastern part of the city in the SW cor. NW¼ sec. 31. According to Jacob King, water superintendent, the well was drilled in 1923 by the Kelly Well Company and has a depth of 63 feet and a diameter of 18 inches. The well is located near the boundary between the alluvium of the

Republican River Valley and the Belleville formation. The well penetrates 25 feet of silt and clay, 32 feet of fine sand, and 5 feet of gravel.

The well is equipped with a turbine pump having a capacity of 120 gallons per minute and operated by a 7½-horsepower electric motor. The city has a standpipe having a capacity of 50,000 gallons.

An analysis of the water (Table 6) indicates a total hardness of 160 parts per million and a fluoride content of 0.1 part per million.

Scandia.—The water supply for Scandia is obtained from one well (173) located south of the city just north of the Chicago, Rock Island, and Pacific Railroad and between Republican River and the Missouri Pacific Railroad. This well is in the alluvium of the Republican River Valley. It was drilled by the Layne-Western Company in 1932. The well has a depth of 43 feet and a diameter of 18 inches. It is equipped with a turbine pump having a capacity of 140 gallons per minute which is driven by a 10-horsepower electric motor. The city has another well (169) located just south of the pump house that was used for the municipal supply prior to 1932 and which is being maintained as a standby well in case of fire or damage to the other well. This well has a depth of 31.2 feet and a diameter of 20 feet. It is equipped with a turbine pump and may be operated by a 10-horsepower electric motor or by a tractor. The city also has an abandoned well (172) located near the river and southwest of the Missouri Pacific depot.

Storage is provided by a standpipe located on a hill north of the city. The standpipe has a capacity of 86,000 gallons. The estimated average consumption of water is about 50,000 gallons per day.

An analysis of the water (Table 6) indicates a total hardness of 318 parts per million and a fluoride content of 0.5 part per million.

Concordia.—The water supply for Concordia is obtained from 11 wells. Eight wells (258, 259, 261-266) are located north of the city in the alluvium of the Republican River Valley; the other 3 wells (267, 268, and 289) are located within the city limits and obtain their water supply from a sandstone of the Dakota formation. Well 267 is located at the water tower near Sixth Street and Third Avenue; well 268 is located near the intersection of Tenth and Niagra Streets; and well 289 is located near the intersection of Fifteenth and Republican Streets.

The 8 wells in the alluvium north of the city were drilled by the Air-made Well Company in 1925 and 1926. The depth of these wells ranges from about 118 to 123 feet. They penetrate only about 50 to 80 feet of alluvium but they were drilled into the Dakota formation so there would be enough submergence to pump the wells by the air-lift method. The wells are pumped with 2 air pumps located in the pumping station at the west end of Mill Street. Each air pump is driven by a 125-horsepower electric motor. The deep wells in the Dakota formation are equipped with electrically driven turbine pumps.

The city has a surface reservoir at the pumping station that holds 300,000 gallons and an elevated steel tank at Third Avenue and Sixth Streets that holds 300,000 gallons. The city uses an average of about 250,000,000 gallons of water a year. For the 10-year period from 1927 to 1936 the minimum pumpage occurred in 1927 and amounted to 224,980,000 gallons. The maximum annual pumpage for the same period was in 1929 and amounted to 280,630,000 gallons. An analysis of the water (Table 6) indicates a total hardness of 344 parts per million and a fluoride content of 0.5 part per million.

During the summer of 1942 the wells in the alluvium were being pumped at approximately the rates given in Table 5. The deeper wells were being maintained on a standby basis.

TABLE 5.—*Yields of public-supply wells at Concordia, Kansas*

WELL NO.	Rate of pumping, gallons a minute
258 (Concordia well 8)	250
259 (Concordia well 7)	250
261 (Concordia well 4)	250
262 (Concordia well 6)	250
263 (Concordia well 1)	300
264 (Concordia well 3)	75
265 (Concordia well 5)	100
266 (Concordia well 2)	250

AVAILABILITY OF LARGE GROUND-WATER SUPPLIES

In normal years the wells in most of Republic County generally yield adequate water for domestic and stock use although the supplies are very meager on some farms, especially in the surficial deposits overlying the Carlile shale. Other areas of meager or moderate supplies include those underlain by the Greenhorn limestone and the Dakota formation. It is desired to call attention to two formations that will yield a perennial supply that is more than adequate to meet the needs of the domestic and stock wells and in which properly located wells will furnish adequate supplies for industrial, municipal, and irrigation uses. These two formations are the alluvium in most parts of the Republican River Valley in Republic and northern Cloud Counties and the Belleville formation in northern Republic County. The availability and quality of water in these formations are discussed under Water-bearing formations.

Chemical Character of Water

The general chemical character of the ground waters in Republic County and northern Cloud County is indicated by the analyses of water from 58 wells distributed as uniformly as practicable within the area and among the principal water-bearing formations (Table 6). Table 6 includes analyses of water of the 8 public water supplies. The samples of water were analyzed by Howard A. Stoltenberg, Chemist, in the Water and Sewage Laboratory of the Kansas State Board of Health. The constituents given were determined by the methods used by the U. S. Geological Survey.

CHEMICAL CONSTITUENTS IN RELATION TO USE

The following discussion of the chemical constituents of ground water in relation to use has been adapted from publications of the United States Geological Survey.

Dissolved Solids.—When water is evaporated the residue that is left consists mainly of the mineral constituents listed below and generally includes a small quantity of organic material and a little water of crystallization. Waters containing less than 500 parts per million of dissolved solids generally are entirely satisfactory for domestic use, except for difficulties resulting from their hardness or occasional excessive content of iron. Waters containing more than 1,000 parts per million are likely to include enough of certain constituents to produce a noticeable taste or to make the water unsuitable in some other respects.

TABLE 6.—*Analyses of water from wells in Republic County and northern Cloud County, Kansas*

Analyzed by H. A. Stoltenberg. Dissolved constituents given in parts per million[a], and (in italics) in equivalents per million[b]

No. on Plate 1	LOCATION	Depth (feet)	Geologic subdivision	Date of collection, 1942	Temperature (°F)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K) (c)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Total dissolved solids	Hardness (calculated as $CaCO_3$)		
																Total	Carbonate	Non-carbonate
	T. 1 S., R. 1 W.																	
4	NW NE sec. 11	40.5	Carlile	Aug. 20	56	5.2	137 *6.84*	27 *2.22*	39 *1.70*	349 *5.72*	105 *2.18*	70 *1.97*	0.7 *.04*	53 *.85*	612	453	286	167
5	SW SW sec. 15	253.0	Dakota	Feb. 4	......	......	22 *1.10*	8 *.66*	357 *15.52*	444 *7.28*	188 *3.91*	214 *6.03*	1.1 *.06*	0 *0*	1,031	88	88d	0
8	NW NW sec. 27	11.8	Greenhorn	Aug. 20	60	.96	482 *24.05*	48 *3.94*	195 *8.49*	473 *7.76*	1,060 *22.05*	210 *5.92*	.7 *.04*	44 *.71*	2,277	1,400	388	1,012
9	NE NE sec. 28	244.0	Dakota	Aug. 20	......	1.2	34 *1.70*	8.8 *.72*	223 *9.69*	434 *7.12*	169 *3.52*	46 *1.30*	1.1 *.06*	7.1 *.11*	707	121	121e	0
10	SE SW sec. 33	39.1	Greenhorn	Aug. 20	......	.12	110 *5.49*	11 *.90*	50 *2.18*	345 *5.66*	53 *1.10*	47 *1.32*	.3 *.02*	29 *.47*	473	320	283	37
	T. 1 S., R. 2 W.																	
12	SE NE sec. 5	78	Belleville	Aug. 20	57	.28	60 *2.99*	12 *.99*	30 *1.30*	144 *2.36*	16 *.33*	26 *.73*	.2 *.01*	115 *1.85*	332	199	118	81
19	SW SE sec. 33	62	Belleville	May 8	......	......	135 *6.74*	17 *1.40*	48 *2.10*	354 *5.81*	132 *2.75*	44 *1.24*	.2 *.01*	27 *.43*	636	407	290	117
21	NW SW sec. 2	215	Belleville	Feb. 17	......	......	83 *4.14*	9.0 *.74*	17 *.73*	290 *4.76*	13 *.27*	18 *.51*	.1 *.01*	3.8 *.06*	353	244	238	6
	T. 1 S., R. 3 W.																	
	SE SE sec. 4	111.3	Belleville	July 30	57	1.0	94 *4.69*	12 *.99*	12 *.50*	310 *5.08*	12 *.25*	26 *.73*	.1 *.01*	7.1 *.11*	319	284	254	30
26	SE SE sec. 10	80.5	Belleville	July 30	57	12	95 *4.74*	14 *1.15*	7.8 *.34*	324 *5.31*	10 *.21*	18 *.51*	.1 *.01*	12 *.19*	331	294	266	28
27	SW SW sec. 18	171.0	Belleville	July 30	57	14	88 *4.39*	12 *.99*	6.9 *.30*	293 *4.80*	5.3 *.11*	14 *.39*	.2 *.01*	23 *.37*	310	269	240	29

	T. 1 S., R. 4 W.																
30	NE NW sec. 4	160.2	Belleville	July 31	56	1.2	85 *4.24*	13 *1.07*	21 *.91*	268 *4.39*	28 *.58*	34 *.96*	.2 *.01*	18 *.29*	334	266	220	46
33	SW SE sec. 17	54.7	Belleville	July 30	57	8.7	13 *.65*	5.4 *.44*	.69 *.03*	27 *.44*	8.0 *.17*	3 *.08*	.1 *.01*	26 *.42*	92	54	22	32
40	SW NW sec. 31	63	Belleville	Mar. 10	......	17	52 *2.59*	7.6 *.62*	....	165 *2.71*	19 *.40*	24 *.68*	.1 *.01*	8 *.13*	240	160	135	25
45	SE NE sec. 34	115.2	Belleville	July 30	57	40	89 *4.44*	9.8 *.80*	26 *1.13*	307 *5.03*	11 *.23*	23 *.65*	.1 *.01*	28 *.45*	380	262	252	10
	T. 1 S., R. 5 W.																
53	NW NW sec. 6	....	Alluvium	July 30	58	21	78 *3.89*	16 *1.32*	54 *2.36*	346 *5.67*	40 *.83*	18 *.51*	.5 *.03*	33 *.53*	434	260	260f	0
58	SW SE sec. 14	60.7	Alluvium	July 30	56	1.0	49 *2.44*	9.7 *.80*	22 *.96*	157 *2.57*	15 *.31*	20 *.56*	.3 *.02*	19 *.31*	228	162	150	12
63	NW NW sec. 18	74.7	Belleville	July 30	56	6.1	73 *3.64*	12 *.99*	16 *.70*	264 *4.33*	9.7 *.20*	25 *.70*	.2 *.01*	5.8 *.09*	280	232	216	16
	T. 2 S., R. 1 W.																
82	NW NW sec. 10	7.4	Greenhorn	Aug. 20	59	.26	120 *5.99*	12 *.99*	34 *1.47*	359 *5.89*	56 *1.16*	25 *.70*	.4 *.02*	42 *.68*	469	349	294	55
86	SW SW sec. 36	27.9	Alluvium	Aug. 21	55	1.4	162 *8.08*	16 *1.32*	22 *.97*	422 *6.92*	114 *2.37*	9.5 *.27*	.3 *.02*	49 *.79*	585	470	346	124
	T. 2 S., R. 2 W.																
88	NE NW sec. 16	21.6	Belleville	Aug. 21	57	.10	110 *5.49*	15 *1.23*	49 *2.15*	333 *5.46*	41 *.85*	40 *1.13*	.2 *.01*	88 *1.42*	510	336	273	63
90	NE NE sec. 26	28.2	Belleville	Aug. 21	57	.52	115 *5.74*	11 *.90*	51 *2.21*	354 *5.80*	60 *1.25*	53 *1.49*	.3 *.02*	18 *.29*	486	332	290	42
	T. 2 S., R. 3 W.																
96	NW NW sec. 19	33.4	Belleville	July 30	59	12	98 *4.89*	13 *1.07*	49 *2.13*	249 *4.08*	46 *.96*	89 *2.51*	.3 *.02*	32 *.52*	464	298	204	94
97	SW NW sec. 23	22.3	Belleville	July 30	55	1.1	200 *9.98*	27 *2.22*	140 *6.10*	248 *4.07*	173 *3.60*	192 *5.41*	.4 *.02*	323 *5.20*	1,180	610	204	406
99	SW SW sec. 27	157.5	Dakota	July 30	......	3.1	52 *2.59*	47 *3.86*	2,927 *127.34*	527 *8.64*	543 *11.29*	4,020 *113.36*	2.8 *.15*	22 *.35*	7,880	322	322g	0
	T. 2 S., R. 4 W.																
107	SE SE sec. 7	42.2	Alluvium	July 31	57	.34	95 *4.74*	18 *1.48*	25 *1.10*	359 *5.89*	24 *.50*	26 *.73*	.2 *.01*	12 *.19*	380	311	294	17
	T. 2 S., R. 5 W.																
118	SE NW sec. 2	19.3	Alluvium	July 30	56	.16	363 *18.11*	71 *5.84*	66 *2.88*	559 *9.17*	792 *16.47*	39 *1.10*	.6 *.03*	4 *.06*	1,615	1,198	458	740

TABLE 6.—*Analyses of water from wells in Republic County and northern Cloud County, Kansas—Continued*

No. on Plate 1	LOCATION	Depth (feet)	Geologic subdivision	Date of collection, 1942	Temperature (°F)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K) (c)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Total dissolved solids	Hardness (calculated as $CaCO_3$)		
																Total	Carbonate	Non-carbonate
	T. 3 S., R. 1 W.																	
138	SW sec. 8	217	Dakota	May 23	......	......	42 *2.10*	13 *1.07*	176 *7.67*	427 *7.00*	143 *2.97*	26 *.73*	.5 *.03*	7.1 *.11*	642	158	158h	0
	T. 3 S., R. 2 W.																	
143	NW NE sec. 2	37.9	Belleville	Aug. 21	56	6.4	108 *5.39*	11 *.90*	56 *2.45*	351 *5.76*	48 *1.00*	63 *1.78*	.3 *.02*	11 *.18*	479	314	288	26
	T. 3 S., R. 3 W.																	
149	SW SW sec. 7	25.8	Carlile	July 31	......	.14	632 *31.55*	46 *3.78*	50 *2.17*	339 *5.56*	1,186 *24.70*	165 *4.65*	1.0 *.05*	159 *2.56*	2,409	1,766	278	1,488
151	NE NE sec. 13	121.0	Dakota	Aug. 22	56	30	31 *1.55*	13 *1.07*	802 *34.91*	747 *12.25*	229 *4.76*	685 *19.32*	1.4 *.07*	8.0 *.13*	2,203	131	131 i	0
155	NE NE sec. 30	97.2	Dakota	Aug. 24	57	32	116 *5.79*	13 *1.07*	132 *5.76*	411 *6.74*	152 *3.16*	50 *1.41*	.4 *.02*	80 *1.29*	781	343	337	6
157	SE SE sec. 35	23.6	Dakota	Aug. 22	56	5.3	139 *6.94*	11 *.90*	37 *1.62*	382 *6.26*	55 *1.14*	27 *.76*	.2 *.01*	80 *1.29*	546	392	313	79
	T. 3 S., R. 4 W.																	
164	SE SE sec. 9	69.2	Greenhorn	July 31	57	.26	116 *5.79*	15 *1.23*	65 *2.84*	371 *6.08*	99 *2.06*	54 *1.52*	.2 *.01*	12 *.19*	547	351	304	47
173	NW SE sec. 17	43	Alluvium	Apr. 17	......	3.6	106 *5.29*	13 *1.07*	46 *2.01*	299 *4.90*	102 *2.12*	46 *1.30*	.5 *.03*	1.3 *.02*	527	318	245	73
176	NE SE sec. 29	13.5	Alluvium	July 31	......	1.8	108 *5.39*	21 *1.73*	88 *3.85*	390 *6.40*	54 *1.12*	118 *3.33*	.5 *.03*	5.8 *.09*	593	356	320	36
	T. 3 S., R. 5 W.																	
186	SE SE sec. 13	56.2	Greenhorn	July 31	57	.48	130 *6.49*	20 *1.64*	150 *6.52*	368 *6.04*	296 *6.16*	78 *2.20*	.5 *.03*	14 *.22*	873	406	302	104
189	SE SE sec. 16	67	Carlile	Aug. 7, 1944	......	......	236 *11.78*	32 *2.63*	121 *5.24*	300 *4.92*	477 *9.92*	168 *4.74*	.7 *.04*	2.1 *.03*	1,202	720	246	474
191	NW NW sec. 25	64.0	Carlile	July 31	57	7.7	580 *28.94*	54 *4.44*	579 *25.18*	438 *7.18*	1,532 *31.86*	640 *18.05*	.9 *.05*	88 *1.42*	3,700	1,669	359	1,310
194	NW NW sec. 32	116.3	Dakota	July 31	56	32	775 *38.67*	98 *8.06*	532 *23.13*	223 *3.66*	1,029 *21.40*	1,320 *37.22*	.6 *.03*	469 *7.55*	4,367	2,336	183	2,153

	T. 4 S., R. 1 W.																	
197	NW NW sec. 13	38.0	Dakota	Aug. 23	54	2.6	378 *18.86*	31 *2.55*	191 *8.32*	187 *3.07*	615 *12.79*	258 *7.28*	.7 *.04*	407 *6.55*	1,979	1,070	154	916
202	SE NW sec. 36	38.4	Dakota	Aug. 23	56	.50	53 *2.64*	11 *.90*	23 *1.02*	90 *1.48*	68 *1.41*	34 *.96*	.3 *.02*	43 *.69*	278	177	74	103
	T. 4 S., R. 2 W.																	
204	SW SE sec. 9	52.3	Dakota	Aug. 23	56	.40	129 *6.44*	15 *1.23*	167 *7.26*	442 *7.25*	166 *3.45*	119 *3.36*	.4 *.02*	53 *.85*	871	384	362	22
207	NW SW sec. 18	26.8	Alluvium	Aug. 22	55	3.0	114 *5.69*	9.8 *.80*	12 *.54*	368 *6.04*	29 *.60*	9 *.25*	.2 *.01*	8 *.13*	370	324	302	22
208	NW NW sec. 20	70	Dakota	Aug. 22	59	1.6	68 *3.39*	17 *1.40*	47 *2.03*	166 *2.72*	32 *.66*	30 *.85*	.5 *.03*	159 *2.56*	438	240	136	104
	T. 4 S., R. 3 W.																	
209	SE NE sec. 1	42.9	Pleistocene	Aug. 21	56	.54	186 *9.28*	20 *1.64*	94 *4.10*	405 *6.64*	33 *.69*	134 *3.78*	0 *0*	243 *3.91*	913	546	332	214
215	SE SE sec. 14	64.2	Dakota	Aug. 22	57	5.0	129 *6.44*	21 *1.73*	166 *7.21*	249 *4.08*	206 *4.28*	233 *6.57*	.3 *.02*	27 *.43*	912	408	204	204
217	SW NW sec. 15	25.8	Dakota	Aug. 24	55	.09	176 *8.78*	18 *1.48*	69 *3.00*	395 *6.48*	79 *1.64*	53 *1.49*	.1 *.01*	226 *3.64*	819	513	324	189
	T. 4 S., R. 4 W.																	
227	NW NW sec. 14	125.8	Dakota	Aug. 24	58	2.6	39 *1.95*	17 *1.40*	1,184 *51.48*	565 *9.27*	172 *3.58*	1,440 *40.61*	3 *.16*	9.3 *.15*	3,181	168	168j	0
237	SW SW sec. 32	34.7	Alluvium	July 31	56	.46	97 *4.84*	13 *1.07*	35 *1.52*	371 *6.08*	33 *.69*	18 *.51*	.2 *.01*	8.4 *.14*	391	296	296k	0
239	NE SE sec. 36	74.7	Dakota	Aug. 24	58	.73	116 *5.79*	9.8 *.80*	34 *1.47*	404 *6.62*	51 *1.06*	10 *.28*	.4 *.02*	5.3 *.08*	429	330	330 l	0
	T. 4 S., R. 5 W.																	
241	NW SW sec. 7	41.6	Greenhorn	July 31	55	2.0	208 *10.38*	16 *1.32*	79 *3.45*	399 *6.54*	228 *4.74*	96 *2.71*	.4 *.02*	71 *1.14*	900	585	327	258
243	SW NW sec. 23	127.8	Dakota	July 31	58	39	19 *.95*	15 *1.23*	1,526 *66.36*	920 *15.09*	258 *5.37*	1,655 *46.67*	5.5 *.29*	12 *.19*	4,018	109	109m	0
244	NW NW sec. 30	84.0	Dakota	July 31	57	4.0	124 *6.19*	8.8 *.72*	30 *1.29*	296 *4.86*	39 *.81*	65 *1.83*	.3 *.02*	43 *.69*	462	346	242	104
	T. 5 S., R. 3 W.																	
253	SW NW sec. 22	78	Alluvium	Apr. 15, 1943	......	......	107 *5.34*	59 *4.85*	1,646 *67.26*	415 *6.81*	468 *9.73*	2,150 *60.63*	.4 *.02*	16 *.26*	4,590	510	340	170
255	NW NW sec. 28	51	Alluvium	May 25, 1943	......	......	58 *2.89*	13 *1.07*	54 *2.36*	292 *4.79*	40 *.83*	23 *.65*	.5 *.03*	1.3 *.02*	383	198	198n	0
262	NE NE sec. 32	122	Alluvium	Jan. 2, 1945	......	......	110 *5.49*	17 *1.40*	78 *3.40*	381 *6.25*	91 *1.89*	72 *2.03*	.5 *.03*	5.8 *.09*	589	344	312	32

TABLE 6.—*Analyses of water from wells in Republic County and northern Cloud County, Kansas—Concluded*

No. on Plate 1	LOCATION	Depth (feet)	Geologic subdivision	Date of collection, 1942	Temperature (°F)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K) (c)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Total dissolved solids	Hardness (calculated as $CaCO_3$)		
																Total	Carbonate	Non-carbonate
290	*T. 6 S., R. 3 W.* SE SE sec. 6	305	Dakota	Nov. 3	58	5.7	7.8 *.39*	2.8 *.23*	371 *16.12*	677 *11.10*	93 *1.93*	70 *1.97*	9 *.47*	4.1 *.07*	938	31	31o	0
291	*T. 6 S., R. 4 W.* NW SW sec. 36	308	Dakota	Nov. 3	56	7.6	7.6 *.38*	5.0 *.41*	681 *29.63*	733 *12.02*	151 *3.14*	490 *13.82*	5.5 *.29*	5.8 *.09*	1,752	40	40p	0

a. One part per million is equivalent to one pound of substance per million pounds of water or 8.33 pounds per million gallons of water.
b. An equivalent per million is a unit chemical equivalent weight of solute per million unit weights of solution. Concentration in equivalents per million is calculated by dividing concentration in parts per million by the chemical combining weight of the substance or ion.
c. Calculated.
d. Total alkalinity, 370 parts per million; excess alkalinity, 282 parts per million.
e. Total alkalinity, 356 parts per million; excess alkalinity, 235 parts per million.
f. Total alkalinity, 284 parts per million; excess alkalinity, 24 parts per million.
g. Total alkalinity, 432 parts per million; excess alkalinity, 110 parts per million.
h. Total alkalinity, 354 parts per million; excess alkalinity, 200 parts per million.
i. Total alkalinity, 662 parts per million; excess alkalinity, 531 parts per million.
j. Total alkalinity, 516 parts per million; excess alkalinity, 348 parts per million.
k. Total alkalinity, 304 parts per million; excess alkalinity, 8 parts per million.
l. Total alkalinity, 331 parts per million; excess alkalinity, 1 part per million.
m. Total alkalinity, 801 parts per million; excess alkalinity, 692 parts per million.
n. Total alkalinity, 242 parts per million; excess alkalinity, 38 parts per million.
o. Total alkalinity, 613 parts per million; excess alkalinity, 584 parts per million.
p. Total alkalinity, 654 parts per million; excess alkalinity, 614 parts per million.

The amount of dissolved solids in the samples of ground water collected in Republic and Cloud Counties are indicated in Table 7.

TABLE 7.—*Dissolved solids in water samples from wells in Republic County and northern Cloud County*

DISOLVED SOLIDS (parts per million)	Number of samples
Less than 250	3
250–500	21
501–750	12
751–1,000	8
1,001–2,000	5
2,001–3,000	3
3,001–4,000	2
4,001–5,000	2
More than 5,000	1

Hardness.—The hardness of a water is commonly recognized by the increased amount of soap needed to produce a lather, and by the curdy precipitate that forms before a permanent lather is obtained. Calcium and magnesium are the constituents that cause practically all the hardness of ordinary waters and they are also the active agents in the formation of the greater part of all the scale formed in steam boilers and in other vessels in which water is heated or evaporated.

In addition to the total hardness the table of analyses shows the carbonate hardness and the noncarbonate hardness. The carbonate hardness is that caused by calcium and magnesium bicarbonates and can be almost entirely removed by boiling. In some reports this type of hardness is called temporary hardness. The noncarbonate hardness is due to calcium and magnesium sulfates or chlorides. It cannot be removed by boiling and has sometimes been called permanent hardness. With reference to use with soaps, there is no difference between the carbonate and noncarbonate hardness. In general, the noncarbonate hardness forms harder scale in steam boilers.

Water having a hardness of less than 50 parts per million is generally rated as soft, and its treatment for the removal of hardness is rarely justified. Hardness between 50 and 150 parts per million does not seriously interfere with the use of water for most purposes, but it does slightly increase the consumption of soap, and its removal by a softening process is profitable for laundries or other industries that use large quantities of soap. Treatment for the prevention of scale is necessary for the successful operation of steam boilers using water in the upper part of this range of hardness. Hardness of more than 150 parts per million can be noticed by anyone, and where the hardness is 200 or 300 parts per million it is common practice to soften water for household use or to install cisterns to collect soft rain water. Where public supplies are softened, an attempt is generally made to reduce the hardness to 60 or 80 parts per million. The additional improvement from further softening of a whole public supply is not deemed worth the additional cost.

The hardness of the 58 samples of water that were analyzed is indicated in Table 8.

TABLE 8.—*Hardness of water samples from wells in Republic County and northern Cloud County*

HARDNESS (parts per million)	Number of samples
Less than 50	2
50–100	2
101–150	3
151–200	6
201–300	11
301–400	17
401–500	5
501–600	3
601–700	1
701–1,000	0
1,001-2,000	5
More than 2,000	1

There are two processes in general use for softening water, the lime and soda process and the exchange silicate or so-called "zeolite" process. Both of these methods also effectively remove undesirable amounts of iron.

Iron.—Next to hardness, iron is the constituent of natural waters that in general receives the most attention. The quantity of iron in ground waters may differ greatly from place to place, even in waters from the same formation. If a water contains much more than 0.1 part per million of iron the excess may separate out after exposure to the air and settle as a reddish sediment. Iron, which may be present in sufficient quantity to give a disagreeable taste and to stain cooking utensils, may be removed from most waters by simple aeration and filtration, but a few waters require the addition of lime or some other substance.

The iron content of the samples of ground water that were analyzed is indicated in Table 9.

TABLE 9.—*Iron content of water samples from wells in Republic County and northern Cloud County*

IRON (parts per million)	Number of samples
Less than 0.1	1
0.1–0.5	10
0.6–1.0	5
1.1–2.0	9
2.1–5.0	7
5.1–10.0	9
10.1–15.0	4
More than 15.0	7

Fluoride.—Although determinable quantities of fluoride are not so common as fairly large quantities of the other constituents of natural waters, it is desirable to know the amount of fluoride present in waters that are likely to be used by children. Fluoride in water has been shown to be associated with the dental effect known as mottled enamel which may appear on the teeth of children who drink water containing appreciable fluoride during the period of formation of the permanent teeth. It has been stated that waters containing 1 part per million or more of fluoride are likely to produce mottled enamel, although the effect of 1 part per million is not usually very serious (Dean, 1936). If the water contains as much as 4 parts per million of fluoride, 90 percent of the children exposed are likely to have mottled enamel and 35 percent or more of the cases will be classified as moderate or worse. Small quantities of fluoride, not sufficient to cause mottled enamel, are likely to be beneficial by decreasing dental caries (Dean, Arnold and Elvove, 1942).

The fluoride content of the samples of ground water that were analyzed is given in Table 10.

Water for Irrigation.—The suitability of water for use in irrigation is commonly believed to depend mainly on the total quantity of soluble salts and on the ratio of the quantity of sodium to the total quantity of soluble salts and on the ratio of the quantity of sodium to the total quantity of sodium, calcium, and magnesium together. The quantity of chloride may be large enough to affect the use of the

TABLE 10.—*Fluoride content of water samples from wells in Republic County and northern Cloud County*

FLUORIDE (parts per million)	Number of samples
Less than 0.1	1
0.1–0.5	34
0.6–1.0	12
1.1–2.0	4
2.1–3.0	2
3.1–5.0	0
5.1–10.0	3

water and in some areas other constituents, such as boron, may be present in sufficient quantity to cause difficulty. In a discussion of the interpretation of analyses with reference to irrigation in southern California, Scofield (1933) states that if the total concentration of dissolved salts is less than 700 parts per million there is not much probability of harmful effects in irrigation use. If it exceeds 2,100 parts per million there is a strong probability of damage to either the crops or the land or both. Water containing less than 50 percent sodium (the percentage being calculated as 100 times the ratio of the sodium to the total bases, in equivalents) is not likely to be injurious, but if it contains more than 60 percent its use is inadvisable. Similarly, a chloride content of less than 142 parts per million is not objectionable, but more than 355 parts per million is undesirable. It is recognized that the harmfulness of irrigation water is so dependent on the nature of the land, the crops, the manner of use, and the drainage that no hard and fast limits can be adopted.

All but one of the samples of water collected in the Republican River Valley in Republic County are within the limits suggested by Scofield for safe waters for use in irrigation. The sample of water from well 118 contained 1,615 parts per million of total dissolved solids, and this water may not be entirely suitable for irrigation. All the samples of water collected from the Belleville formation are well within the limits suggested by Scofield. Some of the ground water in the Republican River Valley in Cloud County contains sufficient chloride to be unsuitable for irrigation. The salinity of this water is discussed on pages 113-121.

SANITARY CONSIDERATIONS

The analyses of water given in Table 6 show only the amounts of dissolved mineral matter in the water and do not indicate the sanitary quality of the water.

Dug wells and springs are more likely to become contaminated than are properly constructed drilled wells, but great care should be taken to protect from pollution every well and spring used for domestic or public supply. It is important that the top of the casing be sealed in such a manner as to prevent surface water from entering the wells, and, where pump pits are used, the top of the casing should extend above the floor of the pit so that surface water cannot drain into the well. In constructing wells equipped with ordinary lift or force pumps, it is a good plan to allow the casing to extend several inches above the platform so that the pump base will fit down over the top of the casing, thus effecting a tight seal. If the casing is left flush with the top of the platform opportunity is afforded for drainage into the well and for possible contamination. Wells should not be located where there are possible sources of contamination such as drainage from the vicinity of buildings, privies, or cesspools.

QUALITY IN RELATION TO WATER-BEARING FORMATIONS

The Belleville formation, the alluvium in the Republican River Valley and in other smaller valleys, and the Dakota formation are the most important water-bearing formations in this area. Analyses of typical waters from each of these units are shown graphically in Figure 5. The graphic representation of analyses by the block diagram (Fig. 5) has been explained by Collins (1927, p. 256). Since one equivalent of calcium carbonate ($CaCO_3$) is 50, the coördinates for equivalents represent hardness as $CaCO_3$ in units of 50 parts per million. The total hardness is measured on the diagram to the top of the magnesium. The carbonate hardness is measured to the top of the bicarbonate if this is below the top of the magnesium (wells 176, 23, 27, and 202). In such a water the distance from the top of the bicarbonate to the top of the magnesium measures the noncarbonate hardness. If the bicarbonate extends above the magnesium there is no noncarbonate hardness; the water has more alkalinity than hardness and is commonly said to contain sodium bicarbonate or carbonate (wells 53, 290, 99, and 9).

The Dakota formation in this area is characterized by at least 4 types of water as shown by the block diagrams in Figure 5. Samples from wells 202 and 208 are typical waters of the Dakota in the southeastern part of Republic County where the formation crops out. Samples from wells 9 and 141 are typical of the waters in deeper wells that are located a few miles west of the outcrop area.

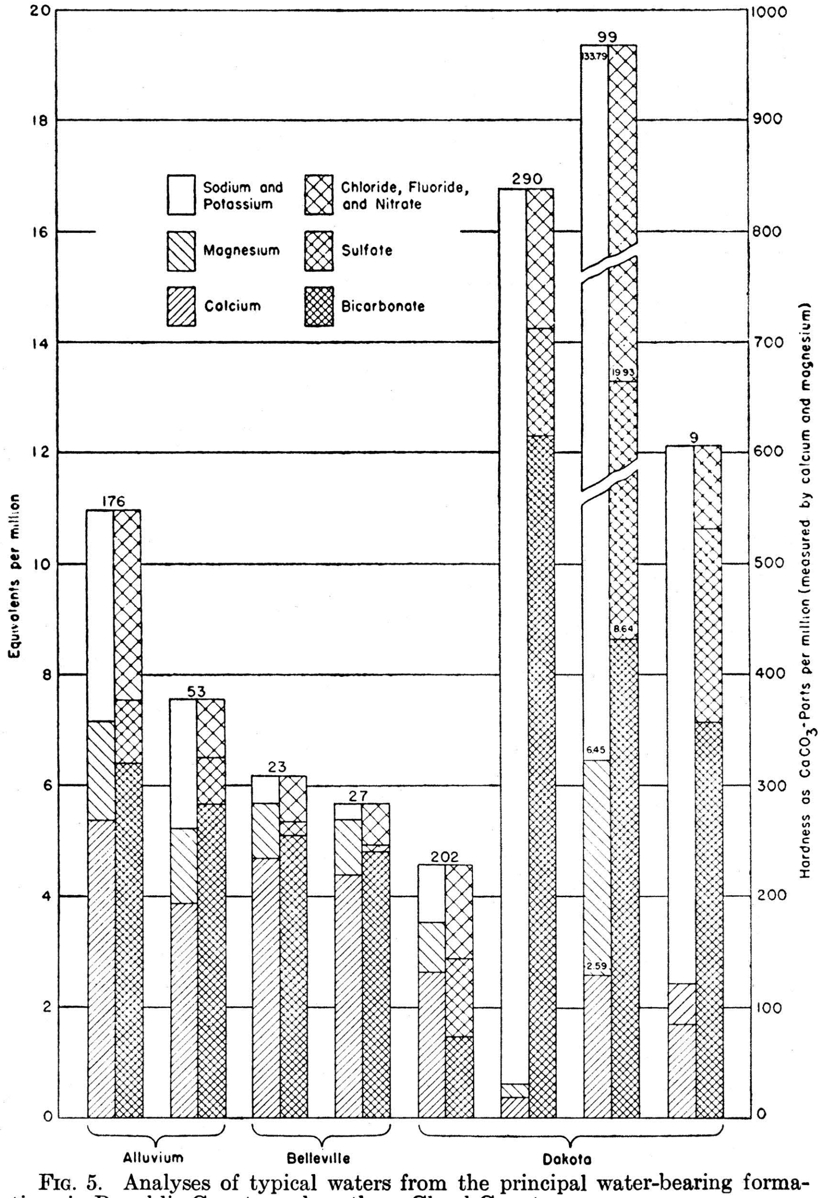


FIG. 5. Analyses of typical waters from the principal water-bearing formations in Republic County and northern Cloud County.

The water from well 9 has a total hardness of 121 parts per million. Samples of water were collected from wells 290 and 291 located southwest of Concordia. These samples had total solids amounting to 938 and 1,752 parts per million and had 31 and 40 parts of total hardness, respectively. They had 677 and 733 parts per million of bicarbonate and 9.0 and 5.5 parts of fluoride. A fourth type of water from the Dakota is represented by the sample from well 99. The City of Belleville originally obtained its water supply from similar wells in the Dakota formation, and most of the wells in the Dakota in the western part of Republic County and in Jewell County yield similar waters. The sample of water from well 99 contained 7,880 parts per million of total solids, 4,020 parts of chloride, 543 parts of sulfate, and 2,927 parts of sodium and potassium.

The chemical character of the samples of water collected in Republic County and northern Cloud County is summarized in Table 11.

GEOLOGIC FORMATIONS AND THEIR WATER-BEARING PROPERTIES

The geologic summary of the Mesozoic water-bearing formations in Republic County and northern Cloud County has been adapted largely from Wing (1930), and the geology of the Quaternary deposits is discussed by S. W. Lohman.

Paleozoic Rocks

Information regarding the Permian and older rocks beneath the surface in Republic and Cloud Counties is based on the records of deep tests for oil and gas and on the exposures of these rocks about 20 miles east of Republic County. The records of a few deep tests for oil and gas indicate that about 900 to 1,300 feet of rocks of Permian age underly the Cretaceous rocks in this area. Permian rocks were penetrated at a depth of about 150 feet in the Danelson well in sec. 1, T. 5 S., R. 1 W. They were reached at a depth of about 300 feet in the Walker well in sec. 23, T. 2 S., R. 1 W. and in the Kouba well in sec. 24, T. 4 S., R. 2 W.

The Permian rocks are underlain by about 900 to 1,400 feet of rocks of Pennsylvanian age. The following groups of the Pennsylvanian rocks were tentatively identified by Wing as being represented in this area—Wabaunsee, Shawnee, Douglas, Kansas City, Lansing, Marmaton, and Cherokee.

TABLE 11.—*Summary of the chemical characteristics of the samples of ground water collected in Republic County and northern Cloud County*

RANGE (parts per million)	Number of samples				
	Allu-vium	Belle-ville forma-tion	Carlile shale	Green-horn lime-stone	Dakota forma-tion
Dissolved solids:					
Less than 250	1	1	0	0	0
250–500	4	10	0	2	4
501–750	1	1	1	1	2
751–1,000	0	0	0	2	5
1,001–2,000	1	1	0	0	2
More than 2,000	0	0	2	1	5
Hardness:					
Less than 100	0	1	0	0	2
100–200	1	1	0	0	5
201–300	2	7	0	0	1
301–400	3	3	0	3	6
401–500	0	0	1	1	1
501–600	0	0	0	1	1
More than 600	1	1	2	1	2
Iron:					
Less than 0.3	1	2	1	3	1
0.3–0.5	2	0	0	1	1
0.6–1.0	0	2	0	1	2
1.1–2.0	2	3	0	0	2
2.1–5.0	1	0	0	1	4
5.1–10.0	0	2	2	0	4
More than 10.0	1	4	0	0	4
Fluoride:					
Less than 0.3	3	9	0	1	2
0.3–0.5	1	4	0	3	6
0.6–1.0	3	0	2	2	3
1.1–2.0	0	0	1	0	2
2.1–5.0	0	0	0	0	2
5.1–10.0	0	0	0	0	3

No wells are known to obtain water supplies from these rocks in Republic and Cloud Counties. It is probable that any water encountered would be salty and highly mineralized.

CRETACEOUS SYSTEM

The Cretaceous rocks that are represented in Republic County and northern Cloud County are the Dakota formation consisting of sandstone and shale, the Graneros shale, the Greenhorn limestone consisting of alternate beds of limestone and shale, and the Carlile shale.

GULFIAN SERIES

Dakota Formation

Character.—The strata of the Dakota formation consist of lenticular beds of quartz sandstone and beds of variegated shale, clay, and siltstone. The beds of sandstone are fine- to medium-grained, range in color through gray, yellow, buff, brown, and reddish brown, and generally are cross-bedded. Because the sandstone beds of the Dakota are exposed prominently in many places, the formation is generally thought to be composed almost entirely of sandstone (Pl. 3A). Wing (1930, pp. 31-33) stated:

> In general three sandstones can be recognized which, with the intervening shales, constitute five divisions in all. The lowest sandstone crops out in the extreme southeastern corner of Cloud County, where its maximum thickness is approximately 100 feet. Its upper few feet may be seen in the creeks near Miltonvale, while almost its entire thickness is exposed in the creek valley three miles south and a mile east. . . .
>
> The next overlying member is composed of mottled clay shale. It is approximately 100 feet thick and is overlaid in turn by the 20-40-foot intermediate sandstone. The latter outcrops at the top of the hills two miles northeast of Miltonvale. . . .
>
> The upper shale member is similar to the lower in texture and color. It ranges in thickness from 80 to 100 feet and is overlaid by the upper sandstone member, which is 40 to 80 feet thick. The latter outcrops on the hills southwest of Glasco, on the higher hills between Glasco and Miltonvale and on the bluff south of the river near Concordia. Other prominent outcrops occur on the higher knolls in the southeastern part of Republic County. . . .

In a recent study of the stratigraphy of the Dakota formation Plummer and Romary (1942, pp. 327-328) found that

> In some places the coarser sandstone has the appearance of being relatively thin and horizontally persistent. This seems particularly true of sandstone that caps a series of hills. Where such occurences have been studied in detail, it was found that the capping sandstone occupies different stratigraphic positions, although the dark, case-hardened sandstone on the hill top has the appearance of being thin, horizontally persistent "sheets."
>
> Despite expressed qualifications and warnings, the geologist is prone to fix his eye on resistant beds in a published columnar section. For this reason no channel sandstone is described in the following generalized section of the Dakota formation. Any one desirous of doing so may insert a lenticular sandstone in any portion of the section and be reasonably assured that such a sandstone occurs at that stratigraphic position somewhere in the area of the outcrop.

Generalized section of the Dakota formation in north-central Kansas
By N. Plummer and J. F. Romary

	Range of thickness in area discussed (feet)
CRETACEOUS—Gulfian	
Graneros shale	
Shale; dark, fissile; contains rusty, yellow to brown partings, selenite crystals, and, locally, channel sandstones; marine fossils present	21.0 to 40.0
Dakota formation	
Janssen clay member	
17. Limonite, siderite, or hematite, concretionary, associated with some silt or fine sand; may be a difficultly discernible bed, or a part of a transitional bed grading from typical Dakota to typical Graneros	01.1 to 5.0
16. Siltstone, gray to light gray, commonly fairly resistant; contains fragments of lignitized wood, some fossil leaves, and small vertical channels, some of which look like worm borings and others like molds of stems or roots. This zone generally contains much limonite or siderite, and, in a few cases, lignitized stems or roots. In some small areas a channel sandstone occupies this horizon	0.5 to 4.0
15. Lignite and black lignitic clay; this bed may be massive or shaly	0.1 to 4.0
14. Clay, silty, gray, plastic, and some silt; typically medium gray in color; contains lignite particles and an abundance of fossil leaves. Locally, this zone is occupied by rather uniform dark to medium gray silty shale. All samples taken from this bed are fire clays	15.0 to 30.0
13. Clay, mottled, gray and light red, lithologically similar to overlying bed except for greater percentage of ferric iron. This bed is missing is many places, or, locally, it is lenticular	0.0 to 10.0
12. Clay, silty to plastic, gray, stained yellow or orange yellow, especially on and adjoining irregular oblique joints. The clay is massive and breaks with a conchoidal fracture. One or two zones of limonite or siderite pellets are commonly found in this clay	15.0 to 30.0
Terra Cotta clay member	
11. Clay or silt containing an abundance of concretionary iron in the form of siderite, limonite or hematite "shot." The iron is sufficiently concentrateed in many places to form a resistant bed	0.1 to 4.0
10. Clay, massive, locally silty; this zone may or may not be stained yellow or mottled red	0.0 to 10.0

9. Silt and sandstone, very fine, gray or yellow, generally thin-bedded and containing lignite particles. In many places this bed is "quartzitic," or contains ellipsoidal concretions of "quartzite," but it may be missing entirely, bed no. 11 of the Janssen member occuring immediately above it	0.0 to 10.0
8. Clay, massive, gray, of fire-clay type; commonly contains some fossil leaves and lignite particles......	1.0 to 5.0
7. Clay, massive, lignitic, dark gray; contains fossil leaves	0.1 to 3.0
6. Clay, mottled gray and red, massive, of the fire-clay type obliquely jointed irregularly and breaking out with a conchoidal fracture. This zone contains economically important beds of gray fire clay having a high alumina and low iron content. Some seemingly persistent zones of concretionary iron in the form of limonite, siderite, or hematite pellets, or of granular hematite, occur in this division. There are also some thin beds of sandstone and silt, not channels or bars, in which "quartzite" concretions are commonly found	100.0 to 150.0
5. Clay to clayey silt, mottled gray, red, and yellow, having an abundance of limonite, siderite, or hematite pellets, or granular hematite; the granular hematite is most common	1.0 to 6.0
4. Clay, mottled light gray and red, kalolinitic, gradational contact at top and bottom	1.0 to 5.0
3. Kaolin, white; does not slake readily, and appears as a band of white fragments on weathered surface. At some places this bed is not evident on exposures, but generally it can be identified by ceramic tests and chemical analyses.............	0.1 to 1.5
2. Clay with silt, gray to dark gray, or fine sandstone bands, lignite and fossil leaves common. In some sections portions of this bed are shale or thin-bedded clay. A highly lignitic, darker band commonly occurs toward the bottom, and pyrite, also. This bed is mostly a refractory fire clay; and unless yellow stain is marked, samples fire to ivory or cream colors	5.0 to 30.0
1. Siltstone and fine sandstone, mostly thin-bedded, but locally cross-bedded; this zone characteristically contains "quartzite" concretions, which, if not quartzitic, are likely to be very friable. Fossil leaves, fragments of lignite, and nodules are common. This zone is missing in places, in which case Dakota clay (bed 2) rests directly on Kiowa shale or older rocks	up to 20.0

Black lignite has been found in the Dakota formation and is mined near Minersville between Belleville and Concordia. The lignite is described by Wing as consisting of two layers, an upper layer about 8 inches thick and a lower layer about 12 inches thick, which are separated by as much as 4 inches of "black jack," or impure coal. The upper layer contains more sulfur and burns more quickly than the lower layer.

Distribution and Thickness.—The Dakota formation, which is the oldest formation exposed in the two counties, crops out in the southeastern part of Republic County and adjacent Cloud County, along some small creeks near the middle of the eastern part of Republic County, and along the Republican River Valley throughout its course in Cloud County. So far as is known the Dakota formation is present at or below surface everywhere in Republic County and northern Cloud County. It was encountered by the municipal wells at Cuba and Narka and the abandoned municipal wells at Belleville. Many wells in the southwest quarter of Republic County terminated in the Dakota formation.

According to Wing nearly 400 feet of the Dakota formation crops out in Cloud and Republic Counties. The Walker oil-test well in sec. 23, T. 2 S., R. 1 W. penetrated about 300 feet of the formation. The Danelson oil-test well in the northeastern corner of Cloud County penetrated only about 125 feet of the formation, the upper part of the formation having been removed by erosion.

Water supply.—The Dakota formation is an important water-bearing formation in several other states and is a notable source of artesian water. In Republic County and northern Cloud County it is also an important water-bearing formation but in parts of the area the water is of very poor quality and unsuitable for stock and domestic use. The water generally is under some artesian head, but in most places the head is not sufficient to produce flowing wells. Logan (1897, p. 213) stated: "In one of the Republic County salt marshes an artesian flow was obtained with sufficient pressure to lift the water 12 feet high."

The Dakota formation in the outcrop area in southeastern Republic and northern Cloud Counties yields an abundant supply of good water for stock and domestic use, but south and west of Talmo the water is too salty for stock use. Several deep wells between Cuba and Narka obtain water of good quality from the Dakota formation. The analyses of the municipal supplies at Cuba and Narka are given in Table 6. About 5 miles west of Narka the water becomes very salty as indicated by the analyses of waters from wells 16 and 17 given in Table 6. Practically no information is available regarding the quality of water in the Dakota formation where it is overlain by the Belleville formation, as adequate water supplies are obtained from the Belleville formation and wells are not drilled on into the Dakota formation except along the fringe of the Belleville. In the vicinity of Belleville and north and east of Scandia the formation yields highly mineralized water. In the area west of U. S. Highway 81 and south of Scandia it is not possible to predict the quality of water that would be obtained from a well penetrating the Dakota formation. Many wells in the Dakota in this area yield water that is very highly mineralized whereas other wells in the same section may yield good water.

Numerous theories have been advanced to account for the large variance in the mineral content of the well water obtained from the Dakota formation. As the ground water is fresh in the greater part of the outcrop area it seems reasonable to believe that rainfall infiltration over a period of thousands of years has diluted and flushed out much of the salty water leaving water of a much lower mineral content.

Logan (1897, pp. 209-10) suggested that the highly mineralized water may be caused by certain shale horizons, and stated:

> Resting upon the lignite is a bed of shales which are, in the majority of instances, highly saliferous in character. They vary in thickness from 15 to 30 feet. By the disintegration of these shales salt marshes have been formed in many localities along the exposure of the upper Dakota horizon. The marshes occur on Marsh Creek in Cloud County; on West Creek, Marsh Creek and Salt Creek in Republic County. The saline properties of the Great Spirit Spring, which is located in an outlier of the Dakota near Cawker City, are due to these shales. Salt springs occur in this horizon in Mitchell, Jewell, and Republic Counties, and the water of the wells which pass through the shales is invariably saline. Above the saliferous shales is a bed of shales varying in thickness from 10 to 20 feet. These shales are thin, laminated and of loose texture. They contain quantities of gypsum crystals.

Wing (1930, p. 49) seemed to agree with Logan concerning the source of the salty water. He stated:

> In some of the wells the water contains so much salt, gypsum, and iron that it cannot be used even for watering stock. Whether this condition is a local one with all the principal sandstones in the formation yielding salt water or whether this objectionable water comes only from certain beds cannot be determined from data at hand. It seems to the writer, from experience gained elsewhere and through knowledge of the conditions existing in the Dakota, that the wells yielding fresh water produce from different beds than those in which the water is salty. This offers the hope that fresh water may be pro-

duced in any locality from the Dakota if the the driller will very carefully obtain and test unadulterated samples of water from each and properly case off the strata producing salt water. The discovery of fresh-water horizons in localities where the Dakota has heretofore produced only salt water and where water from other sources is insufficient would be of great value.

Graneros Shale

Character.—The Graneros shale is a noncalcareous clay shale ranging in color from dark blue to black. It contains numerous lemon-yellow flakes of sandstone and transparent crystals of gypsum. In some places there is a bed of brown sandstone near the middle and thinner rusty-colored lenses both above and below. The shale weathers to a heavy clay which shows numerous desiccation cracks during the dry season.

Distribution and thickness.—The Graneros shale underlies all Republic County except the southeastern part. It underlies only a small area in the northern part of Cloud County. It crops out in small areas along the stream valleys in the southern and eastern parts of Republic County and in the northwestern part of Cloud County (Pl. 1). According to Wing the fromation has a thickness of 20 to 30 feet in Republic and Cloud Counties, but is thinner to the north and east.

Water supply.—No wells are known to derive water supplies from the Graneros shale in Republic and Cloud Counties. The shale is relatively impermeable and would yield little or no water to wells.

Greenhorn Limestone

Character.—The Greenhorn limestone contains the only limestones cropping out in either Cloud or Republic Counties. These white-layered rocks can be seen around the edges of the hills and in many road cuts. Some beds of the Greenhorn limestone have been extensively quarried and used for fence posts, flagging, and building purposes. The Greenhorn limestone has been studied by Rubey and Bass (1925, pp. 45-51) in Russell County, by Bass (1926, pp. 31-35) in Ellis County, and by Wing (1930, pp. 24-30) in Cloud and Republic Counties.

The Greenhorn limestone consists of thin chalky and crystalline limestone and bentonitic clay and an upper series of interbedded chalky shales and chalky limestones capped by the "Fencepost" bed of limestone (Pl. 11). On fresh exposure the beds of limestone and shale are dull gray in color and the bentonitic clays are light pearly gray. Upon weathering the color of the limestone changes to tan, buff, or orange-tan, and the shales weather tan or light gray in the upper part and tan or orange-tan in the lower part.

The Greenhorn limestone was subdivided by Rubey and Bass (1925, p. 45) into four members which from top to bottom are the Pfeifer shale, Jetmore chalk, Hartland shale, and Lincoln limestone members. Wing (1930, p. 24) stated that in Cloud and Republic Counties only the upper two were recognized and the lower two were not differentiated. He characterized the subdivisions of the Greenhorn limestone as follows:

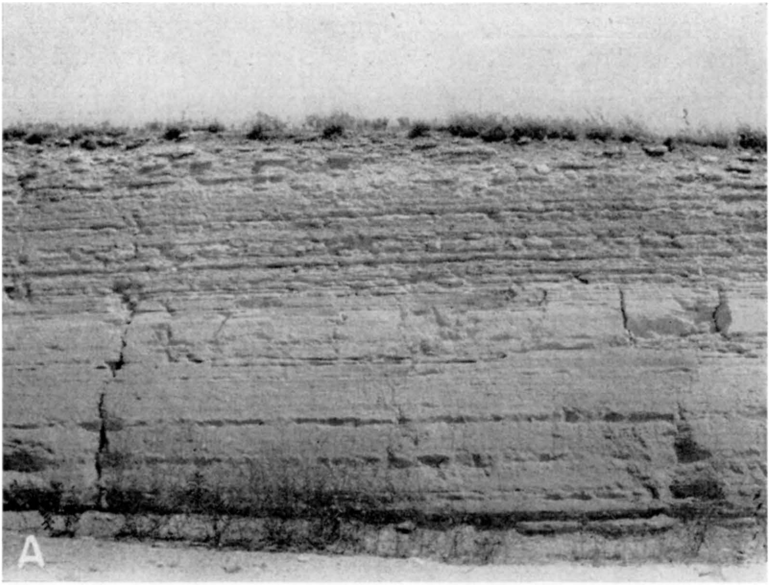
Members of the Greenhorn limestone with characteristics and thickness

	Feet
Pfeifer shale:	
"Fence post" limestone bed and underlying gray calcareous shale....	15–16
Jetmore limestone:	
"Shell rock" at top and thin limestone beds below, alternating with gray calcareous shale	13–14
Lower Greenhorn undifferentiated:	
Blue-gray, calcareous shale containing thin crystalline limestones, numerous bentonite-clay layers, and a crystalline limestone bed at the base	45–53

Distribution and thickness.—The Greenhorn limestone is either at the surface or underlies all Republic County except the southeastern part where the Dakota formation crops out. It also underlies or crops out in a large area in the northwestern part of Cloud County (Pl. 1). It crops out along Rose Creek in the northeastern part of Republic County, along Mill Creek in the eastern part of the county, and along all the streams that flow in a southerly direction from the county.

According to Wing the thickness of the Greenhorn limestone in Republic and Cloud Counties is about 83 feet, but the entire thickness is not exposed at any one place. The thickness of each member is given above.

Water supply.—Very few wells that receive their entire water supply from the Greenhorn limestone were observed in Republic County or northern Cloud County. A few very shallow dug wells that receive their water supply from seeps issuing just above impervious layers in the formation were observed along hillsides (Pl. 10B). Such wells might more properly be classed as springs, however. The water-yielding capacity of the formation is low, and very small supplies of comparatively hard water may be expected from wells penetrating this formation.



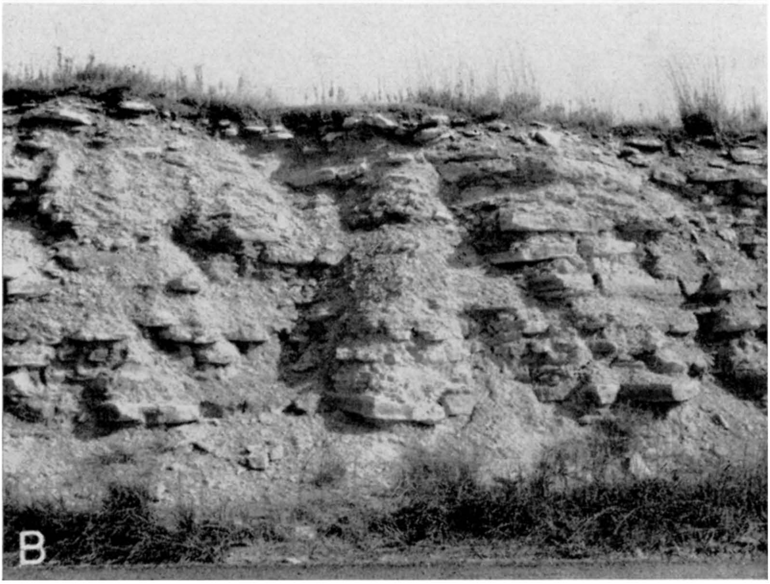


PLATE 11. Greenhorn limestone. *A,* In NW cor. sec. 21, T. 4 S., R. 3 W. *B,* 2 miles west of Belleville on north side of U. S. Highway 36.

Carlile Shale

Character.—The Carlile shale is the youngest Cretaceous formation exposed in Cloud and Republic Counties. Because of its topographic position and its argillaceous character it has been removed by erosion to such an extent that only a thin and badly weathered layer is present capping the uplands. Generally it is covered by slopewash so that very few exposures may be seen. Wing (1930, p. 22) stated:

To the southwest it has been divided into a lower calcareous phase called the Fairport member and an upper noncalcareous part named the Blue Hills shale member. Although these divisions can be recognized in Republic County the contact between them is not sharp, and consequently the Carlile is not subdivided in this report. . . . It is impossible from the scattered sections taken to give a complete detailed section of the Carlile in Cloud and Republic counties, but the following partial sections show the character of the lower and middle parts of the formation:

Section of the lower part of the Carlile shale near the southeast corner of sec. 19, T. 2 S., R. 2 W., Republic County. (Wing,* 1930, p. 22)

	Feet	Inches
Carlile shale:		
11. Limestone, reddish-buff at top	..	5
10. Shale, blue gray; calcereous. Contains numerous *Ostrea* shells	5	..
9. Limestone, dark buff. Varies greatly in thickness. Splits into thin layers	..	3–7
8. Shale, light gray. Calcareous	6	..
7. Limestone. Splits into three distinct layers. The two upper layers are separated by an ochre-red seam of clay along which the limestone is reddish-buff in color. Middle layer is more compact than the other two and is slightly banded. Lowermost layer is chalky and weathers rapidly	..	8–9
6. Shale, gray. Calcareous	2	10
5. Limestone, gray. Intermediate ¼-inch is cross laminated	..	1
4. Shale, gray. Calcareous	2	6
3. Limestone. Lower part light buff; upper reddish-buff,	..	3½–4
2. Shale, calcareous	..	2
Greenhorn limestone—Pfeifer shale member:		
1. "Fence post" limestone	..	9

* Wing gives this location as sec. 20, T. 12 S., R. 2 W. However, since this location (T. 12 S.) is obviously erroneous, the location has been corrected as above.

Section of the middle part of the Carlile shale exposed along bluff in the SW¼ of sec. 2, T. 2 S., R. 5 W., Republic County. (Wing, 1930, p. 23)

	Feet	Inches
14. Clay, sand and gravel belonging to the Tertiary	10–12	..
13. Shale, blue-gray. Contains lemon-yellow flakes and fragments of large-shelled *Inoceramus*	23	..
12. Bentonite, thin white	..	½
11. Shale, blue-gray. Contains numerous fragments of large-shelled *Inoceramus*	10	..
10. Clay, brown, containing thin flakes and small crystals of gypsum. Has bentonitic seam at center	..	2
9. Shale, blue	5	..
8. Gray limestone bed containing many small shells of *Inoceramus.* At the top of this is a zone containing small brownish concretions 1 to 4 inches in diameter	..	4
7. Shale, blue	..	5
6. Clay, similar to No. 10	..	3
5. Shale, blue papery; containing numerous fragments of large *Inoceramus* shell and *Ostrea*	2	..
4. Clay, similar to No. 10	..	3
3. Shale, blue	4	..
2. Clay, brownish	..	1
1. Shale, blue, papery; contains numerous *Ostrea shells*	12	..

Distribution and thickness.—According to Wing the total thickness of the Carlile shale is approximately 280 feet. The upper 100 feet is not exposed in Cloud or Republic Counties, but may be seen under the protecting edge of the Fort Hays limestone member of the Niobrara formation in the bluff across the line in Jewell County, 1 mile southwest of White Rock.

As shown on Plate 1 the Carlile shale caps the uplands in Republic County between the area mantled by the Belleville formation and the outcrops of the Greenhorn limestone. It underlies the greater part of the Belleville formation.

Water supply.—Although many shallow dug wells obtain meager supplies of water from the weathered near-surface part of the shale, it is not considered a good water-bearing formation. One well (191) that receives its entire water supply from the shale below the weathered zone was observed. The owner reported that shale was encountered at a depth of 28 feet and that no water was found above the shale. The water contained 1,532 parts per million of sulfate and 3,700 parts per million of dissolved solids.

In some parts of Republic County where the farmers must depend on water supplies from wells in the weathered zone of the Carlile shale, the amount of water obtained is inadequate to supply their requirements for stock and domestic use. Just north of Scandia and just south of Courtland the wells yield very meager supplies. Also west of the Republican River Valley and south of U. S. Highway 36 is a strip of land about 1 mile wide parallel to the Republican River Valley where the wells yield little or no water. Many wells are dug into the underlying shale without finding water.

Quaternary System

Geology by S. W. Lohman
Hydrology by V. C. Fishel

PLEISTOCENE SERIES

Belleville formation

Redefinition of name.—The Belleville formation in northern Republic County was named and described by Wing (1930, pp. 19-21) who stated (p. 21) concerning its age:

> It is clearly of Tertiary age and probably equivalent to a part of the Ogallala formation of western Kansas, but because of great distance the correlation is made provisionally. . . . Middle Pliocene age is indicated by the identification of teeth of trilophodon, a bunomastodon or long-jawed Proboscidean represented among living forms by the elephant.

After a detailed study of the Pleistocene deposits of Nebraska Lugn (1934, p. 355; 1935, p. 197) stated:

> The "Belleville formation" of northern Republic County, Kansas, described as sand, gravel, and clay, and assigned to the Tertiary on the basis of two questionably identified Mastodon teeth, is the extension of the fluviatile Pleistocene sand and gravel formations of Nebraska. The formation is continuous with the Pleistocene deposits (Grand Island formation) in Nuckolls and Thayer Counties. Equus and other Pleistocene mammalian remains have been gotten from the same deposits at the same locations described by Mr. Wing. Since the "Belleville formation" has been defined and described in print as a Tertiary formation; and, while it seems to be wholly or in part a southeastward extension of the Grand Island formation in Nebraska, it is not as typical in its development in Republic County, Kansas, as at Grand Island, Nebraska; it is believed best to recommend the acceptance of the term Grand Island for this upper sand and gravel sheet, in preference to the application of "Belleville," even in a redefined sense. Also, there is some possibility that the lower part of the sand and gravel in this vicinity may include the Fullerton formation and more or less of the Holdredge sand and gravel. However, well logs at Chester, Byron, and Deshler do not suggest the presence of these lower units, and, so far, it appears to be only the Grand Island formation which seems to occupy the "Chester basin" and the buried channel, which extends from west to east across Republic County, Kansas.

I agree with Lugn as to the Pleistocene age of the Belleville formation, for which additional paleontologic evidence is given below, but I am not in agreement with Lugn that the name Belleville should be discarded and that the deposits in northern Republic County be classed as Lugn's Grand Island formation, for these reasons. (1) The name Belleville assigned by Wing in 1930 has priority, even though the age assigned by Wing obviously was incorrect (though it is not to be inferred that priority alone be given undue weight without other substantiating evidence). (2) The Pleistocene deposits in northern Republic County seem to be equivalent not only to Lugn's Grand Island formation but also to his underlying Fullerton and Holdrege formations except that here his three units cannot be recognized and differentiated and hence his formational names are not usable. The possible existence of representatives of the two lower units in northern Republic County was admitted by Lugn in the quotation given above, but he suggested the probable absence of the Holdrege on the grounds that the Fullerton was not detected in the logs of wells from the area. That Lugn's Fullerton formation does not everywhere separate the other two formations and hence that all three units are of doubtful formational rank is well stated by Cady (in press) who describes the Pleistocene deposits in and near the Republican River Valley in southern Nebraska just upstream from Republic County:

> The early Pleistocene sand and gravel deposits were studied by Lugn in the Platte Valley and upland area between that valley and the valley of the Republican. . . . Lugn found that many of the wells and test holes in the areas studied by him encountered a layer or zone of fine-grained material at some point about midway between the top and the base of the sand and gravel deposit, and that in many localities the owners and drillers of water wells recognized an upper and a lower source of water. . . . Believing the lower gravel, the intervening bed of finer-grained material (in some places clay, in other places silt, clayey sand, silty sand, or fine sand) and the upper gravel to be appropriately continuous, he [Lugn] proposed formational status for them, and offered the respective names of Holdrege formation, Fullerton formation, and Grand Island formation. . . .
>
> Without going into a critical discussion of the inferences and evidence that support Lugn's classification, it is necessary to remark that in the Republican Valley area the early Pleistocene sand and gravel deposit is not divisible into a lower and upper part, since no distinctive zone of clay or other fine-grained material is seen in the outcrop nor encountered in wells and test holes. Hence, the formational names cannot be used.

Inspection of the logs given at the end of this report and of the cross sections in Plate 5 will indicate that the same holds true in northern Republic County. Thin lenses of fine-grained material separating larger bodies of sand and gravel were encountered in test hole 11 (cross section E-E′) but were not persistent enough to carry through to test hole 12 near by. Similar discontinuous lenses are shown in cross sections D-D′ and G-G′ (Pl. 5). Such lenses can hardly be regarded as constituting a formation; hence there seems to be no good reason for assigning separate formational names to the units of sand and gravel immediately above and below such lenses. Moreover, where such lenses are absent the sand and gravel forms a single lithologic unit.

For the reasons given above, the name Belleville formation is retained in this report to designate the stream-deposited sand and gravel in northern Republic County that occurs in and near the channel of the ancestral Republican River and below the loess, but it is redefined as being of Pleistocene age. Fossil evidence and correlation in support of this redefinition are given below under Age and correlation.

Character.—The Belleville formation consists mainly of cross-bedded coarse sand containing beds and lenses of medium to coarse gravel, but also contains thin lenses of clay, some of which are green and gritty. Much of the sand and gravel is stained or streaked by iron oxide giving outcrops a rusty brown appearance. Some beds are partly cemented but most of them are unconsolidated. The finer grains are composed mainly of quartz or pink feldspar and the larger pebbles are mainly of pink granite.

The Belleville is poorly exposed in most parts of northern Republic County, being generally covered by "loess" and in places covered by dune sand. It is exposed at a few sand and gravel pits north of Belleville (Pls. 1 and 7B), in a sand and gravel pit northeast of Republic City in sec. 20, T. 1 S., R. 4 W., and along some of the small streams. An excellent exposure of the equivalent Pleistocene sand and gravel in Nebraska is shown in Plate 7A.

Distribution and thickness.—The general distribution of the Belleville formation in northern Republic County is shown on Plate 1 and is taken from a geologic map prepared by Wing (1930, Pl. 2). The mapped area may include some reworked younger sand and gravel and is also the area underlain by the thickest deposits of "loess" and by dune sand, so that the exact boundaries are difficult to determine.

The Belleville ranges in thickness from a few feet along the southern margin of its outcrop to 30-40 feet in places north of Belleville, and attains its maximum thickness of about 120 feet in the deepest part of the channel of the ancestral Republican River southwest of Chester, Nebraska (Pl. 5).

Age and correlation.—Vertebrate fossils collected from sand and gravel pits in the Belleville formation during the present investigation and some collected by previous investigators were examined by Claude W. Hibbard, formerly of the Museum of Vertebrate Paleontology, University of Kansas, who made the following statement (personal communication, Nov. 8, 1945):

The *Stegomastodon* molar (no. 395) which was taken by Elias and Wing in the McCullough sand pit in sec. 16, T. 2 S., R. 3 W., teeth of *Equus cf. excelsus* Leidy (no. 6642) from the gravel pit in the SW SE sec. 20, T. 1 S., R. 4 W., as well as the isolated *Stegomastodon* teeth and the Imperial elephant tooth that I examined from the Republic County gravel pits indicate mammals that lived in that area during early Pleistocene time.

The Belleville formation seems to be correlative wholly or in part with the Holdrege, Fullerton, and Grand Island formations of Lugn in southern Nebraska, though no divisions of his formations seem possible in this area. The possible time of deposition of the Belleville within the Pleistocene is discussed on pp. 31-32.

Water supply.—Information regarding ground-water conditions in the ancestral Republican River Valley is based on the records of the domestic and stock wells in the area, the Belleville municipal wells that were drilled in 1927, and the test drilling by the Federal and State Geological Surveys in 1942. The farm wells penetrate only a few feet into the saturated gravel and sand and hence are a poor index of the availability of ground water in the area. They yield adequate water for domestic and stock use with small drawdowns. Many farmers in the area had reported that their wells yielded "unlimited quantities" of water, but the ground-water potentialities of the formation remained unknown until 1927 when the Layne-Western Company drilled test holes in their search for a water supply for Belleville. Prior to 1927, Belleville obtained its water supply from deep wells in the Dakota formation located within the city limits (pp. 59-61). These wells yielded rather brackish water. After test drilling for a new water supply near Belleville proved unsuccessful, the Layne-Western Company undertook a test drilling program to check the numerous reports of the large available supplies in the Belleville formation. The resulting wells located in section 2, T. 1 S., R. 3 W. penetrated approximately 100 feet of saturated coarse gravel, and yield 425 gallons a minute with a drawdown of 4.5 feet. Thus, the specific capacity of the wells is 94 gallons a minute per foot of drawdown.

The thick deposits of loess overlying much of the Belleville formation are relatively impermeable; hence ground-water recharge of the Belleville formation is probably very small. Recharge to the Belleville probably is much better in a limited area northeast of the City of Republic in which the Belleville is overlain by dune sand.

A perennial water supply from this formation will depend largely on the movement of ground water into the area from the sides of the formation, most of which will be from the north from Nebraska and from the recharge area northeast of the City of Republic where the surface deposits are composed of dune sand. The direction of movement of the ground water is shown by Plate 8.

Data are not available concerning the permeability of the gravel and sand deposits of the Belleville formation; hence it is not feasible to attempt an estimation of the perennial water supply that could be obtained. The Belleville municipal wells would probably yield as much as 2,000 gallons a minute with adequate drawdown based on a specific capacity of 94 gallons a minute per foot of drawdown. It would be unwise to concentrate many wells of large capacity in a small area, however, as the resulting drawdown would be large.

The water table is too deep in most of the area for economical irrigation at the present time and it seems unlikely that in the next few decades there will be much withdrawal of water for irrigation. Unless new industries are brought into the area the perennial water supply of the formation will be more than adequate to supply the needs of the domestic and stock supplies and the municipal water supplies of the cities located in or adjacent to the area.

Water from the Belleville formation is relatively hard, but it is suitable for most ordinary uses. The iron content is relatively high in most of the area.

Loess

General features.—Two distinct types of "loess" separated by a well-defined soil zone cover most of the area underlain by the Belleville formation (Pl. 1) and also cover some of the interstream areas and valley sides in parts of the area south of the mapped limits of the Belleville. The probable origin and some of the characteristic features of the loess are discussed on pp. 32-33.

The lower "loess," which is not all loess or silt but contains also beds and lenses of sand, gravel, and clay and some calcareous material, generally is reddish brown and contains at the top a well defined dark soil zone. The lower part of the material seems to have been stream-deposited and reworked in part from the underlying materials—the Belleville formation or some of the Cretaceous formations. The upper part of the lower "loess" may have been deposited by water or by wind, and consists mostly of silt and fine sand. The lower "loess" ranges in thickness from a feather edge to about 100 feet—the maximum thickness being found over the ancestral Republican River Valley.

The upper grayish-buff to yellow silt or "loess" overlies the soil zone except in places where the lower "loess" has been removed by erosion. It ranges in thickness from a feather edge to perhaps 20 or 30 feet.

Good exposures of the "loess" may be seen along the bluffs bordering the Republican River Valley north of the City of Republic, between Norway and Scandia, just west of Concordia, and along road cuts and small streams in parts of the uplands. An especially good exposure showing the entire sequence was observed along a small stream in the NE¼ SE¼ NE¼ sec. 13, T. 1 S., R. 5 W., and is shown in Plate 6B. A similar sequence several hundred feet west of the section shown in the photograph was measured by Charles C. Williams and Claude W. Hibbard, and is given below:

Measured section of "loess" in the NE¼ SE¼ NE¼ sec. 13, T. 1 S., R. 5 W.

	Thickness, feet	Thickness, inches
Soil, dark brown	2	0
QUATERNARY—Pleistocene		
"Peorian loess"		
Silt, buff; contains some fine to medium sand and some pebbles ½-inch in diameter. Where photo (Pl. 6B) was taken this interval is only 4 feet thick and is composed of fine to coarse sand and some tan silt	9	5
"Loveland loess"		
Soil zone, light brown, sandy	2	3
Sand, fine to coarse; contains some silt and some pebbles up to 2 inches in diameter	5	0
Clay, dark brown	0	6
Sand, fine to coarse, and some buff to brown silt	7	8
Belleville formation		
Sand, fine to coarse, and some gravel; cross-bedded. (To bed of stream)	3	0

A less complete section along a road cut just south of the Chicago, Rock Island, and Pacific Railway cut in the SW¼ NW¼ sec. 24, T. 2 S., R. 2 W. was measured by Charles C. Williams and S. W. Lohman, as follows:

Measured section of "loess" in the SW¼ NW¼ sec. 34, T. 2 S., R. 2 W.

	Thickness, feet
Soil	..
QUATERNARY—Pleistocene	
"Peorian loess"	
Silt, buff; contains fragments of reworked Cretaceous rocks	4
"Loveland loess"	
Soil zone, dark, silty	2.3
Silt, clayey, buff to tan	5
Gravel, fine	.6
Sand, medium, gray, grading downward to coarse sand and fine gravel	1.6
Caliche	.1–.2
CRETACEOUS—Gulfian	
Carlile shale	
Shale, yellow; contains brownish streaks, very fossiliferous (To bottom of exposure)	4

Age and correlation.—The age of the material within the Pleistocene and correlation with equivalent units in Nebraska is discussed on pp. 32-33. The lower reddish-brown "loess" and overlying soil zone are correlative with the Loveland loess of Nebraska, and the upper gray-buff to yellow "loess" is correlative with Lugn's Peorian loess of Nebraska. The entire sequence seems to be correlative also with the Sanborn formation of western Kansas (Elias, 1931, p. 163), which has been traced as far eastward as Jewell County by Hibbard, Frye, and Leonard (1944).

Fossil material collected from the lower reddish-brown "loess" during the course of the investigation was examined by Claude W. Hibbard, Museum of Vertebrate Paleontology, University of Kansas, who stated as follows (personal communication, Nov. 8, 1945):

The materials collected from the "Loveland" in the NW corner, sec. 18, T. 3 S., R. 4 W., are the remains of the Prairie-dog *Cynomys ludovicianus* (Ord) (Nos. 7313-7322), and are the same as other Prairie-dog remains which are found in deposits of this age to the west. So far as known *Cynomys ludovicianus* does not appear in deposits earlier than late Pleistocene.

Water supply.—No water is obtained from the "loess" deposit because they lie above the zone of saturation. Because "loess" has low permeability, it retards the downward movement of rain water and thus hinders the recharge of the ground-water reservoir.

PLEISTOCENE AND RECENT SERIES

Alluvial material of Pleistocene and Recent age is found principally in the Republican River Valley and in the valleys of some of the creeks (Pl. 1). Creeks having little or no alluvium include Rose, Mill, Beaver, Oak, East Marsh, White Rock, and Otter Creeks.

The alluvium is typical of stream-laid deposits, ranging in texture from silt to sand and coarse gravel. The youngest deposits consist largely of sand and silt deposited over the flood plain in time of flood or under normal conditions in the channel of the stream. Beneath the finer surficial deposits are beds of sand and gravel that are somewhat older. The older alluvium in the Republican River Valley is of Pleistocene age. The character, age, and origin of this alluvium and of the associated terrace deposits are discussed on pages 33-36, and its distribution, thickness, and hydrologic character are discussed below in a separate section.

The smaller stream valleys are partly filled with alluvium consisting mainly of silt and fine sand, but some, such as the valley of Salt Creek (Pl. 5, section M-M′) contain some gravel. Good exposures of the alluvium along Riley Creek, a tributary of Salt Creek, are found in the NW ¼ sec. 1, T. 4 S., R. 3 W. An old gravel pit revealed a section capped by 8 to 10 feet of reddish-brown silt containing many small pebbles of limestone. This material resembles the lower water-laid part of the "Loveland" loess. The silt is underlain by about 30 feet of cross-bedded coarse sand and fine to medium gravel containing some angular fragments of ironstone which may have been derived from the Dakota formation. Only part of the 30 feet of sand and gravel is exposed, the rest having been encountered in sinking a near-by well (209). The same sequence of materials is exposed just to the north along the south bank of Riley Creek, except that here about 3 or 4 feet of the gravel has been cemented to a hard conglomerate. As noted, some of the Belleville formation may have been deposited along southward-flowing streams this far south of the old drainage divide, but the presence of the fragments of ironstone plus the lime-cemented gravel suggest that the material probably was derived at later date from erosion of the Belleville formation.

Alluvium of the Republican River Valley

Distribution and thickness.—Republican River enters Republic County about 1 mile south of the northwest corner of the county, then flows south, entering Cloud County about 8 miles east of the western border where it turns southeast for about 8 miles and then flows east, leaving Cloud County about 6 miles south of the Cloud-Republic County line. The Republican River Valley ranges in width from 1.4 miles near Scandia to 3.6 miles near Concordia.

The alluvium in the Republican River Valley consists at the top of sand and silt deposited over the flood plain in time of flood or under normal conditions in the channel of the stream. Beneath the finer surficial deposits are layers of sand and gravel. The alluvium supplies water to many domestic and stock wells in the valley and yields abundant supplies to some irrigation wells. Very little was known concerning the thickness, character, and distribution of the alluvium, and the quality of the water, other than from the statements of many well owners.

In order to determine the thickness, character, and extent of water-bearing alluvium on both sides of the river and the locations of any deep channels that might have been excavated into bedrock, 45 test holes were put down along the five lines shown in Plate 2. The test holes were drilled through the entire thickness of alluvium and from 1 to 10 feet into the underlying bedrock. Samples of material were collected at regular intervals or whenever the slightest change in the character of the material was noted.

The results of the test drilling are shown graphically in Plate 5, are given in the logs at the end of this report, and were used in drawing the contours on the bedrock shown in Plate 2. In cross-section B-B′ north of the City of Republic the alluvium is shallow but extends over a wide area, a condition resulting from the early geologic history of the valley which is described by S. W. Lohman in an earlier section of this report. The thickness of the saturated sand and gravel deposits at this cross section averages only about 20 feet. In cross section H-H′ between Republic and Scandia the valley is narrower but the alluvium is much thicker than at cross section B-B′.

The sand and gravel deposits at Scandia (section J-J′) are as much as 70 feet thick but the valley at this point is very narrow—approximately 1½ miles. The deepest part of the bedrock channel is about three-fourths of a mile west of the present river.

The alluvium in cross section K-K′ at Norway is about 3 miles wide and in some places is more than 100 feet in thickness. The saturated gravel and sand deposits have a thickness of more than 80 feet in some places.

The cross section (L-L′) at Concordia is comparable to the one at Norway, the alluvium being about 3½ miles wide and a little thicker than at Norway.

Hydrologic properties of the water-bearing materials.—The quantity of ground water that a water-bearing formation will yield to wells depends upon the hydrologic properties of the material. The two hydrologic properties of greatest significance are permeability and specific yield. Permeability is a measure of the ability of a formation to transmit water; specific yield is a measure of the quantity of water that the formation will yield when it is drained.

The specific yield of a water-bearing formation is defined by Meinzer (1923, p. 26) as the ratio of (1) the volume of water which, after being saturated, it will yield by gravity to (2) its own volume. It is a measure of the quantity of water that a formation will yield when it is drained by a lowering of the water table.

The permeability of a water-bearing formation is the discharge per unit of area per unit of hydraulic gradient. It may be measured in terms of the number of gallons of water a day, at 60° F., conducted laterally through each mile of the water-bearing bed under investigation (measured at right angles to the direction of flow), for each foot of thickness of the bed, and for each foot per mile of hydraulic gradient (Stearns, 1927, p. 148).

Specific yield.—Not all the water in the interstices of saturated materials is available for recovery through wells—a fact of great practical importance in the development of ground-water supplies in places where the water comes largely from storage and must be replenished periodically from precipitation or stream flow. A part of the water in the interstices will drain into wells, and a part will be retained in the formation by capillary action. The part that will drain into wells is called the specific yield and the part that is retained is called the specific retention. The specific yield and specific retention are expressed in percentages of the total volume of material. The specific yield and the specific retention of a rock or soil are together equal to the porosity.

Lugn and Wenzel (1938, p. 90) reported that the Pleistocene sand and gravel deposit near Grand Island, Kearney, and Lexington has a specific yield of about 24 percent. Cady (in press) stated that the alluvium in the Republican River Valley in Nebraska has a specific yield of about 18 percent.

Determinations of the specific yield of the alluvium of the part of the valley considered in this report were not made. As shown in Plate 5 the saturated part of the alluvium is composed almost entirely of sand and gravel that is similar in texture and appearance to the material described by Lugn and Wenzel and by Cady. For purposes of indicating the importance of specific yield and the amount of water held in storage that is available for pumping, a specific yield of 18 percent is assumed for the sand and gravel in this area. This is the specific yield given by Cady for the sand and gravel in the Republican River Valley in Nebraska. It is less than the specific yield of the Pleistocene sand and gravel near Grand

Island, Kearney, and Lexington, Nebraska. A cubic foot of saturated material having a specific yield of 18 percent will lose by drainage 0.18 cubic foot of water. Conversely, if an area underlain by such material is covered with water to a depth of 0.18 foot, and all of the water percolates downward to the water table, the water level in a well situated within the area will rise 1 foot.

A column of saturated alluvium 1 mile square and 1 foot thick having a specific yield of 18 percent, if completely drained, would yield 37.5 million gallons of water (115 acre-feet). The saturated part of the alluvium in the Republican River Valley near Norway and Concordia has average thicknesses of about 42 and 57 feet, respectively. Thus, assuming a specific yield of 18 percent, a column of this alluvium 1 mile square, if completely drained, would yield an average of 1.6 billion gallons of water (4,670 acre-feet) at Norway and an average of 2.1 billion gallons of water (6,470 acre-feet) at Concordia. The large quantity of ground water held in storage is available in part for pumping during dry seasons provided that conditions are favorable so that it will be replenished by recharge from precipitation during successive seasons of abundant precipitation or by recharge from the river, or both. Although the above quantities of water may be available from storage, the rate at which the water could be pumped from storage would become progressively lower as the water table declined.

Laboratory determinations of permeability.—Samples of material penetrated in test drilling were collected and dried in the field by James B. Cooper and Oscar S. Fent, who also prepared the logs given at the end of this report. When dry, the samples were sacked and taken to the laboratory of the U. S. Geological Survey at Lawrence, where mechanical analyses and determinations of the coefficients of permeability were made by Dwight C. Gilkison.

The samples collected from the test holes were washed to the surface by the drilling mud and therefore cannot be regarded as truly representative of the materials as they occur. The water or light mud used in drilling may have removed some of the finer particles that occur naturally in the sands and gravels. Despite these difficulties in sampling, however, it is believed that the laboratory determinations of permeability gave values that are of the right order of magnitude for determining the underground movement of water. The coefficients of permeability given below were determined by means of an apparatus designed by C. V. Theis and described by me (Wenzel, 1942, p. 59). The laboratory determinations made on samples of material from the test holes are given in Table 12.

TABLE 12.—*Physical properties of water-bearing materials from test holes in the Republican River Valley between the Nebraska State line and Concordia, Kansas*

(Collected by James B. Cooper and Oscar S. Fent; analyzed by Dwight C. Gilkison)

Test hole number on Plate[1]	Depth of sample (feet)	Mechanical analyses (percent by weight): Medium and coarse gravel (larger than 2.0 mm)	Fine gravel (2.0–1.0 mm)	Coarse sand (1.0–0.50 mm)	Medium sand (0.50–0.25 mm)	Fine sand (0.25–0.125 mm)	Very fine sand (0.125–0.062 mm)	Silt and clay (less than .062 mm)	Coefficient of permeability,[2] gallons per day per sq. ft.
25	20–33	7.2	16.8	28.2	29.4	7.0	5.8	5.2	15
	50–60	13.6	33.1	33.0	17.1	2.2	.5	.5	2,250
	70–80	45.7	22.4	17.8	9.8	2.3	.9	1.0	132
34	10–18	30.5	22.5	23.6	19.1	2.7	.5	1.1	300
	18–30	20.5	26.2	29.8	20.6	2.2	.3	.4	1,450
	30–36	3.3	42.3	43.6	9.9	.7	.2	.3	4,090
35	7–10	2.7	4.0	18.1	61.8	7.9	3.0	2.6	140
	10–16	.7	5.3	34.3	48.0	7.2	2.6	1.8	430
38	1½–10	5.3	6.6	27.5	50.2	7.3	1.9	1.2	450
	10–21½	14.2	14.9	23.7	33.1	7.7	4.3	2.1	135
43	30–40	12.7	13.6	22.9	35.8	4.6	6.7	3.8	56
	40–44	8.3	25.4	44.0	18.5	1.2	.8	1.7	820
62	3–10	2.1	5.0	27.3	56.8	5.3	1.9	1.6	525
	10–22	8.9	30.5	35.4	21.2	2.2	.8	1.0	1,160
65	0–10	.6	1.7	10.0	57.0	18.1	7.3	5.3	147
	10–20	62.8	25.5	5.6	3.7	1.4	.5	.5	6,200
	20–30	42.3	32.4	10.9	8.6	2.9	1.3	1.6	1,100
	30–40	24.5	37.0	17.5	13.7	4.2	1.5	1.6	350
	40–50	26.3	21.9	20.2	22.8	5.9	1.6	1.3	480
	50–61	38.1	28.7	12.2	13.4	4.5	1.5	1.6	193

TABLE 12.—*Continued*

Test hole number on Plate[1]	Depth of sample (feet)	Mechanical analyses (percent by weight): Medium and coarse gravel (larger than 2.0 mm)	Fine gravel (2.0–1.0 mm)	Coarse sand (1.0–0.50 mm)	Medium sand (0.50–0.25 mm)	Fine sand (0.25–0.125 mm)	Very fine sand (0.125–0.062 mm)	Silt and clay (less than .062 mm)	Coefficient of permeability,[2] gallons per day per sq. ft.
67	1–10	9.5	16.8	15.9	29.6	13.9	8.7	5.6	....
	10–20	34.2	26.6	16.3	15.6	3.7	2.0	1.6	800
	20–27	33.2	25.3	22.4	14.1	3.1	1.2	.8	2,100
66	1.5–7	5.3	3.8	4.9	77.2	7.6	.1	1.1	....
	7–10	17.2	12.9	16.4	39.4	11.9	.3	1.9	....
	10–20	28.3	19.7	11.1	29.8	8.3	1.5	1.3	....
	20–30	21.8	13.6	15.0	37.2	8.3	2.3	1.8	....
	30–40	16.7	12.4	12.4	40.9	7.9	4.8	2.9	18
	40–50	10.2	16.6	23.4	35.0	7.8	3.9	3.1	42
	50–60	20.6	25.3	22.3	20.4	6.1	2.9	2.4	55
	60–71	9.2	26.0	24.6	26.6	7.1	3.6	2.9	....
74	8–12	1.0	3.9	23.0	54.5	10.2	5.1	2.3	260
	12–20	8.7	15.0	35.6	33.3	5.0	1.4	1.0	730
	20–29	2.4	8.9	40.2	41.6	5.1	1.0	.7	920
	29–30	15.8	23.1	36.5	20.5	2.5	.8	.8	915
	30–40	74.8	18.7	3.8	1.4	.4	.4	.5	31,950
	40–50	58.8	26.0	10.0	3.1	.6	.6	.9	9,850
76	10–22	12.0	24.0	32.8	25.1	3.9	1.1	1.0	760
	30–41	13.8	29.1	33.7	19.7	2.6	.5	.5	360
78	20–26	33.6	33.3	15.6	11.9	3.6	.9	1.1	205
	50–60	28.0	45.4	19.0	4.7	1.3	.7	.9	650
	84–90	38.1	33.9	18.5	4.3	2.2	1.2	1.8	4,640

TABLE 12.—*Concluded*

Test hole number on Plate[1]	Depth of sample (feet)	Mechanical analyses (percent by weight)							Coefficient of permeability,[2] gallons per day per sq. ft.
		Medium and coarse gravel (larger than 2.0 mm)	Fine gravel (2.0–1.0 mm)	Coarse sand (1.0–0.50 mm)	Medium sand (0.50–0.25 mm)	Fine sand (0.25–0.125 mm)	Very fine sand (0.125–0.062 mm)	Silt and clay (less than .062 mm)	
82	40–50	19.5	58.4	9.3	3.7	1.5	2.7	5.0	400
	64.5–70	16.4	55.9	12.2	4.5	2.0	3.8	5.2	280
84	40–50	41.5	26.7	21.4	8.4	.9	.4	.7	1,800
	55–60	74.8	16.9	4.4	1.2	.5	.8	1.4	720
97	10–18	6.1	14.4	34.0	38.1	5.3	1.4	.7	480
	40–50	7.6	26.1	48.4	14.6	1.3	.8	1.3	710
	70–80	3.6	3.0	33.8	54.1	4.5	.6	.4	350
	90–100	68.0	12.9	7.1	4.4	2.1	2.0	3.5	13,100
98	22–30	2.6	6.6	35.3	45.6	5.5	2.5	1.9	115
	40–50	59.6	26.1	10.1	3.0	.4	.3	.5	10,100
	60–70	23.1	40.0	26.3	8.5	.9	.5	.7	1,900
104	7–10	6.9	11.1	19.1	48.7	5.7	5.1	3.4	65
	20–30	28.6	55.9	9.3	2.3	.9	1.3	1.7	4,600
	54–60	.5	6.1	27.2	57.2	6.8	1.4	.7	420
	80–86	55.3	34.7	6.3	2.0	.6	.5	.6	13,100
106	9–22	36.5	50.8	4.8	2.7	2.5	1.5	1.2	1,650
	30–38	54.1	32.6	6.9	2.6	1.8	1.1	.9	7,000

1. Test holes 25 to 84 were in Republic County; 97 to 106 were in CloudCounty.
2. Corrected to standard temperature of 60° F.

Permeability tests were made on a few samples from representative test holes and the resulting coefficients of permeability were weighted to obtain an average permeability of the alluvium along each cross section. These tests indicate that the permeability of the alluvium increases downstream. The coefficients of permeability obtained along cross section B-B′ near the City of Republic ranged from an average of about 250 g. p. d. per sq. ft. in the middle of the valley to about 1,500 g. p. d. per sq. ft. in the sands and gravels at the edges of the valley. No permeability determinations were made for section H-H′, as these test holes were drilled at a later date. The average coefficient of permeability was about 1,100 g. p. d. per sq. ft. for the Scandia section (J-J′), about 1,400 for the Norway section (K-K′), and about 4,900 for the Concordia section (L-L′). These values are considerably less than the coefficient of permeability obtained from a pumping test on a well east of Concordia, but may be too high because of the fact that they were obtained by tests on disturbed samples of material.

Pumping-test determinations of permeability.—The permeability of the alluvium in the Republican River Valley was determined by two pumping tests, using the recovery method involving the formula developed by Theis (1935, p. 522) and also described by Wenzel (1942, p. 94) for computing the transmissibility of an aquifer. (The coefficient of transmissibility is equal to the coefficient of permeability, not corrected for temperature, multiplied by the thickness of the aquifer.)

$$T = \frac{264\ q\ \log_{10} t/t'}{s}$$

in which T = coefficient of transmissibility, in gallons per day per foot
q = pumping rate, in gallons per minute
t = time since pumping began, in minutes
t′ = time since pumping stopped, in minutes
s = residual drawdown at the pumped well, in feet, at time t′

The residual drawdown (s) is computed by substracting the static water level before pumping began from appropriate water levels taken from the recovery curve.

The proper ratio of ($\log_{10}$ t/t′) to s is determined graphically by plotting ($\log_{10}$ t/t′) against corresponding values of s. By plotting t/t′ on the logarithmic coördinate of semi-logarithmic paper this procedure is simplified. For any convenient value of ($\log_{10}$ t/t′) the corresponding value of s may be obtained from the curve.

Adjustment for temperature in the following pumping tests was unnecessary as the temperature of the water was just slightly under 60° F.

Wright pumping test.—A pumping test was made on well 245 (Pl. 10A) completed in May 1942 on the farm of W. T. Wright located 7 miles east of Concordia in the NW¼ SW¼ sec. 25, T. 5 S., R. 2 W. It is the only active irrigation well in the main part of the valley in the vicinity of Concordia and it is illustrative of the type of irrigation wells that could be developed in the valley between Scandia and Concordia. The well was pumped on August 27, 1942, at a rate of 730 gallons a minute from 8:28 a. m. to 2:40 p. m. At the end of the pumping period the drawdown was 12.27 feet, and the specific capacity was about 60 gallons a minute per foot. The water-level measurements made during and following the pumping period are given in Table 13.

TABLE 13.—*Water-level measurements in Wright irrigation well* (245) *made during the pumping test on August 27, 1942* (*rate of pumping, 730 gallons a minute*)

TIME	Depth to water level, feet	Remarks	TIME	Depth to water level, feet	Remarks
8:20 a. m.	18.43	Static water level	2:46:30 p.m.	19.08	
8:28	....	Pumping started	2:47	19.06	
8:40	30.32		2:48	19.02	
9:10	30.55		2:49	18.99	
9:40	30.59		2:50	18.97	
10:45	30.62		2:52	18.92	
11:40	30.55		2:54	18.89	
1:00 p. m.	30.78		2:56	18.86	
2:30	30.70		2:58	18.84	
2:40	....	Pumping stopped	3:00	18.82	
2:40:15	24.13		3:05	18.80	
2:41	20.51		3:10	18.77	
2:42	19.64		3:15	18.76	
2:42:30	19.48		3:20	18.75	
2:43	19.38		3:30	18.72	
2:43:30	19.32		3:40	18.68	
2:44	19.25		4:00	18.64	
2:44:30	19.20		4:20	18.62	
2:45	19.16		4:40	18.59	
2:45:30	19.13		5:00	18.59	
2·46	19.10		5:30	18.57	

In applying the Theis recovery formula to the data given in Table 13, the value of T (coefficient of transmissibility) was found to be 449,000. The coefficient of transmissibility (449,000) divided by the thickness of saturated water-bearing material (47 feet) gives a coefficient of permeability of 9,500.

Ward pumping test.—A pumping test was made on well 260 situated on the farm of Roy Ward in the SW¼ NW¼ sec. 31, T. 5 S., R. 3 W. This well was pumped on August 26, 1942, at a rate of 47 gallons a minute from 11:40 a. m. to 1:40 p. m. At the end of the pumping period the drawdown in this well was 24.32 feet, and the specific capacity was only 1.9 gallons a minute per foot of drawdown. This is a very low specific capacity, indicating a very poor well. The water-level measurements made during and following the pumping period are given in table 14.

TABLE 14.—*Water-level measurements in Ward irrigation well* (260) *during the pumping test on August 26, 1942* (*rate of pumping, 47 gallons a minute*)

TIME	Depth to water level, feet	Remarks	TIME	Depth to water level, feet	Remarks
11:30 a. m.	23.05	Static water level	2:09 p. m.	23.77	
11:40 a. m.	....	Pumping started	2:10:30	23.72	
12:05 p. m.	42.60		2:12:30	23.75	
12:35	47.08		2:14	23.72	
1:10	47.38		2:16:30	23.72	
1:40	....	Pumping stopped	2:20	23.68	
1:45	26.40		2:21	23.67	
1:48	24.89		2:22:30	23.66	
1:51	24.57		2:25	23.65	
1:53:30	24.49		2:35	23.58	
1:54:30	24.45		2:50	23.46	
1:56	24.35		2:57	23.42	
1:57	24.30		3:14	23.35	
11:58	24.24		3:30	23.30	
2:00:30	24.13		3:49	23.25	
2:02:30	24.13		4:01	23.22	
2:05	23.81		4:18	23.19	
2:06:30	23.77		4:34	23.18	

In applying the Theis formula to the data given in Table 14, the coefficient of transmissibility was found to be 1,970. The coefficient of permeability is then equal to 1,970 divided by 28 (thickness of saturated water-bearing material), or 70. It is not known whether this low value for the coefficient of permeability is truly representative of the material, or whether this value and the low specific capacity may be attributed at least in part to the inability of the well to let the water in at a higher rate.

Pumping tests at Concordia Prisoner of War Camp.—Pumping tests were made on wells 253 and 254 (Prison Camp wells 1 and 2) which were drilled by the Layne-Western Company in the SE¼ NW¼ sec. 22, T. 5 S., R. 3 W. Well 253 is 500 feet north and 500 feet west of the center of the section; well 254 is 500 feet north and 1,000 feet west of the center of the section or 500 feet west of well 253. Both wells are finished with 18-inch concrete screens and are gravel packed. Well 253 is 95 feet deep and well 254 is 93 feet deep. During the tests the wells were equipped with turbine pumps driven by gasoline engines. They were to be equipped later with electric motors.

Well 253 was pumped on March 20 and 21, 1943, at a rate increasing from 200 gallons a minute at the beginning of the test to 560 gallons a minute at the end of the pumping period. The average pumping rate was about 400 gallons a minute. At the end of the pumping period the drawdown was 3.18 feet, and the specific capacity was 176 gallons a minute per foot of drawdown. The water-level measurements made during and following the pumping period are given in Table 15.

In applying the Theis formula to the data given in Table 15, the coefficient of transmissibility was found to be 158,000. The coefficient of permeability is then equal to 158,000 divided by 60 (thickness of saturated water-bearing material), or 2,600.

Well 254 was pumped on March 5 and 6, 1943, at a rate increasing from 156 gallons a minute at the beginning of the test to 548 gallons a minute at the end of the pumping period. The average pumping rate was about 350 gallons a minute. At the end of the pumping period the drawdown was 3.95 feet, and the specific capacity was 137 gallons a minute per foot of drawdown. The water-level measurements made during and following the pumping period are given in Table 16.

TABLE 15.—*Water-level measurements in well 253 at Concordia Prisoner of War Camp during the pumping test on March 20 and 21, 1943*

Date, 1943	Time	Discharge, gallons per minute	Water level, feet above sea level	Drawdown,† feet	Remarks
March 20..	9:30 a. m.	200	1337.49	0.00	Pumping started
	10:30 a. m.	200	1336.57	0.92	
	11:30 a. m.	200	1336.57	0.92	
	12:30 p. m.	250	1336.05	1.44	
	1:45 p. m.	250	1336.05	1.44	
	2:45 p. m.	400	1335.40	2.09	
	3:30 p. m.	400	1335.33	2.16	
	4:40 p. m.	402	1335.32	2.17	
	5:45 p. m.	402	1335.32	2.17	
	6:40 p. m.	412	1335.29	2.20	
	7:30 p. m.	412	1335.29	2.20	
	8:30 p. m.	412	1335.29	2.20	
	9:30 p. m.	412	1335.25	2.24	
	10:30 p. m.	412	1335.25	2.24	
	11:45 p. m.	412	1335.23	2.26	
March 21..	12:45 a. m.	480	1334.90	2.59	
	1:45 a. m.	480	1334.88	2.61	
	2:30 a. m.	477	1334.88	2.61	
	3:30 a. m.	477	1334.86	2.63	
	4:30 a. m.	480	1334.83	2.66	
	5:30 a. m.	480	1334.83	2.66	
	6:30 a. m.	560	1334.39	3.10	
	7:25 a. m.	563	1334.31	3.18	
	8:40 a. m.	560	1334.31	3.18	
	9:30 a. m.	560	1334.31	3.18	Pumping stopped
	9:30 a. m.	....	1334.31	3.18	
	9:40 a. m.	....	1336.82	.67	
	9:50 a. m.	....	1336.90	.59	
	10:00 a. m.	....	1336.98	.51	
	10:10 a. m.	....	1337.06	.43	
	10:20 a. m.	....	1337.10	.39	
	10:30 a. m.	....	1337.15	.34	
	11:35 a. m.	....	1337.25	.24	
	1:50 p. m.	....	1337.35	.14	
	6:00 p. m.	....	1337.45	.04	

† No drawdown was apparent in Well 2 during this test.

TABLE 16.—*Water-level measurements in well 254 at Concordia Prisoner of War Camp during the pumping test on March 5 and 6, 1943*

Date, 1943	Time	Discharge, gallons per minute	Water level, feet above sea level	Drawdown, feet	Remarks
March 5	1:30 p. m.	156	1337.45	....	Pumping started
	2:30 p. m.	156	1336.53	0.92	
	3:30 p. m.	156	1336.60	0.85	
	4:30 p. m.	210	1336.20	1.25	
	5:30 p. m.	227	1336.00	1.45	
	6:30 p. m.	235	1336.00	1.45	
	7:30 p. m.	277	1335.7	1.75	
	8:40 p. m.	277	1335.7	1.75	
	9:45 p. m.	275	1335.6	1.85	
	10:35 p. m.	276	1335.6	1.85	
	11:30 p. m.	238	1335.8	1.65	
March 6	12:40 a. m.	305	1335.6	1.75	
	1:35 a. m.	350	1335.3	2.15	
	2:30 a. m.	339	1335.2	2.25	
	3:40 a. m.	293	1335.5	1.95	
	4:30 a. m.	412	1334.7	2.75	
	5:30 a. m.	448	1334.4	3.05	
	6:30 a. m.	433	1334.4	3.05	
	7:30 a. m.	448	1334.5	2.95	
	8:40 a. m.	448	1334.2	3.25	
	9:45 a. m.	536	1333.7	3.75	
	10:45 a. m.	536	1333.6	3.85	
	11:40 a. m.	548	1333.5	3.95	
	12:35 p. m.	548	1333.5	3.95	
	2:00 p. m.	548	1333.5	3.95	Pumping stopped
	2:00 p. m.	....	1333.5	3.95	
	2:10 p. m.	....	1336.76	0.69	
	2:20 p. m.	....	1336.79	0.66	
	2:30 p. m.	....	1336.88	0.57	
	2:40 p. m.	....	1336.94	0.51	
	2:50 p. m.	....	1336.95	0.50	
	3:00 p. m.	....	1337.01	0.44	
	4:00 p. m.	....	1337.08	0.37	
	5:00 p. m.	....	1337.16	0.29	
	9:10 p. m.	....	1337.30	0.15	
March 7	11:10 a. m.	....	1337.40	0.05	

The ratio t/t′ (time since pumping started, in minutes, divided by the time since pumping stopped, in minutes) is plotted against the drawdown in Figure 6. In applying the Theis formula to the data

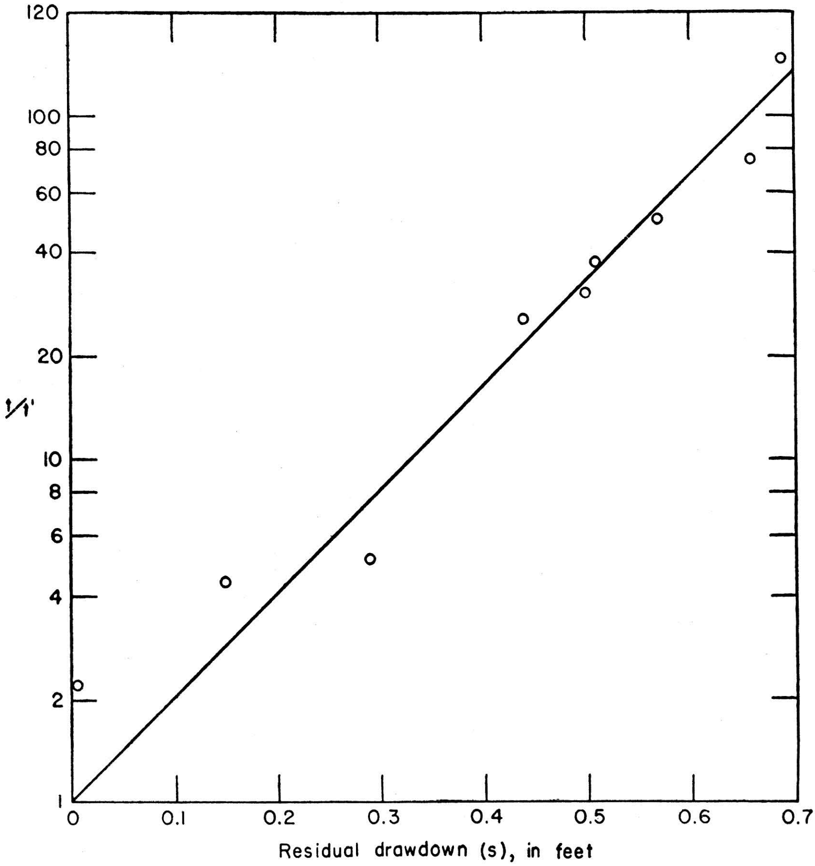


FIG. 6. Pumping test on well 254 at the Concordia Prisoner of War Camp obtained by plotting s against t/t′.

shown in Figure 6 it is found that when t/t′ = 10, s = 0.33, and q = 350.

$$T = \frac{264 \times 350 \times 1}{.33} = 280{,}000$$

The coefficient of permeability is then equal to 280,000 divided by 60 (thickness of saturated water-bearing material), or 4,600.

Summary.—The coefficients of permeability obtained by the four pumping tests are: Wright well, 9,500; Ward well, 70; Concordia Prisoner of War Camp, well 253, 2,600; Concordia Prisoner of War Camp, well 254, 4,600.

The average coefficient of permeability obtained in the four tests is 4,190. The average coefficient of permeability obtained by omitting the Ward well is 5,560. These values compare favorably with the coefficient of permeability (4,900) obtained by averaging the values from laboratory tests on drill cuttings. In submitting the results of the above permeability tests it is not intended to infer that the results are exact but pending additional permeability tests they do show that the water-bearing material in the Republican River Valley near Norway and Concordia is very permeable.

The laboratory tests were made on samples of sand and gravel collected from test holes put down by a hydraulic-rotary drill and hence cannot be expected to give exact results. The Ward pumping test was made on a well that was poorly constructed, was situated at the edge of the alluvium, and was outside the most permeable material. The pumping tests of the wells at the Concordia Prisoner of War Camp were not made by the Geological Survey and do not follow the standard procedure of the Geological Survey for making a pumping test in that the wells were pumped at a variable rate and hence the data thus obtained do not conform to the requirements of the Theis formula. The Theis formula was applied to the data from these wells, however, as it is believed that although the coefficients of permeability thus obtained are not exact they are probably of the right order of magnitude and give additional evidence concerning the permeability of the water-bearing materials.

Yield of wells.—Records of 143 wells in the Republican River Valley are given in Table 22 and the locations of the wells are shown on Plate 1. Records of most of the wells were obtained for the preparation of the water-table contour map (Plate 8), and generally do not indicate the quantity of water available. However, some of the wells are or have been irrigation or municipal wells that are equipped with large pumps and hence give a better idea of the potential yield of the alluvium. The yield of two wells (245 and 260) was measured in August 1942. The municipal well at Scandia (173) was tested by the Layne-Western Company in February 1932. The municipal well at Republic (40) is equipped with a pump having a capacity of 120 gallons a minute. The drawdown in well 40 was measured by Jacob King, water superintendent. The reported yields of six other irrigation wells were also obtained. Wells 253, 254, 255, and 256 at the Concordia Prisoner of War Camp were tested by the Layne-Western Company according to specifications outlined by the engineering firm of Howard, Tammen, Needles, and Bergendorf. The yields of the 14 wells are given in Table 17.

TABLE 17.—*Yield, drawdown, and specific capacity of wells in the Republican River Valley in Cloud and Republic Counties, Kansas*

No. of well on Plate 1	Yield, gallons per minute		Draw-down, feet	Specific capacity[1]	Remarks
	Reported	Measured			
40	120	....	3.0	40	Municipal well
50	200	....	....	....	Unused irrigation well
52	150	....	....	....	Irrigation well
64	200	....	....	....	ditto
67	100	....	....	....	Unused irrigation well
173	....	220	7.3	30	Municipal well
230	1,200	....	....	....	Unused irrigation well
245	....	730	12.4	59	Irrigation well
253	....	560	3.2	176	Prisoner of War Camp well
253[2]	....	500	2.6	192	ditto
254	....	548	4.9	137	ditto
255	....	350	2.5	140	ditto
256	....	350	2.0	175	ditto
260	....	47	24.3	1.9	Irrigation well
276	500	....	....	....	ditto

1. The specific capacity of a well is the discharge in gallons a minute per foot of drawdown.
2. Test made after the lower 17 feet of the well was plugged with concrete in an attempt to eliminate salty water.

Two tests were made on well 253 at the Concordia Prisoner of War Camp. One test was made on March 20 and 21, 1943, when the well was first completed at which time the well had a specific capacity of 176 gallons per minute per foot. The water was found to be too salty for use and the lower 17 feet of the well was plugged with concrete in an attempt to eliminate the salty water near the bottom of the alluvium. It was then tested on May 14, 1943, when the specific capacity was 192 gallons per minute per foot. The increase in specific capacity may have been caused by an increase in the yield of the well resulting from better development of the well by pumping or it may represent the limit of accuracy of the discharge measurements.

The information on the irrigation and municipal wells and the logs of the test holes indicate that, in general, wells located between the Nebraska State line and Scandia are likely to yield 200 gallons or less per minute. The alluvium in this area is not sufficiently thick or permeable to furnish adequate supplies of water for satisfactory irrigation wells. The one exception in this area is the municipal well at the City of Republic which yields 120 gallons a minute with a drawdown of only 3 feet.

Between Scandia and Concordia the records of wells and test holes indicate that yields of more than 1,000 gallons per minute might be expected from wells tapping the deeper parts of the old channel. Wells 254 and 262 are situated at the edge of the alluvium where the water-bearing materials are not sufficiently permeable and thick to supply large quantities of water to irrigation wells.

Underflow.—The rate at which ground water is moving down the Republican River Valley, in gallons per day, can be computed by Darcy's law: Q = PIA, in which P is the coefficient of permeability in gallons per day per square foot, I is the hydraulic gradient in feet per mile, and A is the cross-sectional area of the valley below the water table, expressed as the product of the width in miles and the thickness in feet. The effective downstream component of the hydraulic gradient as determined from the water-table contour map is about 5 feet per mile. The cross-sectional area of the valley can be determined from the cross sections given in Plate 5. The coefficient of permeability is the most uncertain factor in computing underflow and is the most difficult to determine. The average coefficients of permeability as determined in the laboratory for the cross sections at Scandia (J-J′) and Norway (K-K′) have been used in computing the underflow at those points. A coefficient of permeability of 4,500 gallons per day per square foot has been used to compute the underflow at the Concordia cross section (L-L′). It is the approximate average of the average coefficient obtained by the four pumping tests (4,190) and the average coefficient as determined in the laboratory (4,900). The underflow of the Republi-

TABLE 18.—*Computation of underflow in the Republican River Valley near Scandia, Norway, and Concordia*

CROSS SECTION, Plate 5	Width, miles	Average thickness of saturated material, feet	Hydraulic gradient, feet per mile	Assumed coefficient of permeability, gallons per day per sq. ft.	Underflow, gallons per day
Scandia (J-J′).....	1.4	28	5	1,100	210,000
Norway (K-K′)....	3.1	42	5	1,400	900,000
Concordia (L-L′)...	3.6	57	5	4,500	4,600,000

can River Valley near Scandia, Norway, and Concordia is given in Table 18.

Salinity.—Data collected on the domestic, municipal, and irrigation wells that receive their water supply from the alluvium in the Republican River Valley in Cloud and Republic Counties indicate that the chloride content of the water is very low. The chloride content of samples of water from 8 wells ranged from 18 parts to 118 parts per million. Information obtained during the spring of 1943, however, showed that for certain areas in the Republican River Valley the ground water was too salty for most purposes. Two wells which were constructed near the Cen. sec. 22, T. 5 S., R. 3 W. by the Layne-Western Company for the Prisoner of War Camp near Concordia yielded water having a chloride content of 6,835 parts per million. Subsequent test drilling by the Layne-Western Company for the prison camp and by the Geological Survey showed that there is quite an extensive area where the water in the alluvium is contaminated by salt water.

In the outcrop area of the Dakota formation in northern Cloud County and southeastern Republic County the water is fresh. However, to the northwest in Republic and Jewell Counties, where the Dakota formation is overlain by several hundred feet of other Cretaceous rocks, the water in the Dakota formation is too salty for domestic use. The alluvium in the valley near Concordia has a known maximum thickness of about 120 feet, and the deepest part of the channel seemingly has been cut into a salty lens of the Dakota formation and as the water in the Dakota is under a greater head than the water in the overlying alluvium the salty water is moving upward into the alluvium. At the same time the alluvium is also receiving fresh water along its edges from shallower beds of the Dakota formation and from rainfall infiltration. The resultant salinity of the water varies with depth and its position in the alluvium. It depends on the presence and extent of clay lenses in the alluvium and on the relative amounts of water derived from the various sources.

Thirteen test holes were drilled by the Layne-Western Company and 20 by the Geological Survey in the vicinity of Concordia to determine the character of the alluvium, the salinity of the water, and the areal extent of the salty water. The locations of the test holes and the salinity of the samples of water that were collected are given in Table 19 and are shown on Plate 12. Test holes 1A to 13A were drilled by the Layne-Western Company, and 85 to 112 were drilled by the Geological Survey.

TABLE 19.—*Locations of test holes in the Republican River Valley in Cloud County, Kansas, and the chloride content of the water in parts per million*

(Test holes 1A to 13A were drilled by the Layne-Western Company for the Prisoner of War Camp. Test holes 85 to 112 were drilled by the State and Federal Geological Surveys).

Test hole No.	LOCATION	Depth, feet	Chloride content, p. p. m.
1 A	SW cor. NW sec. 22, T. 5 S., R. 3 W.	35– 45	167
		40– 50	388
		50– 60	1,160
		77– 87	13,750
2 A	Near cen. SE sec. 21, T. 5 S., R. 3 W.	37– 47	48
		53– 63	89
		74– 84	2,880
3 A	SE NE NW sec. 28, T. 5 S., R. 3 W.	35– 45	26
		56– 66	74
		76– 86	630
4 A	SW NW NW sec. 28, T. 5 S., R. 3 W.	40– 50	27
5 A	SE NW NW sec. 28, T. 5 S., R. 3 W.	63– 73	79
6 A	NE SE NW sec. 22, T. 5 S., R. 3 W.	25– 35	230
		61– 71	2,335
7 A	SW NW SW sec. 21, T. 5 S., R. 3 W.	40– 50	59
		61– 71	880
8 A	NW SW SE sec. 22, T. 5 S., R. 3 W.	25– 35	331
		55– 65	6,350
9 A	SW cor. NW NW sec. 29, T. 5 S., R. 3 W.	51– 61	45
10 A	SE NW NW sec. 28, T. 5 S., R. 3 W.	41– 51	33
11 A	SW cor. sec. 21, T. 5 S., R. 3 W.	50– 60	34
12 A	NW cor. SW sec. 21, T. 5 S., R. 3 W.	35– 45	25
		68– 78	168
13 A	SE SW SW sec. 15, T. 5 S., R. 3 W.	57– 67	55
85	NE cor. sec. 34, T. 5 S., R. 1 W.	55– 60	212
		95–100	450
86	SE SE NE sec. 34, T. 5 S., R. 1 W.	78–80.5	(*a*)
87	NW cor. SE sec. 19, T. 5 S., R. 2 W.	66– 71	2,450
88	SE cor. NE sec. 26, T. 5 S., R. 2 W.	75– 80	210
		94– 99	3,450
89	NE cor. SE sec. 29, T. 5 S., R. 2 W.	37– 42	23
		60– 65	1,300
		67– 72	1,340
		75– 80	2,650

TABLE 19.—*Concluded*

Test hole No.	LOCATION	Depth, feet	Chloride content, p. p. m.
93	NW cor. sec. 19, T. 5 S., R. 3 W.	85– 90 116–121 122–127	19 850 1,900
94	SW cor. NW NW sec. 20, T. 5 S., R. 3 W.	65– 70 75– 80 102–107	58 413 3,760
95	SE cor. sec. 19, T. 5 S., R. 3 W.	47– 52 62– 67	21 26
97	NW cor. NW sec. 21, T. 5 S., R. 3 W.	45– 50 75– 80 110–115	35 380 10,680
100	SW NE NW sec. 28, T. 5 S., R. 3 W. (680 feet east of Concordia Prison Camp well 3)	31– 36 65– 70 98–103	21 86 4,360
101	SE NW NW sec. 28, T. 5 S., R. 3 W. (380 feet east of Concordia Prison Camp well 3)	35– 42 47– 52 69– 74 102–107	20 30 228 5,040
102	SE NW NW sec. 28, T. 5 S., R. 3 W. (100 feet south of Concordia Prison Camp well 3)	15– 20 35– 40 46– 51 74– 76	14 22 27 1,400
103	NW NW NW sec. 28, T. 5 S., R. 3 W.	45– 50	22
108	SW NE NE sec. 29, T. 5 S., R. 3 W.	89– 94	3,500
109	SW SE sec. 33, T. 4 S., R. 4 W.	119–124	(*a*)
110	NW cor. NE sec. 14, T. 5 S., R. 4 W.	51– 56	47
111	NW cor. sec. 13, T. 5 S., R. 4 W.	34– 39 39– 44	25 43
112	SE cor. sec. 15, T. 5 S., R. 4 W.	60– 65 112–117	450 1,240

a. Water not salty to taste.

The area of the greatest contamination as determined by the test holes is in secs. 21 and 22, T. 5 S., R. 3 W. A sample of water from depths of 77 to 87 feet in test hole 1A near the center of the west boundary of sec. 22 had 13,750 parts per million of chloride. The chloride content of the water from 35 to 45 feet was 167 parts per million. The highest chloride concentration occurs at the base of the alluvium and in the deepest part of the bedrock channel and it decreases with height above the base of the alluvium unless altered by impervious clay lenses.

The chloride concentration of the water in the alluvium decreases both upstream and downstream from secs. 21 and 22. The upstream boundary of the unpotable water is about at the Cloud-Republic County line. The chloride content of the water decreases from 3,760 parts per million in test hole 94 to 1,900 in test hole 93 and 1,240 in test hole 112. The Dakota formation dips below the impervious Graneros shale near the county line and from there to the Nebraska line there have been no reports of salty well water from the alluvium.

The logs of the wells and test holes in sec. 22, T. 5 S., R. 3 W. indicate no impervious clay lenses between the water table and the top of the Dakota formation. All other test holes penetrated at least one clay lens and it was below the bottom clay lens that the waters of the greatest salinity occurred. Well 255 at the Prisoner of War Camp was located at the site of test hole 10A. It was drilled down to a clay lens which apparently extends over a large area. The well yields water having a chloride content of less than 100 parts per million. Test hole 102, which is 100 feet south of this well, yielded water from above the clay lens that contained only 27 parts per million of chloride, but the water below the clay lens contained 1,400 parts. Test hole 101, which is about 400 feet from well 3, yielded water from below the clay lens that contained 5,040 parts per million of chloride. If the clay lens overlying the salty water in the vicinity of wells 3 and 4 is fairly continuous the water from these wells may remain fresh. Lenses of clay in alluvium are not generally continuous over a large area. If the latter conditions prevail near the wells it is likely that continuous pumping will result in the wells becoming contaminated.

Test hole 88 is less than one-quarter mile from a well that is used for irrigation. The water at the bottom of test hole 88 contains 3,450 parts per million of chloride. The chloride content was only 210 parts per million at depths of 75 to 80 feet. The water in the irrigation well is fresh and for intermittent pumping for irrigation it will probably remain fresh.

Well 253 at the Prisoner of War Camp was drilled by the Layne-Western Company in the SE¼ NW¼ sec. 22, T. 5 S., R. 3 W. It has the same location as test hole 4B whose log is given in the back of this report. The salinity of the water in this well is given in Table 20.

TABLE 20.—*Relation of the salinity of the water to depth in well 253 at the Prisoner of War Camp*

Depth, feet	Chloride content, parts per million
19–29	128
35–45	370
45–55	470
55–65	1,525
65–75	4,970
68–78	6,835

As shown in Table 20 the water at the bottom of the hole (78 feet) had a chloride content of 6,835 parts per million. The mixture of waters pumped from the well had a chloride content of 4,300 parts per million which was too high for any ordinary use. At a depth of 60 feet the chloride content was about 1,500 parts per million and a mixture of the waters above this depth probably would contain about 600 parts per million of chloride which would be about on the borderline as a satisfactory water supply. Upon the recommendation of the architect-engineer, the lower 17 feet of the well was plugged with concrete. A pumping test was then made on May 14, 1943, to determine the effect of the concrete plug on the salinity of the water. The test was started at 7:15 a. m. and terminated at 5:10 p. m. The rate of pumping, drawdown, and the chloride content of the water are given in Table 21.

The pumping test was made at a variable pumping rate to determine if there were a relation between the rate of pumping and the salinity of the water. The pumping rate was only 114 gallons a

TABLE 21.—*Discharge, drawdown, and chloride content of the water during pumping test on well 253 on May 14, 1943*

TIME	Discharge, gallons per minute	Drawdown, feet	Chloride content, parts per million
7:15 a. m.	114	0.5	1,100
8:15	148	.5	1,120
9:30	200	.5	1,180
11:00	250	1.0	1,220
12:00 noon	400	1.5	1,300
1:20 p. m.	400	2.0	....
2:30	500	2.6	1,320
3:30	88	.5	....
4:05	88	.5	....
5:10	88	.4	1,420

minute at the beginning and was gradually increased in about 7 hours to 500 gallons a minute. The chloride content of the water increased from 1,100 to 1,320 parts per million. The pumping rate was then reduced to 88 gallons a minute to see whether the chloride content of the water would also lower. The chloride content of the water rose 100 parts per million from 2:30 p. m. to 5:10 p. m. Under conditions of continuous heavy pumping the salinity of the water probably would continue to rise until it approached the salinity of the water obtained before the well was plugged. The opinion is based on the assumption that all water within the cone of depression is moving toward the well and must escape through the well. For a very small drawdown, however, the energy expended by pumping would not be sufficient to raise the denser water at the bottom of the formation to the top of the concrete plug.

Conclusions.—Records of the wells and test drilling indicate that the saturated alluvium in the Republican Valley between the Nebraska State line and Scandia, Kansas, is too thin for the development of large quantities of ground water. Between Scandia and Concordia the alluvium is as much as 100 feet thick and contains thick saturated beds of coarse gravel and sand that are very permeable. The water table is generally within 20 feet of the surface. Properly constructed wells in favorable areas in this part of the valley should yield 1,000 gallons a minute or more with nominal drawdown.

It has been estimated that the amount of recharge from local precipitation is appreciable, and is believed to be the principal source of water that supplies existing wells in the valley. The amount of underflow has been estimated to be about 210,000 gallons per day at Scandia, about 900,000 at Norway, and about 4,600,000 gallons at Concordia. The amount of water derived as underflow thus may be regarded as negligible compared to that which is available from other sources. Much of the water computed as underflow at Concordia comes in from the sides of the valley rather than water moving down the river valley on a subterranean stream from points above.

Under existing conditions the aggregate amount of recharge from the several sources is approximately balanced by the total ground-water discharge, which takes place by evaporation and transpiration, effluent seepage into the river, underflow from the area, and by pumping from the existing wells. Because ground-water recharge and discharge are now approximately equal, it follows that any additional large quantity of water that might be pumped from wells for irrigation would tend to upset this balance and would have to be offset in like amount by (1) reduction in the amount of existing natural ground-water discharge, (2) increase in the present rate of recharge from local precipitation or underflow, (3) establishment of conditions favorable to more ground-water recharge from the river, or (4) a combination of part or all of these factors. The first three factors named will be taken up in the order named.

It has been estimated that ground-water discharge in the valley occurs largely through transpiration and evaporation. The water is transpired by trees that line the river and occupy smaller areas in the valley and by crops raised by "dry farming." As the greater part of the valley is being cultivated, the addition of new irrigation wells to the valley will not decrease total evaporation and transpiration; on the contrary, the total evaporation and transpiration will be increased, for the primary purpose of irrigation is to make available more water for crops.

Lowering of the water table by additional pumping from wells in swampy areas where the water table now stands close to the surface might increase somewhat the recharge from precipitation, for in such areas some recharge now is rejected because of a full ground-water reservoir. Such additional recharge would be small, however, because such areas represent only a small part of the entire valley.

At present the increment of ground water into the area from underflow and by recharge from precipitation seems to be nearly all discharged by evaporation and transpiration, effluent seepage, and by pumping of existing wells. The present rate of pumpage will not be decreased. If it is increased the consumption of ground water by evaporation and transpiration may be reduced materially, but the reduction in the amount of transpiration by crops from the zone of saturation must be more than offset by the amount of pumping if irrigation is to be beneficial. It seems, therefore, that large ground-water supplies for irrigation must be derived largely by recharge from the river. Conditions seem to be favorable for influent seepage, and the amount of influent seepage that might be made available seems to depend more on the amount of stream flow available at times than on the infiltration capacity of the river bed. In considering the entire valley the amount of induced influent seepage could not exceed in amount the average stream flow, a fact that must be recognized in the ultimate irrigation development of the valley. In any given area of the valley to be developed, advantage can be taken of stream flow that enters from upstream areas. Any large ground-water developments in Nebraska, however, will affect the amount of stream flow entering Kansas and will accordingly affect the potential ground-water supply in this part of the valley.

If, in the future, large ground-water supplies are to be developed for industrial use rather than for irrigation, the relative importance of the several sources of recharge and reclaimed discharge would differ somewhat. Reduction of ground-water discharge through transpiration and evaporation in the vicinity of pumped wells would then be more effective; hence the proportion of the supply that would have to come from the river would be smaller. Moreover, much of the water pumped for industrial use generally is discharged again into the river, thus making the water available again as a potential source of influent seepage in downstream areas.

Additional factors would also be presented if irrigation from wells were to be supplemented by irrigation from canals conveying river water from upstream impounding and diversion works. This might reduce the amount of stream flow available as influent seepage to irrigation wells, but in turn, seepage from the canals and tracts irrigated by river water would provide additional ground water recharge.

It is conceivable that heavy pumping from wells might dry up limited stretches of the river during periods of low stream flow. The vast quantity of ground water held in storage is available during such periods of heavy pumping, however, and would be replenished periodically by recharge from precipitation and from the river during periods of normal or greater stream flow. During the non-pumping season such recharge would be especially effective in replenishing the ground-water reservoir. Assuming a specific yield of 18 percent, it is calculated that a column of alluvium 1 mile square and 1 foot thick would contain 37,100,000 gallons of free ground water in storage. Between Norway and Concordia where the thickness of the alluvium averages about 50 feet the total quantity of water in storage, if the specific yield were 18 percent, would amount to about 2,000,000,000 gallons per square mile. Obviously not all this water is recoverable by wells, but the amount that is recoverable is believed to be more than ample as a reserve supply between periods of abundant precipitation and stream flow. It is believed that withdrawals from storage would be more than offset by recharge so that the net lowering of water levels would be very slight. Thus, it appears that between Scandia and Concordia, available ground water in the Republican Valley is adequate for the development of irrigation supplies from wells.

Between Scandia and the Cloud-Republic County line the quality of the water is believed to be suitable for irrigation. In Cloud County the chloride content of some of the ground water in the Republican River Valley is too high to be used for irrigation. The water of highest salinity occurs below a clay lens, hence it may be possible to develop satisfactory irrigation wells by terminating them above the clay lens. The performance of the wells at the Concordia Prisoner of War Camp will serve as an excellent index of the possibility of developing irrigation wells in that area. In any case the construction of an irrigation well should always be preceded by one or more test wells to determine the quality of the water.

RECORDS OF TYPICAL WELLS

Information pertaining to water wells in Republic County and northern Cloud County is tabulated in Table 22. The numbers in the first column correspond to the well numbers on the map (Pl. 1) and in the table of analyses (Table 6). The numbers in parentheses in the first column indicate wells from which samples of water were taken for analysis. The wells are listed in order by townships from north to south and by ranges from east to west. Within a township the wells are listed in the order of the sections. The measured depths of water levels are given to the nearest 0.01 foot, whereas reported depths are given only to the nearest foot and are subject to error.

TABLE 22.—*Records of wells in Republic and Cloud Counties, Kansas*

No. on pls. 1 and 2 (1)	LOCATION	Owner or tenant	Type of well (2)	Depth of well (feet) (3)	Diameter of well (in.)	Type of casing (4)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic source	Method of lift (5)	Use of water (6)	Measuring point: Description	Measuring point: Height above land surface (feet)	Measuring point: Height above mean sea level (feet)	Depth to water level below measuring point (feet) (7)	Date of measurement 1942	Remarks (Yield given in gallons a minute; drawdown in feet)
	T. 1 S., R. 1 W.															
1	SW SE sec. 7	J. Baker	Du	26.1	40	R	Limestone and (clay) shale	Greenhorn	Cy,H	N	Top of platform	1.3	....	23.57	July 11	On west side of gully
2	NE NE sec. 8	M. A. Hudson	Du	31.5	36	R	Shale	Carlile	Cy,H	N	do	1.0	....	18.90	July 11	About 40 feet west of road
3	NW NE sec. 9	Elmer Hardenburger	Du	18.5	36	R	Limestone and shale	Greenhorn	Cy,W	S	do	.9	....	8.55	July 11	
(4)	NW NE sec. 11	G. W. Jotter	Du	40.5	42	R	Shale	Carlile	Cy,W	N	do	1.2	....	9.80	July 11	
(5)	SW SW sec. 15	City of Narka	Dr	253	10	I	Sandstone	Dakota	T,E	P	....	....	....	178	....	Depth to water level reported by water superintendent
6	SW SE sec. 19	Grace E. West	Du	45.1	42	R	Gravel and sand	Belleville	Cy,W	S	Top of concrete block, north side	1.4	....	36.89	July 14	
7	SW NW sec. 25	Mary T. Brosh	Du	52.3	36	R	Shale	Carlile	Cy,H	D	Top of platform	1.6	....	18.20	July 11	
(8)	NW NW sec. 27	Leigh Feil	Du	11.8	48	R	Limestone and shale	Greenhorn	Cy,W	S	Top of platform	1.0	....	5.48	July 14	
(9)	NE NE sec. 28	Leigh Feil	Dr	244.0	5	GI	Sandstone	Dakota	Cy,W	D,S	Top of casing	—4.6	....	151.32	July 14	Reported depth, 272 feet
10	SE SW sec. 33	W. H. Thomas	Du	39.1	36	R	Limestone and shale	Greenhorn	Cy,W	D	Top of casing, northwest side	.0	....	31.27	July 15	Deep wells south of road are salty
	T. 1 S., R. 2 W.															
11	SW NW sec. 4	C. C. Dake	Du	25.5	48	B	Gravel and sand	Belleville	N	N	Top of platform	.1	1,538.62	23.60	June 11	
12	SE NE sec. 5	C. C. Dake	Dr	78	5	I	do	do	Cy,W	D,S	....	....	1,547.55	30	....	
13	SW SW sec. 5	School	Dr	54	5	I	do	do	Cy,H	Sc	Top of casing	.7	1,558.00	30.29	June 11	
14	NE NW sec. 6	A. Aupperle	Dr	90.5	6	GI	do	do	Cy,W	D,S	Top of casing, north side	—4.0	1,597.77	87.21	June 11	
15	SE SE sec. 15	Anton Rytch	Du	13.7	48	R	Clay	Carlile	Cy,H	N	Top of rock curb	1.7	1,539.35	7.11	July 14	

16	NE NE sec. 21	Ed Thomas	Dr	235	5	GI	Sandstone	Dakota	Cy,W	S				165		
17	SE NE sec. 23	W. A. Carpenter	Dr	212	6	I	do.	do.	Cy,H	S				45		Too salty for domestic use
18	SE SE sec. 23	James Wilson	Du	52.9			Gravel and sand	Belleville	Cy,W	N	Top of casing	.0	1,612.40	37.95	July 14	About 40 feet from southeast corner of section
19	SW SE sec. 33	City of Munden	Du	62	72	B	do.	do.	T,E	P						
	T. 1 S., R. 3 W.															
20	NW NW sec. 2	Chester Sawyer	Du	127.0	36	B	do.	do.	N	N					June 11	Well was dry
(21)	NW SW sec. 2	City of Belleville	Dr	215	18	C	do.	do.	T, E	P			1,624.00	120		North well
(22)	NW SW sec. 2.0	do.	Dr	215	18	C	do.	do.	T,E	P			1,618.05	120		Wells have yield of 425 g. p. m., drawdown 4.5 feet
(23)	SE SE sec. 4	Ralph M. Barnes	Dr	111.3	4	I	do.	do.	Cy,W	D,S	Top of casing	1.3	1,592.30	96.72	July 4	
24	SW SE sec. 8	James Wessel	Dr	143.2	6	GI	do.	do.	Cy,W	D.S	Top of board across pit	.3	1,650.21	142.87	June 18	
25	NW NW sec. 10	Federal Land Bank	Dr	124.5	4	I	do.	do.	Cy,H	D,S	Top of casing	.8	1,590.80	95.21	July 4	
(26)	SE SE sec. 10	Gravatt Estate	Dr	80.5	6	GI	do.	do.	Cy,W	D,S	do.	.7	1,594.97	78.46	June 11	
(27)	SW SW sec. 18	Marjorie Gray	Dr	171.0	4	I	do.	do.	Cy,W	D,S	do.	.3	1,668.04	157.20	June 5	
28	SW SW sec. 31	School	Dr	65.8	6	GI	do.	do.	Cy,H	Sc	do.	.5	1,654.93	53.47	May 30	
29	NE NE sec. 33	School	Dr	46.8	6	GI	do.	do.	Cy,H	Sc	do.	.8	1,603.76	34.96	June 11	
	T. 1 S., R. 4 W.															
(30)	NE NW sec. 4	Unknown	Dr	160.2	5½	GI	do.	do.	Cy,W	S	Top of platform	1.7	1,669.28	148.02	July 6	
31	NE NE sec. 12	——— Lasby	Dr	152.0	6	I	do.	do.	Cy	N	Top of casing	1.2	1,661.36		July 4	Well was dry
32	SE SE sec. 13	——— Whipple	Dr	170.0	6	GI	do.	do.	Cy	N	do.	.8	1,672.21	159.76	June 18	
(33)	SW SE sec. 17	School	Dr	54.7	8	GI	do.	do.	Cy,H	Sc	Top of platform	1.3	1,568.93	50.69	July 3	
34	SW NW sec. 20	James Persinger	B	52.0	6	T	do.	do.	Cy,W	N	Top of tile, north side	.5	1,563.55	48.90	July 3	
35	SE SW sec. 20	R. S. Price	B	39.4	6	T	do.	do.	Cy,H	N	Top of platform	2.0	1,550.43	35.52	July 3	
36	SW SW sec. 23	C. I. Banks	Dr	103.1	4	I	do.	do.	Cy	N	do.	.1	1,612.98	101.38	July 6	
37	SE NE sec. 26	Nathan Stafford	Dr	156.1	4	I	do.	do.	Cy	N	do.	1.1	1,672.53	154.90	July 6	
38	SW SE sec. 29	Frank Stover	Dr	54.2	6	I	do.	do.	Cy,H	N	Top of casing	1.5	1,574.14	53.91	July 1	

TABLE 22.—*Records of wells in Republic and Cloud Counties, Kansas—Continued*

No. on pls. 1 and 2 (1)	Location	Owner or tenant	Type of well (2)	Depth of well (feet) (3)	Diameter of well (in.)	Type of casing (4)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic source	Method of lift (5)	Use of water (6)	Measuring point: Description	Measuring point: Height above land surface (feet)	Measuring point: Height above mean sea level (feet)	Depth to water level below measuring point (feet) (7)	Date of measurement 1942	Remarks (Yield given in gallons a minute; drawdown in feet)
39	SE SE sec. 29	Charles Heater	B	54.5	......	......	Gravel and sand	Belleville	Cy,W	S	Bottom edge of pump base	.1	1,558.64	37.64	July 1	
(40)	SW NW sec. 31	City of Republic	Dr	63	18	C	do	Alluvium	T,E	P	Top edge of 1-inch hole beside pump	.8	1,510.55	36.06	Sept. 6	
41	NW SW sec. 31	A. V. H. McClure	Dn	19.6	1¼	I	do	do	N	N	Top of concrete cover	2.0	1,495.13	8.26	June 5	
42	SW SE sec. 31	G. A. Holton	Dr	54.5	6	GI	do	Belleville	Cy,W	D,S	Top of platform	0.3	1,522.92	52.51	July 1	
43	NE NE sec. 32	Charles Heater	Dr	69.5	......	......	do	do	Cy,W	D,S	do	.1	1,574.09	57.02	July 1	
44	NW NW sec. 34	Dora M. Albert	Dr	72.9	5½	I	do	do	Cy,W	N	do	.5	1,594.16	70.79	July 6	
(45)	SE NE sec. 34	Alex Davis	Dr	115.2	4	I	do	do	Cy,W	S	do	.6	1,632.54	112.89	July 6	
46	SW NW sec. 35	John McEwen	Dr	91.0	6	GI	do	do	N	N	do	.5	1,621.54	......	June 15	Well was dry
	T. 1 S., R. 5 W.															
47	NE NE sec. 5	Russell Hale	Dr	......	6	GI	Gravel and sand	Alluvium	Cy,H	D	Top of platform, south side	.6	1,558.77	42.86	May 27	
48	NE NW sec. 5	Mo. Pac. Railway	Dr	25.5	6	GI	do	do	Cy,W	S	Top of platform, south side	.1	1,534.45	17.22	May 27	
49	NW NW sec. 5	George Powell	B	31.2	6	GI	do	do	Cy,W	D,S	Top of platform, north side	.5	1,530.90	15.07	May 27	
50	SE NE sec. 5	Joe Gillilan	B	26.3	18	GI	do	do	N	N	Top edge of 2- by 12-inch board across pipe	.5	1,520.59	6.96	May 27	Formerly used for irrigation
51	NE NE sec. 6	E. W. Bjorling	B,Dn	......	1¼	I	do	do	Cy,H	S	Top edge of concrete curb	.7	1,526.52	11.54	May 27	
52	NE NE sec. 6	do	Du	20.8	36	B	do	do	C,T	I	Top of casing, north side	.0	1,518.40	7.51	May 27	
(53)	NW NW sec. 6	Carl Boylan	Dn	......	1½	I	do	do	Cy,H	D	Top of platform, south side	.4	1,516.02	5.49	May 27	
54	NE NE sec. 7	J. W. Singer	Dr	33.2	3	I	do	do	N	N	Top of casing	.2	1,508.28	2.24	June 23	

55	NE NW sec. 11	William Moeller	Dr	80	6	GI	do.	Belleville	Cy,W	D,S			1,614.08	74	May 29	
56	SW SE sec. 11	F. W. Willis	Dr	75	6	GI	do.	do.	Cy,W	D,S			1,593.71	69	May 28	
57	NW SW sec. 13	Walter Fischer	Dr	75	6	GI	do.	do.	Cy,W	D,S			1,593.78	66	May 28	
(58)	SW SE sec. 14	C. W. Duval	B	60.7	6	GI	do.	do.	Cy,W	D,S	Top of platform, north side	1.6	1,544.25	44.97	May 28	
59	NE NE sec. 16	James Hurley	Du	16.0	24	B	do.	Alluvium	Cy,W	S	Bottom of base of pump	1.0	1,503.26	10.97	June 6	
60	NW NW sec. 16	George Powell	Dn	6.1	1¼	I	do.	do.	Cy,W	S	Top of concrete cover	.8	1,504.07	4.97	June 5	
61	NW SW sec. 16	H. C. Aurund	Dn	10.1	1¼	I	do.	do.	Cy,W	S	do.	.3	1,501.12	4.81	June 5	
62	SW NW sec. 17	George Powell	Dr	62.8	8		do.	Belleville	Cy,W	D,S	do.	.2	1,586.93	45.60	June 5	
(63)	NW NW sec 18	Gertrude Sweet	Dr	74.7	8	T	do.	do.	Cy,W	D,S	Top of platform	0.8		62.45	July 8	
64	SW NW sec. 21	Eugene Aurnd	Du	25.9	72	C	do.	Alluvium	C,T	I	Top of casing, south side	1.6	1,512.40	13.80	June 5	
65	SE NE sec 21	H. C. Aurnd	Dn	19.6	1¼	I	do.	do.	N	N	Top of concrete cover	2.0	1,495.13	8.26	June 5	
66	SW SW sec. 22	C. Tallant	B	25.7	5	GI	do.	do.	Cy,W	D,S	Bottom of pump base	2.1	1,502.87	17.61	June 6	
67	SW SE sec. 23	Dan Rickel	Du	16.1	18	GI	do.	do.	Cy,W	S	Top of 3- by 12-inch board across casing	1.0	1,490.00	6.02	May 29	Formerly used for irrigation
68	SW SE sec. 25	Burt Shenaman	Dr	20.4	4	GI	do.	do.	Cy,H	S	Top of casing	.3	1,502.45	12.14	May 29	
69	NE NE sec. 26	C. B. Sims	Dr	27.6	6	GI	do.	do.	Cy,W	S	Bottom of pump base	1.1	1,497.33	13.06	May 28	
70	SW NW sec. 27	L. V. Garmen	B	43.1	6	GI	do.	do.	Cy,H	D	Top of casing	.5	1,502.39	22.69	June 6	
71	SW SW sec. 27	do.	B	29.6	6	GI	do.	do.	N	N	do.	1.2	1,502.07	23.58	June 6	
72	NE NE sec. 28	Kelley Estate	B	33.0	6	GI	do.	do.	Cy,E	S	Top of board above casing	1.5	1,502.85	26.00	June 6	
73	SE NW sec. 28	Clayton Meyers	B	28.7	12	T	do.	do.	Cy,W	S	Top of platform	.7	1,516.42	20.00	June 6	
74	SW SW sec. 28	Fred Nitcher	B	32.8	8	T	do.	do.	Cy,W	D	Top of stone cover	2.5	1,508.14	21.54	June 6	
75	SE SW sec. 28	C. T. Helmer	Du	29.5	48	B	do.	do.	Cy,W	S	Top of concrete cover	.2	1,506.13	23.20	June 6	
76	NW NE sec. 33	Mayme W. Lower	B	35.2	8	T	do.	do.	P,H	D	do.	.8	1,498.06	24.41	June 6	
77	NW NW sec. 35	T. J. Charles	B	19.3	5½	GI	do.	do.	Cy,W	S	Top of casing	.8	1,486.34	11.09	June 1	
78	NW NW sec. 36	John Hurley	Du	7.3	40	B	do.	do.	Cy,W	S	Top of platform	1.2	1,479.67	4.93	June 1	

TABLE 22.—*Records of wells in Republic and Cloud Counties, Kansas—Continued*

No. on pls. 1 and 2 (1)	Location	Owner or tenant	Type of well (2)	Depth of well (feet) (3)	Diameter of well (in.)	Type of casing (4)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic source	Method of lift (5)	Use of water (6)	Measuring point: Description	Measuring point: Height above land surface (feet)	Measuring point: Height above mean sea level (feet)	Depth to water level below measuring point (feet) (7)	Date of measurement 1942	Remarks (Yield given in gallons a minute; drawdown in feet)
79	SE NW sec. 36	Elmer Evert	B	20.3	6	GI	Gravel and sand	Alluvium	Cy,W	S	Top of support above casing	2.5	1,485.58	7.76	June 1	
80	SE SW sec. 36	F. E. Beck	Dn	20.7	1¼	I	do.	do.	Cy,W	S	Top of board across pit	.7	1,482.43	8.65	June 1	
	T. 2 S., R. 1 W.															
81	SW SW sec. 8	B. B. Houdek	Du	18.1	36	R	Clay and sand	Alluvium	Cy,W	S	Top of platform	1.9	....	4.34	July 15	
(82)	NW NW sec. 10	Frank Chopp	Du	7.4	36	R	Limestone and clay	Greenhorn	Cy,H	S	do.	2.3	....	4.51	July 14	
83	SE SW sec 10	Hy Marsicek	Du	9.2	......	......	do.	do.	Cy,W	S	do.	.4	....	5.49	July 14	
84	SE NW sec. 30	William Hirman	Dr	169.0	6	I	Sandstone	Dakota	N	N	Top of casing	.7	....	45.49	July 11	Water supply for drilling oil well
85	NE NW sec. 35	School	Dr	75.1	6	GI	do.	do.	Cy,H	Sc	do.	.6	....	64.89	Sept. 1	
(86)	SW SW sec. 36	J. P. Devore	Du	27.9	42	R	Sand and clay	Alluvium	B	D	Top of cover over well	2.8	....	16.78	July 16	
	T. 2 S., R. 2 W.															
87	NW NE sec. 5	Art Neubauer	Du	36.7	36	R	Gravel and sand	Belleville	Cy,W	S	Top of platform	1.0	1,619.44	22.56	July 15	
(88)	NE NW sec. 16	Helen Gurnea	Du	21.6	36	R	do.	do.	Cy,W	S	do.	1.3	1,580.76	17.89	July 15	
89	NW NW sec. 20	W. G. Splichal	Du	19.4	36	R	Weathered shale	Carlile	Cy,W	S	Top of casing	1.3	1,572.36	9.81	July 14	
(90)	NE NE sec. 26	Henry Skucins	Du	28.2	36	R	Gravel and sand	Belleville	Cy,H	D,S	Top of platform	.7	1,577.80	27.84	July 11	
91	SW SW sec. 29	W. G. Saip	Du	27.1	......	......	Limestone and clay	Greenhorn	Cy,H	N	Top of concrete block, east side	1.3	1,502.76	9.54	July 14	
92	SE SE sec. 34	F. M. Barton	Du	48.8	48	R	Gravel and sand	Belleville	Cy,W	S	Top of platform	.9	1,603.70	47.15	June 8	

	T. 2 S., R. 3 W.														
93	SE SE sec. 2	School	Dr	43.5	6	GI	Gravel and sand	Belleville	Cy,H	Sc	Top of casing, north side	.1	1,610.57	34.74	June 11	
94	SW SW sec. 12	W. A. Seaman	Du	17.6	36	R	do	do	Cy,W	S	Top of platform	1.4	1,555.36	7.44	July 15	
95	SW NW sec. 14	H. E. Nixon	Du	47.6	36	R	do	do	Cy,W	D,S	Top of rock, east side	1.2	1,625.80	46.19	June 11	Observation well
(96)	NW NW sec. 19	John Kerstin	B	33.4	5	GI	Weathered shale	Carlile	Cy,W	D,S	Top of casing*	.7	1,633.78	31.24	May 30	
(97)	SW NW sec. 23	F. W. Collins	Du	22.3	60	R	Gravel and sand	Belleville	Cy,W	S	Top of platform	1.6	1,594.03	20.95	June 11	
98	NE NE sec. 27	Frank Hanzlick	Du	23.6	42	R	Weathered shale	Carlile	Cy,W	N	do	.9	1,567.25	8.06	June 11	Yield of well inadequate for stock supply
(99)	SW SW sec. 27	Ernest Klaumann	Dr	157.5	5½	GI	Sandstone	Dakota	Cy,W	S	Bottom of pump base	.4	1,538.10	124.99	July 15	Too salty for domestic use
100	NE NW sec. 31	A. G. Goodwin	Du	25.4	36	......	Weathered shale	Carlile	Cy,H	S	Top of platform	.7	1,563.95	4.62	May 30	Goes dry in dry years
101	SW SW sec. 36	J. W. Oliver	Dr	72.3	6	GI	do	do	Cy,W	N	do	.8	....	....	June 8	Well was dry
	T. 2 S., R. 4 W.															
102	NE NE sec. 3	Belleville State Bank	B	60.5	18	T	Gravel and sand	Belleville	Cy,H	N	Top of platform	0.7	1,591.72	50.34	June 15	
103	SW NW sec. 4	C. R. Johnson	Du	27.4	42	CB	do	do	Cy,W	S	Top of casing, south side	.8	1,546.27	22.39	July 1	
104	SW SW sec. 6	Elmer Evert	Dr	30.0	5½	GI	do	Alluvium	Cy,W	S	Top of platform	3.1	1,483.72	17.35	June 2	
105	NE NE sec. 7	F. E. Beck	Dr	62.5	6	GI	do	Belleville	Cy,W	D,S	do	.7	1,519.39	52.54	June 2	
106	SW NW sec. 7	W. A. Emmert	B	24.4	6	GI	do	Alluvium	Cy,H	I	Top of outside casing	.5	1,478.45	16.30	June 1	Used for irrigating garden
(107)	SE SE sec. 7	O. A. Berggren	Dr	42.2	10	GI	do	do	Cy,W	D,S	Top of concrete platform	1.0	1,494.98	33.45	June 1	
108	SE NE sec. 12	J. H. Rost	Dr	67.9	......	......	Weathered shale	Carlile	Cy,W	N	Top of platform	.6	1,666.78	64.08	May 13	
109	NE NE sec. 16	H. H. Williams	Du	9.8	36	R	do	do	N	N	Top of rock in casing, northeast side	.2	1,526.04	4.76	July 6	
110	SE NE sec. 19	A. P. Rosene	B	38.8	10	GI	Gravel and sand	Alluvium	Cy,W	D	Top of platform	.0	1,482.84	28.86	June 2	
111	NW SW sec. 20	Ole Johnson	Du	20.6	42	B	do	do	Cy,W	D	Top of platform	.2	1,490.25	18.75	June 2	
112	SW SW sec. 22	Alvin Mercer	Du	37.8	42	T,B	Weathered shale	Carlile	Cy,W	S	Top of 3- by 12-inch board beneath pump	1.9	1,551.95	24.22	June 15	
113	NW NW sec. 29	George Simmons	B	42.5	6	GI	Sand and gravel	Alluvium	Cy,H	S	....	....	1,480.54	31	June 2	
114	NW NW sec. 31	Horton Johnson	Dn	25.7	1¼	I	do	do	P,H	S	Top of pump base, cylinder removed	1.7	1,463.47	18.98	June 2	
115	NE SE sec. 33	Pearl Boman	Du	40.2	36	B	Weathered shale	Carlile	Cy,W	S	Top of platform	.3	1,533.39	28.92	June 15	

TABLE 22.—*Records of wells in Republic and Cloud Counties, Kansas—Continued*

No. on pls. 1 and 2 (1)	Location	Owner or tenant	Type of well (2)	Depth of well (feet) (3)	Diameter of well (in.)	Type of casing (4)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic source	Method of lift (5)	Use of water (6)	Measuring point: Description	Measuring point: Height above land surface (feet)	Measuring point: Height above mean sea level (feet)	Depth to water level below measuring point (feet) (7)	Date of measurement 1942	Remarks (Yield given in gallons a minute; drawdown in feet)
	T. 2 S., R. 5 W.															
116	NW NE sec. 1	E. E. McClure	Dn	......	1¼	I	Sand and gravel	Alluvium	Cy,W	S	Top of platform	.5	1,480.40	5.66	June 1	
117	NE NE sec. 2	do.	Du	12.4	48	CB	do.	do.	Cy,W	D,S	do.	.7	1,475.89	7.14	June 1	
(118)	SE NW sec. 2	Joe Erkenbrach	Dn	19.3	1¼	I	do.	do.	P,H	D	Top of pump base, cylinder removed	1.9	1,479.64	12.66	July 7	
119	SW SW sec. 5	E. J. Elliot	Dr	35.4	6	T	Gravel and sand	do.	Cy,W	S	Top of platform	1.4	1,513.35	21.28	July 8	
120	NE NW sec. 6	W. A. Angle	Du	28.8	60	R	do.	do.	Cy,W	D,S	do.	.8	....	17.10	July 8	
121	NW NW sec. 10	John Moore	Du	19.5	36	B	do.	do.	Cy,H	N	Top of platform	1.1	1,550.40	15.15	July 8	
122	SW SW sec. 10	Carl Wieland	Du	20.0	36	B	do.	do.	Cy,W	S	do.	2.0	1,531.50	15.91	July 8	
123	NW NW sec. 11	T. B. Davidson	B	55.4	6	T	Weathered shale	Carlile	Cy,W	N	do.	1.2	1,571.54	32.45	July 7	
124	SW SE sec. 11	A. Johnson	Du	5.8	36	B	do.	do.	N	N	Top of board across top of well	.1	1,506.54	4.88	July 7	
125	SE NW sec. 13	Elmer Evert	B	17.7	10	GI	Sand and gravel	Alluvium	N	N	Top of casing, north side	.0	1,465.40	5.82	June 2	
126	NW NE sec. 14	A. Anderson	Du	20.1	36	R	Sand and clay	do.	Cy,W	N	Top of board at south side of well	.2	1,503.98	8.86	July 7	
127	NW NW sec. 14	W. W. Anderson	Du	44.6	36	......	Weathered shale	Carlile	N	N	Top of platform	.8	1,554.58	38.74	July 8	
128	SE SE sec. 14	J. D. Weir	Du	18.6	36	B	Sand and clay	Alluvium	Cy,W	S	do.	1.1	1,467.42	15.47	July 8	
129	SE SE sec. 15	Sophia Hoffman	B	28.9	8	T	Weathered shale	Carlile	Cy,W	N	Top of tile, west side	.7	1,509.42	9.42	July 8	
130	NE NE sec. 21	W. S. Weir	B	30.3	8	T	do.	do.	N	N	Top of platform	.3	1,536.66	22.56	July 8	
131	SW SE sec. 23	W. E. Linden	Du	16.3	36	B	Sand and clay	Alluvium	Cy,H	D,S	do.	1.5	1,461.97	11.20	July 8	

132	SW SW sec. 25	Ted Larsen	Du	11.5	42	R	Sand and gravel	do.	Cy,H	D	do.	.2	1,453.03	7.61	July 8	
133	SE SE sec. 26	Ted Larsen	B	48.0			Sand and clay	Alluvium	Cy	N	Top of tile, west side	1.4	1,501.80	36.39	July 8	
134	SE NE sec. 28	Hy Osborne	B	45.5	12	T	Weathered shale	Carlile	Cy,W	S	Top of tile, south side	.9	1,518.37	34.91	July 8	House abandoned
135	NW NW sec. 35	Dwain Johnson	B	47.2	8	T	do.	do.	Cy,W	D,S	Top of tile, east side	1.8	1,508.70	28.73	July 8	
136	SW SW sec 35	C. T. Magnason	Du	28.8	42	B	Sand and clay	Alluvium	Cy,W	N	Top of platform	.4	1,480.05	11.34	July 8	Formerly a stock well
137	NE NW sec. 36	Carl Lindecrantz	Du	11.6	36	N	do.	do.	Cy,H	D,S	do.	.2	1,450.50	7.12	July 8	Well at house is 30 feet deep and reported dry
	T. 3 S., R. 1 W.															
138	SW SW sec. 8	City of Cuba	Dr	217	10	I	Sandstone	Dakota	Cy,E	P						Reported yield, 30 g. p. m.
139	SE SW sec. 8	do.	Dr	217	10	I	do.	do.	Cy,E	P						
140	NW SW sec. 26	School	Dr	32.8	5½	GI	Sand and clay	Alluvium	Cy,H	Sc	Top of casing	.5		11.87	July 16	
141	SE SW sec. 29	J. Kopsa	Dr	13.5	36	R	do.	do.	Cy,H	N	Top of casing, north side	.2		12.05	July 20	
142	SE SE sec. 34	D. L. Beckenridge	Dr	91.2	4	GI	Sandstone	Dakota	Cy,W	S	Top of casing	.7		34.95	July 20	
	T. 3 S., R. 2 W.															
(143)	NW NE sec. 2	School	Dr	37.9	6	GI	Gravel and sand	Belleville	Cy,H	Sc	Top of casing	.3		34.09	June 8	
144	NE NE sec. 4	W. G. Saip	Du	15.4	40	R	Weathered shale	Carlile	Cy,H	N	Top of platform	1.0		12.88	June 8	
145	SE SE sec. 26	J. M. Houdek	Du	15.5	40	R	Sand and clay	Alluvium	B	S	do.	.6		5.95	July 20	
146	SE NE sec. 29	M. M. Kasl	Du		42	R	Limestone and clay	Greenhorn	N	N	do.	.3		4.05	July 10	
	T. 3 S., R. 3 W.															
147	SW SE sec. 1	Warren Shambu	Du	72.5	36	R	Limestone and clay	Greenhorn	Cy,W	N	Top of platform	.2		59.35	July 13	
148	SW SW sec. 6	E. D. Reddlebarqer	Du		42	R	Weathered shale	Carlile	Cy,H	N	Top of casing, northwest side	.0		4.90	July 6	
(149)	SW SW sec. 7	Peter Maxton	Du	25.8	40	R	do.	do.	Cy,W	S	Top of platform	.5		13.67	July 21	
150	SW SW sec. 9	J. W. Williams	Dr	154	6	I	Sandstone	Dakota	Cy,H	D,S					Aug. 31	
(151)	NE NE sec. 13	Ames Frint	Dr	121.0	5½	GI	do.	do.	Cy,W	S	Top of casing west side	.2		60.35	July 10	
152	NW SW sec. 24	W. E. Keith	Dr	198.0	6	GI	do.	do.	Cy,W	N	Top of casing	.4		120.42	July 9	
153	NW NE sec. 27	O. L. Dooley	Dr	160	6	GI	do.	do.	Cy,W	D,S					Sept. 7	
154	SE NE sec. 29	——— Cooper	Dr	184	6	GI	do.	do.	Cy,W	D,S	Top of casing	.8		110.74	Aug. 31	

TABLE 22.—*Records of wells in Republic and Cloud Counties, Kansas—Continued*

No. on pls. 1 and 2 (1)	LOCATION	Owner or tenant	Type of well (2)	Depth of well (feet) (3)	Diameter of well (in.)	Type of casing (4)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic source	Method of lift (5)	Use of water (6)	Measuring point: Description	Measuring point: Height above land surface (feet)	Measuring point: Height above mean sea level (feet)	Depth to water level below measuring point (feet) (7)	Date of measurement 1942	Remarks (Yield given in gallons a minute; drawdown in feet)
(155)	NE NE sec. 30	School	Dr	97.2	5½	GI	Sandstone	Dakota	Cy,H	Sc	Top of casing	.6	....	78.01	July 21	
156	SW SW sec. 31	H. H. Beasley	Dr	100+	5½	GI	do	do	Cy,H	D,S	Bottom of pump base	.4	....	27.72	July 21	
(157)	SE SE sec. 35	Lawrence Walter	Du	23.6	36	R	Limestone and clay	Greenhorn	Cy,W	S	Top of platform	2.0	....	13.42	July 8	
	T. 3 S., R. 4 W.															
158	SE SE sec. 1	A. J. Dickerman	B	19.3	4	T	Weathered shale	Carlile	N	N	Top of casing, west side	0.3		16.25	June 6	Used as observation well
159	SE SE sec. 3	C. E. Hall	Du	16.5	36	R	do	do	Cy,H	N	Top of platform	1.5	....	9.08	June 2	
160	NE NE sec. 5	Lottie Lervold	Du	23.8	42	R	do	do	Cy,H	S	do	.9	1,485.34	9.16	June 2	
161	NW NW sec. 7	Ed Swanson	Dn	21.0	1.5	GP	Sand and gravel	Alluvium	P,H	D	Top of pump base, cylinder removed	1.5	1,452.69	13.60	July 8	
162	SW NE sec. 9	——— Larson	Du	45.2	42	R	Weathered shale	Carlile	Cy,W	S	Top of platform	.9	1,523.87	37.09	June 3	Temporarily not in use
163	SW SW sec. 9	Lyle Ocobock	Du	67.3	36	R	Limestone	Greenhorn	Cy,W	N	Top of pump base	.0	1,502.88	65.47	June 3	Reported as having been dry for four years
(164)	SE SE sec. 9	Grant Berggren	Dr	69.2	8	T	do	do	Cy,W	D,S	Top of platform	.4	1,503.10	51.70	June 3	
165	SE SE sec. 15	Nellie A. Nelson	B	14.1	8	T	Weathered shale	Carlile	Cy,W	S	do	.8	1,485.71	9.69	June 4	Located in pit, 4 feet deep
166	NW SW sec. 16	Sam Summers	B	30.5	10	I	Sand and gravel	Alluvium	Cy,H	S	do	.3	1,440.24	10.81	June 3	
167	NE NE sec. 17	William Moe	Dn	22.9	1¼	GP	do	do	P,H	D	Top of pump base, cylinder removed	2.1	1,447.11	18.55	June 5	Located on north side of 4th st., between Grant and Washington streets
168	NE NE sec. 17	Home Oil Co	Dn	21.2	1¼	GP	do	do	Cy,H	D	do	2.2	1,444.71	16.19	June 5	At intersection of 4th and Washington streets
169	SE NE sec. 17	City of Scandia	Du	31.2	240	CB	do	do	T,E,T	P	Edge of manhole	.4	....	10.11	June 5	Standby municipal well

170	NW NE sec. 17	Walter Anderson	Dn	17.9	1¼	GP	do.	do.	Cy,H	D	Top of pump base, cylinder removed	1.4	1,435.84	9.03	June 5	At intersection of 4th and Water streets
171	SW SE sec. 17	Walter Anderson	Dn	12.5	1¼	GP	do.	do.	Cy,H	D	do.	1.5	1,434.80	8.74	June 5	400 feet south and 200 feet west of well 170 and 30 feet east of river
172	SW NE sec. 17	City of Scandia	Du	11.3	48	C	do.	do.	N	N	Top of 2- by 10-inch board across top of well	2.7	1,435.23	8.70	June 5	Abandoned municipal well equipped with automatic water-stage recorder
(173)	NW SE sec. 17	do.	Dr	......	......	......	do.	do.	T,E	P	......	......	......	......	......	
174	NE NW sec. 18	Paul Ericson	Dn	16.7	1¼	GP	do.	do.	Cy,H	D	Top of platform	.1	1,439.29	6.48	July 3	About 10 feet south of house
175	SW SE sec. 28	Carl Larson	Du	40.6	36	B	Limestone	Greenhorn	N	N	Top of wooden curb	2.9	1,459.86	37.31	June 4	Formerly equipped with rope and bucket
(176)	NE SE sec. 29	Benjamin Lervold	Dn	13.5	1¼	GP	Sand and gravel	Alluvium	P,H	S	Top of pump base, cylinder removed	1.7	1,424.14	6.84	June 4	
177	NE NE sec. 31	Gus Gwennersteen	Du	17.2	48	R	do.	do.	Cy,H	D	Top of platform	.3	1,435.86	11.59	June 25	
178	SW SW sec. 29	Evald Peterson	Dn	15.6	1¼	GP	do.	do.	P,H	D	Top of pump base, cylinder removed	1.9	1,424.30	4.18	June 25	
179	SE NE sec. 32	E. J. Melby	Dn	20.0	1¼	GP	do.	do.	P,H	S	do.	2.3	1,421.28	7.64	June 4	
180	SE SE sec. 33	Carl Hugos	Du	26.5	30	B	do.	do.	Cy,H	S	Top edge of 3- by 12-inch board in platform	.3	1,434.20	22.99	June 4	
	T. 3 S., R. 5 W.															
181	SW NW sec. 2	John Naslund	Dr	41.0	10	GI	Weathered shale	Carlile	N	N	Top of casing, south side	1.5	1,493.61	19.88	July 8	Original depth, 180 feet. Water too salty for use
182	SW NW sec. 2	do.	Du	25.5	36	R	do.	do.	B,H	S	Top of casing, north side	1.0	1,486.53	11.63	July 8	
183	SW NW sec. 3	——— Downing	B	31.4	......	......	do.	do.	Cy,H	N	Top of casing, west side	.3	1,514.99	21.01	July 8	
184	NE NE sec. 6	Josephine Makin	B	46.0	12	T	do.	do.	Cy,W	N	Top of casing, east side	1.2	......	24.69	July 22	
185	SW NW sec. 9	C. A. Peterson	B	35.9	10	T	do.	do.	Cy,H	N	Top of platform	0.5	......	22.73	July 22	
186	SE SE sec. 13	Fred Jackson	B	56.2	16	T	do.	do.	Cy,W	S	Top of 2-inch board across casing	2.2	1,496.85	45.08	June 25	
187	SW SW sec. 16	City of Courtland	Du	......	......	......	do.	do.	Cy,G	N	Top edge of manhole cover	0	......	18.23	June 10	Formerly public-supply well, west well
188	SW SW sec. 16	do.	Du	53.2	......	......	do.	do.	Cy,G	N	do.	0.5	......	18.82	June 10	Formerly pu li -supply well, east well
189	SE SE sec. 16	do.	B	67	16	I	Gravel and sand	Pleistocene(?)	T,E	P	......	......	......	27	June 10	Reported yield, 75 g. p. m.
190	NW NE sec. 24	Phebe Erickson	Du	40.1	42	R	Weathered shale	Carlile	Cy,W	D,S	Top of platform	.3	1,497.75	31.09	June 26	
(191)	NW NW sec. 25	M. E. Humphrey	Dr	64.0	10	GI	Shale	do.	Cy,W	S	Top of tile, level with platform	1.6	1,495.97	35.86	June 26	Owner reports shale at depth of 28 ft.; no water above shale

TABLE 22.—*Records of wells in Republic and Cloud Counties, Kansas—Continued*

No. on pls. 1 and 2 (1)	Location	Owner or tenant	Type of well (2)	Depth of well (feet) (3)	Diameter of well (in.)	Type of casing (4)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic source	Method of lift (5)	Use of water (6)	Measuring point: Description	Measuring point: Height above land surface (feet)	Measuring point: Height above mean sea level (feet)	Depth to water level below measuring point (feet) (7)	Date of measurement 1942	Remarks (Yield given in gallons a minute; drawdown in feet)
192	SW SE sec. 26	H. J. Anderson	Du	48.9	36	R	Weathered shale	Carlile	Cy,W	N	Top of platform	.1	1,468.03	25.65	June 26	
193	NE SE sec. 31	Fred Mainquist	Dr	134.2	5½	GI	Sandstone	Dakota	N	N	Top of casing, north side	.1	....	49.69	July 22	Water salty; shallow wells dry
(194)	NW NW sec. 32	Edd Mainquist	Dr	116.3	6	I	do.	do.	Cy,W	S	Bottom edge of pump base	.5	....	17.91	July 22	
195	SE NE sec. 35	J. E. Thomas	Dr	100+	6	T	do.	do.	Cy,W	S	Top of platform	1.3	1,476.77	53.95	June 27	
	T. 4 S., R. 1 W.															
196	SE SW sec. 7	—— Cibolsky	Du	31.6	42	R	Sandstone	Dakota	Cy,H	S	Top of platform	0.9	....	20.34	July 10	
(197)	NW NW sec. 13	Rachel Myers	Du	38.0	36	R	do.	do.	Cy,H	S	do.	.3	....	21.08	July 16	
198	NW SE sec. 16	G. W. Ryman	Du	33.1	36	B	do.	do.	N	N	Top of casing, northeast side	.1	....	32.80	July 13	
199	NW SW sec. 24	J. H. Kalivoda	Dr	147.0	......	......	do.	do.	Cy,W	S	Top edge of 2- by 8-inch board above casing	1.9	....	83.95	July 16	
200	SW SW sec. 35	S. Broadfoot	Du	39.6	36	B	do.	do.	Cy,W	S	Top of platform	.2	....	37.14	July 16	
201	NE NW sec. 36	C. E. Erickson	Du	33.5	36	R	do.	do.	N	N	do.	.2	....	33.45	July 16	
(202)	SE NW sec. 36	C. E. Erickson	Du	38.4	42	R	do.	do.	Cy,W	D,S	do.	1.6	....	36.15	Aug. 23	
	T. 4 S., R. 2 W.															
203	NW SE sec. 9	Burlington Railroad	Du	46.2	36	R	do.	do.	N	N	Top of casing	.3	....	43.40	July 13	Located north of depot at Wayne
(204)	SW SE sec. 9	do.	Du	52.3	120	R	do.	do.	Cy,W	D	Top of platform	2.0	....	39.64	July 13	
205	NW SW sec. 15	Mrs. C. A. Chapman	Du	35.5	36	R	do.	do.	Cy,H	N	do.	.5	....	23.30	July 10	
206	SE SE sec. 15	H. D. Bolles	Du	6.3	36	R	do.	do.	Cy,W	S	do.	1.0	....	3.34	July 13	

(207)	NW SW sec. 18	Adlord Hubert	Du	26.8	36	B	Sand	Alluvium	Cy,H	D	do	.3	....	16.35	July 13	
(208)	NW NW sec. 20	H. Morgsion	Dr	70	6	GI	Sandstone	Dakota	Cy,W	D,S	do	1.2	....	12.25	July 13	
	T. 4 S., R. 3 W.															
(209)	SE NE sec. 1	Glenn B. Snapp	Du	42.9	42	R	Gravel and sand	Pleistocene	Cy,E	S	do	.8	....	33.53	Aug. 21	Used as observation well
210	NE NE sec. 3	F. K. Novak	Dr	209	5	I	Sandstone	Dakota	Cy,W	S	....	....	....	....	Aug. 31	Water is salty
211	NW NW sec. 4	E. W. Runft	Dr	111.3	5	I	do	do	Cy,W	S	Top of platform	.8	....	....	Aug. 31	Pump caking, could not measure water level
212	SE SE sec. 5	——— Lash	Dr	108.5	5½	GI	do	do	Cy,W	N	Top of casing	.2	....	71.66	July 21	
213	SE NE sec. 12	School	Du	33.9	40	R	Sand	Alluvium	Cy,H	Sc	Top of platform	.5	....	26.13	Aug. 20	
214	SW SW sec. 14	M. M. Fate	Dr	260	6	I	Sandstone	Dakota	Cy,W	D,S	Top of casing	.9	....	62.25	Aug. 31	Water reported to be very corrosive
(215)	SE SE sec. 14	William Krohn	Dr	64.2	6	GI	do	do	Cy,W	S	Top of platform	.7	....	51.35	Aug. 22	Located about 250 feet north of house
216	SE SE sec. 14	William Krohn	Du	42.3	42	R	do	do	Cy,H	S	do	.3	....	40.69	Aug. 20	Located about 25 feet north of house
(217)	SW NW sec. 15	E. Krohn	Du	25.8	36	R	Sandstone	Dakota	Cy,W	S	Top of rock curb	0.7	....	19.46	Aug. 20	
218	SW SW sec. 16	A. C. Jewell	Dr	128.4	5½	GI	do	do	N	N	Top of casing, east side	.6	....	68.06	July 9	
219	NW NW sec. 22	C. B. Carbutt	Du, Dr	31.3	42	R	do	do	Cy,W	D,S	Top of platform	.3	....	17.44	June 22	Dug 25 feet, deepened by drilling
	T. 4 S., R. 4 W.															
220	SW NW sec. 3	E. M. Eastvedt	Du	29.8	42	B	Sand and gravel	Alluvium	Cy,W	D,S	Top edge of 2- by 12-inch board	2.0	1,435.27	27.30	June 4	
221	SE SE sec. 4	Victor Herman	Du	20.5	48	B	do	do	Cy,H	D	Top of concrete curb	.4	1,428.80	19.92	June 4	
222	NW NW sec. 6	Sophie Munson	Dr	69.3	5½	GI	Limestone	Greenhorn	Cy,H	D,S	Top of casing	1.3	1,471.66	45.89	June 27	
223	NW NE sec. 7	Edward Isaccson	Du, Dr	49.2	......	......	do	do	Cy,W	D,S	Top of platform	.7	1,450.21	40.76	June 27	Dug 34.3 feet, deepened by drilling
224	SE NE sec. 7	Swen Carlson	Dr	50.3	5½	GI	do	do	Cy,W	S	Bottom of pump base	.3	1,441.66	32.98	June 25	
225	NE NW sec. 7	Swen Larson	Dr	50.4	5½	GI	do	do	Cy,W	D,S	Top of platform	.3	1,421.60	18.03	June 25	
226	SW SW sec. 12	Tootle Farms Co.	Dr	43.0	5½	GI	do	do	Cy,W	S	Bottom of pump base	1.2	....	12.26	July 21	
(227)	NW NW sec. 14	Carl Hugos	Dr	125.8	8	I	do	do	Cy,W	S	Top of casing, west side	.4	1,464.82	67.69	June 6	
228	SE NE sec. 19	W. J. Dunlap	Dr	91.7	......	......	do	do	Cy,W	S	Top of casing	.3	1,451.36	56.05	June 27	
229	SE SE sec. 19	N. A. Christianson	Dr	112.0	5½	GI	do	do	Cy,W	N	Top of casing, southwest side	.4	1,499.50	97.82	June 27	

TABLE 22.—*Records of wells in Republic and Cloud Counties, Kansas—Continued*

No. on pls. 1 and 2 (1)	Location	Owner or tenant	Type of well (2)	Depth of well (feet) (3)	Diameter of well (in.)	Type of casing (4)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic source	Method of lift (5)	Use of water (6)	Measuring point: Description	Measuring point: Height above land surface (feet)	Measuring point: Height above mean sea level (feet)	Depth to water level below measuring point (feet) (7)	Date of measurement 1942	Remarks (Yield given in gallons a minute; drawdown in feet)
230	NE SW sec. 21	Lloyd Blosser	Du	48.0	24	GI	Sand and gravel	Alluvium	T,G	N	Top of casing, south side	.2	1,401.60	6.65	June 22	Used as an irrigation well from 1931 to 1935. Damaged by flood in 1935
231	NE SE sec. 23	P. T. Gile	Dr	124.0	5½	GI	Limestone	Greenhorn	N	N	do	3.6	1,474.35	41.94	June 22	Just completed, not yet equipped with pump
232	NW SW sec. 26	J. F. Kullberg	Dr	44.4	5½	GI	Sand and clay	Alluvium	Cy,W	S	Top of casing, west side	.7	1,419.24	28.02	June 6	
233	SW SW sec. 26	do	Du	32.3	30	R	do	do	Cy,H	N	Top of platform	.4	1,417.31	28.69	June 6	Formerly a domestic well
234	NE SE sec. 27	Russell Jacobsen	Du	34.1	36	R	Sand and gravel	do	Cy,W	S	do	.4	1,420.27	30.64	June 6	
235	SE SE sec. 27	L. H. Stensass	Du	27.3	36	R	do	do	Cy,W	S	Top of platform, east of pump	1.5	1,411.44	23.94	June 6	
236	SW SW sec 29	W. H. Christensen	Du	51	36	R	do	do	Cy,H	D	Top of platform	.3	1,424.13	36.60	June 27	
(237)	SW SW sec. 32	John Lundblade	Dr	34.7	4	I	do	do	Cy,H	D	do	.2	1,407.37	22.22	June 27	
238	SW SE sec. 33	Morris McGreggor	Du	19.3	72	R	do	do	N	N	Top of 2- by 6-inch board	1.1	1,397.26	12.32	July 9	Formerly used for irrigation
(239)	NE SE sec. 36	Orval Barleen	Dr	74.7	26	R	Limestone	Greenhorn	Cy,W	D,S	Top of platform	1.0	1,472.81	51.49	June 6	Dug 43 feet, deepened by drilling
	T. 4 S., R. 5 W.															
240	SW NW sec. 7	Ira Blanding	Dr	38.9	......	......	do	do	Cy,W	S	Top of casing	.9	....	16.02	July 22	
241	NW SW sec. 7	Pete A. Hansen	Du	41.6	36	R	do	do	Cy,H	D,S	Top of platform	1.9	....	13.40	July 31	
242	NW NE sec. 22	O. W. Carlson	Dr	123.2	......	......	Sandstone	Dakota	Cy,W	S	do	.3	....	102.83	July 22	
243	SW NW sec. 23	Minnie Houghton	Dr	127.8	6	GI	do	do	Cy,W	S	Top of casing	.5	....	115.50	July 22	
(244)	NW NW sec. 30	Aaron Carlsen	Dr	84.0	6	GI	do	do	Cy,W	S	Top of casing, north side	.7	....	29.39	July 22	

	T. 5 S., R. 2 W.														
245	NW SW sec. 25	W. T. Wright	Dr	65.6	18	GI	Sand and gravel	Alluvium	T,E	I	Top of casing, west side	.8	....	18.31	May 26	Constructed May, 1942
	T. 5 S., R. 3 W.														
246	SW SW sec. 6	G. H. Bassett	Du	34.7	40	C	Sandstone	Dakota	Cy,W	S	Top of casing	1.0	1,423.71	33.30	Aug. 10	
247	SE SE sec. 7	C. D. Avery	Du	55.0	36	R	do	do	Cy,W	D,S	Top of platform	.5	1,400.33	51.55	Aug. 10	
248	SW SW sec. 10	S. J. Swenson	Dr	97.0	5	GI	do	do	Cy,W	D,S	do	.3	1,429.19	57.65	Aug. 11	
249	SW SW sec. 16	Mrs. Mary Murdock	Dr	33.0	5	GI	Sand and gravel	Alluvium	Cy,W	S	Top of casing	.0	1,373.06	30.70	Aug. 11	
250	NE NW sec. 17	C. Sjogren	Du	54.5	30	R	Sandstone	Dakota	N	N	Top of concrete curb	1.2	1,409.13	54.50	Aug. 11	
251	SW NW sec. 20	G. L. Swenson	Dr	28.0	6	GI	Sand and gravel	Alluvium	Cy,W	D,S	Top of platform	.5	1,356.75	12.00	Aug. 11	
252	NE SW sec. 21	Ralph Miller	Dr	22.5	5	GI	do	do	Cy,H	S	do	.3	1,358.84	13.44	June 27	Dug well deepened by drilling
253	SW NW sec. 22	War Prison Camp	Dr	78	18	C	do	do	N	N	Top of casing	....	....	....	....	War Prisoner Camp well 1; too salty to use
254	SW NW sec. 22	do	Dr	77	18	C	do	do	N	N	Top of casing	....	....	....	....	War Prisoner Camp well 2; too salty to use
255	NW NW sec. 28	do	Dr	51	18	C	do	do	T,E	D	do	....	....	....	....	Water supply for prison camp
256	NW NW sec. 28	do	Dr	48	18	C	do	do	T,E	D	do	....	....	....	....	Do
257	NW SW sec. 28	Warren Weitzel	Dn	18.7	1¼	GP	do	do	P,E	S	Top of pump base, cylinder removed	1.7	....	10.41	June 24	
258	SE SE sec. 29	City of Concordia	Dr	122	18	C	do	do	A,E	P	....	....	....	....	....	Concordia well No. 8
259	SE SE sec. 29	do	Dr	122	18	C	do	do	A,E	P	....	....	....	....	....	Concordia well No. 7
260	SW NW sec. 31	Roy Ward	Du	54.0	8	I	do	do	C,G	I	Top of wooden cover	.2	1,372.75	21.65	Aug. 20	Well was dug 28 feet and then deepened by drilling
261	NE NE sec. 32	City of Concordia	Dr	122	18	C	do	do	A,E	P	....	....	....	....	....	Concordia well No. 4
262	NE NE sec. 32	do	Dr	122	18	C	do	do	A,E	P	....	....	....	....	....	Concordia well No. 6
263	NE NE sec. 32	do	Dr	122	18	C	do	do	A,E	P	....	....	....	....	....	Concordia well No. 1
264	NE NE sec. 32	do	Dr	122	18	C	do	do	A,E	....	....	....	....	....	....	Concordia well No. 3
265	NW NE sec. 32	do	Dr	122	18	C	do	do	A,E	....	....	....	....	....	....	Concordia well No. 5
266	NW NE sec. 32	do	Dr	122	18	C	do	do	A,E	....	....	....	....	....	....	Concordia well No. 2

TABLE 22.—*Records of wells in Republic and Cloud Counties, Kansas—Concluded*

No. on pls. 1 and 2 (1)	LOCATION	Owner or tenant	Type of well (2)	Depth of well (feet) (3)	Diameter of well (in.)	Type of casing (4)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic source	Method of lift (5)	Use of water (6)	Measuring point: Description	Measuring point: Height above land surface (feet)	Measuring point: Height above mean sea level (feet)	Depth to water level below measuring point (feet) (7)	Date of measurement 1942	Remarks (Yield given in gallons a minute; drawdown in feet)
267	SE SE sec. 32	do.	Dr	250	10	I	Sandstone	Dakota	T,E							Located beside water tower
268	SE SW sec. 34	do.	Dr	150	10	I	do.	do.	T,E							Located near fair grounds at 10th and Niagra streets
	T. 5 S., R. 4 W.															
269	SW NW sec. 2	G. C. Dutton	Du	24.3	30	R	Sand and gravel	Alluvium	N	N	Top of platform	.5	1,398.99	19.45	Aug. 10	
270	SE SE sec. 8	C. Hitchcox	Dr	22.6	5	GI	do.	do.	Cy,W	S	do.	.5	1,387.85	12.30	Aug. 19	
271	SE SW sec. 10	R. H. Hanson	Dn	21.2	1¼	GP	do.	do.	Cy,H	S	do.	.5	1,378.52	8.38	Aug. 20	
272	NE NW sec. 11	E. S. Lagasse	Du		3		do.	do.	Cy,W	D,S	do.	1.0	1,390.76	47.58	Aug. 10	
273	NW NW sec. 12	J. R. Poore	B	48.2	5	GI	Sandstone	Dakota	Cy,W	D	Top of casing	—6.0	1,426.93	46.30	Aug. 10	
274	SE SE sec. 18	C. McMillan	Dr	48.0	6	GI	do.	do.	Cy,W	D,S	Bottom of pump base	1.2	1,404.23	33.62	Aug. 17	
275	SW SW sec. 19	P. A. Paulsen	Du	18.0	40	R	Sand and gravel	Alluvium	Cy,H	S	Top of platform	1.3	1,383.17	9.00	Aug. 18	
276	SW NE sec. 25	Frank Hannum	Dr	78	4	I	do.	do.	C,G	I	do.	.0		7.50	June 24	Gravel reported at depth of 50 feet, sandstone at 55 feet
277	NW SW sec. 26	M.V.B. Van De Mark	Dn	31.0	1½	GP	do.	do.	Cy,H	D	do.	.0	1,374.59	19.58	Aug. 20	
278	SE SW sec. 26	do.	Dr	54.4	5	GI	Sandstone	Dakota	Cy,W	S	Bottom of pump base	.0	1,392.16	32.85	Aug. 20	
279	SE NE sec. 28	J. P. Jones	Dr	119.0	6	GI	do.	do.	Cy,W	S	do.	.0	1,411.31	37.75	Aug. 19	
280	NE SW sec. 28	Bertha E. Neel	Dr	54.0	5	GI	do.	do.	Cy,W	S	Top of casing	1.4	1,405.36	22.90	Aug. 18	
281	NE SW sec. 29	A. Rund	Du	68.0	48	R	Limestone	Greenhorn	Cy,H	D,S	Bottom of pump base	.2	1,401.11	31.50	Aug. 18	

282	NE NW sec. 36	J. P. Christensen	B	37.7	5	GI	Sand and gravel	Alluvium	N	N	Top of concrete cover	.0	1,370.48	17.95	Aug. 20	
	T. 5 S., R. 5 W.															
283	SW SW sec. 11	——— Galloway	Dr	43.0	8	T	Sandstone	Dakota	Cy,H	D	Concrete floor of porch	3.0	1,415.75	34.05	Aug. 18	
284	SE SE sec. 12	——— Sutherland	Dr	68.0	6	GI	do	do	Cy,H	D,S	Top of concrete cover	.6	1,426.85	45.10	Aug. 18	
285	NE SE sec. 13	N. M. French	Dr	30.1	8	T	Sand and gravel	Alluvium	Cy,W	S	Top of collar	1.0	1,385.57	23.30	Aug. 17	
286	SE SW sec. 14	E. M. French	Dr	......	5	GI	do	do	Cy,W	D,S	Top of platform	3.4	1,393.18	11.60	Aug. 18	
287	SE NE sec. 23	S. H. Rank	Dr	21.0	5	GI	do	do	N	N	Top of casing	0.0	1,398.74	17.95	Aug. 18	
288	NE NE sec. 26	B. F. Hodgson	Dr	81.0	6	GI	Sandstone	Dakota	Cy,W	D,S	do	4.6	1,418.67	51.00	Aug. 18	
	T. 6 S., R. 3 W.															
289	NW NW sec. 4	City of Concordia	Dr	350	10	I	Sandstone	Dakota	Cy,T	P	....	....	....	....	....	Located at 15th and Republican streets
(290)	SE SE sec. 6	B. E. Thurston	Dr	305	8	I	do	do	Cy,W	D,S	Top of casing	1.3	....	127	Aug. 20	
	T. 6 S., R. 4 W.															
(291)	NW SW sec. 36	M.V.B. Van De Mark	Dr	308	5	I	Sandstone	Dakota	Cy,W	S	....	....	....	90	June 5	Water contains 5.5 p.p.m. of fluoride

1. Well number in parentheses indicates that analysis of water is given in Table 6.
2. B, bored well; DD, dug and drilled well; Dn, driven well; Dr, drilled well; Du, dug well.
3. Reported depths below the land surface are given in feet; measured depths are given in feet and tenths below measuring points.
4. Bs, boiler steel; C, concrete; GI, galvanized sheet iron; GP, galvanized-iron pipe; I, iron; N, none; OB, oil barrels; OW, oil-well casing; R, rock; W, wood.
5. Method of lift: C, horizontal centrifugal; CY, cylinder; F, natural flow; N, none; P, pitcher pump; S, submersible turbine; T, turbine; VC, Vertical centrifugal.
   Type of power: B, butane; E, electric; G, gas engine; H, hand operated; T, tractor; W, windmill.
6. D, domestic; I, irrigation; In, industrial; N, not being used; O, observation; P, public supply; S, stock.
7. Measured depths to water level are given in feet, tenths, and hundredths; reported depths to water level are given in feet.

WELL LOGS

On the pages that follow are given the logs of test holes drilled by the State Geological Survey in Republic and Cloud Counties. Eighty-four test holes were drilled in Republic County and 29 in Cloud County. The logs were prepared from field studies of the well cuttings by James B. Cooper and O. S. Fent supplemented by laboratory studies by me. Also given are the logs of four test holes drilled by the Bureau of Reclamation in the Republican River Valley, two test holes drilled by the Layne-Western Company near Concordia, and seven test holes drilled by the Air-Made Well Company near Concordia.

REPUBLIC COUNTY

1. *Sample log of test hole 1 in the NW cor. sec. 6, T. 1 S., R. 2 W., 30 feet north and 33 feet east of center of road intersection. Surface altitude, 1,579.1 feet.*

	Thickness, feet	Depth, feet
Soil, dark gray; contains much medium to fine sand	2	2
Silt, clayey, gray black	4	6
QUATERNARY—Pleistocene		
"Loess"		
Silt, light brown	4	10
Silt, buff	15	25
Silt, clayey, light brown and brownish gray; contains some fine sand and caliche	35	60
Silt, clayey, white and dull greenish gray, grading downward to gray green; contains some coarse to fine sand and caliche	12	72
Belleville formation		
Sand, coarse to fine, some medium to fine gravel, and yellow-green silt	10	82
(Water level, 73.3 feet below land surface.)		
CRETACEOUS—Gulfian		
Greenhorn limestone		
Shale, calcareous, yellow, white, and orange. Thin hard limestones	9	91
Shale, calcareous, dark gray; contains many thin gray limestones	4	95

2. *Sample log of test hole 2 in the NW cor. sec. 1, T. 1 S., R. 3 W., 12 feet north and 6 feet east of center of the road intersection. Surface altitude 1,623.5 feet.*

	Thickness, feet	Depth, feet
Road fill	2	2
QUATERNARY—Pleistocene		
"Loess"		
Silt, dull yellow green	6	8
Silt, dark brown	5	13
Silt, clayey, dark tan	12	25
Silt, yellowish buff	5	30
Silt, buff; contains much medium to fine sand	42	72
Silt, clayey, gray buff downward to greenish gray	8	80
Silt, gray buff; contains some caliche	5	85
Silt, yellow buff	5	90
Silt, clayey, light brown and light gray; contains some sand	12	102
Silt, clayey, gray green; contains much medium to fine sand	5	107
Belleville formation		
Gravel, fine to coarse, sand, and silt	30	137
Gravel, medium to fine, sand, and silt	43	180
Gravel, medium to fine, and sand	40	220
Gravel, medium to fine, interbedded with some white and yellow buff silt	14	234
CRETACEOUS—Gulfian		
Graneros (?) shale		
Shale, noncalcareous, light blue gray, some pyrite	6	240

3. *Sample log of test hole 3 in the NW cor. NW¼ NE¼ sec. 2, T. 1 S., R. 3W., 72 feet south and 15 feet west of first telephone pole east of half-mile line. Surface altitude, 1,616.8 feet.*

	Thickness, feet	Depth, feet
Soil, clayey, dark gray brown	2	2
QUATERNARY—Pleistocene		
"Loess"		
Silt, soft yellow gray	3	5
Silt, blocky, dark gray brown	3	8
Silt, clayey, tan gray	12	20
Silt, compact, buff streaked with some light green-gray clay; contains some sand	22	42
Sand, medium to fine, and some buff silt	15	57
Silt, clayey, light gray; contains some caliche	13	70
Silt, buff; contains much fine sand	8	78
Silt, clayey, light gray	9	87
Silt, gray; contains much coarse to fine sand and some medium gravel	6	93
Belleville formation		
Sand, coarse to fine, and some medium to fine gravel	17	110
Gravel, fine to medium, and sand	10	120

	Thickness, feet	Depth, feet
Gravel, fine to coarse, and sand	10	130
Gravel, fine to medium, and sand	10	140
Gravel, medium to fine, and sand	30	170
Gravel, fine to medium, and sand	21	191
CRETACEOUS—Gulfian		
Greenhorn limestone		
Shale, calcareous, dark gray; contains much very fine hard sandstone	7	198

4. *Sample log of test hole 4 in the NE cor. sec. 3, T. 1 S., R. 3 W., 66 feet south and 12 feet west of the center of road intersection. Surface altitude, 1,617.2 feet.*

	Thickness, feet	Depth, feet
Soil, clayey, brown and black	3	3
QUATERNARY—Pleistocene		
"Loess"		
Silt, clayey, gray	5	8
Silt, clayey, weathered, black	4	12
Silt, clayey, tan	2	14
Silt, silty, tan	16	30
Sand, very fine, clayey, tan	10	40
Silt, silty, tan	10	50
Sand, fine, gray	13	63
Silt, clayey, white and gray, calcareous	17	80
Silt, clayey, gray	17	97
Belleville formation		
Sand, fine, gray and yellow	5	102
Gravel, medium, and gray clay	18	120
Gravel, medium, brown	10	130
(Water level, 123.6 feet below land surface.)		
Gravel, medium, and fine brown sand	10	140
Sand, medium, and fine brown gravel	20	160
Gravel, medium, and medium brown sand	19	179
Gravel, coarse, and calcareous clay	1	180
CRETACEOUS—Gulfian		
Greenhorn limestone		
Shale, dark gray blue, white speckled, calcareous	10	190

5. *Sample log of test hole 5 in the SW cor. SW¼ NW¼ sec. 2, T. 1 S., R. 3 W., 28 feet north and 39 feet east of center of road at concrete culvert. Surface altitude, 1,631.6 feet.*

	Thickness, feet	Depth, feet
Soil, gray black	2.5	2.5
QUATERNARY—Pleistocene		
"Loess"		
Silt, clayey, gray green, limonitic streaks	6.5	9
Silt, clayey, compact, light brown and gray	6	15
Silt, clayey, compact, tan	3	18
Silt, pink buff	2	20
Silt, light gray buff; contains some sand	16	36

	Thickness, feet	Depth, feet
Sand, medium to fine, and some buff silt	4	40
Silt, buff; contains much medium to fine sand	8	48
Sand, medium to fine	2	50
Silt, buff; contains much medium to fine sand	3	53
Sand, medium to fine	14	67
Silt, buff; contains much fine sand	24	91
Silt, clayey, light buff to white; contains some sand and gravel	19	110
Belleville formation		
Sand, coarse to fine, some medium gravel, and buff and gray silt	10	120
Gravel, fine to medium, and sand	20	140
(Water level, 126.7 feet below land surface.)		
Gravel, medium to fine, and sand	40	180
Gravel, fine to coarse, and sand	11	191
CRETACEOUS—Gulfian		
Greenhorn limestone		
Shale, calcareous, dark gray	5	196

6. *Sample log of test hole 6 in the SW cor. sec. 2, T. 1 S., R. 3 W., 117 feet east and 14 feet north of center of road intersection. Surface altitude, 1,599.5 feet.*

	Thickness, feet	Depth, feet
Soil and road fill, clayey, light gray brown	6	6
QUATERNARY—Pleistocene		
"Loess"		
Silt, light gray buff; contains some sand	14	20
Sand, medium to fine, interbedded with light gray-buff silt	6	26
Silt, clayey, tan	2	28
Silt, buff; contains some sand and nodular caliche	8	36
Silt, clayey, gray green; contains some sand	10	46
Silt, light brown to grayish brown	29	75
Silt, light gray green; contains much coarse to fine sand and some caliche	5	80
Belleville formation		
Sand, coarse to fine, some medium to fine gravel, and gray silt	20	100
Gravel, medium to fine, sand, some light gray-green silt,	10	110
Gravel, coarse to fine, sand, and some light-gray and buff silt	10	120
Gravel, fine to medium, and sand	22	142
Silt, soft, light green gray; contains much sand	18	160
Gravel, fine to medium, and sand	10	170
Gravel, coarse to fine, and sand	10	180
Gravel, medium to fine, and sand	25	205
CRETACEOUS—Gulfian		
Graneros (?) shale		
Shale, noncalcareous, blue gray, some pyrite	13	218

7. *Sample log of test hole 7 in the NE cor. NE¼ NW¼ sec. 3, T. 1 S., R. 3 W., 15 feet north and 21 feet west of corner fence post. Surface altitude, 1,633.6 feet.*

	Thickness, feet	*Depth, feet*
QUATERNARY—Pleistocene		
"Loess"		
Silt, clayey, gray brown	3	3
Silt, yellowish gray	5	8
Silt, blocky, dark brown	5	13
Silt; contains much sand	5	18
Sand, medium to fine, and some light-gray silt	11	29
Silt, light buff; contains much fine sand	19	48
Sand, medium to fine, and some light-buff silt	22	70
Silt, light buff and gray white	30	100
Silt, light gray buff and greenish gray; contains some sand	8	108
Belleville formation		
Sand, coarse to fine, and gravel	22	130
Gravel, medium to fine, and sand	20	150
(Water level, 133.6 feet below land surface.)		
Gravel, fine to medium, and sand	10	160
Gravel, medium to fine, and sand	20	180
Gravel, coarse to fine, and sand	17	197
CRETACEOUS—Gulfian		
Greenhorn limestone		
Shale, calcareous, dark gray, and some gray-blue bentonite	3	200

8. *Sample log of test hole 8 in the NE cor. sec. 4, T. 1 S., R. 3 W., 63 feet west and 9 feet south of center of road intersection. Surface altitude, 1,635.2 feet.*

	Thickness, feet	*Depth, feet*
Road fill	1	1
QUATERNARY—Pleistocene		
"Loess"		
Silt, clayey, compact, brown	1	2
Silt, clayey, dull yellow green and yellow gray	8	10
Silt, blocky, dark brown	6	16
Silt, clayey, dull tan and buff	4	20
Silt, clayey, buff	11	31
Silt, gray; contains some sand	5	36
Sand, medium to fine	7	43
Silt, yellow gray; contains much sand	11	54
Sand, medium to fine	18	72
Silt, buff; contains some sand	28	100
Silt, yellow gray, limonitic; contains much sand and some gravel	6	106
Belleville formation		
Gravel, medium to fine, sand, and some silt	24	130

	Thickness, feet	Depth, feet
Gravel, medium, sand, and silt	40	170
(Water level, 131.2 feet below land surface.)		
Gravel, medium to fine, and sand	40	210
Gravel, fine to medium, and sand	15	225
CRETACEOUS—Gulfian		
Greenhorn limestone		
Shale, calcareous, dark gray and light blue gray	2	227

9. *Sample log of test hole 9 in the NE cor. sec. 5, T. 1 S., R. 3 W., 9 feet south and 66 feet west of center of road intersection. Surface altitude, 1,659.9 feet.*

	Thickness, feet	Depth, feet
Road fill	1	1
QUATERNARY—Pleistocene		
"Loess"		
Silt, clayey, brown	2	3
Silt, greenish gray and yellow green	5	8
Silt, brown	6	14
Silt, tan	3	17
Silt, yellow buff	28	45
Silt, buff; contains much sand	13	58
Sand, medium to fine, and light gray silt	21	79
Silt, yellow gray and buff	33	112
Belleville formation		
Sand, coarse to fine, much gravel, and silt	8	120
Gravel, fine to medium, and sand	10	130
Gravel, medium to fine, and sand; contains much silt	20	150
(Water level, 140.6 feet below land surface.)		
Gravel, medium to fine, and sand	40	190
Gravel, coarse to fine, and sand	10	200
Gravel, medium to fine, and sand	16	216
CRETACEOUS—Gulfian		
Greenhorn limestone		
Shale, calcareous, dark gray; contains some bentonite	4	220

10. *Sample log of test hole 10 in the NE cor. sec. 1, T. 1 S., R. 4 W., 80 feet south and 7 feet west of center of crossroads. Surface altitude, 1,653.5 feet.*

	Thickness, feet	Depth, feet
Soil, clayey, brown	2	2
Clay, compact, gray to brown	12	14
QUATERNARY—Pleistocene		
"Loess"		
Silt, clayey, compact, tan	9	23
Silt, clayey, gray to tan	13	36
Silt, tan	4	40
Silt, fine sandy, tan	10	50
Sand, silty, tan	10	60

	Thickness, feet	Depth, feet
Sand, medium, tan	17	77
Silt, tan	29	106
Clay, silty, some medium gray gravels	4	110
Belleville formation		
Gravel, medium to coarse, and coarse brown sand	20	130
(Water level, 124.9 feet below land surface.)		
Gravel, medium to fine, and medium brown sand	40	170
Gravel, medium gray	2	172
CRETACEOUS—Gulfian		
Greenhorn limestone		
Shale, dark gray	8	180

11. *Sample log of test hole 11 in the Cen. sec. 6, T. 1 S., R. 3 W., 126 feet north and 78 feet west of fence intersection. Surface altitude, 1,646.3 feet.*

	Thickness, feet	Depth, feet
Soil, clayey, brown	2	2
QUATERNARY—Pleistocene		
"Loess"		
Silt, clayey, gray	3	5
Silt, tan	4	9
Silt, weathered, brown	5	14
Silt, clayey, tan	3	17
Silt, tan	13	40
Sand, very fine, silty, tan	10	50
Sand, fine, tan	20	70
Silt, fine sandy, tan	10	80
Silt, gray	10	90
Silt, clayey, gray and white, calcareous	12	102
Belleville formation		
Sand, coarse, and fine gray gravel	38	140
(Water level, 137.9 feet below land surface.)		
Sand, medium, some brown gravel	10	150
Gravel, medium, and medium brown sand	27	177
Clay, gray, and reddish gravel	5	182
Gravel, medium, and coarse gray and brown sand	8	190
Sand, medium, and fine brown gravel	16	206
Gravel, coarse, and gray clay	6	212
Gravel, coarse, and coarse gray sand	8.5	220.5
CRETACEOUS—Gulfian		
Greenhorn limestone		
Shale, dark gray blue, white speckled, calcareous	9.5	230

12. *Sample log of test hole 12 in the NE cor. sec. 7, T. 1 S., R. 3 W., 33 feet south and 5 feet west of crossroads. Surface altitude, 1,660.4 feet.*

	Thickness, feet	*Depth, feet*
Soil, silty, gray black	5	5
QUATERNARY—Pleistocene		
"Loess"		
Silt, gray	9	14
Silt, weathered, dark brown	4	18
Silt, clayey, tan	22	40
Silt, tan	67	107
Silt, clayey, light gray	4	111
Silt to fine sand, gray brown	7	118
Belleville formation		
Sand, very fine, silty, brown	2	120
Gravel, medium to coarse, and medium brown sand	40	160
(Water level, 153.2 feet below land surface.)		
Sand, medium, and fine brown gravel	40	200
Gravel, medium, and coarse brown sand	30	230
Sand, coarse, and fine gray gravel	4	234
CRETACEOUS—Gulfian		
Greenhorn limestone		
Shale, dark blue gray, white speckled	6	240

13. *Sample log of test hole 13 in the Cen. sec. 8, T. 1 S., R. 3 W., 200 feet southwest of fence intersection. Surface altitude, 1,650.4 feet.*

	Thickness, feet	*Depth, feet*
Soil, black	2	2
QUATERNARY—Pleistocene		
"Loess"		
Silt, gray	8	10
Silt, weathered, black	4	14
Silt, clayey, tan	6	20
Silt, tan	16	36
Silt, very fine sandy, tan	24	60
Sand, fine, gray	15	75
Silt, tan	15	90
Silt, gray to tan	20	110
Belleville formation		
Sand, fine, tan	10	120
Gravel, fine, and medium brown sand	20	140
Gravel, medium, and medium brown sand	55	195
(Water level, 144.8 feet below land surface.)		
Gravel, coarse, brown and blue-gray clay	2	197
CRETACEOUS—Gulfian		
Greenhorn limestone		
Shale, dark blue and gray, white speckled, laminated, calcareous	3	200

14. *Sample log of test hole 14 in SE cor. sec. 8, T. 1 S., R. 3 W., 60 feet north and 7 feet west of crossroads. Surface altitude, 1,637.7 feet.*

	Thickness, feet	Depth, feet
Soil, clayey, yellow	7	7
Clay, brown	6	13
QUATERNARY—Pleistocene		
"Loess"		
Silt, few gravels, tan and brown	12	25
Silt, tan	25	50
Silt; contains some gray gravels	30	80
Clay, white and tan, many limestone fragments	21	101
Belleville formation		
Gravel, medium to coarse, some brown and gray clay	9	110
Gravel, medium to coarse, brown and gray	10	120
Gravel, medium, and medium brown and gray sand	20	140
Gravel, medium, some brown and gray sand	10	150
Gravel, medium to coarse, and fine brown and gray sand	10	160
CRETACEOUS—Gulfian		
Greenhorn limestone		
Limestone fragments, buff, and white and brown clay	7	167
Shale, dark gray, some white speckled	3	170

15. *Sample log of test hole 15 in the NW cor. sec. 14, T. 1 S., R. 3 W., 7 feet south and 84 feet east of center of road intersection. Surface altitude, 1,574.3 feet.*

	Thickness, feet	Depth, feet
Road fill	3.5	3.5
QUATERNARY—Pleistocene		
"Loess"		
Silt, gray brown and gray	7.5	11
Silt, clayey, limonitic, light gray green	14	25
Silt, dull tan buff; contains some fine sand	25	50
Silt, light gray; contains much fine sand	6	56
Belleville formation		
Sand, coarse to fine, and some gravel, interbedded with light-gray and buff silt	4	60
Sand, coarse to fine, and much medium to fine gravel	10	70
Gravel, medium to fine, and sand; contains much light-gray silt	6	76
(Water level, 73.5 feet below land surface.)		
CRETACEOUS—Gulfian		
Carlile shale		
Shale, calcareous, yellow to yellow white; contains many thin soft limestone layers	14	90

16. *Sample log of test hole 16 in the SE cor. sec. 16, T. 1 S., R. 3 W., 24 feet west and 9 feet north of center of crossroads. Surface altitude, 1,617.4 feet.*

	Thickness, feet	Depth, feet
Soil, clayey, brown	2	2
QUATERNARY—Pleistocene		
"Loess"		
Silt, clayey, weathered; contains gray and brown organic material	10	12
Silt, clayey, yellowish brown	8	20
Silt, tan	8	28
Silt, calcareous, tan	42	70
Silt, clayey, calcareous, tan and white	10	80
Silt, clayey, calcareous, tan, gray, and white	10	90
Silt, clayey; contains few gravels	10	100
Belleville formation		
Sand, gravel, and clay, gray and white	10	110
Gravel, coarse, brown	10	120
Gravel, coarse, some yellow and brown clay	3	123
Clay and gravel, light gray	7	130
CRETACEOUS—Gulfian		
Greenhorn limestone		
Limestone, buff and gray	10	140

17. *Sample log of test hole 17 in the SE cor. sec. 24, T. 1 S., R. 4 W., 75 feet north and 9 feet west of center of crossroads. Surface altitude, 1,656.8 feet.*

	Thickness, feet	Depth, feet
Soil, brown	1	1
QUATERNARY—Pleistocene		
"Loess"		
Silt, gray	2	3
Silt, weathered, clayey, brown	12	15
Silt, clayey, tan	15	30
Silt, tan	40	70
Silt, tan to gray; contains some limy clay	10	80
Silt, clayey, compact, tan to gray	20	100
Belleville formation		
Silt, fine sandy, some gravels and limy clay	10	110
Gravel, medium to coarse, some gray clay	20	130
Gravel, medium and coarse sand, some gray clay	30	160
Clay and gravel, gray	5	165
CRETACEOUS—Gulfian		
Greenhorn limestone		
Shale, dark gray, white speckled	5	170

18. *Sample log of test hole 18 in the NE cor. sec. 31, T. 1 S., R. 3 W., 39 feet south and 7 feet west of concrete culvert south of road intersection. Surface altitude, 1,626.8 feet.*

	Thickness, feet	*Depth, feet*
Soil, clayey, dull greenish-gray and dark brown-gray	6	6
QUATERNARY—Pleistocene		
"Loess"		
Silt, light pink buff and yellow brown	12	18
Silt, light gray	7	25
Silt, yellow buff; contains some fine sand	31	56
(Water level, 55.7 feet below land surface.)		
Silt, clayey, light gray green	9	65
Silt, soft, dark buff; contains mueh sand	19	84
CRETACEOUS—Gulfian		
Carlile shale		
Shale, calcareous, bright yellow and light gray green, partly thinly laminated	26	110
Shale, soft, gray	4	114
Shale, calcareous, thinly laminated, dark gray	6	120

19. *Sample log of test hole 19 in the SE cor. sec. 32, T. 1 S., R. 3 W., 80 feet north and 6 feet west of center of road intersection. Surface altitude, 1,618.9 feet.*

	Thickness, feet	*Depth, feet*
Soil, silty, black	5	5
QUATERNARY—Pleistocene		
"Loess"		
Clay, gray	8	13
Clay, silty, gray and tan	7	20
Clay, silty, yellow buff	10	30
Clay, silty, iron stained, gray	20	50
Clay, silty, white and gray, calcareous	10	60
Clay, silty, tan	10	70
Silt, clayey, calcareous	20	90
Clay, silty, white and gray, calcareous	10	100
Clay, compact, many fine gravels, yellow buff	5	105
Clay, yellow buff, compact	6	111
CRETACEOUS—Gulfian		
Greenhorn limestone		
Shale, dark gray to black, white speckled	9	120

20. *Sample log of test hole 20 in the NE cor. sec. 5, T. 1 S., R. 4 W., 18 feet south and 66 feet west of center of road intersection. Surface altitude, 1,675.1 feet.*

	Thickness, feet	*Depth, feet*
QUATERNARY—Pleistocene		
"Loess"		
Silt, dark gray	1	1
Silt, dull greenish gray	5	6
Silt, blocky, dark brown	2	8
Silt, dull tan downward to pink buff	2	10

	Thickness, feet	Depth, feet
Silt, clayey, buff	20	30
Silt, light yellow buff	10	40
Silt, buff; contains some sand	7	47
Belleville formation		
Sand, medium to fine	16	63
Silt, buff and light gray; contains much medium to fine sand and some nodular caliche	7	70
Sand, medium to fine, and light-gray and yellow silt	16	86
Silt, light gray green; contains some sand	4	90
Silt, light greenish gray, downward to gray, gray white, and yellow; contains some medium to fine sand and caliche	8	98
(Water level, 94.3 feet below land surface.)		
Gravel, medium to fine, and sand	12	110
Gravel, fine, and sand	17	127
Silt, light brown, grading downward to yellow buff	9	136
CRETACEOUS—Gulfian		
Carlile shale		
Shale, calcareous, yellow downward to light greenish gray	10	146
Shale, calcareous, dark gray	2	148

21. *Sample log of test hole 21 in the SE cor. sec. 4, T. 1 S., R. 4 W., 156 feet west and 6 feet north of center of crossroads. Surface altitude, 1,635.4 feet.*

	Thickness, feet	Depth, feet
Soil, silty, tan and brown	10	10
QUATERNARY—Pleistocene		
"Loess"		
Silt, gray	15	25
Silt, tan	25	50
Silt, some gravels, gray	16	66
Belleville formation		
Gravel, silty, tan	4	70
Sand, medium and medium brown gravel	20	90
Gravel, medium to coarse, and medium brown sand	25	115
Gravel, medium, and gray clay	2	117
Gravel, medium to coarse, some brown sand	23	140
(Water level, 121.9 feet below land surface.)		
Gravel and sand, coarse, brown and gray	30	170
Gravel and sand, coarse, some gray clay	6	176
CRETACEOUS—Gulfian		
Greenhorn limestone		
Shale, dark gray blue to black	4	180

22. *Sample log of test hole 22 in the NE cor. sec. 15, T. 1 S., R. 4 W., 54 feet south and 6 feet west of center of crossroads. Surface altitude, 1,679.3 feet.*

	Thickness, feet	Depth, feet
Soil, clayey, brown and gray	12	12
QUATERNARY—Pleistocene		
"Loess"		
Silt, clayey, tan and brown	13	25
Silt, clayey, tan	25	50
Silt; contains calcite nodules	22	72
Silt, few gravels, tan	8	80
Silt, tan	25	105
Silt, fine sandy, gray	19	124
Belleville formation		
Gravel, medium, and fine sand, some gray clay	6	130
Gravel, coarse, some fine brown sand	20	150
(Water level, 166.7 feet below land surface.)		
Gravel, medium to coarse, and medium brown sand	50	200
Sand, medium, and medium to coarse gray gravel	6	206
Gravel, medium to coarse, gray	1	207
CRETACEOUS—Gulfian		
Greenhorn limestone		
Shale, gray blue to black, speckled white	3	210

23. *Sample log of test hole 23 in the Cen. sec. 14, T. 1 S., R. 4 W., 40 feet south and 20 feet west of fence intersection. Surface altitude, 1,665.2 feet.*

	Thickness, feet	Depth, feet
Soil, black	2.5	2.5
Clay, compact, gray	2.5	5
QUATERNARY—Pleistocene		
"Loess"		
Silt, clayey, gray, iron stained	6	11
Silt, weathered, clayey, brown	2	13
Silt, clayey, some fine gravels, tan	17	30
Silt, tan	20	50
Silt, clayey, gray to tan	12	62
Silt, gray	18	80
Silt, few gravels, gray to tan	10	90
Silt, tan	18	108
Belleville formation		
Silt, sandy, calcareous, tan and white	5	113
Gravel, fine, some brown clay	17	130
Gravel, medium, brown	20	150
Gravel, medium and sand, some brown clay	30	180
(Water level, 153.3 feet below land surface.)		
Gravel, fine, and medium silty brown sand	10	190
Clay and gravel, brown and gray	20	210
Gravel, medium, clayey, gray	12	222

	Thickness, feet	Depth, feet
CRETACEOUS—Gulfian		
Greenhorn limestone		
Shale, dark gray blue, speckled white, calcareous	3	225

24. *Sample log of test hole 24 in the SE cor. sec. 14, T. 1 S., R. 4 W., 110 feet north and 6 feet west of center of crossroads. Surface altitude, 1,673.4 feet.*

	Thickness, feet	Depth, feet
Soil, clayey, brown	1.5	1.5
Clay, gray to black	11.5	13
QUATERNARY—Pleistocene		
"Loess"		
Silt, tan	47	60
Silt, few fine gravels, tan	10	70
Silt, clayey, gray	20	90
Silt, gray	20	110
Silt, gray; contains fragments of limy clay	14	124
Belleville formation		
Clay, silty, and medium gray gravel	6	130
Gravel and sand, medium, and clay, gray	20	150
Gravel, medium, and coarse gray sand	33	183
(Water level, 160.9 feet below land surface.)		
Clay, silty; contains many gray gravels	19	202
Gravel, medium, and coarse sand, much gray clay	18	220
Gravel, medium, gray	11	231
CRETACEOUS—Gulfian		
Greenhorn limestone		
Shale, blue gray and black, speckled white; contains some fragments of limestone	9	240

25. *Sample log of test hole 25 in the NE. cor. sec. 24, T. 1 S., R. 5 W., 42 feet south and 6 feet west of center of crossroads. Surface altitude, 1,562.9 feet.*

	Thickness, feet	Depth, feet
Soil, silty, brown	0.5	0.5
QUATERNARY—Pleistocene		
"Loess"		
Silt, clayey, gray	5.5	6
Silt, weathered, brown, some gravels	11	17
Silt, sandy, tan	3	20
Belleville formation		
Sand, medium, silty, some tan gravels	13	33
Gravel, medium to coarse, and sand, coarse, gray	27	60
(Water level, 51.6 feet below land surface.)		
Gravel, medium to coarse, some brown sand	20	80
Sand, coarse, and fine gray gravel	7	87
CRETACEOUS—Gulfian		
Greenhorn limestone		
Shale, gray blue, laminated, white speckled, calcareous,	3	90

26. *Sample log of test hole 26 in the Cen. sec. 19, T. 1 S., R. 4 W., 125 feet south and 50 feet east of fence intersection. Surface altitude, 1,548.5 feet.*

	Thickness, feet	Depth, feet
Soil, clayey, brown	1.5	1.5
QUATERNARY—Pleistocene		
"Loess"		
Silt, clayey, gray	5.5	7
Silt, clayey, weathered, brown	3	10
Silt, clayey, tan	6	16
Sand, very fine, clayey, tan	4	20
Silt, clayey, tan	14	34
Silt, fine sandy, dark brown	2	36
Belleville formation		
Sand, medium, and medium brown gravel	14	50
(Water level, 37.5 feet below land surface.)		
Gravel, medium, and medium brown sand	20	70
Sand, medium, gray	5	75
CRETACEOUS—Gulfian		
Greenhorn limestone		
Shale, silty, dark gray to black	5	80

27. *Sample log of test hole 27 in the NE cor. sec. 25, T. 1 S., R. 5 W., 63 feet south and 8 feet west of center of crossroads. Surface altitude, 1,547.0 feet.*

	Thickness, feet	Depth, feet
Soil, clayey, brown	3	3
QUATERNARY—Pleistocene		
"Loess"		
Clay, silty, compact, gray	11	14
Clay; contains some fine brown sand grains	1	15
Silt; contains much gritty tan sand	11	26
Silt, clayey, compact, tan	14	40
Clay, compact, gray, some yellow streaks	10	50
Belleville formation		
Gravel, medium and coarse sand, gray and brown	10	60
Gravel, coarse, brown	6.5	66.5
CRETACEOUS—Gulfian		
Greenhorn limestone		
Shale, dark gray blue, laminated, white speckled	3.5	70

28. *Sample log of test hole 28 in the NE cor. sec. 30, T. 1 S., R. 4 W., 76 feet south and 6 feet west of center of crossroads. Surface altitude, 1,539.4 feet.*

	Thickness, feet	*Depth, feet*
QUATERNARY—Pleistocene		
"Loess"		
Clay, sandy, compact, tan	1	1
Silt, sandy, brown	1	2
Clay, sandy, compact, tan	8	10
Belleville formation		
Sand, medium to coarse, and fine gray gravel	32	42
(Water level, 26.2 feet below land surface.)		
Gravel, coarse, brown	5	47
Gravel, medium, and coarse sand; contains some gray clay	11.5	58.5
Gravel, medium, and coarse sand; contains considerable calcareous clay	0.5	59
CRETACEOUS—Gulfian		
Greenhorn limestone		
Shale, laminated, gray blue, some white speckled, calcareous	3	62

29. *Sample log of test hole 29 in the NE cor. sec. 32, T. 1 S., R. 4 W., 52 feet south and 12 feet west of center of crossroads. Surface altitude, 1,562.1 feet.*

	Thickness, feet	*Depth, feet*
Road fill	4	4
Clay, brown	2	6
Clay, sandy, gritty, light brown	2	8
QUATERNARY—Pleistocene		
Belleville formation		
Gravel, coarse to medium, and coarse sand, brown	2	10
Sand, fine, some coarse gray gravels	10	20
Sand, medium, and fine to medium gravel, gray	10	30
Sand, medium to coarse, some gray gravels	8	38
(Water level, 36.3 feet below land surface.)		
Clay, gritty; contains some pebbles of granite	10.5	48.5
Clay, gray, and coarse sand	1	49.5
Clay, gray, and sand; contains some coarse gravels	8.5	58
Gravel and sand, coarse; contains some limy clay	5	63
CRETACEOUS—Gulfian		
Greenhorn limestone		
Shale, dark blue gray, laminated, white speckled	7	70

30. *Sample log of test hole 30 in the SE cor. sec. 25, T. 1 S., R. 5 W., 110 feet north and 6 feet west of center of road intersection. Surface altitude, 1,516.1 feet.*

	Thickness, feet	Depth, feet
Soil, silty, black	3	3
Clay, silty, gray	4	7
QUATERNARY—Pleistocene		
"Loess"		
Clay, silty, some fine gray gravels	3	10
Silt, gray, some fine gravels	10	20
Belleville formation		
Sand, very fine, clayey, brown	7	27
Sand, coarse, and medium gray gravel	13	40
(Water level, 31.5 feet below land surface.)		
Gravel, medium, gray	2	42
CRETACEOUS—Gulfian		
Greenhorn limestone		
Shale, dark gray blue, white speckled, calcareous	8	50

31. *Sample log of test hole 31 in the NE cor. sec. 1, T. 1 S., R. 6 W., 7 feet south and 75 feet west of center of road intersection. Surface altitude, 1,516.4 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene and Recent		
Alluvium		
Silt, clayey, dark gray; contains some gravel and sand,	4	4
(Water level, 2.9 feet below land surface.)		
Sand, coarse to fine, and some fine gravel	14	18
CRETACEOUS—Gulfian		
Carlile shale		
Shale, calcareous, greenish gray	12	30

32. *Sample log of test hole 32 in the NW cor. NW¼ SW¼ sec. 7, T. 1 S., R. 5 W., 54 feet south and 12 feet west of corner post on east side of road at half-mile line. Surface altitude, 1,524.8 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene and Recent		
Alluvium		
Soil, dark gray; contains some sand	3	3
Sand, coarse to fine	1	4
Silt, dark yellowish gray downward to dull yellow gray,	14	18
(Water level, 15.6 feet below land surface.)		
Silt, clayey, soft, blue gray	8	26
Sand and some gravel, coarse to fine	4	30
Gravel, coarse to fine, and sand	9.5	39.5
CRETACEOUS—Gulfian		
Carlile shale		
Shale, calcareous, thin-bedded, gray	1	40.5

33. *Sample log of test hole 33 in the NE cor. sec. 14, T. 1 S., R. 5 W., 48 feet south and 9 feet west of center of crossroads. Surface altitude, 1,598.3 feet.*

	Thickness, feet	Depth, feet
Road fill	3	3
Clay, some gravels, gray	4	7
QUATERNARY—Pleistocene		
Belleville formation		
Silt, sandy, some brown gravels	3	10
Sand, fine, some brown silt	14	24
Silt, sandy, tan	3.5	27.5
Gravel and sand, medium, brown	12.5	40
Sand, medium, some gray gravel	20	60
(Water level, 61.1 feet below land surface.)		
Gravel, coarse, brown	12.5	72.5
CRETACEOUS—Gulfian		
Greenhorn limestone		
Shale, gray blue, laminated, white speckled, calcareous,	2.5	75

34. *Sample log of test hole 34 in the NE cor. sec. 23, T. 1 S., R. 5 W., 246 feet south of east T road and 8 feet west of middle of north-south road. Surface altitude, 1,515.1 feet.*

	Thickness, feet	Depth, feet
Soil, silty, brown and black	5	5
Clay, silty, gray	5	10
QUATERNARY—Pleistocene		
Belleville formation		
Sand, medium and coarse gravel, some clay	8	18
(Water level, 10.5 feet below land surface.)		
Sand and gravel, medium, gray	12	30
Sand, coarse, some fine gray gravel	6	36
CRETACEOUS—Gulfian		
Greenhorn limestone		
Shale, gray black, white speckled, calcareous	4	40

35. *Sample log of test hole 35 in the NE¼ NW¼ sec. 23, T. 1 S., R. 5 W., 45 feet west of railroad tracks and 6 feet south of center of road. Surface altitude, 1,491.4 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene and Recent		
Alluvium		
Soil, silty, black to gray	3	3
Sand, silty, gray	4	7
Sand, medium, brown to gray, and some fine gravel	3	10
Sand, coarse, brown to gray, and some fine gravel	6	16
CRETACEOUS—Gulfian		
Greenhorn limestone		
Shale, black, speckled with white, and some gray clay	4	20

36. *Sample log of test hole 36 in the SW cor. sec. 14, T. 1 S., R. 5 W., 0.3 mile west of test hole 35, 12 feet east and 6 feet north of road intersection. Surface altitude, 1,493.5 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene and Recent		
Alluvium		
Sand, fine to coarse, brown, and some gravel	12	12
(Water level, 4.1 feet below land surface.)		
Gravel, coarse, some sand, and fragments of gray clay,	8	20
CRETACEOUS—Gulfian		
Greenhorn limestone		
Shale, light grayish blue, clayey to silty	2	22
Shale, black, speckled with white	3	25

37. *Sample log of test hole 37 at Cen. N. line NE¼ sec. 22, T. 1 S., R. 5 W., 0.27 mile west of test hole 36. Surface altitude, 1,492.8 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene and Recent		
Alluvium		
Soil, very fine sandy, brown	1	1
Sand, very fine, brown	4	5
Clay, very fine sandy, brown	1	6
Sand, medium, brown	4	10
Sand, coarse, and fine gray gravel	10	20
CRETACEOUS—Gulfian		
Greenhorn limestone		
Shale, light gray blue	1	21

38. *Sample log of test hole 38 in NE¼ NW¼ sec. 22, T. 1 S., R. 5 W., 0.27 mile west of test hole 37. Surface altitude, 1,492.5 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene and Recent		
Alluvium		
Soil, silty to fine sandy	1.5	1.5
Sand, coarse, and fine brown gravel	8.5	10
(Water level, 6.2 feet below land surface.)		
Gravel, medium, coarse gray sand, and some gray clay,	11.5	21.5
CRETACEOUS—Gulfian		
Greenhorn limestone		
Shale, black; contains a few white spots	3.5	25

39. *Sample log of test hole 39 in the Cen. S. line SW¼ sec. 15, T. 1 S., R. 5 W., 0.2 mile west of test hole 38, 30 feet east and 30 feet north of corner fence post. Surface altitude, 1,490.4 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene and Recent		
Alluvium		
Soil, silty to very fine sandy, brown	1	1
Sand, coarse, and some gravel; contains a few fragments of shale near base	15.5	16.5
CRETACEOUS—Gulfian		
Greenhorn limestone		
Shale, black; contains a few white spots	3.5	20

40. *Sample log of test hole 40 in the SE cor. sec. 16, T. 1 S., R. 5 W., 6 feet west of intersection of crossroads. Surface altitude, 1,496.0 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene and Recent		
Alluvium		
Soil, silty to fine sandy, gray	2	2
Sand, very fine, gray	2	4
Sand, coarse, and medium gravel; contains much brown sandy clay	6	10
(Water level, 8.3 feet below land surface.)		
Sand, medium, and fine gray gravel	10	20
Gravel and sand, coarse, gray	10.5	30.5
CRETACEOUS—Gulfian		
Greenhorn limestone		
Shale, gray blue; contains white spots	4.5	35

41. *Sample log of test hole 41 in NW¼ NE¼ sec. 21, T. 1 S., R. 5 W., 0.33 mile west of test hole 40, and 13 feet north of center of road. Surface altitude, 1,497.1 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene and Recent		
Alluvium		
Soil, very fine sandy	5	5
Sand, medium to coarse, and medium gravel	25	30
(Water level, 8.7 feet below land surface.)		
CRETACEOUS—Gulfian		
Greenhorn limestone		
Shale, gray blue	1	31

42. *Sample log of test hole 42 in SW cor. sec. 16, T. 1 S., R. 5 W., 30 feet east and 6 feet north of intersection of crossroads. Surface altitude, 1,508.6 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene and Recent		
Alluvium		
Soil, very fine sandy, brown	2	2
Clay, silty to fine sandy, gray	2	4
Clay, silty, brown, gray; contains some fragments of limestone	16	20
(Water level, 8.9 feet below land surface.)		
Gravel, medium, and coarse sand, gray, some blue gray clay	17	37
CRETACEOUS—Gulfian		
Greenhorn limestone		
Shale, blue gray; contains white spots	3	40

43. *Sample log of test hole 43 in SW¼ SE¼ sec. 17, T. 1 S., R. 5 W., 0.4 mile west of test hole 42 and 7 feet north of middle of road. Surface altitude, 1,532.1 feet.*

	Thickness, feet	Depth, feet
Soil, silty to fine sandy, brown	4	4
QUATERNARY—Pleistocene		
"Loess"		
Clay, silty, brown	2	6
Silt, gray	24	30
(Water level, 19.8 feet below land surface.)		
Belleville formation		
Sand, coarse to fine, and some fine gravel, brown	10	40
Gravel, fine, and coarse sand, yellow brown	9	49
CRETACEOUS—Gulfian		
Greenhorn limestone		
Shale, dark gray black; contains white spots	2	51

44. *Sample log of test hole 44 in the SW¼ SW¼ sec. 17, T. 1 S., R. 5 W., 0.2 mile east of road intersection, 15 feet north and 57 feet west of mail box. Surface altitude, 1,585.3 feet.*

	Thickness, feet	Depth, feet
Soil, dark gray brown	2	2
QUATERNARY—Pleistocene		
"Loess"		
Silt, dull yellow green, some nodular caliche	13	15
Silt, brown	1.5	16.5
Silt, pink buff	13.5	30
Silt, buff	16	46
Silt, dark buff, some nodular caliche	4	50
Silt, yellow gray	25.5	75.5
Belleville formation		
Gravel, medium to fine, and sand	11	86.5
CRETACEOUS—Gulfian		
Carlile shale		
Shale, gray blue	3.5	90

45. *Sample log of test hole 45 in the SW cor. SE¼ sec. 18, T. 1 S., R. 5 W., 9 feet north and 54 feet east of center of road at half-mile line. Surface altitude, 1,564.9 feet.*

	Thickness, feet	Depth, feet
Soil, brown and gray green	2	2
QUATERNARY—Pleistocene		
"Loess"		
Silt, tan	3	5
Silt, buff	5	10
Silt, dull tan; contains some nodular caliche	10	20
Silt, buff, grading downward to light gray buff (Water level, 29.8 feet below land surface)	20	40
Silt, clayey, compact, light brown	6	46
Silt, soft, yellow gray, grading downward to light gray blue; contains some sand	4	50

	Thickness, feet	Depth, feet
Silt, soft, gray blue and light gray	5	55
Belleville formation		
Gravel, medium to fine, and sand	5	60
Gravel, medium to fine, and some sand	6	66
CRETACEOUS—Gulfian		
Carlile shale		
Shale, blue black	2	68

46. *Sample log of test hole 46 in the SW cor. sec. 18, T. 1 S., R. 5 W., 8 feet north and 63 feet east of center of road intersection. Surface altitude 1,595.6 feet.*

	Thickness, feet	Depth, feet
Soil, clayey, brown gray	2	2
QUATERNARY—Pleistocene		
"Loess"		
Silt, yellow gray	14	16
Silt, dark brown	2	18
Silt, pink buff grading downward to buff	12	30
Silt, buff, grading downward to light brown	15	45
Silt, compact, gray	2	47
Silt, yellow gray; contains some nodular caliche	23	70
Silt, brownish gray, downward to blue gray and light yellow gray; contains some sand	9	79
Belleville formation		
Gravel, medium to fine, and sand	11	90
CRETACEOUS—Gulfian		
Carlile shale		
Shale, calcareous, yellow and blue black	1	91

47. *Sample log of test hole 47 in SW cor. sec. 19, T. 1 S., R. 5 W., 9 feet south and 60 feet east of corner iron fence post. Surface altitude, 1,567.8 feet.*

	Thickness, feet	Depth, feet
Soil, dark gray	1	1
QUATERNARY—Pleistocene		
"Loess"		
Silt, clayey, yellow gray	3	4
Silt, blocky, brown	8	12
Silt, light tan, downward to buff	13	25
Silt, light greenish gray; contains some gravel and sand,	10	35
Belleville formation		
Gravel, medium to fine, and sand	10	45
(Water level, 35.8 feet below land surface.)		
Silt, gray; contains much sand	2	47
Gravel, medium to fine, sand, and silt	16	63
CRETACEOUS—Gulfian		
Carlile shale		
Shale, calcareous, dark gray	3	66

48. *Sample log of test hole 48 in the NE cor. sec. 36, T. 1 S., R. 6 W., 72 feet south and 9 feet west of center of road intersection. Surface altitude, 1,564.3 feet.*

	Thickness, feet	Depth, feet
Road fill	1	1
QUATERNARY—Pleistocene		
"Loess"		
Silt, limonitic, gray green	10	11
Silt, clayey, brown	3	14
Silt, yellow tan, downward to buff	12	26
(Water level, 22.4 feet below land surface.)		
Silt, light brownish gray	2	28
Silt, clayey, cream buff	24	52
Clay, silty, blue gray	11	63
Clay, silty, gray green	5	68
Belleville formation		
Gravel, fine, sand, and clay, gray green	4	72
CRETACEOUS—Gulfian		
Carlile shale		
Shale, calcareous, light gray, speckled, and brownish gray	2	74

49. *Sample log of test hole 49 in the NE cor. sec. 1, T. 2 S., R. 6 W., 15 feet south and 6 feet west of center of road intersection. Surface altitude, 1,556.0 feet.*

	Thickness, feet	Depth, feet
Road fill	1	1
QUATERNARY—Pleistocene		
"Loess"		
Silt, yellow gray	3	4
Silt, blocky, brown	3	7
Silt, light tan	2	9
Silt, compact, buff	6	15
Silt, clayey, light greenish gray and mottled yellow	15	30
(Water level, 26.7 feet below land surface.)		
Silt, clayey, light blue gray, mottled yellow; contains much Niobrara rubble in lower part	9	39
CRETACEOUS—Gulfian		
Carlile shale		
Shale, slightly calcareous, yellow downward to dark gray	1	40

50. *Sample log of test hole 50 in the SW¼ SW¼ sec. 19, T. 2 S., R. 1 W., about 0.2 mile east of road intersection, 3 feet south and 48 feet west of north end of concrete culvert. Surface altitude, 1,564.4 feet.*

	Thickness, feet	Depth, feet
Road fill	0.5	0.5
QUATERNARY—Pleistocene		
"Loess"		
Silt, dull greenish gray	4.5	5

	Thickness, feet	Depth, feet
Silt, blocky, brown	3	8
Silt, clayey, buff	8	16
Silt, clayey, light gray and buff; contains much gravel and sand	2	18
Belleville formation		
Gravel, medium to fine, and sand	10	28
(Water level, 22.7 feet below land surface.)		
CRETACEOUS—Gulfian		
Greenhorn limestone		
Shale, calcareous, yellow white	0.5	28.5
Limestone, yellow buff to white	1	29.5

51. *Sample log of test hole 51 in the NE cor. sec. 9, T. 2 S., R. 3 W., 30 feet south and 6 feet west of the center of road intersection. Surface altitude, 1,624.7 feet.*

	Thickness, feet	Depth, feet
Soil, clayey, compact, dark brown	2	2
QUATERNARY—Pleistocene		
"Loess"		
Clay, silty, gray	8	10
Clay, silty, black	2	10
Silt, clayey, tan	10	20
Silt, tan	20	40
Clay, silty, tan and white, calcareous	18	58
Clay, silty, tan, some gravels	4	62
Clay, silty, yellow	11	73
CRETACEOUS—Gulfian		
Greenhorn limestone		
Shale, dark gray to black, white speckled	7	80

52. *Log of test hole 52 in the SW cor. sec. 11, T. 2 S., R. 3 W., 60 feet east and 5 feet north of center of road intersection. Surface altitude, 1,627.6 feet.*

	Thickness, feet	Depth, feet
Soil, silty, yellow brown	4	4
QUATERNARY—Pleistocene		
"Loess"		
Clay, dark brown	4	8
Clay, white and gray, few gravels, calcareous	22	30
Belleville formation		
Sand, very fine, silty, gray	7	37
Sand, coarse, brown	3	40
Gravel, medium, and sand, medium, gray	5	45
(Water level, 42.8 feet below land surface.)		
Clay, silty, yellow	3.5	48.5
CRETACEOUS—Gulfian		
Greenhorn limestone		
Shale, black	1.5	50

53. *Sample log of test hole 53 in the SW cor. sec. 17, T. 2 S., R. 4 W., 51 feet north and 7 feet east of center of road intersection. Surface altitude, 1,520.3 feet.*

	Thickness, feet	Depth, feet
Road fill	2	2
QUATERNARY—Pleistocene		
Alluvium		
Silt, light brown; contains some nodular caliche	3	5
Sand, coarse to fine, and buff silt	10	15
Silt, clayey, light brown and yellow; contains some gravel and sand	11	26
Silt, clayey, yellow and green gray; contains many shale fragments	9	35
CRETACEOUS—Gulfian		
Carlile shale		
Shale, calcareous, dark gray	5	40

54. *Sample log of test hole 54 in the SW¼ SE¼ sec. 18, T. 2 S., R. 4 W., 0.33 mile west of road intersection. Surface altitude, 1,482.3 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene and Recent		
Alluvium		
Silt, brown gray; contains some sand	7	7
Silt, blocky, black	2	9
Silt, brown gray	4	13
Silt, clayey, yellow gray and gray (Water level, 22.7 feet below land surface.)	18	31
Gravel, medium to fine, and sand	9	40
Gravel, medium to fine, and sand	4	44
CRETACEOUS—Gulfian		
Greenhorn limestone		
Shale, calcareous, hard, gray speckled, and some bentonite, blue	4	48

55. *Sample log of test hole 55 in the SE¼ SW¼ sec. 18, T. 2 S., R. 4 W., 0.66 mile west of road intersection, 6 feet north of center of road and 228 feet east of lane to house. Surface altitude, 1,471.6 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene and Recent		
Alluvium		
Silt, light brown-gray	4	4
Silt, dark gray, containing some sand	2	6
Silt, clayey, light gray, interbedded with some sand and some caliche nodules	3	9
Sand, fine and some silt, clayey (Water level, 12.5 feet below land surface.)	11	20
Gravel, fine, and sand	10	30
Gravel, coarse to fine, and sand	8	38
CRETACEOUS—Gulfian		
Greenhorn limestone		
Shale, calcareous, hard, light to dark gray, and some clay, gray white; contains granular calcite	2	40

56. *Sample log of test hole 56 in the SW cor. sec. 18, T. 2 S., R. 4 W., 63 feet north and 9 feet east of road intersection. Surface altitude, 1,471.1 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene and Recent		
Alluvium		
Silt, alternating dark gray and yellow gray	4	4
Silt, clayey, light gray	4.5	8.5
Sand, medium to fine	1.5	10
Sand, coarse to fine, and gravel (Water level, 11.9 feet below land surface)	10	20
Gravel, fine, sand, and some pebbles	10	30
Gravel, medium to fine, sand, and some dark blue-gray clay	6	36
CRETACEOUS—Gulfian		
Greenhorn limestone		
Shale, calcareous, dark brownish gray, speckled	4	40

57. *Sample log of test hole 57 in the SW¼ SE¼ sec. 13, T. 2 S., R. 5 W., 0.34 mile west of road intersection, 18 feet south and 66 feet east of telephone pole at east end of grove. Surface altitude, 1,459.0 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene and Recent		
Alluvium		
Silt, clayey, gray black	2	2
Silt, gray; contains some caliche	4	6
(Water level, 3.7 feet below land surface.)		
Gravel, fine, and sand	17.5	23.5
CRETACEOUS—Gulfian		
Carlile shale		
Shale, silty, calcareous, gray	16.5	40

58. *Sample log of test hole 58 in the NE¼ NW¼ sec. 24, T. 2 S., R. 5 W., 0.74 mile west of road intersection, 6 feet south and 21 feet east of north post of gate at end of road. Surface altitude, 1,456.9 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene and Recent		
Alluvium		
Silt, dark gray, grading downward to brown gray	2	2
Gravel, fine, and sand	8	10
(Water level, 4.2 feet below land surface.)		
Gravel, medium to fine, and sand	7	17
CRETACEOUS—Gulfian		
Carlile shale		
Shale, calcareous, gray to light gray; contains some gray-blue bentonite	3	20

59. *Sample log of test hole 59 in the NE cor. sec. 23, T. 2 S., R. 5 W., 32 feet south and 54 feet east of corner post of "T" fence. Surface altitude, 1,459.0 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene and Recent		
Alluvium		
Silt, gray and light gray; contains much sand	6.5	6.5
Gravel, fine, and sand	6.5	13
(Water level, 8.7 feet below land surface.)		
CRETACEOUS—Gulfian		
Carlile shale		
Shale, calcareous, partly laminated, dark gray; contains some blue bentonite	5	18

60. *Sample log of test hole 60 in the SE¼ SE¼ sec. 14, T. 2 S., R. 5 W., 33 feet north and 9 feet west of corner post of "T" fence south of road. Surface altitude, 1,470.1 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene and Recent		
Alluvium		
Silt, light brownish gray	9	9
Silt, dark gray; contains much sand	1	10
Silt, yellow gray	6	16
(Water level, 12.9 feet below land surface.)		
Sand, coarse to fine, and some gravel	4	20
CRETACEOUS—Gulfian		
Carlile shale		
Shale, thin-bedded, dark gray	2	22

61. *Sample log of test hole 61 in the NE cor. sec. 12, T. 2 S., R. 6 W., 14 feet south and 21 feet east of first power pole south of section line. Surface altitude, 1,532.7 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
"Loess"		
Silt, clayey, dark brown gray	1	1
Silt, dull greenish gray; contains many limonite concretions	6	7
Silt, gray	2	9
Silt, clayey, light blue gray and yellow buff	15	24
(Water level, 19.1 feet below land surface.)		
Silt, clayey, yellow buff; contains some gravel and sand,	4	28
CRETACEOUS—Gulfian		
Carlile shale		
Shale, noncalcareous, dark blue gray and dull yellow gray; contains some gypsum	2	30

62. *Sample log of test hole 62 in the NW¼ NE¼ sec. 17, T. 3 S., R. 4 W., 20 feet west and 120 feet south of south edge of east pillar of bridge across Republican River. Surface altitude, 1,433.9 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene and Recent		
Alluvium		
Soil, silty, gray	3	3
(Water level, 4.6 feet below land surface.)		
Sand, medium, gray	7	10
Sand, medium to coarse, and fine gravel, gray	12	22
CRETACEOUS—Gulfian		
Greenhorn limestone		
Shale, black; contains white spots	8	30

63. *Sample log of test hole 63 near Cen. N. line of sec. 17, T. 3 S., R. 4 W., 50 feet west and 100 feet south of west end of bridge across Republican River. Surface altitude, 1,436.3 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene and Recent		
Alluvium		
Soil, silty to clayey, some gravel, gray	2	2
Soil, silty, black	1	3
Sand, medium, brown, and some fine gravel	7	10
(Water level, 6.4 feet below land surface.)		
Gravel, coarse, sand, medium, and some fragments of gray clay and shale	10	20
CRETACEOUS—Gulfian		
Greenhorn limestone		
Shale, black and gray; contains white spots	10	30

64. *Sample log of test hole 64 in NW¼ NE¼ sec. 17, T. 3 S., R. 4 W., 0.2 mile west of test hole 63 and 0.2 mile east of test hole 65, 60 feet south of highway. Surface altitude, 1,434.6 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene and Recent		
Alluvium		
Soil, silty, brown and black; contains some gravel (Water level, 4.5 feet below land surface.)	5	5
Gravel, coarse to fine, and sand, medium to coarse, gray and green; contains a few shells	21	26
CRETACEOUS—Gulfian		
Greenhorn limestone		
Shale, silty to clayey, black; contains some white spots,	4	30

65. *Sample log of test hole 65 in NW cor. of sec. 17, T. 3 S., R. 4 W., 210 feet south of section corner and 6 feet east of center of road. Surface altitude, 1,432.4 feet.*

	Thickness, feet	*Depth, feet*
QUATERNARY—Pleistocene and Recent		
Alluvium		
Sand, medium, brown (Water level, 2.0 feet below land surface.)	10	10
Gravel, coarse, some coarse sand, green and gray	10	20
Gravel, medium, and coarse sand, green and gray	20	40
Gravel, medium, and coarse sand, green and gray; contains fragments of limestone	10	50
Gravel, medium to coarse, some medium sand; contains many fragments of white-buff limestone and some shell fragments	11	61
CRETACEOUS—Gulfian		
Greenhorn limestone		
Shale, fine sandy to clayey, dark gray	9	70

66. *Sample log of test hole 66 in the NW¼ NE¼ sec. 18, T. 3 S., R. 4 W., 65 feet south of center of highway. Surface altitude, 1,435.6 feet.*

	Thickness, feet	*Depth, feet*
QUATERNARY—Pleistocene and Recent		
Alluvium		
Soil, silty, brown, and some gravel	1.5	1.5
Sand, medium, tan; contains fine gravel at base (Water level, 3.4 feet below land surface.)	5.5	7
Sand, coarse, and gravel, medium	3	10
Gravel, medium, and coarse sand, green and gray	10	20
Gravel, medium to coarse, and medium sand; contains fragments of green and gray clay	20	40
Gravel, medium to coarse, and medium sand; contains much gray, brown, and white clay	10	50
Gravel, medium, and fine to medium sand; contains many fragments of limestone and shells	21	71
Clay, soft, gray	4	75
CRETACEOUS—Gulfian		
Greenhorn limestone		
Shale, silty to clayey, black; contains much charcoal	5	80

67. *Sample log of test hole 67 in the Cen. N. line sec. 18, T 3 S., R. 4 W., 0.23 mile west of test hole 66, 25 feet east of lane into farmhouse, and 70 feet south of center of U. S. Highway 36. Surface altitude, 1,437.3 feet.*

	Thickness, feet	*Depth, feet*
QUATERNARY—Pleistocene and Recent		
Alluvium		
Soil, silty, brown, and some gravel	1	1
Sand, fine to coarse, gravel, fine, and much silt, brown, (Water level, 4.0 feet below land surface.)	9	10
Gravel, medium to coarse, and coarse sand	17	27
CRETACEOUS—Gulfian		
Greenhorn limestone		
Shale, black; contains white specks and some fragments of limestone	3	30

68. *Sample log of test hole 68 in the NE¼ NE¼ sec. 21, T. 3 S., R. 5 W., 0.2 mile west of road intersection, 36 feet south and 15 feet west of east post of gate into city well. Surface altitude, 1,480.8 feet.*

	Thickness, feet	Depth, feet
Road fill	2	2
Clay, silty, dull green gray, mottled brown	2	4
Clay, silty, light brown; contains some nodular caliche,	8	12
Silt, cláyey, yellow gray	8	20
Silt, light tan; contains some caliche	4	24
Silt, clayey, gray green	19	43
Silt, clayey, dull yellow green; contains many pebbles of limestone	11	54
CRETACEOUS—Gulfian		
Carlile shale		
Shale, calcareous, yellow buff	2	56
Shale, calcareous, dark gray	4	60

69. *Sample log of test hole 69 in the NW¼ NE¼ SW¼ sec. 6, T. 4 S., R. 2 W., 12 feet south and 6 feet west of fence post in northeast corner of wheat field. Surface altitude, 1,388.3 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene and Recent		
Alluvium		
Soil, gray black	7	7
Silt, clayey, dark gray brown downward to buff	9	16
(Water level, 14.6 feet below land surface.)		
Silt, soft, light gray and buff	9	25
Silt, soft, dark blue gray; contains some fine sand	10	35
Gravel, coarse to fine	2	37
CRETACEOUS—Gulfian		
Dakota formation		
Clay, gray white and red	3	40

70. *Sample log of test hole 70 in the SE¼ SE¼ NE¼ sec. 1, T. 4 S., R. 3 W., 45 feet north and 7 feet west of center of north end of wooden bridge. Surface altitude, 1,376.2 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene and Recent		
Alluvium		
Road fill and soil, gray black	4	4
Silt, soft, gray buff	6	10
Silt, soft, gray buff; contains much coarse to fine sand,	5	15
(Water level, 11.5 feet below land surface.)		
Sand, coarse to fine, gray and buff silt, and much coarse to fine gravel	5	20
Gravel, fine to medium, and medium sand	1	21
Silt, soft, light gray and blue gray	4	25
Sand, and much gravel, coarse to fine	5	30
Sand, coarse to fine, much coarse to fine gravel, and some light-buff silt	8	38
CRETACEOUS—Gulfian		
Dakota formation		
Clay, light blue gray	2	40

71. *Sample log of test hole 71 at the SW cor. SE¼ SE¼ NE¼ sec. 1, T. 4 S., R. 2 W., 87 feet south of power pole at southwest corner of barn, 600 feet west of test hole 70. Surface altitude, 1,399.9 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene and Recent		
Alluvium		
Silt, clayey, compact, tan downward to buff	8	8
Silt, partly clayey, yellow; contains some fine sand	1	9
Silt, partly clayey, yellow	2	11
Sand, medium to fine, some fine gravel, and some yellow silt	2	13
Silt, clayey, yellow buff	1	14
Sand, coarse to fine, some medium to fine gravel, and some yellow-buff silt	6	20
Gravel, coarse to fine, and sand	2.5	22.5
Silt, clayey, light gray and yellow-buff, interbedded with some gravel and sand	14.5	37
(Water level, 35.7 feet below land surface.)		
Gravel, medium to fine, and sand, interbedded with buff and light-gray silt	6	43
Gravel, coarse to fine, and sand	7	50
Gravel, fine to coarse, medium sand, and light brown-buff silt	19	69
Silt, soft, blue gray to dark gray	12	81
CRETACEOUS—Gulfian		
Dakota formation		
Clay, greenish gray and red, mottled	6	87

72. *Sample log of test hole 72 in the SE¼ SW¼ NE¼ sec. 1, T. 4 S., R. 3 W., 655 feet west of test hole 71, 8 feet south and 6 feet west of fence post. Surface altitude, 1,408.6 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene and Recent		
Alluvium		
Soil, gray black	2	2
Silt, light gray	4	6
Silt, brown, changing downward to tan	9	15
Silt, yellow; contains some sand	2	17
Silt, yellow	10	27
(Water level, 24.4 feet below land surface.)		
Gravel, fine to medium, and sand	3	30
Silt, yellow; contains much fine sand	9.5	39.5
Gravel, coarse to fine, medium sand, and much buff silt,	7	46.5
CRETACEOUS—Gulfian		
Dakota formation		
Clay, light blue gray; contains much fine sand	3.5	50

73. *Sample log of test hole 73 in the NW¼ NW¼ SE¼ sec. 1, T. 4 S., R. 3 W.; 900 feet west of test hole 72, 264 feet east of half-mile road, and 9 feet south of fence line. Surface altitude, 1,422.0 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene and Recent		
Alluvium		
Soil, dark gray	1	1
Silt, yellow gray	5	6
Silt, blocky, brown	3	9
Silt, tan, downward to buff	11	20
CRETACEOUS—Gulfian		
Dakota formation		
Sandstone, very fine, silty, light gray, and some clayey, light blue-gray silt	10	30

74. *Sample log of test hole 74 in the NE cor. sec. 8, T. 4 S., R. 4 W., 18.5 feet south of windmill in farmyard of Dr. E. P. Ahrens. Surface altitude, 1,411.7 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene and Recent		
Alluvium		
Soil, silty, black (Water level, 5.4 feet below land surface.)	2	2
Clay, silty to fine-sandy, gray	6	8
Sand, fine to coarse, and fine gravel	4	12
Gravel, fine, and coarse sand, gray and green	17	29
Gravel, fine, coarse gray and green sand, some shells, some dark-gray clay, and fragments of limestone and shale	1	30
Gravel, medium, and coarse sand, gray and green	20	50
Gravel and sand, coarse, and fragments of limestone; contains much tan clay	21	71
CRETACEOUS—Gulfian		
Greenhorn limestone		
Shale, clayey, light gray	9	80

75. *Sample log of test hole 75 in the NW¼ NW¼ sec. 20, T. 4 S., R. 4 W. Surface altitude, 1,406.1 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene and Recent		
Alluvium		
Road fill	1	1
Soil, silty, black	1	2
Soil, silty, brown	6	8
Gravel, fine to medium, and coarse to medium sand (Water level, 8.2 feet below land surface.)	12	20
Gravel, medium to fine, and some sand	6	26
Gravel, medium to fine, brown sand, and much buff-yellow sandy clay	7	33
Gravel, medium and fragments of yellowish-brown limestone	6	39

CRETACEOUS—Gulfian

Greenhorn limestone	Thickness, feet	Depth, feet
Shale, gray blue, clayey, soft	7	46
Shale, light gray blue, silty	4	50

76. *Sample log of test hole 76 in the NW¼ NW¼ sec. 20, T. 4 S., R. 4 W. Surface altitude, 1,404.4 feet.*

QUATERNARY—Pleistocene and Recent

Alluvium	Thickness, feet	Depth, feet
Soil, silty, to clayey; contains some black lime	5	5
Soil, silty, light gray blue	3.5	8.5
(Water level, 7.1 feet below land surface.)		
Sand, coarse to fine, and fine gravel, brown	1.5	10
Sand, coarse to fine, and fine gravel, gray green	12	22
Gravel, medium to fine, and silty clay, black to light gray; contains snail shells	4	26
Gravel, medium, and coarse to medium sand	15	41
Gravel, medium, shale, and fragments of yellow-brown rotten limestone	4	45

CRETACEOUS—Gulfian

Greenhorn limestone		
Shale, gray and black; contains some charcoal	5	50

77. *Sample log of test hole 77 in the NE¼ NW¼ sec. 20, T. 4 S., R. 4 W. Surface altitude, 1,404.2 feet.*

QUATERNARY—Pleistocene and Recent

Alluvium	Thickness, feet	Depth, feet
Soil, brown red, some black soil at surface	4	4
Clay, silty, gray	1	5
Sand, medium, and fine gravel, brown	5	10
(Water level, 6.8 feet below land surface.)		
Sand, coarse, and fine gravel, gray	11	21
Clay, silty, gray black; contains some snail shells	6	27
Gravel, fine, and coarse sand, gray	23	50
Gravel, fine, and medium sand, gray	11	61

CRETACEOUS—Gulfian

Greenhorn limestone		
Shale, silty, gray	9	70

78. *Sample log of test hole 78 in the NW¼ NE¼ sec. 20, T. 4 S., R. 4 W. Surface altitude, 1,400.8 feet.*

QUATERNARY—Pleistocene and Recent

Alluvium	Thickness, feet	Depth, feet
Road fill	0.5	0.5
Sand, medium, silty	1.5	2
Clay, silty, black	4	6
Gravel, medium, and coarse sand	20	26

	Thickness, feet	Depth, feet
Clay, silty, gray blue	14	40
Gravel, medium, and coarse sand	30	70
Gravel, medium, and coarse sand; contains fragments of limestone and many shell fragments	14	84
Gravel, coarse to medium, and coarse sand; contains fragments of limestone and shell fragments	16	100
Gravel, fragments of limestone and shale, gray blue	12	112
CRETACEOUS—Gulfian		
Graneros shale		
Shale, gray blue, some brown red	8	120

79. *Sample log of test hole 79 in the NE¼ sec. 20, T. 4 S., R. 4 W. Surface altitude, 1,401.2 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene and Recent		
Alluvium		
Silt, and very fine sand, brown, gray	4	4
Clay, silty, black	1	5
(Water level, 3.8 feet below land surface.)		
Sand, medium, tan gray	5	10
Gravel, fine to medium, and coarse to medium sand, gray	40	50
Gravel, medium to fine, and coarse to medium sand	20	70
Gravel, fine to medium, medium to fine sand, and some fragments of limestone	10	80
Gravel, fine to medium, medium to fine sand, and fragments of limestone	6	86
CRETACEOUS—Gulfian		
Graneros shale		
Drilled extremely hard, no sample obtained	1	87

80. *Sample log of test hole 80 in the NW¼ sec. 21, T. 4 S., R. 4 W. Surface altitude, 1,400.2 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene and Recent		
Alluvium		
Topsoil, silty to clayey, black and brown	3	3
Sand, medium	7	10
(Water level, 3.6 feet below land surface.)		
Gravel, fine, and coarse to fine sand	20	30
Gravel, coarse to fine, and coarse sand, pebbles up to 1 inch	10	40
Gravel, medium to fine, and coarse sand	20	60
Sand, coarse to medium, and some fine gravel	9	69
CRETACEOUS—Gulfian		
Graneros shale		
Shale, gray to black	1.5	70.5

81. *Sample log of test hole 81 in the NW¼ sec. 21, T. 4 S., R. 4 W. Surface altitude, 1,409.6 feet.*

	Thickness, feet	*Depth, feet*
QUATERNARY—Pleistocene and Recent		
Alluvium		
Soil, silty black	2	2
Sand, fine, silty, gray	6	8
Silt, sandy, gray	2	10
Sand, medium, brown, and some fine gravel (Water level, 10.8 feet below land surface.)	10	20
Gravel, fine to medium, and coarse sand, gray	20	40
Gravel, fine to medium, and coarse to medium sand, gray	20	60
Gravel, fine to medium, some coarse gravel, and coarse to medium sand, gray	17	77
Gravel, fine, and coarse to medium sand, gray	2	79
CRETACEOUS—Gulfian		
Graneros shale		
Clay, reddish, some yellow	1	80

82. *Sample log of test hole 82 in the NE¼ sec. 21, T. 4 S., R. 4 W. Surface altitude, 1,414.0 feet.*

	Thickness, feet	*Depth, feet*
QUATERNARY—Pleistocene and Recent		
Alluvium		
Soil, silty, black	5	5
Silt, brown and gray (Water level, 15.4 feet below land surface.)	16	21
Gravel, fine, and coarse to medium sand, brown and white	9	30
Gravel, fine to medium, some coarse gravel, and coarse sand, brown and gray	34.5	64.5
Gravel, fine to medium, and coarse sand, brown and gray, some limestone fragments	6.5	71
CRETACEOUS—Gulfian		
Graneros shale		
Fragments of limestone, brown, and sandy yellow clay,	4	75

83. *Sample log of test hole 83 in the NW cor. sec. 22, T. 4 S., R. 4 W. Surface altitude, 1,411.7 feet.*

	Thickness, feet	*Depth, feet*
QUATERNARY—Pleistocene and Recent		
Alluvium		
Soil, silty clayey, black	4	4
Clay, silty, brown	3	7
Clay, silty, limy, gray (Water level, 13.1 feet below land surface.)	15	22
Sand, and some gravel, medium, brown and gray	8	30
Gravel, fine to medium, and coarse to medium sand	10	40
Sand, coarse, and fine gravel, gray	5	45
CRETACEOUS—Gulfian		
Graneros shale		
Shale, gray; contains fragments of charcoal	5	50

84. *Sample log of test hole 84 in the NW cor. NE¼ sec. 22, T. 4 S., R. 4 W. Surface altitude, 1,424.4 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene and Recent		
Alluvium		
Soil, silty, black and brown	7	7
Clay, silty, limy, light brown (Water level, 27.4 feet below land surface.)	33	40
Gravel, fine to medium, and coarse sand, few brown pebbles to 1 inch	10	50
Gravel, fine to coarse, and coarse sand, brown	5	55
Gravel, fine to coarse, some brown sand, and some fragments of limestone	5	60
CRETACEOUS—Gulfian		
Graneros shale		
Shale, gray, much yellow brown and some red clay; contains rusty fragments of limestone	20	80

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85. *Sample log of test hole 85 in NE¼ NE¼ sec. 34, T. 5 S., R. 1 W., 2 feet south of center of road and 12 feet west of stop sign for State highway.*

	Thickness, feet	Depth, feet
Road fill	3	3
QUATERNARY—Pleistocene and Recent		
Alluvium		
Silt, soft, gray; contains much sand and many caliche nodules	4	7
Gravel, fine, and coarse to fine sand	3	10
Gravel, medium to fine, and coarse to fine sand, green,	13	23
Clay, silty, blue gray; contains some sand	.5	23.5
Gravel and sand, coarse to fine, green	6.5	30
Gravel, medium to fine, and coarse to fine sand, green and brown	10	40
Gravel, coarse to fine, and coarse to medium sand	10	50
Gravel, fine, and coarse sand, green	13	63
Silt, soft, buff, grading downward into gray; contains some sand	7	70
Silt, soft, dark gray and gray green; contains some gravel	20	90
Silt, clayey, dark gray	5	95
CRETACEOUS—Gulfian		
Dakota formation		
Sandstone, soft, medium, white; contains some charcoal and pyrite	5	100

86. *Sample log of test hole 86 in SW¼ NW¼ sec. 35, T. 5 S., R. 1 W., 0.45 mile south of section line and 9 feet east of center of road.*

	Thickness, feet	Depth, feet
Road fill	2	2
QUATERNARY—Pleistocene and Recent		
Alluvium		
Silt, soft, light yellow gray; contains some sand	6	8
Gravel and sand, coarse to fine, green	22	30
Gravel, medium to fine, and coarse to fine sand, green,	10	40
Gravel, fine, and coarse to fine sand, green	10	50
Gravel and sand, coarse to fine, brown and green	10	60
Gravel, fine, and coarse to fine sand, brown	6	66
Silt, soft, buff; contains some sand	2	68
Silt, clayey, gray; contains some sand	2	78
Gravel, medium to fine, and coarse to medium sand	2.5	80.5
Silt, clayey, gray	2.5	83
CRETACEOUS—Gulfian		
Dakota formation		
Sandstone, soft, coarse to medium, white; contains some pyrite	17	100

87. *Sample log of test hole 87 in NW¼ SW¼ sec. 19, T. 5 S., R. 2 W., 0.6 mile south of section line and 30 feet south of curve of road to gravel pit.*

	Thickness, feet	Depth, feet
Road fill	1	1
QUATERNARY—Pleistocene and Recent		
Alluvium		
Silt, dark and light gray; contains some fine sand (Water level, 5.3 feet below land surface.)	6	7
Gravel, medium to fine, and coarse to medium sand	3	10
Gravel, medium to fine, and coarse to fine sand, green; contains some clayey green silt	20	30
Gravel, fine, and coarse to fine sand, brown	10	40
Gravel, medium to fine, and coarse to fine sand, brown,	31	71
CRETACEOUS—Gulfian		
Dakota formation		
Clay, gray, yellow, and pink; contains some fine sand	4	75

88. *Sample log of test hole 88 in NE¼ NE¼ sec. 26, T. 5 S., R. 2 W., 0.25 mile south of section line and 33 feet west of center of road.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene and Recent		
Alluvium		
Soil, gray black; contains some sand	3	3
Silt, yellow gray; contains some sand	3.5	6.5
Silt, gray black; contains some sand	.5	7
Silt, soft yellow gray, and fine to medium sand	9.5	16.5

	Thickness, feet	Depth, feet
Gravel, fine, and coarse to fine sand	8.5	25
(Water level, 18.2 feet below land surface.)		
Gravel, medium to fine, coarse to fine sand, green, and soft gray silt	5	30
Gravel, medium to fine, coarse to medium sand and some soft gray silt	10	40
Gravel and sand, coarse to fine	10	50
Gravel, medium to fine, and coarse to fine sand	10	60
Gravel, medium to fine, coarse to fine sand and soft gray silt	10	70
Gravel, medium to fine, and coarse to fine sand	9	79
Silt, soft, buff	4	83
Silt, soft, gray and gray black; contains some sand	3	86
Gravel, coarse to fine, and coarse to medium sand	11.5	97.5
CRETACEOUS—Gulfian		
Dakota formation		
Clay, light gray; contains some sand, sandstone, and hard gray limestone	12.5	110

89. *Sample log of test hole 89 in NW¼ SW¼ sec. 28, T. 5 S., R. 2 W., 0.55 mile south of section line and 9 feet east of center of road.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene and Recent		
Alluvium		
Soil, silty, dark gray; contains some sand	3	3
Silt, clayey, yellow gray; contains some sand	2	5
(Water level, 4.3 feet below land surface.)		
Sand, coarse to fine, and fine gravel, green	5	10
Gravel, medium to fine, and coarse to fine sand, green	10	20
Gravel and sand, coarse to fine	10	30
Gravel, medium to fine, and coarse to fine sand	10	40
Gravel and sand, coarse to fine	10	50
Gravel, medium to fine, and coarse to fine sand	6.5	56.5
Silt, soft, light green; contains some fine sand	.5	57
Gravel and sand, coarse to fine	8	65
Silt, soft, buff and green	3	68
Gravel, coarse to fine	4	72
Silt, soft, buff; contains very fine sand	3	75
Gravel, medium to fine	4	79
Silt, soft, buff and blue gray; contains much fine sand	10	89
CRETACEOUS—Gulfian		
Dakota formation		
Clay, gray and gray white; contains much sand, soft light gray sandstone, and some hard buff limestone	17	106

90. *Sample log of test hole 90 in NW¼ NW¼ sec. 16, T. 5 S., R. 3 W., 0.15 mile south of crossroads. Altitude of land surface, 1,411.3 feet.*

	Thickness, feet	*Depth, feet*
Road fill	0.5	0.5
QUATERNARY—Pleistocene and Recent		
Soil, silty, brown	0.5	1
Silt, tan and gray (Water level, 54.2 feet below land surface.)	62	63
CRETACEOUS—Gulfian		
Dakota formation		
Clay, and fragments of yellow, buff, and gray siltstone,	4	67
Clay, light gray, contains limonite	3	70

91. *Sample log of test hole 91 in NW¼ SW¼ sec. 16, T. 5 S., R. 3 W., 0.35 mile north of test hole 8. Altitude of land surface 1,382.2 feet.*

	Thickness, feet	*Depth, feet*
Road fill	0.5	0.5
Soil, silty	4.5	5
Silt, tan and brown	25	30
QUATERNARY—Pleistocene and Recent		
Alluvium		
Clay, sandy; contains some tan gravel (Water level, 35.5 feet below land surface.)	13	43
Gravel, medium, and coarse sand, brown	16	59
CRETACEOUS—Gulfian		
Dakota formation		
Clay, mottled red, gray, and yellow	6	65

92. *Sample log of test hole 92 in NE cor. sec. 20, T. 5 S., R. 3 W., 78 feet south and 7 feet west of crossroads. Surface altitude, 1,368.1 feet.*

	Thickness, feet	*Depth, feet*
Soil, silty, black and brown	2	2
Silt, tan and brown	20	22
QUATERNARY—Pleistocene and Recent		
Alluvium		
Sand, medium; contains some brown gravel (Water level, 23.5 feet below land surface.)	8	30
Gravel, fine, and coarse sand, brown	10	40
Gravel, medium, and coarse sand, brown	10	50
Sand, coarse, and fine gravel, brown	40	90
Sand, coarse, and fine gravel; contains some yellow-brown clay	3	93
Gravel, medium, and coarse sand; contains yellow limestone, gravel, and clay	7	100
CRETACEOUS—Gulfian		
Dakota formation		
Clay, very fine sandy, yellow	10	110

93. *Sample log of test hole 93 in NW cor. sec. 19, T. 5 S., R. 3 W., 25 feet west of junction of angle road with curve and 9 feet south of center of angle road.*

	Thickness, feet	Depth, feet
Road fill	3	3
QUATERNARY—Pleistocene and Recent		
Alluvium		
Silt, soft, gray; contains some fine sand	3	6
Silt, soft, yellow gray; contains some fine sand	4	10
Clay, silty, yellow gray; contains some fine sand	11	21
(Water level, 19.9 feet below land surface.)		
Gravel, fine, and coarse to fine sand brown	9	30
Gravel and sand, coarse to fine, brown, and some soft blue-gray silt	10	40
Gravel and sand, coarse to fine, greenish	14	54
Silt, soft, buff; contains little fine sand	5	59
Gravel, fine, and coarse to fine sand	11	70
Gravel, medium to fine, and coarse to fine sand	20	90
Gravel, medium to fine, coarse to fine sand and soft buff silt	5	95
Silt, clayey, blue gray and gray	5	100
Silt, soft, gray and black; contains some sand	10	110
Gravel and sand, coarse to fine, and some soft buff silt,	12	122
CRETACEOUS—Gulfian		
Dakota formation		
Sandstone, soft, fine, pink, brown, white and gray black, carbonaceous, some hematite and pyrite	8	130

94. *Sample log of test hole 94 in the SW cor. NW¼ sec. 20, T. 5 S., R. 3 W.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene and Recent		
Alluvium		
Soil, sandy, gray black	3	3
Silt, clayey, gray	4	7
(Water level, 7.0 feet below land surface.)		
Silt, soft, gray and blue gray; contains much sand and gravel	3	10
Gravel and sand, coarse to fine, green, and some compact greenish-gray silt	10	20
Gravel and sand, coarse to fine	10	30
Gravel, medium to fine, and coarse to medium sand,	10	40
Gravel, coarse to fine, and coarse to medium sand	20	60
Gravel, coarse to medium, coarse to fine sand, brown, and some clayey tan silt	12	72
Silt, soft, tan and blue gray; contains some medium to fine sand	3	75
Gravel, fine to coarse	2.5	77.5
Silt, clayey, dark gray; contains some medium to fine sand	10.5	88

	Thickness, feet	Depth, feet
Clay, silty, gray, and some medium to fine sand	14	102
Gravel, medium to fine	4	106
CRETACEOUS—Gulfian		
Dakota formation		
Silt, clayey, gray white and pink; contains some medium to fine sand and some soft coal	14	120

95. *Sample log of test hole 95 in SE cor. sec. 19, T. 5 S., R. 3 W., 5 feet north and 30 feet west of center of T road intersection.*

	Thickness, feet	Depth, feet
Road fill	2	2
QUATERNARY—Pleistocene and Recent		
Alluvium		
Silt, soft, gray white; contains some fine sand and caliche nodules	5	7
(Water level, 5.4 feet below land surface.)		
Gravel, medium to fine, green coarse to fine sand and clayey greenish-gray silt	10	17
Clay, silty, greenish gray	.5	17.5
Gravel, and sand, coarse to fine, green and some greenish-gray silt	12.5	30
Gravel and sand, coarse to fine, brown and green	13	43
Silt, soft, gray white; contains much coarse to medium sand	3	46
Gravel and sand, coarse to fine	4	50
Gravel, fine to medium, and coarse sand	12	62
CRETACEOUS—Gulfian		
Dakota formation		
Sandstone, soft, medium, yellow brown	6	68
Clay, gray	2	70
Clay, silty, light gray; contains some fine sand	8	78
Coal, lignitic, and dark-gray clay; contains some sand,	2	80
Clay, dark gray, medium to fine sand, and sandstone	10	90

96. *Sample log of test hole 96 in NW¼ NW¼ sec. 21, T. 5 S., R. 3 W., 0.15 mile south of road intersection and 6 feet east of center of road. Surface altitude, 1,355.1 feet.*

	Thickness, feet	Depth, feet
Road material	3	3
QUATERNARY—Pleistocene and Recent		
Alluvium		
Soil, silty, brown and black	2	5
Clay, silty, gray	5	10
Sand, silty, fine, and fine brown gravel (Water level, 10.5 feet below land surface.)	10	20
Gravel, medium, and coarse sand gray green	20	40

	Thickness, feet	Depth, feet
Gravel, medium, and coarse sand, yellow, brown, and gray	40	80
Gravel, medium; contains limestone gravel, and much clay	12	92
CRETACEOUS—Gulfian		
Dakota formation		
Clay, gray, contains some charcoal	8	100

97. *Sample log of test hole 97 in NW cor. SW¼ sec. 21, T. 5 S., R. 3 W., 100 feet south of east-west road and 15 feet east of center of north-south road.*

QUATERNARY—Pleistocene and Recent	Thickness, feet	Depth, feet
Alluvium		
Soil	3	3
Sand, coarse to fine, and some medium to fine gravel, brown (Water level, 6.8 feet below land surface.)	12	15
Gravel, fine, and coarse to fine sand, green	5	20
Gravel, very coarse to fine, and some coarse to medium sand	10	30
Gravel, coarse to fine, and some coarse to medium sand,	10	40
Gravel, coarse to fine, and coarse sand	10	50
Gravel, fine to medium, and coarse sand	10	60
Gravel, medium to fine, coarse to fine sand and soft gray and buff silt	10	70
Gravel, fine, coarse to medium sand, and soft gray silt,	10.5	80.5
Silt, clayey, gray	28.5	109
Gravel, medium to fine, and coarse to medium sand	7	116
CRETACEOUS—Gulfian		
Dakota formation		
Clay, compact, pink and white	4	120

98. *Sample log of test hole 98 in SW¼ SW¼ sec. 21, T. 5 S., R. 3 W., 0.37 mile south of test hole 4, 108 feet south of south end of bridge and 12 feet east of center of road. Surface altitude, 1,348.8 feet.*

QUATERNARY—Pleistocene and Recent	Thickness, feet	Depth, feet
Alluvium		
Soil, silty, brown and black	2	2
Gravel, medium, and medium to coarse sand brown (Water level, 4.8 feet below land surface.)	18	20
Gravel, medium to coarse, and coarse sand gray green,	50	70
Sand, medium to coarse, and medium gravel, brown and gray	8	78
Clay, very fine sandy, gray to brown; contains some gravel	22	100
Gravel, medium to coarse; contains much limestone, gravel, and some yellow-buff clay	6	106
CRETACEOUS—Gulfian		
Dakota formation		
Shale, clayey, red and white mottled	4	110

99. *Sample log of test hole 99 in the NE¼ SE¼ sec. 27, T. 5 S., R. 3 W., in center of road, 0.45 mile north of section line and 0.95 mile north of road intersection.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene and Recent		
Alluvium		
Silt, gray black; contains much sand	2	2
Sand, coarse to fine, and some fine gravel, brown	8	10
(Water level, 3.9 feet below land surface.)		
Gravel, fine to medium, and much medium sand	12.5	22.5
Silt, soft, blue gray	.5	23
Sand, coarse to fine, and some medium gravel	7	30
Gravel, medium to fine, and coarse to fine sand	20	50
Gravel, fine, and coarse to fine sand	10	60
Gravel, fine, and coarse to fine sand	15	75
Silt, soft, buff and gray, interbedded with gravel and sand	7.5	82.5
Gravel and sand, coarse to fine	3.5	86
Silt, soft, tan; contains much fine sand	5	91
Gravel, coarse to fine, and sand	6.5	97.5
CRETACEOUS—Gulfian		
Dakota formation		
Clay, dark gray; contains some fine sand, pyrite, and fairly hard, black, lustrous coal	7.5	105

100. *Sample log of test hole 100 in NW¼ NW¼ sec. 28, T. 5 S., R. 3 W., 1,086 feet south of north section line and 1,334 feet east of west section line. Surface altitude, 1,346 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene and Recent		
Alluvium		
Sand, medium to fine, and gray silt	5	5
Silt, gray black; contains some medium to fine sand and some pebbles	6	11
(Water level, 8.1 feet below land surface.)		
Gravel, medium to fine, and coarse to fine sand	12	23
Silt, clayey, gray green	2.5	25.5
Gravel, coarse to medium, and coarse to fine sand	4.5	30
Gravel and some sand, coarse to fine	30	60
Gravel, fine, and coarse sand	3	63
Clay, silty, light gray green; contains a little coarse to fine sand	2	65
Gravel, fine to coarse, and coarse sand	10	75
Silt, soft, clayey, buff; contains some fine sand	5	80
Silt, soft, clayey, buff and dark gray; contains some fine sand	10	90
Silt, clayey, gray and greenish blue gray; contains a little medium to fine sand	11	101
Gravel, coarse to medium	2	103
CRETACEOUS—Gulfian		
Dakota formation		
Clay, red, white, and yellow	2	105

101. *Sample log of test hole 101 in NW¼ NW¼ sec. 28, T. 5 S., R. 3 W., 1,071 feet south of north section line and 1,148 feet east of west section line and 380 feet east of War Prisoner Camp well 3. Surface altitude, 1,347.5.*

	Thickness, feet	*Depth, feet*
QUATERNARY—Pleistocene and Recent		
Alluvium		
Sand, medium to fine, and soft black silt	2.5	2.5
Sand, coarse to medium, some fine brown gravel	9.5	12
(Water level, 7.0 feet below land surface.)		
Sand, coarse to medium, medium to fine gray gravel and greenish-gray silt	18	30
Gravel, medium to fine, and some coarse sand	20	50
Gravel, coarse to fine, and coarse to medium sand	5.5	55.5
Silt, soft, buff, gray, and brown; contains much fine sand	7.5	63
Gravel, fine to coarse, and some coarse to fine sand	13	76
Clay, silty, buff and gray	4	80
Clay, silty, gray and black	10	90
Clay, silty, gray black and gray green	11	101
Gravel, medium to fine	6	107
CRETACEOUS—Gulfian		
Dakota formation		
Clay, red and white	3	110

102. *Sample log of test hole 102 in NW¼ NW¼ sec. 28, T. 5 S., R. 3 W., 885 feet east of west section line and 1,075 feet south of north section line. Surface altitude, 1,340.8 feet.*

	Thickness, feet	*Depth, feet*
QUATERNARY—Pleistocene and Recent		
Alluvium		
Soil, gray sandy	1.5	1.5
Sand, fine, and gray silt	1.5	3
Sand, coarse to medium, much medium to fine gravel	2	5
Sand, coarse to medium, some medium to fine gravel	4	9
(Water level, 5.8 feet below land surface.)		
Sand, coarse to medium, green	11	20
Gravel, medium to fine, much coarse to medium sand	10	30
Gravel, coarse to fine, some coarse to fine sand	10	40
Gravel, medium to fine, and coarse to medium sand	11	51
Silt, soft, buff; contains much fine sand	9	60
Silt, soft, clayey, dark gray; contains some fine sand	16	76
CRETACEOUS—Gulfian		
Dakota formation		
Silt, soft, red, white, and yellow, some soft yellow and brown sandstone	4	80
Clay, red, yellow, and white	3	83

103. *Sample log of test hole 103 in NW¼ NW¼ sec. 28, T. 5 S., R. 3 W., 1,210 feet south of north section line and 450 feet east of west section line. Surface altitude, 1,347.1 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene and Recent		
Alluvium		
Soil, gray black	2	2
Sand, medium to fine, and silt, gray	2	4
Gravel, fine, and coarse to medium sand	6	10
Gravel, medium to fine, and coarse sand, some silty dark-gray clay	4	14
Gravel, medium to fine, some coarse, and coarse sand	6	20
Gravel, coarse to fine, some coarse sand, some dark-gray clay	10	30
Gravel, medium to fine, some coarse, few pebbles	10	40
Gravel, medium to fine, and coarse sand	8	48
Silt, clayey, light yellow buff; contains some sand and fragments of limestone	7	55

104. *Sample log of test hole 104 in the SW¼ NW¼ sec. 28, T. 5 S., R. 3 W., 115 feet north of T road from east just south of river, 5 feet east of center of road. Surface altitude, 1,349.8 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene and Recent		
Alluvium		
Soil, silty to clayey, black	3	3
Clay, very fine sandy, gray (Water level, 6.0 feet below land surface.)	4	7
Sand, medium, and fine gravel, brown; contains some limestone gravel	3	10
Sand, medium to coarse, brown	10	20
Gravel, medium to coarse, and some coarse sand	10	30
Gravel, medium to coarse, and medium to coarse gray-green sand	24	54
Gravel, very coarse, and tan clay	16	70
Gravel, coarse, and fragments of limestone, yellow-brown to white	16	86
CRETACEOUS—Gulfian		
Dakota formation		
Shale, clayey, red and white, and fragments of limestone,	4	90

105. *Sample log of test hole 105 in NW¼ SW¼ sec. 28, T. 5 S., R. 3 W., 0.25 mile north of test hole 2, 0.25 mile south of test hole 104, and 9 feet east of center of road. Surface altitude, 1,349.9 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene and Recent		
Alluvium		
Soil, silty, brown and black	4	4
Gravel, fine, coarse sand, and clay, brown and gray (Water level, 7.8 feet below land surface.)	4	8
Gravel, medium, and coarse sand, gray green	26	34

	Thickness, feet	Depth, feet
Gravel, coarse, and some coarse sand; contains many fragments of brown rotten sandstone and ironstone,	7	41
CRETACEOUS—Gulfian		
Dakota formation		
Clay, yellow, buff, and gray	6	47
Clay, red, yellow, and gray	3	50

106. *Sample log of test hole 106 in the NE¼ SE¼ sec. 29, T. 5 S., R. 3 W., 360 feet north of the northeast municipal well of the City of Concordia and 9 feet west of center of road. Surface altitude, 1,349.8 feet.*

	Thickness, feet	Depth, feet
Road material	2	2
QUATERNARY—Pleistocene and Recent		
Alluvium		
Sand, very fine, and silt, brown	7	9
Gravel, fine to coarse, and coarse sand brown (Water level, 10.8 feet below land surface.)	13	22
Gravel, fine to coarse, and coarse sand, gray green	19	41
CRETACEOUS—Gulfian		
Dakota formation		
Clay, slightly sandy, yellow, buff, and gray	9	50

107. *Sample log of test hole 107 in NE¼ NE¼ sec. 29, T. 5 S., R. 3 W., 18 feet west and 30 feet south of center of east T road and 50 feet north of river. Surface altitude, 1,349.3 feet.*

	Thickness, feet	Depth, feet
Road material	1	1
QUATERNARY—Pleistocene and Recent		
Alluvium		
Soil, silty, brown	7.5	8.5
(Water level, 5.3 feet below land surface.)		
Sand, medium; contains some brown gravel	4.5	13
Gravel, medium, and coarse sand, gray green	19	32
Clay	2	34
Gravel, medium, and coarse sand, gray green	18	52
Clay, silty, yellow buff	8	60
Sand, fine, and clay; contains some gray gravel	10	70
Gravel, medium; contains many fragments of limestone	21	91
CRETACEOUS—Gulfian		
Dakota formation		
Clay, light gray mottled to red	9	100

108. *Sample log of test hole 108 in NE¼ NE¼ sec. 29, T. 5 S., R. 3 W., 0.2 mile west of test hole 5, 100 feet east and 75 feet north of wooden bridge.*

	Thickness, feet	Depth, feet
Road fill	2	2
QUATERNARY—Pleistocene and Recent		
Alluvium		
Sand, coarse to medium, and some fine to medium gravel	9	11
Sand, coarse to medium, fine to medium gravel, green, and clayey greenish-gray silt	9	20
Gravel, medium to fine, and coarse to medium sand	24	44
Silt, soft, light brown; contains some fine sand	6	50
Silt, soft, light brown and gray; contains some fine sand	10	60
Silt, soft gray brown and blue gray; contains some fine sand	10	70
Silt, very soft, blue gray and gray	10	80
Silt, soft, gray black and green; contains some gravel and sand	10	90
CRETACEOUS—Gulfian		
Dakota formation		
Clay, yellow, red, and white, some soft yellow-brown sandstone	8	98

109. *Sample log of test hole 109 in SW¼ SE¼ sec. 33, T. 4 S., R. 4 W., 0.3 mile west of section line and 7 feet north of center of road.*

	Thickness, feet	Depth, feet
Road fill	1	1
QUATERNARY—Pleistocene and Recent		
Alluvium		
Silt, soft, yellow gray and black; contains some sand	2	3
Clay, compact, dark and light gray; contains some sand	7	10
(Water level, 4.9 feet below land surface.)		
Sand, coarse to fine, some fine gravel, green	5	15
Gravel, medium to fine, green some coarse to fine sand, some caliche nodules	5	20
Gravel, and some sand, coarse to fine, green	44	64
Silt, clayey, buff, some caliche	6	70
Silt, soft, partly clayey, buff, many caliche nodules	30	100
Silt, soft, gray green; contains some fine sand	10	110
Silt, soft, carbonaceous, gray and brown; contains some medium to fine sand	5	115
Gravel, coarse to fine	9	124
CRETACEOUS—Gulfian		
Dakota formation		
Clay, gray, pink, and yellow; contains some fine sand some pyrite and lignite, and some limestone	6	130

110. *Sample log of test hole 110 in the SW cor. SE¼ sec. 11, T. 5 S., R. 4 W., 150 feet north of center of road and 150 feet east of half section line.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene and Recent		
Alluvium		
Soil, gray black, and yellow-gray silt; contains some sand, fine	5	5
Silt, compact, clayey, gray brown; contains some fine sand	2	7
Silt, soft, yellow gray, very fine sand and some caliche nodules	13	20
(Water level, 19.6 feet below land surface.)		
Silt, soft, gray, and fine to very fine sand	7	27
Gravel, medium to fine, and coarse to fine sand, brown,	23	50
Gravel, coarse to fine, and silt, yellow; contains some sand	6	56
CRETACEOUS—Gulfian		
Dakota formation		
Clay, silty, cream and pink; contains some yellow-brown sandstone	4	60

111. *Sample log of test hole 111 in the SE cor. sec. 11, T. 5 S., R. 4 W., 45 feet north and 9 feet west of right angle road off curve of county road 781.*

	Thickness, feet	Depth, feet
Road fill	3	3
QUATERNARY—Pleistocene and Recent		
Alluvium		
Silt, clayey, brown gray	7	10
Silt, clayey, yellow gray	9	19
(Water level, 19.3 feet below land surface.)		
Silt, soft, buff; contains some gravel and sand	4	23
Gravel, fine, and coarse to fine sand	7	30
Gravel, medium to fine, and coarse to fine sand, brown,	11	41
CRETACEOUS—Gulfian		
Dakota formation		
Clay, gray, and fine yellow-brown sandstone	6	47
Clay, carbonaceous, dark gray; contains some soft, medium, brown and white sandstone	6	53
Clay, gray white; contains some fine sand	3	56

112. *Sample log of test hole 112 in SE cor. sec. 15, T. 5 S., R. 4 W., 221 feet east of county highway 354 and 6 feet north of center of road.*

	Thickness, feet	Depth, feet
Road fill	2	2
QUATERNARY—Pleistocene and Recent		
Alluvium		
Silt, soft, yellow gray; contains much sand	6	8
Sand and gravel, coarse to fine	12	20
Gravel and sand, coarse to fine, and some clayey blue-gray silt	6	26

	Thickness, feet	Depth, feet
Silt, soft; contains some sand and gravel	14	40
Gravel and sand, coarse to fine	10	50
Gravel, medium to fine, and coarse to fine sand	20	70
Gravel, coarse to fine, and some brown sand	10	80
Gravel, medium to fine, dark brown, and some coarse to fine sand	5	85
Silt, soft, buff and gray; contains some fine sand	5	90
Silt, clayey, gray	18	108
Gravel, medium to fine, and some coarse to fine sand,	9.5	117.5
CRETACEOUS—Gulfian		
Dakota formation		
Clay, gray, reddish brown and gray white; contains some hard white sandstone	2.5	120

113. *Sample log of test hole R1 in the SE cor. sec. 20, T. 3 S., R. 4 W., drilled by Bureau of Reclamation, 1941. Surface altitude, 1,423.1 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene and Recent		
Alluvium		
Soil	1	1
Sand (Water level, 5 feet below land surface.)	9	10
Sand, coarse	14	24
Silt	2	26
Sand, coarse, and gravel	19	45
Sandstone, soft, decomposed, yellow	4	49
Sandstone, soft, yellow	9	58

114. *Sample log of test hole R2 in the SE cor. sec. 10, T. 4 S., R. 4 W., drilled by Bureau of Reclamation, 1941. Surface altitude, 1,413.6 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene and Recent		
Alluvium		
Soil	4	4
Clay, brown (Water level, 13.5 feet below land surface.),	12.5	16.5
Sand, brown	8.5	25
Sand and gravel	12	37
Shale, blue	7	44

115. *Sample log of test hole R3 in the SE cor. sec. 33, T. 4 S., R. 4 W., drilled by Bureau of Reclamation, 1941.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene and Recent		
Alluvium		
Soil	4	4
Clay, yellow	2	6
Sand, fine (Water level, 7.8 feet below land surface.)	4	10
Sand, fine, white	20	30
Sand and gravel	48	78
CRETACEOUS—Gulfian		
Graneros (?) shale		
Shale, blue	1	79

116. *Sample log of test hole R5 in the NE cor. sec. 17, T. 5 S., R. 4 W., drilled by Bureau of Reclamation, 1941. Surface altitude, 1,377.3 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene and Recent		
Alluvium		
Soil	3	3
Clay, yellow	15	18
Sand, fine, yellow	7	25
Sand and gravel	40	65
Sand, fine, white	10	75
Sand and gravel	18.5	93.5
CRETACEOUS—Gulfian		
Dakota formation		
Shale, brown	1.5	95

Logs 117 to 124, inclusive, are logs of test holes 1B to 7B drilled by the Air-Made Well Company for the Concordia Prison Camp.

117. *Drillers log of test hole 1B, 2,880 feet north and 2,140 feet east of the SW cor. sec. 15, T. 5 S., R. 3 W. Surface altitude, 1,413.3 feet.*

	Thickness, feet	Depth, feet
Clay, yellow	11	11
Clay, brown	8.5	19.5
Clay, dark blue	9.5	29
Clay, yellow; contains white streaks of soapstone	23.5	52.5
Sand, very fine	0.5	53
Clay, hard, blue	3	56
Sand, fine, tight	13	69
Shale, blue	3	72

118. *Drillers log of test hole 2B, 200 feet north and 2,140 feet east of the SW cor. sec. 15, T. 5 S., R. 3 W. Surface altitude, 1,372.3 feet.*

	Thickness, feet	Depth, feet
Clay, sandy, yellow	9	9
Clay, light	5	14
Sand, fine	3	17
Clay, hard, light	1	18
Sand, very fine	10	28
Clay, hard, light	0.5	28.5
Sand rock	7.25	35.75

119. *Drillers log of test hole 3B, 1,600 feet south and 2,140 feet east of the NW cor. sec. 22, T. 5 S., R. 3 W. Surface altitude, 1,359.6 feet.*

	Thickness, feet	Depth, feet
Soil, black	3	3
Clay, hard, yellow	13	16
Mud, fine, sandy	19	35
Sand, medium fine	16	51
Sand, medium coarse	14	65
Sand, coarse	13	78

120. *Drillers log of test hole 4B, 2,140 feet south and 2,140 feet east of the NW cor. sec. 22, T. 5 S., R. 3 W. Surface altitude, 1,355.4 feet.*

	Thickness, feet	*Depth, feet*
Soil, black	3	3
Clay, yellow	18	21
Sand, fine	15	36
Sand, medium coarse	19	55
Sand, coarse	40	95

121. *Drillers log of test hole 5B, 2,140 feet south and 2,640 feet east of the NW cor. sec. 22, T. 5 S., R. 3 W. Surface altitude, 1,350.6 feet.*

	Thickness, feet	*Depth, feet*
Soil, black	2	2
Clay, yellow	14	16
Sand, fine	13	29
Sand, medium coarse	13	42
Sand, coarse	23	65
Shale, light	5	70

122. *Drillers log of test hole 6B, 2,140 feet south and 1,640 feet east of the NW cor. sec. 22, T. 5 S., R. 3 W. (Location of well 2 at the Concordia Prison Camp). Surface altitude, 1,352.9 feet.*

	Thickness, feet	*Depth, feet*
Soil, black	3	3
Clay, yellow	16	19
Sand, fine	12	31
Sand, coarse	62	93

123. *Drillers log of test hole 7B, 1,300 feet north and 3,560 feet east of the SW cor. sec. 15, T. 5 S., R. 3 W. Surface altitude, 1,387.9 feet.*

	Thickness, feet	*Depth, feet*
Soil	35	35
Rock	5	40

124. *Drillers log of test hole L W 4 drilled by the Layne-Western Company in SE¼ NE¼ sec. 32, T. 5 S., R. 3 W.*

	Thickness, feet	*Depth, feet*
Soil	5	5
Clay	15	20
Sand	5	25
Sand and gravel	17	42
Sand fine	6	48
Sand, fine, packed	4	52
Clay	3	55
Sand, fine, packed	21	76
Soapstone (Dakota ? formation)	2	78

125. *Drillers log of test hole L W 6 drilled by the Layne-Western Company in SE¼ NE¼ sec. 32, T. 5 S., R. 3 W.*

	Thickness, feet	Depth, feet
Soil	5	5
Clay	25	30
Sand, fine	5	35
Sand and gravel	15	50
Sand, fine, packed	5	55
Clay	1	56
Soapstone (Dakota ? formation)	2	58

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