Geology and Ground-Water Resources of Pawnee and Edwards Counties, Kansas

By

THAD G. McLAUGHLIN

UNIVERSITY OF KANSAS PUBLICATIONS
STATE GEOLOGICAL SURVEY OF KANSAS

Bulletin 80

1949

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BULLETIN 80

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By THAD G. McLAUGHLIN
with analyses by
H. A. STOLTENBERG

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

Printed by authority of the State of Kansas
Distributed from Lawrence

UNIVERSITY OF KANSAS PUBLICATIONS
MARCH, 1949

PRINTED BY
FERD VOILAND, JR., STATE PRINTER
TOPEKA, KANSAS
1949

22-4221

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GEOLOGY AND GROUND-WATER RESOURCES OF PAWNEE AND EDWARDS COUNTIES, KANSAS

By THAD G. McLAUGHLIN

ABSTRACT

The report describes the geography, geology, and ground-water resources of Pawnee and Edwards Counties in central Kansas. These counties have an area of about 1,368 square miles and had a population of 14,042 in 1945. The area consists of gently rolling upland plains together with large areas of sand hills and relatively flat flood plains and terraces. The climate is subhumid, the average annual precipitation being between 20 and 24 inches. Farming and the raising of livestock are the principal occupations in the area. Irrigation from Pawnee River and from wells has been practiced extensively in Pawnee Valley and irrigation from wells has been developed to a lesser extent in Arkansas Valley and in the dune-sand areas south of the valley.

The rocks that crop out in this area range in age from Cretaceous to Recent. The Cretaceous rocks are exposed in the upland areas in northern Pawnee County and in the area between Pawnee and Arkansas Rivers in southwestern Pawnee County and northwestern Edwards County. The Ogallala formation crops out only in small areas in northwestern Edwards County and southwestern Pawnee County. The alluvium and terrace deposits underlie the principal valleys and the adjacent areas and dune sand covers the large area lying south of the Arkansas Valley. The alluvium in Pawnee and Arkansas Valleys and the Meade formation, which underlies the dune-sand area, yield large quantities of water to wells. Other formations generally yield only small to moderate quantities of water to wells. The report contains a map showing the areas of outcrop of the rock formations and a diagrammatic cross section of the area showing the distribution of the formations that lie above the Permian redbeds, as determined by extensive test drilling.

The report contains a map of the area showing the locations of wells for which records were obtained and the depths to water level. The depth to water level in areas of Tertiary and Quaternary rocks generally is less than 50 feet. In other areas the depth to water may be only a few feet or may be as much as 200 feet, depending upon which bedrock formation supplies water to the well. A map showing by means of contours the shape and slope of the water table is also included in this report. The map shows that ground water moves eastward to northeastward through a large part of the area.

The ground-water reservoir is recharged principally from rain and snow that fall within the area, by percolation from streams and depressions, and by underflow from adjacent areas. Ground water is discharged from the ground-water reservoir by seepage into perennial streams, by transpiration and evaporation, by movement into adjacent areas, and by wells.

Most of the wells in the area are drilled or driven, but a few are dug or bored. Of the 360 wells listed in the report, 127 are irrigation wells. In 1943, 76 of these wells were used to irrigate about 3,380 acres of land, and about 3,400 acre-feet of ground water was pumped for this purpose. The areas most favorable for the development of large supplies of water for irrigation and industrial use are the Arkansas Valley, the Pawnee Valley, and the dune-sand area south of the Arkansas Valley.

Ground water in the Pawnee-Edwards area generally is hard, but is suitable for most uses. Waters from the Dakota formation generally contain a large amount of dissolved solids, but may be only moderately hard owing to natural softening. These waters generally are high in fluoride. Water from the alluvium is hard, but it is of slightly better quality in the Pawnee Valley than in the Arkansas Valley. The formation that yields the largest quantities of the most suitable water is the Meade formation, which underlies the area south of the Arkansas Valley.

The report contains a section in which the character, distribution and thickness, age and correlation, and water supply of the rock formations are described. This discussion deals with all formations down to and including the Permian redbeds.

The field data upon which this report is based are given in tables; they include records of 360 wells, chemical analyses of water from 71 representative wells, and logs of 144 wells, including 131 test holes put down as a part of this investigation and two test holes put down at the Edwards-Kiowa county line as a part of the investigation of the geology and ground-water resources of Kiowa County.

INTRODUCTION

Purpose and Scope of the Investigation

An investigation of the geology and ground-water resources of Pawnee and Edwards Counties was begun in July 1944 by the United States Geological Survey and the State Geological Survey of Kansas, 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.

Ground water is one of the principal natural resources of Kansas. Almost the entire population of Pawnee and Edwards Counties obtains its water supply from wells. Ground water is also used to water livestock and to irrigate more than 3,000 acres of land. It is replenished by precipitation, by streams, or by both. If withdrawals of ground water are kept within safe limits, the supply will last indefinitely.

The extended drought between 1931 and 1939 caused repeated crop failures and a renewed interest in irrigation from wells in this area, and the number of irrigation wells in Pawnee County increased from 34 in 1930 to 69 in 1945. There is no record of the number of irrigation wells in Edwards County in 1930, but by 1945 there were 58 irrigation wells.

The investigation in Pawnee and Edwards Counties was made to determine the quantity, quality, movement, and availability of ground water, and the feasibility of further development of irrigation from wells. It is hoped that the data given herein will facilitate the development of the ground-water resources of these counties.

Location and Extent of the Area

Pawnee and Edwards are adjacent counties in southwest-central Kansas (Fig. 1). They are bordered on the north by Rush County, on the east by Barton, Stafford, and Pratt Counties, on the south by Kiowa County, and on the west by Ness, Hodgeman, and Ford Counties. The area comprises 38 townships or 1,368 square miles.

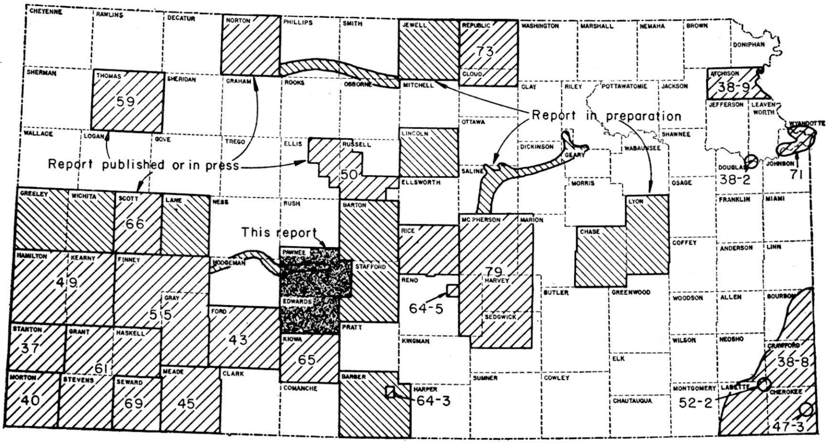

Fig. 1. Index map of Kansas showing area covered by this report and areas for which coöperative ground-water reports have been published or are in preparation.

Previous Investigations

Geologic and hydrologic studies in western Kansas were made in 1895 by Haworth (1897), who discussed the regional geology and the occurrence of ground water in the Dakota and younger formations. Johnson (1901, 1902) reported on the utilization of the southern High Plains with special reference to the source, availability, and use of ground water in western Kansas. Parker (1911) briefly described the geology and ground-water resources of this area in his report on the chemical character of the water supplies of Kansas.

The geology of Pawnee and Edwards Counties was mapped by M. K. Elias for use in the geologic map of Kansas (Moore and Landes, 1937) and Courtier (1934) mapped this area as a part of his study of south-central Kansas. No other studies of the geology or ground-water resources of this area were published prior to this investigation, but a report on the geology and ground-water resources of Ford County has been published (Waite, 1942).

Methods of Investigation

Field work was begun in Pawnee County in July 1944 and continued until October 1944. The field work in Edwards County was done during July and August 1945. During this season I was assisted by Milton Sears and Nels Florell. Data were obtained for 360 wells, most of which were measured with a steel tape to determine the depth of the well and the depth to the water level below some fixed measuring point (generally the top of the casing). Additional data were obtained from well owners concerning the yield and drawdown of wells and the character of the water-bearing materials. Samples of water were collected from 74 representative wells and were analyzed by Howard Stoltenberg, chemist in the Water and Sewage Laboratory of the Kansas State Board of Health.

One hundred thirty-one test holes were drilled at strategic points in the area by the portable hydraulic-rotary drilling machine of the State Geological Survey, operated by Oscar S. Fent and James B. Cooper. The drill cuttings were collected and studied in the field by Oscar S. Fent and examined later with a microscope by William J. Powell and me. The altitudes of the measuring points of the measured wells and of the test-hole locations were determined with a plane table and alidade by Charles K. Bayne and R. W. Ball.

The field data were recorded on maps prepared for the Kansas Highway Planning Board by the Kansas Highway Department. The data were then plotted on maps prepared by the Soil Conservation Service (Pls. 1 and 2). The roads were corrected by field observations.

The wells shown on Plate 2 were located within the sections by use of an odometer, and the locations are believed to be accurate within 0.1 mile. The wells in each county are numbered by townships from north to south and by ranges from east to west, and within a township the wells are numbered in the same order as the sections. The wells in Pawnee County are numbered from 1 to 185 and the wells in Edwards County are numbered from 186 to 360.

For each well shown on Plate 2 the number above the line corresponds to the number of the well in the well tables and the number below the line is the depth to the ground-water table below land surface.

Acknowledgments

Residents of the area were very coöperative in supplying information about their wells and in permitting test drilling on their land. Particular thanks are due Hugh Richwine and C. B. Dennis of the Soil Conservation Service and Lytle Martin, Otis Shuck, and Roy Delp, drilling contractors. Leo Myers, superintendent of the Larned public utilities, supplied information on the municipal wells at Larned and on several irrigation wells.

The manuscript for this report has been critically reviewed by several members of the Federal Geological Survey and the State Geological Survey of Kansas; by George S. Knapp of the Division of Water Resources, Kansas State Board of Agriculture; and by Ben L. Williamson and Ogden S. Jones of the Division of Sanitation, Kansas State Board of Health. The maps and illustrations were prepared by Woodrow Wilson and Donald C. Forrey.

GEOGRAPHY

Topography and Drainage

Pawnee and Edwards Counties are in the High Plains section of the Great Plains physiographic province. For the purpose of detailed description, Pawnee and Edwards Counties may be divided into three areas based on topography: (1) upland area, (2) valley area, and (3) dune-sand area.

Upland area.—This area includes most of Pawnee County lying north of the Pawnee Valley and parts of Pawnee and Edwards Counties lying between Pawnee Valley and Arkansas Valley. The area consists primarily of low rounded hills which are separated by the many valleys that have been carved by the tributaries of Pawnee and Arkansas Rivers. The maximum relief in this area generally is less than 100 feet and in a few places in northwestern Edwards County the land is relatively flat. The maximum altitude in the area is about 2,300 feet at the Ford-Edwards county line north of Offerle.

Valley area.—The valley area consists primarily of the valleys of Pawnee and Arkansas Rivers. The area contains flat, relatively featureless bottomlands and terraces. The Arkansas Valley slopes from an altitude of about 2,260 feet at the Ford-Edwards county line to about 1,920 feet at the Pawnee-Barton county line. The average gradient of Arkansas River is about 7 feet per mile. The Pawnee Valley enters Pawnee County near Burdett and converges with the Arkansas Valley near Larned. It consists of a relatively flat alluvial plain transected by many abandoned channels of Pawnee River. Adjacent to the bottomland is a broad flat terrace which generally extends about a mile on each side of the bottomland. The Pawnee Valley slopes from an altitude of about 2,080 feet at the Pawnee-Hodgeman county line to about 1,990 feet at its confluence with the Arkansas Valley. The average gradient of Pawnee River is about 2 feet per mile.

Dune-sand area.—The dune-sand area consists of the part of Pawnee and Edwards Counties lying south of the Arkansas Valley. The topography ranges from relatively flat areas to irregular areas containing high sand hills. Most of the sand hills are adjacent to Arkansas River and they contain many undrained basins (Pl. 4). The areas of more moderate relief are flat to hummocky and are in part drained by streams such as Hubbard Creek, Wild Horse Creek, and Rattlesnake Creek.

Climate

The climate in Pawnee and Edwards Counties is similar to that in other parts of the High Plains section. The area has relatively low precipitation, rapid evaporation, and a wide range of temperatures. The summer days generally are hot, but the summer nights are relatively cool, owing to the movement of wind and to the relatively low humidity.

The precipitation in Pawnee and Edwards Counties is sporadic; hence the amount of rainfall in one storm may differ greatly from one part of the area to another. The greatest annual precipitation recorded in this area was 39.63 inches at Larned in 1915. (All climatic data, unless otherwise stated, are based on records of the U. S. Weather Bureau stations at Larned and Trousdale.) The second greatest precipitation was 39.11 inches at Trousdale in 1944. The least precipitation recorded was 7.97 inches at Larned in 1872. The normal annual precipitation at Larned is 23.48 inches (Fig. 2) and at Trousdale it is 22.44 inches (Fig. 3). The greatest precipitation in the Pawnee-Edwards area occurs during late spring and summer and the least during the winter.

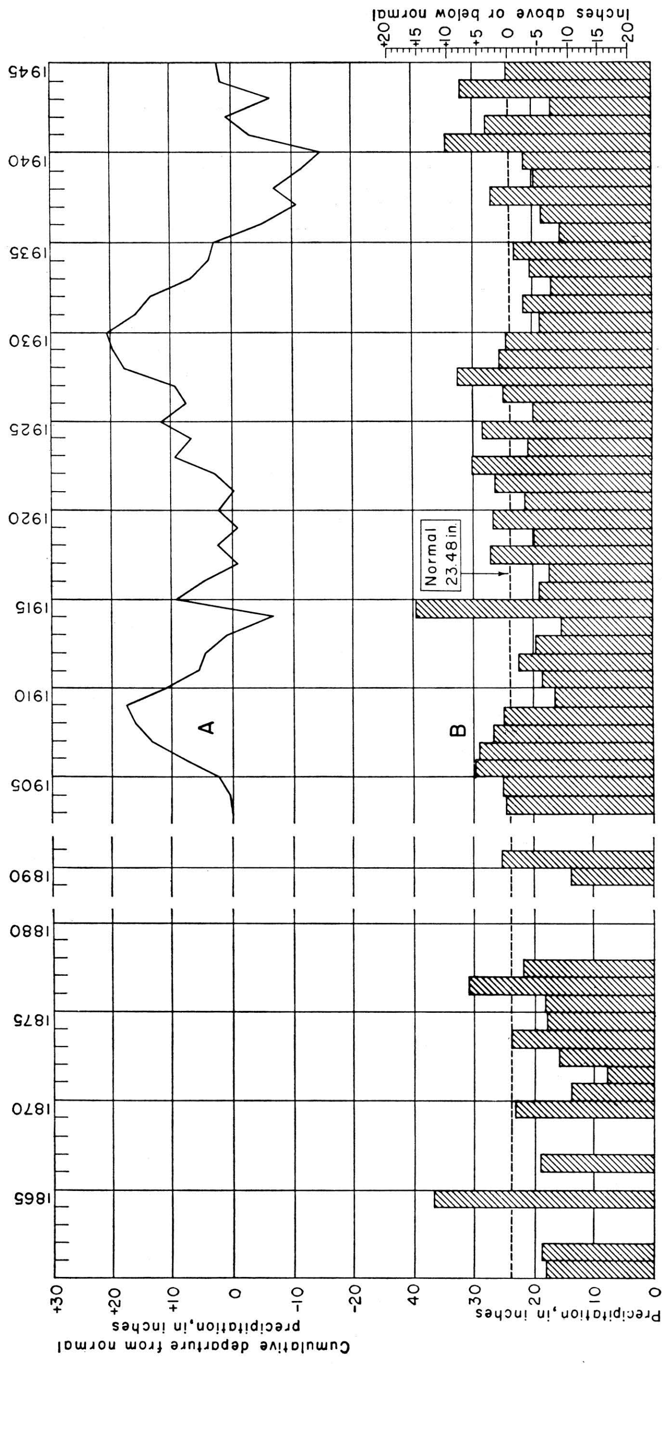

FIG. 2.—Graphs showing (A) the cumulative departure from normal precipitation at Larned and (B) the annual precipitation at Larned.

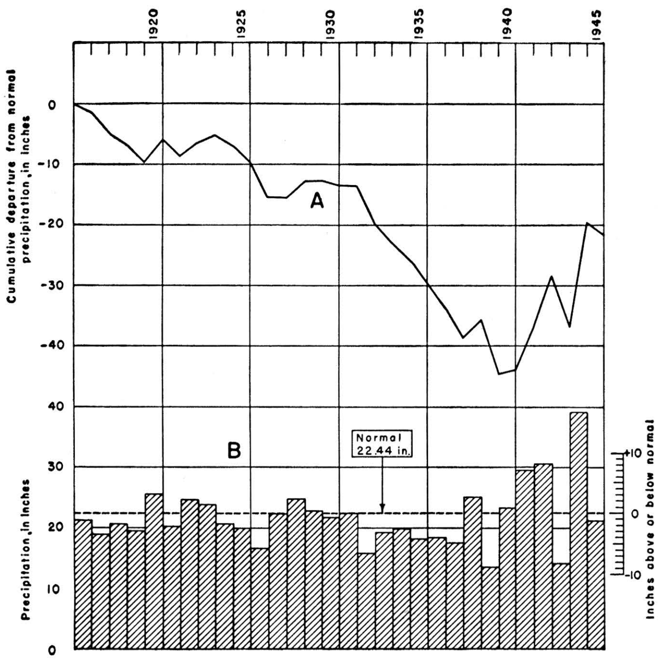

Fig. 3. Graphs showing (A) the cumulative departure from normal precipitation at Trousdale and (B) the annual precipitation at Trousdale.

Mineral Resources

The principal mineral resources of Pawnee and Edwards Counties are oil and gas. The oil and gas pools in this area in 1945 included the Belpre oil and gas pool in Edwards County and the Pawnee Rock, Benson, and Ryan oil pools, the Shady gas pool, and the Zook oil and gas pool in Pawnee County. A successful wildcat well was completed in Pawnee County late in 1945 opening the Ryan Southeast pool. The reader is referred to Ver Wiebe (1947) for a more detailed discussion of oil and gas in this area.

Other mineral resources in Pawnee and Edwards Counties include sand, gravel, and building stone. Sand and gravel has been taken from the alluvium of Arkansas River in both Pawnee and Edwards Counties. It is used primarily as road metal.

Building stone has been quarried from the Greenhorn limestone in the northern part of Pawnee County. The stone generally is quarried from the "Fencepost" limestone bed at the top of the Greenhorn limestone although other beds of limestone in the Greenhorn have been quarried in a few places. The stone is used in the construction of buildings and as fence posts.

Agriculture

There were 644,820 acres of land under cultivation in Pawnee and Edwards Counties in 1945. (All agricultural data are from reports of the Kansas State Board of Agriculture.) The principal crop in the area is wheat, which is grown primarily on the upland areas north of Pawnee River and between Pawnee and Arkansas Rivers. In 1944 there was 8,704 acres of land under irrigation in the Pawnee-Edwards area, principally in the Pawnee and Arkansas Valleys. The principal irrigated crops grown in this area were alfalfa, sorghums, and sugar beets. The list of crops grown in Pawnee and Edwards Counties given in Table 1 was compiled for the 1945 census.

Table 1.—*Acreage of principal crops grown in Pawnee and Edwards Counties in 1945*

Wheat	529,391
Sorghums	69,826
Corn	4,066
Barley	19,221
Alfalfa	9,327
Hay (other than alfalfa)	505
Rye	3,898
Oats	8,293
Sugar beets	239
Miscellaneous crops	54
Total	644,820

Population

The population of Pawnee and Edwards Counties increased from 16,380 in 1920 to 17,805 in 1930. The extended drought during the next decade resulted in a decrease of 6.3 percent in the population. In 1945 the population of Pawnee County was 8,255 and of Edwards County was 5,787. Larned, the county seat and principal city of Pawnee County, had a population of 3,595 in 1945, and Kinsley, the county seat of Edwards County, had a population of 2,112. Other cities in these counties include Lewis (population 397), Garfield (population 308), Belpre (population 229), Offerle (population 221), and Rozel (population 204).

Transportation

The main line of the Atchison, Topeka, and Santa Fe Railway crosses Edwards County and serves the communities of Belpre, Lewis, Kinsley, and Offerle. A branch line of the same railroad crosses Pawnee County along Arkansas River and joins the main line at Kinsley. This line serves the communities of Larned and

Garfield. The Atchison, Topeka, and Santa Fe Railway Company also has a spur line that extends from Larned to Jetmore in Hodgeman County. The communities in Pawnee County served by it are Frizell, Sanford, Rozel, and Burdett. A branch line of the Missouri Pacific Railway serves the community of Ray and terminates at Larned.

The principal highways in Pawnee and Edwards Counties are U. S. Highways 50 North and 50 South and Kansas Highway 45. U. S. Highway 50 North crosses Pawnee County and serves Larned, Rozel, and Burdett. U. S. Highway 50 South crosses Edwards County and serves Belpre, Lewis, Kinsley, and Offerle. Kansas Highway 45 enters Edwards County near Offerle and extends along Arkansas River from Kinsley to Great Bend in Barton County. Other highways in this area include U. S. Highway 183 and Kansas Highway 1, which cross the area from north to south, and Kansas Highway 19, which extends from Belpre to near Larned and then eastward into Stafford County.

Pawnee and Edwards Counties have excellent county highways in addition to the many State and Federal highways. Many of the county roads in this area are all-weather hard-surfaced roads, whereas others have been surfaced with sand and gravel.

GEOLOGY

Summary of Stratigraphy*

The rocks that crop out in Pawnee and Edwards Counties are sedimentary, ranging in age from Cretaceous to Recent (Pl. 1). The oldest rocks exposed in this area are Cretaceous, comprising the Dakota formation, Graneros shale, Greenhorn limestone, and Carlile shale. The terrace deposits that cover large areas adjacent to Pawnee River are believed to be Pleistocene in age but may be in part Tertiary. The alluvium in the principal valleys probably is Pleistocene and Recent. Most of the area south of Arkansas River is covered by a thin deposit of dune sand which is largely Recent but which may be in part Pleistocene.

Information on rocks that are not exposed in Pawnee and Edwards Counties but which lie beneath the surface in that area has been obtained from test holes drilled during the course of the investigation and from logs supplied by drillers (Pl. 3).

A generalized section of the geological formations of this area is given in Table 2 and the geologic time scale is given in Table 3.

*The terminology used in this report is that of the State Geological Survey of Kansas and differs in some respects from that of the United States Geological Survey.

TABLE 2.—*Generalized section of the geologic formations of Pawnee and Edwards Counties, Kansas*

SYSTEM	Series	Subdivision	Thickness (feet)	Physical character	Water supply
Quaternary	Recent and Pleistocene	Dune sand	0–50	Fine- to medium-grained quartz sand.	Lies above the water table and hence does not yield water to wells in this area, but serves as a catchment area for rainfall.
		Unconformable on older formations			
		Alluvium	0–100	Coarse sand and gravel containing silt and clay.	Yields large quantities of water to wells in Pawnee and Arkansas Valleys. Principal source of ground water for irrigation.
		Unconformable on older formations			
	Pleistocene	Terrace deposits	0–150	Principally silt and clay. May contain sand and gravel in the lower part in some places.	Yields small to moderate quantities of water to domestic and stock wells and to a few irrigation wells.
		Unconformable on older formations			
		Meade formation	90–300	Sand, gravel, silt, and clay.	Yields moderate to large quantities of water to domestic, stock, and irrigation wells south of the Arkansas River.
		Unconformable on older formations			
Tertiary	Middle Pliocene	Ogallala formation	0–70 ±	Silt, sand, gravel, and caliche.	Yields no water to wells in this area.
		Unconformable on older formations			
Cretaceous	Gulfian[1]	Carlile shale	0–100	Chalky shale containing thin beds of chalky limestone.	Yields small quantities of water to wells in this area.
		Greenhorn limestone	0–120	Chalky shale containing thin beds of crystalline limestone at base and granular to chalky limestone in upper part.	Yields small quantities of water to dug wells in northern Pawnee County.
		Graneros shale	20–35	Dark-gray shale containing sandy shale and lenses of sandstone.	Yields little or no water to wells in this area.
		Dakota formation	0–225	Varicolored sandy shale and clay containing beds of fine-grained lenticular sandstone.	Yields small to moderate quantities of water to domestic and stock wells.
	Comanchean	Kiowa shale	100–200	Dark-gray to black shale containing lenses of sandstone.	Yields little or no water to wells in this area.
		Cheyenne sandstone	25–50	Gray, tan, and white fine- to medium-grained sandstone.	Does not yield water to wells in this area owing to its considerable depth, but is a potential source of ground water.
		Unconformable on older formations			
Permian	Leonardian and Guadalupian[1]	Undifferentiated redbeds	1,000+	Red sandstone and siltstone containing beds of gypsum, anhydrite, and dolomite.	Does not yield water to wells in this area owing to its considerable depth and to the relatively high mineral content of its water.

1. Classification of the State Geological Survey of Kansas.

TABLE 3.—*The geologic time scale*[1]

Major divisions of geologic time			Estimated duration in years
Eras	Periods	Epochs	
Cenozoic	Quaternary	Recent Pleistocene	2,000,000
	Tertiary	Pliocene Miocene Oligocene Eocene Paleocene	58,000,000
Mesozoic	Cretaceous		65,000,000
	Jurassic		32,000,000
	Triassic		28,000,000
Paleozoic.......	Permian		38,000,000
	Pennsylvanian[2]		48,000,000
	Mississippian[2]		38,000,000
	Devonian		45,000,000
	Silurian		27,000,000
	Ordovician		67,000,000
	Cambrian		105,000,000
Proterozoic	Together constitute		900,000,000
Archeozoic	the Pre-Cambrian		550,000,000

1. Adapted from Moore (1933, p. 52).
2. The Pennsylvanian and Mississippian periods together make up the Carboniferous System of the U. S. Geological Survey.

Geologic History

Pawnee and Edwards Counties are underlain by thick deposits of sedimentary rocks consisting of shale, limestone, sandstone, clay, silt, sand, and gravel and smaller amounts of salt, anhydrite, and gypsum. The character, appearance, and relationships of these rocks as studied in well cuttings and at outcrops reveal much of the geologic history of the region.

PALEOZOIC ERA

In the earliest part of the Paleozoic Era the area that now comprises Pawnee and Edwards Counties was part of a land surface that extended over a large part of west-central United States. Submergence of the land began in Middle Cambrian time and the area remained inundated through the remainder of Cambrian and part of Ordovician time, during which the Arbuckle limestone or "Siliceous lime" was deposited. Limestone and dolomite comprising the Viola limestone and Simpson rocks were deposited in this area in Ordovician time.

Rocks of Silurian and Devonian age probably do not underlie Pawnee and Edwards Counties. They either were not deposited in this area or were removed by erosion prior to the deposition of the overlying Mississippian strata. Deposits of marine dolomitic limestone and shale were laid down in this area during the early part of the Mississippian Period. The sea withdrew during part of Mississippian time and again covered the area in the last part of the period.

There was a long time of erosion between deposition of the youngest Mississippian rocks and the oldest Pennsylvanian rocks that overlie them. After this erosion there was alternate submergence by and emergence from the sea, causing the deposition of both marine and continental materials consisting of sandstone, shale, limestone, and coal. The alternating marine and continental deposition continued through Early Permian time but by Late Permian time continental deposition became dominant. These deposits consisted of redbeds containing gypsum, anhydrite, and salt, which indicate an arid climate.

MESOZOIC ERA

Cretaceous Period

The Cheyenne sandstone was deposited over all the Pawnee-Edwards area in Early Cretaceous time. These beds were laid down either in shallow sea water or by streams (Twenhofel, 1924, p. 19). The area was then covered by a sea in which the dark fossiliferous clay that formed the Kiowa shale was deposited. The sandstone and clay of the Dakota formation were laid down in Late Cretaceous time under both fluviatile and near-shore marine conditions. Marine deposits of limestone and shale which were laid down in this area after the deposition of the Dakota formation comprise the Graneros shale, Greenhorn limestone, and Carlile shale. Younger Cretaceous deposits probably covered at least part of this area but they have been removed by erosion.

CENOZOIC ERA

Tertiary Period

The Laramide revolution, which began in Late Cretaceous time and which continued into Tertiary time, probably caused the regional dip of the older beds in this area. After this major deformation (which uplifted the Rocky Mountains) the Ogallala formation of middle Pliocene age (Table 3) was deposited by streams that carried debris from the Rocky Mountains. These deposits mantled the bedrock in large areas in western Kansas. Much of these deposits has been removed by subsequent erosion but the formation still underlies small areas, mainly in northwestern Edwards County (Pl. 1).

Quaternary Period

Pleistocene Epoch.—The thick deposits of silt, sand, and gravel that overlie the Cretaceous bedrock south of Arkansas River (Pl. 3) were laid down during the Pleistocene Epoch and represent stream-laid debris from the Rocky Mountains. Part of the material south of Arkansas River may be terrace deposits which were also laid down during the Pleistocene Epoch.

The ancestral Pawnee River and its tributaries deposited fine-grained materials over a large area in Pawnee County and in northwestern Edwards County. These deposits consist primarily of silt and clay but contain lesser amounts of sand and gravel. They are shown on the map (Pl. 1) as terrace deposits and represent at least two stages of deposition by Pawnee River and its tributaries.

During late Pleistocene and Recent time Arkansas and Pawnee Rivers and their tributaries deposited alluvium in their valleys. Only the alluvium of the principal streams is shown on the map (Pl. 1). Part of the dune sand also may have been deposited in late Pleistocene time, but it is believed that most of the dune sand in the Pawnee-Edwards area is Recent in age.

Recent Epoch.—During Recent time most of the dune sand south of Arkansas River was deposited, as is indicated by the presence of dune sand overlying alluvium. The present topography of Pawnee and Edwards Counties was formed in part during the Recent Epoch. The principal valleys were eroded during the Pleistocene but most of the existing surface features are the result of Recent erosion.

GROUND WATER

Principles of Occurrence

This discussion of the principles governing the occurrence of ground water takes account of conditions in Pawnee and Edwards Counties. Preparation of the discussion has been based chiefly on the authoritative and detailed treatment of the occurrence of ground water by Meinzer (1923), to which the reader is referred for more extended consideration. A general discussion of the principles of ground-water occurrence, with special reference to Kansas, has been published by Moore (1940).

The rocks that make up the outer crust of the earth generally are not entirely solid, but have numerous openings, called voids or interstices, which may contain air, natural gas, oil, or water. The number, size, shape, and arrangement of the interstices in rocks depend upon the character of the rocks. The occurrence of water in any region, therefore, is determined by the geology.

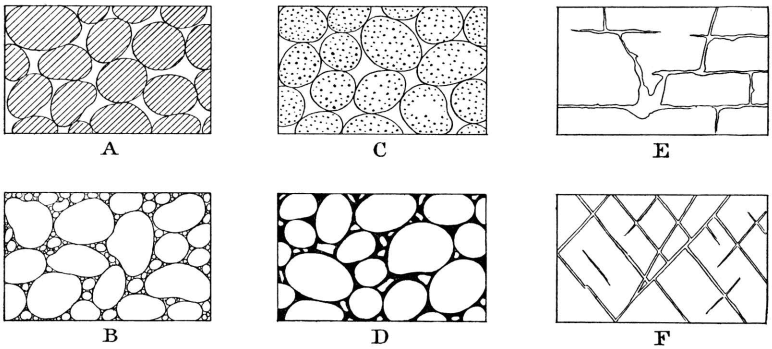

Fig. 4. Diagram showing several types of rock interstices and the relation of rock texture to porosity. A, Well-sorted sedimentary deposit having a high porosity; *B,* poorly sorted sedimentary deposit having low porosity; *C,* well-sorted sedimentary deposit consisting of pebbles that are themselves porous so that the deposit as a whole has a very high porosity; *D,* well-sorted sedimentary deposit whose porosity has been diminished by the deposition of mineral matter in the interstices; *E,* rock rendered porous by solution; *F,* rock rendered porous by fracturing. (From O. E. Meinzer.)

The interstices or voids in rocks range in size from microscopic openings to the huge caverns found in some limestones. The open spaces generally are connected so that water may percolate from one to another, but in some rocks these open spaces are isolated and the water has little or no chance to percolate. Several common types of open spaces or interstices and the relation of texture to porosity are shown in Figure 4.

The porosity of a rock is the percentage of the total volume of the rock that is occupied by interstices. A rock is said to be saturated when all its interstices are filled with water or other liquid, and the porosity is then practically the percentage of the total volume of the rock that is occupied by water. The porosity of a rock determines only the amount of water a given rock can hold, not the amount it may yield to wells. Some rocks may be highly porous, but will not yield an appreciable amount of water to a well. The specific yield of a water-bearing formation is defined 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 yield when the material is drained by a lowering of the water table. The permeability of a water-bearing material is defined as its capacity for transmitting water under hydraulic head, and is measured by the rate at which it will transmit water through a given cross section under a given difference of head per unit of distance. A rock containing very small interstices may be very porous, but it would be difficult to force water through it, whereas a coarser-grained rock, although it may have less porosity, generally is much more permeable. Some water is held in rocks by the force of molecular attraction, which, in fine-grained rocks, is sufficiently great to hold the water against the force of gravity and thus to make the rock relatively impermeable.

Below a certain level in the earth's crust, the permeable rocks generally are saturated with water and are said to be in the zone of saturation (Fig. 5). The upper surface of the zone of saturation is called the ground-water table, or simply the water table. All the rocks above the water table are in the zone of aeration, which ordinarily consists of three parts: the belt of soil water; the intermediate, or vadose zone; and the capillary fringe.

The belt of soil water lies just below the land surface and contains water held by molecular attraction. In this belt the amount of water must exceed that which will be held by gravity before any water can percolate downward to the water table. The thickness of the zone is dependent upon the character and thickness of the soil

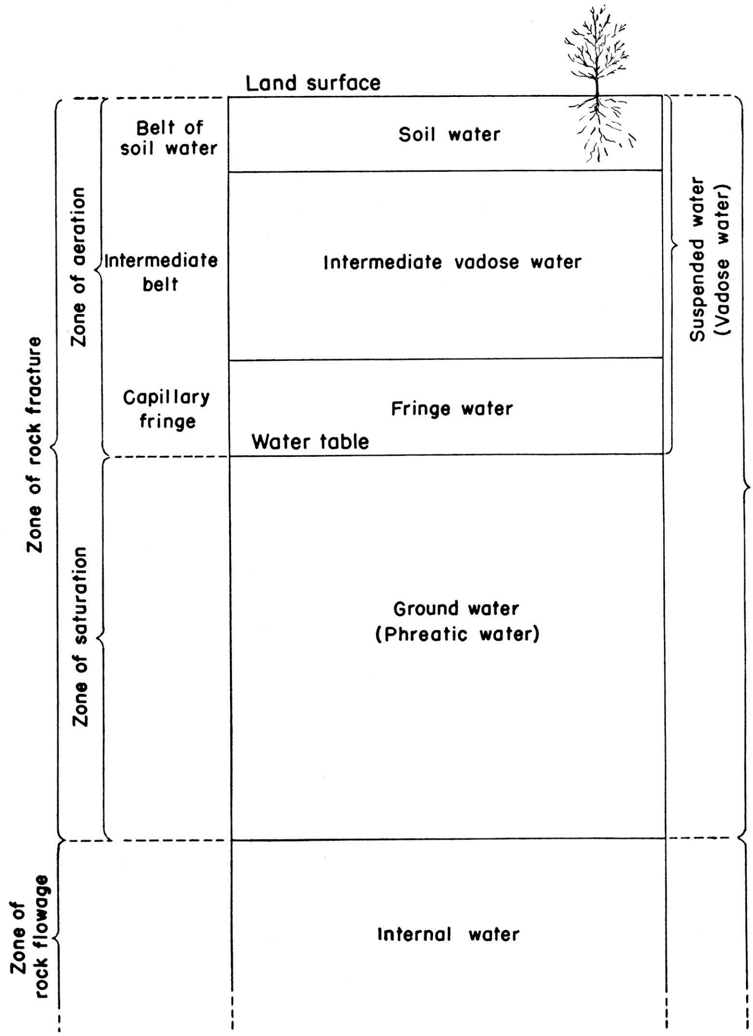

FIG. 5. Diagram showing divisions of subsurface water. (From O. E. Meinzer.)

and upon the precipitation and vegetation. The intermediate belt lies between the belt of soil water and the capillary fringe. In this belt the interstices in the rocks contain some water held by molecular attraction but also may contain appreciable quantities of water while it is moving downward from the belt of soil moisture to the ground-water table. The intermediate belt may be absent in places, such as in some river valleys where the water table is near the surface, or it may be several hundred feet thick.

The capillary fringe lies directly above the water table and is formed by water held above the zone of saturation by capillary force. The water in the capillary fringe is not available to wells, which must be deepened to the zone of saturation before water will enter them. The capillary fringe may be absent or very thin in coarse-grained sediments, in which the capillary action is negligible, or it may be several feet thick in fine-grained sediments.

Artesian Conditions

The head of water has been defined as the height that a column of water will rise in a tightly cased well that has no discharge. Ground water that rises in wells above the level at which it is first encountered is said to be artesian or "piestic" water (Meinzer and Wenzel, 1942, p. 451).

Many of the deeper wells in Pawnee and Edwards Counties have encountered artesian water, but only in a few of them has the head been sufficient to cause them to flow at the surface. A few oil or gas test wells in the Arkansas and Pawnee Valleys encountered water under artesian pressure in the Permian redbeds. One of these wells had a reported flow of 700 gallons a minute. Water from these wells was of such poor quality that it was unfit for use. Test hole 28 drilled by the State Geological Survey obtained a small flow of water from the Permian redbeds at a depth of about 415 feet. The water contained more than 1,500 parts per million of chloride.

Most of the deep domestic and stock wells in the upland areas of Pawnee and Edwards Counties encounter artesian water in the Dakota formation. The water does not have sufficient head to cause it to flow at the surface, but it rises in the well enough to materially decrease the pumping lift. Any well that might be drilled to the Cheyenne sandstone probably would encounter water under artesian pressure, but it is doubtful if that pressure would be sufficient to cause the water to flow.

The Water Table and Movement of Ground Water

The upper surface of the zone of saturation in ordinary permeable soil or rock has been defined as the ground-water table, or simply the water table. Where the upper surface is formed by impermeable material the water table is absent and artesian conditions are said to exist. The water table is not a plane surface in all parts of the area but in some places has irregularities comparable with and related to those of the land surface, although it is less rugged. It does not remain in a stationary position but fluctuates up and down.

The irregularities are caused chiefly by local differences in gain and loss of water, and the fluctuations are due to variations from time to time in gain or loss.

SHAPE AND SLOPE

The shape and slope of the water table in Pawnee and Edwards Counties is shown on the map (Pl. 1) by contour lines drawn on the water table. Each point on the water table on a given contour line has the same altitude. The water-table contours show the configuration of the water surface just as topographic contour lines show the shape of the land surface. The direction of movement of the ground water is at right angles to the contour lines in the direction of the downward slope.

The water-table contours are not shown in the upland areas of Pawnee and Edwards Counties. In and near the areas of outcrop of Cretaceous beds the land is underlain primarily by relatively impermeable beds; therefore, there is no water table in much of this area. Where the surface is covered by terrace deposits there generally is a little ground water at the base of these deposits, but the water surface merely reflects the topography of the underlying bedrock.

The map (Pl. 1) shows that the general movement of ground water in the Pawnee-Edwards area is eastward and northeastward. The rate and direction of movement vary considerably from one part of the area to another. The slope of the water table in the Pawnee Valley, for example, is only one-third as great as it is in parts of the Arkansas Valley, owing primarily to the difference in gradient of the two valleys. The direction of movement of the ground water in most of the area is northeastward but in southern Edwards County the direction of movement is approximately eastward.

The shape and slope of the water table, which determine the direction and rate of movement of ground water, are controlled by several factors. Irregularities of the shape and slope of the water table in Pawnee and Edwards Counties may be caused by: (1) the configuration of the underlying Cretaceous floor; (2) discharge of ground water into streams; (3) recharge of the ground water by ephemeral streams; (4) unequal additions of water to the ground-water reservoir at different places; (5) local differences in the permeability of the deposits; and (6) local depressions on the water table caused by the pumping of water from wells.

The shape of the underlying bedrock floor controls to some extent the direction of movement of the ground water in this area. The regional slope of the bedrock floor is toward the east and southeast. This may be in part the cause of the direction of movement in this area. Local small irregularities in the bedrock surface, however, are not reflected in the shape of the water table.

The discharge of ground water into streams is the cause of the most prominent irregularities in the water table in this area. The upstream flexure of the contour lines along Pawnee River, Arkansas River, and Rattlesnake Creek has been caused by that process.

The recharge of ground water by ephemeral streams has not materially affected the water table in this area, although some water undoubtedly is added to the ground-water reservoir in this manner. An ephemeral or intermittent stream is one that flows only after rains. Their channels lie above the water table and are dry much of the time, but during periods of stream flow part of the water may seep into the stream bed and move downward to the water table. A stream of this type is said to be influent. The movement of ground water from influent streams and to effluent streams is shown by the diagrammatic sections in Figure 6.

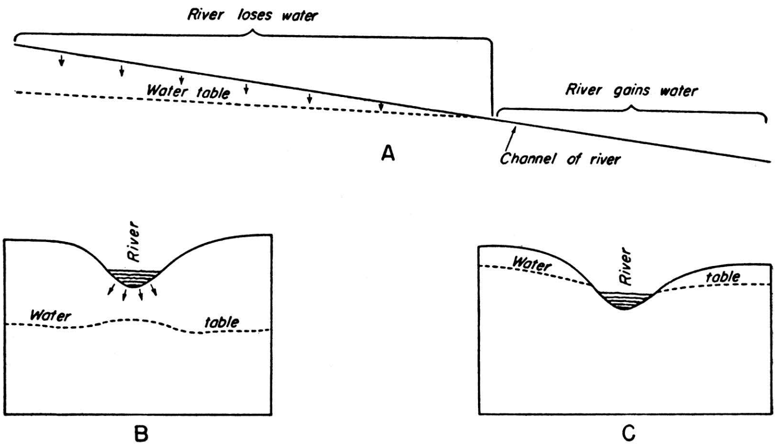

FIG. 6. Diagrammatic sections showing influent and effluent streams. (From Latta, 1944.)

Unequal additions of water to the ground-water reservoir have not been great enough to affect materially the shape or slope of the water table in Pawnee and Edwards Counties. In the sand-hills area south of Arkansas River there are many undrained basins in which water accumulates. Much of this water moves through the porous sandy soil and builds a mound on the underlying water table.

These local mounds are small and, hence would not be shown on a large-scale map such as Plate 1. The curvature of the contour lines along the Arkansas Valley is much greater on the south side of the river than it is on the north side of the river. This probably is the result of rapid recharge of the ground-water reservoir in the large undrained area of sand hills that borders Arkansas River on the south.

The lack of uniformity of gradient across the Pawnee-Edwards area probably is caused in part by local differences in permeability. The gradient along Arkansas River in the southwestern corner of Edwards County, for example, is about 15 feet to the mile, whereas a short distance downstream it is only about 5 feet to the mile. In the southwestern corner of Edwards County the unconsolidated materials through which the water moves probably are less permeable than they are farther downstream; hence the water table must have a steeper slope in order that a given cross-sectional area will transmit the same amount of water.

Local depressions in the water table have been caused by pumping for irrigation but the water table in these depressions generally rises to or nearly to its normal level within a short period after pumping ceases. These depressions, therefore, generally are not permanent features of the water table. Water-level measurements made while an irrigation well was pumping or soon after it stopped pumping were not used in the construction of the water-table contour map shown on Plate 1.

RELATION TO TOPOGRAPHY

The depths to water level in Pawnee and Edwards Counties are shown by a map (Pl. 2). The depth to water level in all wells that obtain water from superficial deposits generally is less than 25 feet and is in no place more than 50 feet. Those wells having water levels greater than 50 feet obtain water from the Dakota formation. The greatest measured depth to water level in this area was 199 feet in well 20, which obtains water from the Dakota formation. In general the shape of the water table in Pawnee and Edwards Counties conforms to the regional topography, but is little affected by minor physiographic features.

FLUCTUATIONS IN WATER LEVEL

The water table in a ground-water reservoir does not remain stationary, but fluctuates up and down much like the water surface of any surface reservoir. Whether the water table rises or declines depends upon the amount of recharge into the ground-water reservoir and the amount of discharge from the reservoir. If the inflow exceeds the draft, the water table will rise; conversely, if the draft exceeds the inflow into the ground-water reservoir, the water table will decline. The water table fluctuates more by the addition or depletion of a certain quantity of water than does the level of a surface reservoir, because ground water occupies only part of the volume of a ground-water reservoir. If the materials comprising a water-bearing formation have an average specific yield of 25 percent, for example, the addition of 1 foot of water to the water-bearing materials will raise the water table in those materials about 4 feet. Changes of water levels record the fluctuations of the water table and hence are a measure of the recharge and discharge of a ground-water reservoir. A rise in water level indicates an excess of recharge over discharge, whereas, a decline in water level indicates that the discharge exceeds the available recharge.

The principal factors that control the rise of the water table in Pawnee and Edwards Counties are the amount of water from precipitation that passes through the soil and moves downward to the water table, the amount of water added to the ground-water reservoir by seepage from streams, and the amount of water that enters the area by subsurface inflow. The principal factors that control the decline of the water table in this area are the amount of water discharged by effluent seepage into streams, the amount of water lost through transpiration and evaporation where the water table is shallow, the discharge of water through springs and wells, and the amount of water leaving the area through subsurface flow into adjacent areas.

Fluctuations of the water table are reflected directly in changes in the water levels in wells. In order to record these changes on a monthly basis, several representative wells in Pawnee and Edwards Counties were selected as observation wells. Periodic measurements of water levels in these wells have been made for several years and their fluctuations are shown by the hydrographs in Figures 7 and 8.

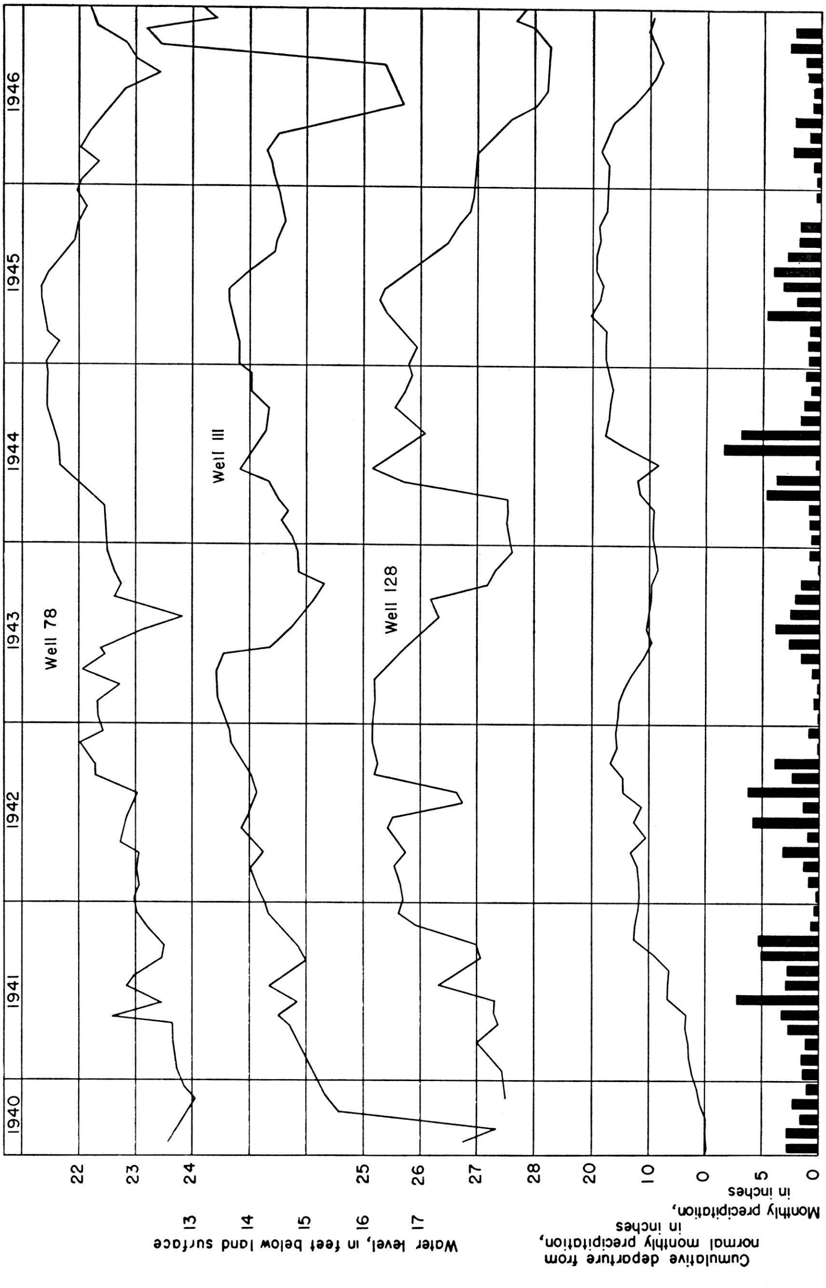

FIG. 7. Hydrographs showing fluctuations of the water levels in three wells in Pawnee Valley in Pawnee County, cumulative departure from normal monthly precipitation at Larned, and monthly precipitation at Larned.

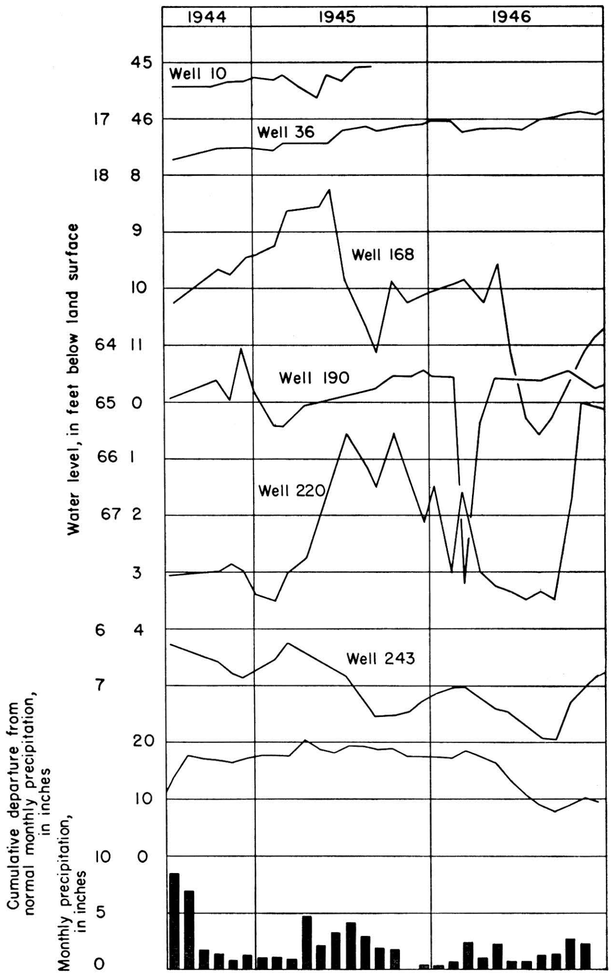

FIG. 8. Hydrographs showing fluctuations of the water levels in six wells in Pawnee and Edwards Counties, cumulative departure from normal monthly precipitation at Larned, and monthly precipitation at Larned.

Ground-water Recharge

Recharge is the addition of water to the ground-water reservoir and may be accomplished in several ways. All ground water within a practical drilling depth in Pawnee and Edwards Counties is derived from water that falls as rain or snow either within the area or within adjacent areas. Once the water becomes a part of the ground-water body it moves down the slope of the water table, later to be discharged farther downstream.

The underground reservoir beneath Pawnee and Edwards Counties is recharged primarily by local precipitation. Other factors that affect recharge in this area are seepage from streams and depressions and subsurface inflow from adjacent areas. The principal methods of recharge are described in the following paragraphs.

Recharge from precipitation.—The mean annual precipitation in Pawnee and Edwards Counties is about 23.5 inches, but only a small part of this water reaches the zone of saturation owing to evaporation, transpiration, and direct surface runoff. Water that is not lost by these processes moves downward into the soil zone and a part reaches the zone of saturation.

The amount of water added to or discharged from the ground-water reservoir is reflected in the fluctuations of the water levels in wells. Periodic water-level measurements have been made in three wells (78, 111, and 128) in the Pawnee Valley in Pawnee County since 1940, and measurements in other observation wells (10, 36, 168, 190, 220, and 243) in Pawnee and Edwards Counties have been made since 1944. The fluctuations of the water levels in these wells are shown in Figures 7 and 8. Wells 78, 111, and 128 are irrigation wells in the Pawnee Valley west of Larned and wells 36, 168, 220, and 243 are shallow wells in the Arkansas Valley or in the sand-hills area south of the valley. Wells 10 and 190 are deeper wells in the upland areas. The water levels in six of the nine wells were higher at the last measurement than at the first measurement because of the relatively abundant precipitation during the period of record. Periods of heavy precipitation generally are reflected in rises in the water levels in the Pawnee Valley wells (78, 111, and 128). The hydrographs of these wells (Fig. 7) obviously indicate the effects of pumping for irrigation also. The water levels rose abruptly following heavy precipitation during June 1941, and during April, May, July, and August 1944. The water levels in all three wells declined in 1943, which was a period of below-normal precipitation. The relations between the water levels and precipitation as depicted in the hydrographs in Figures 7 and 8 show that the ground-water reservoir is recharged by precipitation.

Recharge from streams.—One of the principal sources of recharge of the ground-water reservoir in the Pawnee-Edwards area is the loss of water from the channels of streams. The intermittent streams in this area may carry considerable water during times of floods, during which large volumes of water may percolate through the stream bed and replenish the ground-water reservoir. This type of stream is known as an influent or losing stream (Fig. 6). Recharge from influent streams in Pawnee and Edwards Counties probably is confined primarily to the upland areas and to the dune-sand areas south of Arkansas River.

The principal streams in this area (Arkansas and Pawnee Rivers), as well as some of the smaller streams such as parts of Coon, Sawmill, and Ash Creeks, are effluent or gaining streams (Fig. 6). Their base flow is maintained by the discharge of water from the ground-water reservoir. It is possible, however, that the extensive development of irrigation from wells in the Arkansas and Pawnee Valleys could lower the water table to such an extent that Arkansas and Pawnee Rivers would become influent or losing streams. If this were to happen, there would be greatly increased recharge of the ground-water reservoir by loss of stream flow in these rivers.

Recharge from undrained areas.—The surface of the area underlain by dune sand is marked by many small undrained depressions (Pl. 4) which catch rain-water and prevent surface runoff. Water that accumulates in these undrained areas generally disappears more quickly than it could be discharged by evaporation and transpiration. Inasmuch as these areas are underlain by dune sand, which is in turn underlain by the relatively permeable beds comprising the Meade formation, it is believed that much of this water moves downward and recharges the ground-water reservoir. After the heavy rains in the summer of 1944, the water table in parts of the dune-sand area was higher than it had been in more than 25 years. The water table was so high in some localities that it flooded some basements for the first time in more than 25 years. This indicates very rapid recharge by precipitation and by seepage from undrained depressions.

Recharge from subsurface inflow.—The movement of ground water in Pawnee and Edwards Counties, as indicated by the slope of the water table (Pl. 1), is toward the east and northeast; hence, water derived by recharge from precipitation or stream flow in areas to the west and southwest eventually moves into this area and contributes to the supply of ground water.

Ground water in the Dakota formation may be derived locally from overlying or adjacent water-bearing beds, but where the formation is overlain by the relatively impermeable beds comprising the Graneros shale and Greenhorn limestone, the source of water must be in some adjacent area where the formation either crops out or is overlain by permeable beds. For this reason some of the water

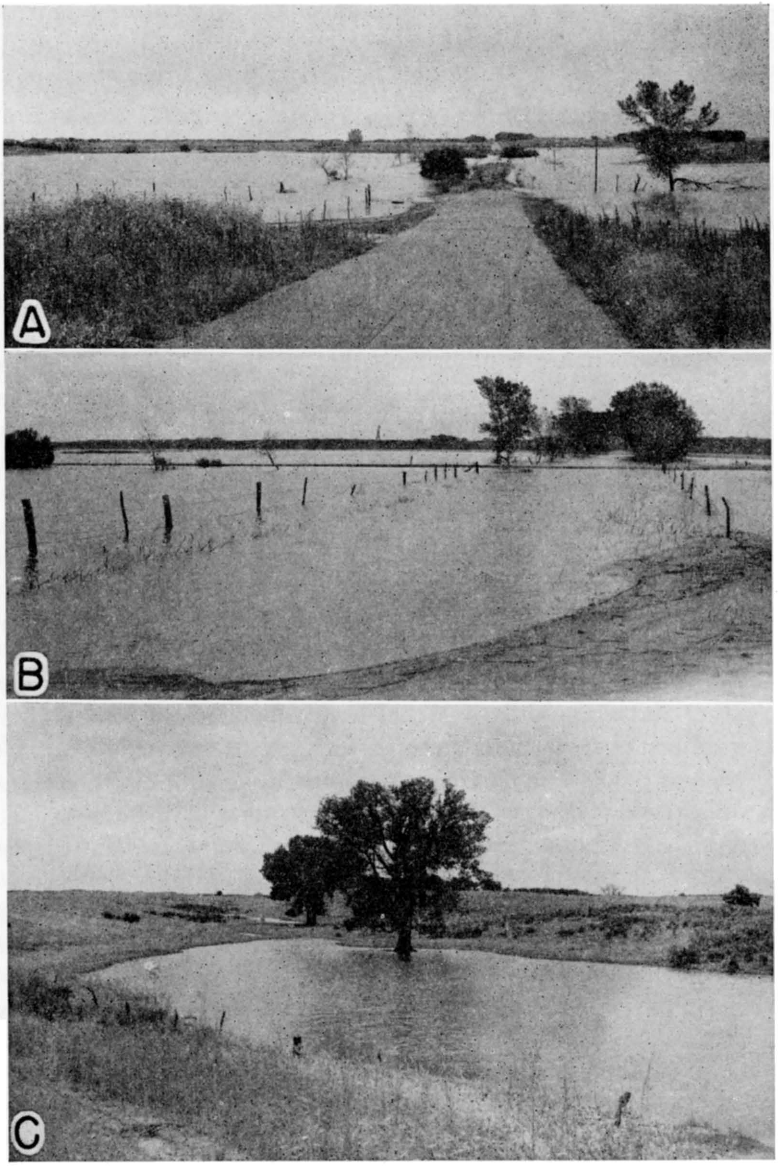

PLATE 4. Water-filled depressions in the dune-sand area. *A* and *B*, North of Trousdale at the corner of secs. 20, 21, 28, and 29, T. 25 S., R. 16 W., Edwards County. *C*, Along a small intermittent stream about 1 mile northwest of Ray, Pawnee County.

in the Dakota formation probably is derived from areas outside Pawnee and Edwards Counties. The Cheyenne sandstone is overlain by the relatively impermeable Kiowa shale in all parts of this area; hence, the water it contains is derived from adjacent areas.

Ground-water Discharge

Ground-water discharge is the discharge of water directly from the zone of saturation or from the capillary fringe, and may take place through evaporation and transpiration or as hydraulic discharge through springs, seeps, wells, or infiltration galleries.

Natural discharge.—Before wells were drilled in Pawnee and Edwards Counties the ground-water reservoir in that area was in a state of approximate equilibrium—that is, the average annual recharge was approximately balanced by the average annual discharge and the water table was moderately stable except for seasonal fluctuations. Water was added to the ground-water reservoir by movement from the west and southwest, by recharge from precipitation, and by seepage from streams. Ground water was discharged from the area principally by movement to the east and northeast and by discharge into Pawnee River, Arkansas River, and Rattlesnake Creek. This is well illustrated by the water table contour map (Pl. 1).

Other methods of ground-water discharge in this area are transpiration and evaporation. Water may be taken into the roots of plants directly from the zone of saturation or from the capillary fringe, and be discharged from the plants by the process known as transpiration. The depth from which plants will lift the ground water in an area of given climate varies with different plant species and different types of soil. The limit of lift by ordinary grasses and field crops is not more than a few feet; however, alfalfa and certain types of desert plants have been known to send their roots to depths of 60 feet or more to reach the water table (Meinzer, 1923, p. 82).

Transpiration in the Pawnee-Edwards area probably is relatively large, owing to the shallow depth to the water table in much of the area. The greatest transpiration probably is in Pawnee and Arkansas Valleys, where the water table is very shallow and where most of the trees of the area grow. This is also where most of the alfalfa is grown.

Discharge of ground water by direct evaporation probably is negligible in this area. The only places where the water table would be sufficiently shallow would be along the banks of the streams and in parts of the stream beds.

Discharge from wells.—The discharge of water from wells is now one of the principal means of the discharge of water from the ground-water reservoir. In 1943, more than 4,000 acre-feet of water was pumped from irrigation, railroad, and public-supply wells in Pawnee and Edwards Counties. During the drought between 1930 and 1940 much more than 4,000 acre-feet per year was discharged by wells, as attested by the fact that only 76 of the 127 irrigation wells listed in Tables 16 and 17 were in operation in 1943. This was caused primarily by improved soil-moisture conditions, but, in part, by the shortage of labor. It is believed that the average pumpage of water for irrigation, railroad, and public-supply use probably exceeded 4,000 acre-feet. Most of the rural residents of the area obtain their supplies of domestic and stock water from wells, but the amount of water used for this purpose is comparatively small. The recovery of ground water from wells is discussed in the next section.

Recovery

PRINCIPLES OF RECOVERY

The discharge from a well is produced by a pump or some other lifting device or by artesian head. (For a more detailed discussion of principles of recovery see Meinzer, 1923a, pp. 60-68.) When water is standing in a well, there is equilibrium between the head of the water inside the well and the head of the water outside the well. Whenever the head inside a well is reduced, a resultant differential head is established and water moves into the well. The head of the water inside a well may be reduced in two ways: (1) by lowering the water level by a pump or some other lifting device, and (2) by reducing the head at the mouth of a well that discharges by artesian pressure. Whenever water is removed from a well there is a resulting drawdown or lowering of the water level or, in a flowing artesian well, an equivalent reduction in artesian head.

When water is being discharged from a well, the water table is lowered in an area around the well to form a depression somewhat resembling an inverted cone. This depression of the water table is known as the cone of depression, and the distance that the water level is lowered is called the drawdown (Fig. 9). In any well, within certain limits, the greater the rate of pumping the greater will be the drawdown.

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 amount by which the water level can be lowered, the

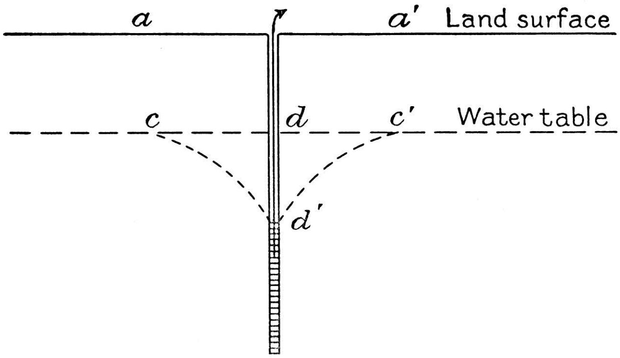

FIG. 9. Diagrammatic section of a well that is being pumped, showing its drawdown (dd'), cone of depression (cc'd'), and area of influence (aa'). (From O. E. Meinzer.)

thickness and permeability of the water-bearing bed, and the construction and condition of the well. The capacity of a well generally is expressed in gallons a minute.

The specific capacity of a well is its rate of yield per unit of drawdown, and it is determined by dividing the tested capacity in gallons a minute by the drawdown in feet. If a well yields 1,000 gallons a minute, for example, and has a drawdown of 10 feet when pumped at that rate, then the specific capacity of that well would be 1,000 divided by 10, or 100 gallons a minute per foot of drawdown, or simply 100.

When water is withdrawn from a well, the water level drops rapidly at first and then more slowly until it finally becomes nearly stationary. When the withdrawal of water from a well ceases, the water level rises rapidly at first and then more slowly until eventually it reaches its original position, or approximately its original position.

DUG WELLS

Dug wells are excavated with picks, shovels, spades, or by power machinery. They generally are between 2 and 10 feet in diametrer and are relatively shallow. Most of the shallow domestic and stock wells in the upland area in northern Pawnee County are dug. Almost all the early irrigation wells were dug to the water table and then drilled the rest of the way, but the newer irrigation wells are drilled. Most of the driven wells in the sand-hills area south of Arkansas River were dug several feet in order to facilitate driving the sand point. In some places the dug part of the well is extended to the water table.

BORED WELLS

Bored wells are made by augers or post-hole diggers in unconsolidated sediments. Many wells in the shallow-water areas in the Arkansas Valley were made in this way.

DRIVEN WELLS

Most of the domestic and stock wells in the sand-hills area and many of the wells in the Arkansas, Pawnee, and Ash Creek Valleys are driven wells. They generally are made by driving a 1¼- to 1½-inch pipe (equipped at the bottom with a screened drive point) down below the water table. Such wells generally can be put down only where the water-bearing material is sufficiently permeable to permit water to flow freely into the pipe, where the material is unconsolidated enough to permit a pipe to be driven, and where the depth to water level is not more than about 20 feet below land surface. Where the material near the surface is too consolidated to permit a pipe to be driven, the well generally is dug to a less consolidated zone and where the depth to water exceeds 20 feet the well generally is dug part way so that the distance from the pump cylinder (at the bottom of the dug part of the well) to the water table is less than 20 feet. Driven wells in the areas of very shallow water in the Arkansas Valley generally are equipped with a pitcher pump, whereas in areas where the water table is deeper they generally are equipped with a cylinder pump, the cylinder being placed at the bottom of the dug part of the well.

DRILLED WELLS

A drilled well is one that is excavated by means of a percussion or rotary drill. In Pawnee and Edwards Counties the drilled domestic and stock wells generally are 4 to 6 inches in diameter and are cased with galvanized-iron or wrought-iron casing. The irrigation and public-supply wells generally are between 8 and 24 inches in diameter. Most of the irrigation and public-supply wells in the valley and sand-hills areas and the deep domestic and stock wells in the upland areas in northern and western Pawnee County and in northwestern Edwards County are drilled wells.

Drilled wells in consolidated deposits.—Almost all the drilled wells in Pawnee and Edwards Counties that are in or near the areas of Cretaceous outcrops are drilled into consolidated deposits. Most of these wells penetrate shale and limestone of the Carlile shale and/or the Greenhorn limestone and end in sandstone in the Dakota formation. They generally are cased to the bottom but a few are cased through the unconsolidated superficial material and a few feet into bedrock. Water may enter the well along the entire uncased part of the hole, but the materials above the Dakota formation in these areas generally are nearly barren of water. In the Pawnee Valley a few wells obtain water from the Dakota formation, the water of poorer quality in the alluvium being cased off.

Drilled wells in unconsolidated materials.—Unconsolidated materials of Quaternary age supply most of the water to wells in Pawnee and Edwards Counties. Wells in these deposits generally are cased nearly to the bottom of the hole with galvanized-iron or wrought-iron casing. Water enters most of the wells through the end of the casing but the irrigation, railroad, and public-supply wells generally have perforated casing to provide better intake facilities. The size of the perforations is an important factor in the construction of a well and the capacity or even the life of the well may be determined by it. If the perforations are too large the fine material may filter through and fill the well, and if the perforations are too small they may become clogged so that water is prevented from entering the well freely.

Some wells in unconsolidated sediments are equipped with well screens or strainers. It is common practice to select a slot size that will pass 30 to 60 percent of the water-bearing material, depending upon the texture and degree of assortment. Retention of the coarser particles around the screen forms a natural gravel packing that greatly increases the effective diameter of the well, hence increasing its capacity.

Gravel-wall wells generally are effective for obtaining large supplies of water from relatively fine-grained unconsolidated deposits, and are widely used for irrigation. In constructing a well of this type, a hole of large diameter, 30 to 60 inches, is first drilled by the rotary method or by means of an orange-peel bucket and is temporarily cased with unperforated pipe. A well screen or perforated casing of smaller diameter than the hole is then lowered into place and centered in the large pipe opposite the water-bearing beds. Unperforated casing extends from the screen to the surface. The annular space between the inner and outer casings is then filled with sorted gravel, preferably of a grain size just a little larger than the openings in the screen or perforated casing, and also slightly larger than that of the water-bearing material. In most wells of this type a medium- or coarse-grained gravel is used, but in very fine-grained deposits a fine-grained gravel or a coarse-grained sand must be used. The outer casing is then withdrawn part way to uncover the screen and to allow the gravel packing to come in contact with the water-bearing material. In deciding whether or not to use gravel-wall construction it is important to know the character of the water-bearing material. If the material is coarse and well sorted, it generally is unnecessary to construct a gravel-wall well.

According to McCall and Davison (1939, p. 29) the drawdown in a well can be kept at a minimum in several ways:

> First, the well should be put down through all valuable water-bearing material. Secondly, the casing should be properly perforated so as to admit water to the well as rapidly as the surrounding gravel will yield the water. Third, the well should be completely developed so that the water will flow freely into the well. . . . Increasing the depth of a well will have a greater effect on reducing the drawdown than will increasing the diameter, so long as additional water-bearing formations are encountered.

A report (Davison, 1939) containing descriptions of different types of pumping plants, the conditions for which each is best suited, construction methods, and a discussion of costs of construction is available from the Division of Water Resources, Kansas State Board of Agriculture, Topeka, Kansas, and the reader is referred to this publication for additional details of well construction.

Methods of Lift and Types of Pumps

Most of the domestic and stock wells in Pawnee and Edwards Counties are equipped with lift or force pumps. The cylinders or working barrels in lift pumps and in force pumps are similar and are located below the land surface, either above or below the water table; a lift pump generally discharges water only at the pump head, whereas a force pump can force water above this point—such as to an elevated tank. Pitcher pumps are used on many of the driven wells in the Arkansas Valley and on a few of the driven wells elsewhere in the area. Domestic and stock wells in the Pawnee-Edwards area generally are operated by windmills but the pitcher pumps and a few of the lift pumps are hand operated.

The discharge pipes in driven wells generally are 1¼ to 1½ inches in diameter and in drilled wells they generally are 1¼ to 3 inches in diameter. The discharge pipes in the larger irrigation and public supply wells are 4 to 10 inches in diameter.

Irrigation and public-supply wells in this area are equipped with large centrifugal and turbine pumps. The centrifugal pumps are used mainly in the old irrigation plants consisting of one or more dug and drilled wells connected to one pump. The turbine pumps are used primarily in the newer deep irrigation and public-supply wells. Both types of pumps generally are equipped with large engines using gasoline or electricity for power.

UTILIZATION OF WATER

A large part of the wells in Pawnee and Edwards Counties supply water for domestic and stock use. Most of the water used in this area, however, is pumped from the comparatively few irrigation wells. A few wells in this area are used for public-supply and industrial purposes.

Domestic and Stock Wells

Domestic wells supply homes with water for drinking, cooking, and washing, and supply those schools not served by municipal wells. Stock wells supply water for livestock, principally cattle. Water for domestic use is obtained almost entirely from wells, but in some of the areas of Cretaceous outcrop a few cisterns probably are used. Most of the stock water also is obtained from wells but in recent years there has been an increased construction of dams on dry watercourses in areas where supplies of ground water are difficult to obtain. Although the water generally is hard, it can be used satisfactorily for most domestic and stock purposes.

Public Water Supplies

Larned, Kinsley, Lewis, and Belpre are the only cities in the Pawnee-Edwards area having public water supplies, and they are supplied from wells. Brief descriptions of the water-supply systems of these cities are given below and details of well construction are listed in the well tables at the end of the report.

Larned.—The City of Larned is supplied from eight wells (44, 50, 51, 52, 53, 54, 56, and 110), of which six obtain water from the Dakota formation and two obtain water from the alluvium of Arkansas River. The wells that obtain water from the Dakota range in depth from 123 feet to 167 feet and are cased with 10-inch wrought-iron casing. They are equipped with turbine pumps powered by electric motors. The wells each have a 5-inch column pipe and a 4-inch discharge pipe. The depth to water level in each well is reported to be 30 feet.

The two wells that obtain water from alluvium (56 and 110) have a much larger yield. Well 56 is 70 feet deep and has a static water level of about 10 feet. It is cased with 19-inch galvanized-iron casing and is equipped with a turbine pump powered by a 100-horsepower electric motor. The well pumps 675 gallons of water a minute into the water system but during an open-flow test it pumped 1,450 gallons a minute with a drawdown of 11 feet after several hours of pumping. The specific capacity of the well, therefore, is 132. Well 110 is a dug well 20 feet in diameter and cased with concrete. Water enters the well by means of 54 screened drive points that extend laterally from the well. The drive points are 6 inches in diameter. The well is 26 feet deep and is equipped with two 5-inch centrifugal pumps powered by 100-horsepower electric motors. Each pump has an open-flow yield of 1,000 gallons a minute but yields 600 gallons a minute when pumping into the mains. The total capacity of the eight wells when pumping into the mains is about 2,775 gallons a minute. The water is pumped directly into the mains; the excess water is stored in an elevated steel tank having a capacity of 500,000 gallons.

The average daily consumption of water in 1943 was 260,000 gallons, or 75 gallons per capita. The total amount of water pumped in 1943 was 136,500,000 gallons, of which 95,000,000 gallons was used for domestic purposes, 14,200,000 gallons was used by industries, and 27,300,000 was charged to loss. (This includes water used by fire department, street department, and city parks.)

The ground water used by the City of Larned is hard, but is suitable for most domestic uses (analysis 56, Table 9).

Kinsley.—The water supply for Kinsley is obtained from two wells (264 and 265) penetrating the Meade formation in the sand-hills area south of Arkansas River. The wells are in the NW¼ sec. 6, T. 25 S., R. 18 W., about 3 miles east-southeast of the city. Well 264 is 86 feet deep and has a static water level of 41 feet, whereas well 265, which is at a lower altitude, is 72 feet deep and has a static water level of 32 feet. Both wells are cased with 18-inch wrought-iron casing and are equipped with turbine pumps powered by 20-horsepower electric motors. The wells are reported to yield about 600 gallons a minute with a drawdown of 15 feet; hence, the specific capacity of each is 40.

The municipal supply formerly was obtained from two shallow wells in the alluvium of Arkansas River at Kinsley, but owing to the considerable hardness of the water a new supply was sought in the sand-hills area where the water is of much better quality. Water from the new wells is pumped into a short pipeline which carries the water across Arkansas River and connects with the city mains. The excess water is stored in two standpipes having an aggregate capacity of 345,000 gallons, and in one surface reservoir having a capacity of 350,000 gallons. Water is distributed from the standpipes into the mains by the force of gravity, whereas water in the surface reservoir is forced into the mains by means of two centrifugal pumps having capacities of 400 and 600 gallons a minute, respectively.

The ground water used by the City of Kinsley is relatively soft, as indicated by analysis 265 in Table 10.

Lewis.—The two wells that supply water for Lewis (223 and 224) are located within the city at the site of the elevated storage tank. They obtain water from the Meade formation. They are reported to be 150 feet deep and to have a static water level of 32 feet. Well 223 is equipped with an air-lift pump powered by a gasoline engine, and well 224 is equipped with a turbine pump powered by a 20-horsepower electric motor. The turbine pump forces water into the mains, the excess going into the elevated steel tank. Water raised by the air-lift pump goes into a buried reservoir from which it is pumped into the mains by means of a centrifugal pump, and the excess water goes into the elevated tank. The water is moderately hard but is suitable for most uses. (See analysis 223 in Table 10.)

Belpre.—The City of Belpre is supplied with water from a dug well (210) 12 feet in diameter and 61 feet deep. The water level was 29 feet below land surface when the well was dug but the water level rose 12 feet as a result of above-normal precipitation between 1941 and 1944. The well is cased with concrete and is equipped with two 4-inch centrifugal pumps powered by 15-horse power electric motors. The water is pumped into the mains at the rate of 300 gallons a minute, and the excess water goes into an elevated steel tank. The water is moderately hard but otherwise is of good quality (anlaysis 210, Table 10).

Estimated use.—Accurate data on the rate of consumption of ground water for municipal use are available only for the public-supply system at Larned. The average daily use of water at Larned in 1943 was 75 gallons per capita. If it is assumed that the per capita consumption of water was about the same in all the cities in this area that have a public water supply, then the total pumpage of water by these cities in 1943 probably was between 750 and 800 acre-feet.

Industrial Supplies

Pawnee and Edwards Counties are agricultural areas having very few industries and, hence, very few industrial wells. Almost all the industries are situated at Larned or at Kinsley and they obtain most of their water from the municipal water systems in those cities. The only data on the consumption of ground water for industrial use are those available for the City of Larned. In 1943, the industries in Larned purchased 14,200,000 gallons of water from the city. One of the industrial users of water in Pawnee and Edwards Counties is the Atchison, Topeka, and Santa Fe Railway Company which has wells in most of the communities in this area. These generally are small-diameter drilled wells having a comparatively small yield. Most of the oil and gas companies drill water wells to supply water for use in drilling the oil and gas tests. These are used only during the drilling of the deep wells and then generally are abandoned.

Possibilities of further development of industrial supplies from wells.—The prospects for developing additional supplies of ground water for industrial use in Pawnee and Edwards Counties is very good. The unconsolidated water-bearing materials that underlie the broad area of dune sand south of the Arkansas River are essentially undeveloped. Part of this area may be irrigated in the future, but the development of irrigation will be greatly limited by the type of soil and by the slope of the land. These factors are not adverse to the development of industrial supplies. Throughout this area the pumping lift is small and the recharge conditions are favorable. Additional industrial supplies of ground water could be obtained from wells in the alluvium of the Arkansas and Pawnee Valleys. There, however, the water is of poorer quality and the land is more favorable for the extensive development of irrigation.

Irrigation Supplies

Many large wells in this area (Pl. 5) supply water to irrigate crops—principally alfalfa, row crops, and sugar beets. Irrigation is carried on principally in the Pawnee Valley, but there has been considerable development in the Arkansas Valley and in the dune-sand area south of Arkansas River. The upper part of the alluvium in the Pawnee Valley consists primarily of silt. The soil in this valley, therefore, is more favorable for the growth of irrigated crops than are the sandy soils of the Arkansas Valley and the dune-said areas.

During the summers of 1944 and 1945 an inventory of the irrigation wells in Pawnee and Edwards Counties was made, and estimates of the total pumpage and of the acreage irrigated in 1943 were obtained. The records of all the irrigation wells visited are

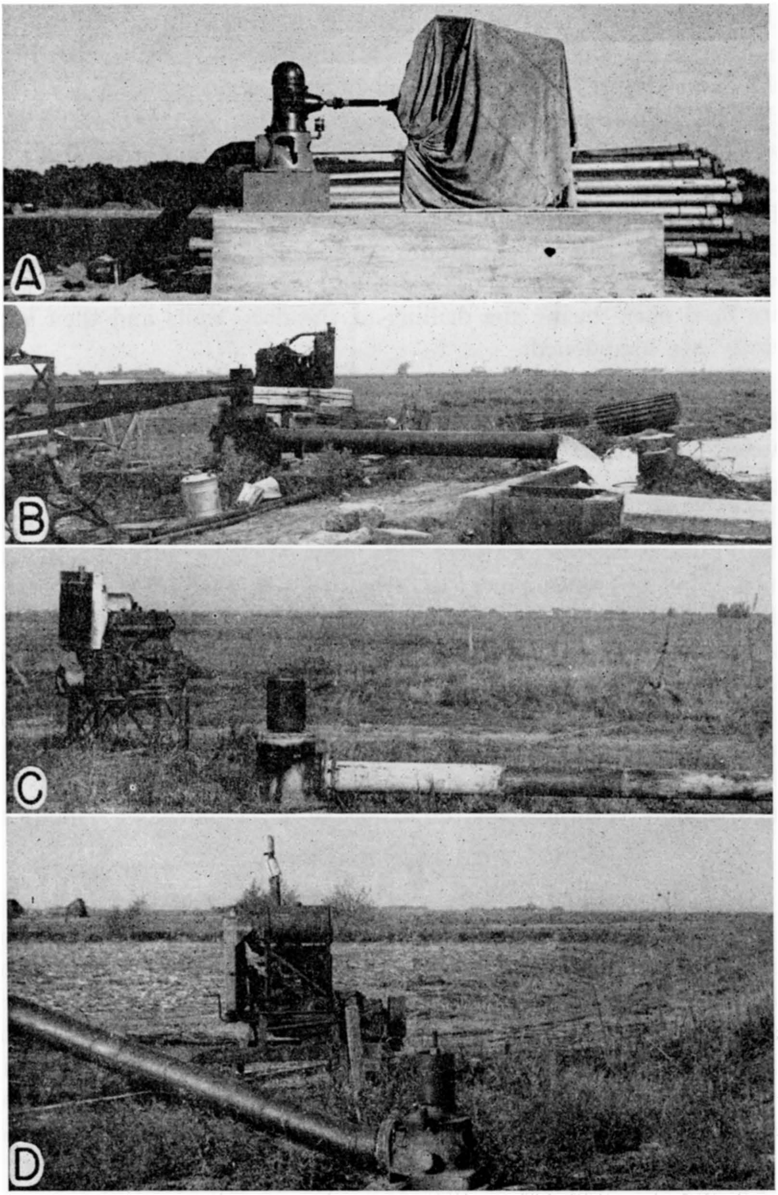

PLATE 5. Irrigation wells in the Pawnee-Edwards area. *A,* Phinney well (58) and sprinkler system. *B,* Thomas well (69). *C,* Stockwell well (144). *D,* Eddy well (147).

given in Tables 15 and 16 and the locations of the wells are shown on Plate 2. Records of 127 irrigation wells (69 in Pawnee County and 58 in Edwards County) were obtained; only 76 were in use in 1943. The records indicate that about 3,400 acre-feet of water was pumped in 1943 to irrigate about 3,380 acres of land.

During the years of below-normal precipitation between 1930 and 1940, irrigation in this area was extensive and many new irrigation wells were constructed. After 1940, however, the precipitation generally was far above normal and the shortage of farm laborers was acute. As a result, only about 60 percent of the irrigation wells were in use in 1943 and additional wells were abandoned after 1943. The pumpage from those wells in use had declined sharply by 1943. Although the precipitation in this area was below normal in 1943, the soil moisture was above normal and the labor shortage remained acute; hence, the total pumpage was about 1 acre-foot of water for each acre of land irrigated. During this investigation an attempt was made to learn the number of acres of land under ditch so that an estimate of the prewar irrigated acreage could be made, but this proved unsuccessful. The irrigated acreage in Pawnee and Edwards Counties in 1944 was 7,780 and 924 acres, respectively.

YIELD

The yields of the irrigation wells in Pawnee and Edwards Counties vary widely. A few of the smaller plants yield less than 250 gallons a minute, whereas some of the larger plants yield nearly 2,000 gallons a minute. The yields of the irrigation wells given in Tables 15 and 16 were reported by the owners and may be subject to considerable error. In Table 4 the irrigation wells of Pawnee and Edwards Counties are classified according to their yield.

TABLE 4. *Yield of irrigation wells in Pawnee and Edwards Counties*

Yield (gallons a minute)	Number of Wells		
	Pawnee County	Edwards County	Total
Less than 250	1	5	6
251-750	20	15	35
751-1,250	32	17	49
Greater than 1,250	9	8	17
Unknown	7	13	20
Total	69	58	127

The yield of many of the earlier plants in this area (particularly in Pawnee Valley) were increased by connecting a battery of shallow wells to one pump. These plants used centrifugal pumps;

hence the yields were limited because the drawdown could not exceed the suction limit. In recent years the tendency has been to drill single deep gravel-wall wells and to equip them with turbine pumps. The newer wells generally draw water from all water-bearing materials above the Cretaceous bedrock.

CONSTRUCTION

Most of the larger irrigation wells in Pawnee and Edwards Counties were constructed by professional well drillers; however, many of the wells, particularly in Edwards County, were drilled by farmers. The home-made plants generally are poorly constructed and have low efficiencies. This probably accounts in part for the high rate of abandonment of irrigation wells in Edwards County.

Several methods of well construction have been used in Pawnee and Edwards Counties. The older irrigation wells in this area were constructed by digging a pit nearly to the water table and then drilling a well through the bottom of the pit. The sides of the pit generally were walled with wood or concrete and the drilled part was cased with perforated galvanized-iron casing. In wells having a small yield and a small drawdown, the pumps were placed at the ground surface, but where the anticipated yield and drawdown were large, the pumps were placed at the bottom of the pit. Where greater yields were desired, several wells of this type were dug and drilled and were connected to one pump. These wells generally were only 30 to 50 feet deep and did not utilize the entire thickness of coarse water-bearing material.

Most of the newer plants in the Pawnee-Edwards area consist of a single gravel-wall well that penetrates all water-bearing materials above the Cretaceous bedrock. These wells are equipped with deep-well turbine pumps (Pl. 5). The details of construction of this type of gravel-wall well are described on page 40.

Wells of greater capacity and efficiency than many now in use could be obtained in this area if better methods of well construction were used. Most of the home-made plants in Edwards County do not penetrate the entire thickness of water-bearing material. Many of the plants consisting of a battery of wells are poorly constructed and the individual wells are never spaced widely enough to prevent mutual interference. The wells of a plant practically never are aligned in a direction at right angles to the direction of movement of ground water, but instead are generally aligned along a fence or a road, causing an increase in the mutual interference of the wells.

Some wells in Pawnee and Edwards Counties penetrate water-bearing formations that are so fine-grained that the wells should be gravel-packed; others have been gravel-packed with gravel that is less satisfactory than the water-bearing material it replaced. For detailed descriptions of gravel-packing, the reader is referred to Rohwer (1940), Bennison (1943), and Davison (1939).

DEPTH AND DIAMETER

More than half the irrigation wells in the Pawnee-Edwards area are less than 50 feet deep, owing to the large number of shallow home-made wells in Edwards County and to the many old dug and drilled wells in the Pawnee Valley. The deeper wells are largely the newer wells that are equipped with turbine pumps. The irrigation wells in Pawnee and Edwards Counties are classified in Table 5 according to depth.

The diameters of the irrigation wells in this area range from 8 inches in a few of the small plants to several feet in a few dug wells. Most of the wells are cased with galvanized-iron casing ranging in diameter from 16 to 24 inches. The irrigation wells in this area are classified in Table 6 according to diameter. For wells that are dug and drilled, the diameter of the drilled part is given.

TABLE 5.—*Depth of irrigation wells in Pawnee and Edwards Counties*

Depth (feet)	Number of wells		
	Pawnee County	Edwards County	Total
Less than 50	22	47	69
51–75	16	8	24
76–100	21	3	24
101–125	6	0	6
Unknown	4	0	4
Total	69	58	127

PUMPS

Most of the irrigation wells in Edwards County and the older irrigation wells in Pawnee County are equipped with centrifugal pumps, ranging in diameter of discharge pipe from 3 to 10 inches.

TABLE 6.— *Diameter of irrigation wells in Pawnee and Edwards Counties*

Diameter (inches)	Number of wells			Diameter (inches)	Number of wells		
	Pawnee County	Edwards County	Total		Pawnee County	Edwards County	Total
Less than 16	3	6	9	22	0	13	13
16.......	6	9	15	24	17	5	22
18.......	2	4	6	Greater than 24	4	8	12
19.......	29	1	30	Unknown	4	10	14
20.......	4	2	6	Total	69	58	127

Most of the newer deep wells are equipped with turbine pumps, although some of the new shallow wells have centrifugal pumps. The diameters of the discharge pipes of the turbine pumps range from 6 to 10 inches.

PUMP POWER

Stationary gasoline engines and tractors are used to operate most of the irrigation wells in Pawnee and Edwards Counties. Twenty-three plants are operated by electric motors and only one is operated by a natural-gas engine (Table 7). The power units generally are belted to the pump pulleys, but in some of the newer plants the motors are direct-connected to the shafts.

TABLE 7.—*Type of power used for pumping irrigation wells in Pawnee and Edwards Counties*

Type of power	Number of wells		
	Pawnee County	Edwards County	Total
Electric motor....................	19	4	23
Gasoline engine..................	31	20	51
Natural-gas engine...............	1	0	1
Tractor..........................	15	29	44
Unknown..........................	3	5	8
Total........................	69	58	127

POSSIBILITIES OF FURTHER DEVELOPMENT OF IRRIGATION SUPPLIES FROM WELLS

For the purpose of discussion, Pawnee and Edwards Counties may be divided into three areas based upon the possibilities of further development of irrigation supplies from wells: (1) dune-sand area, (2) Arkansas Valley, and (3) Pawnee Valley.

Dune-sand area.—The development of irrigation in the area of dune sand lying south of the Arkansas Valley is limited primarily by soil and surface slope. In the areas of youthful and mature dunes (Pl. 1) the soil is loose and sandy and is not suitable for irrigation and, in addition, the slope of the land is too great. In the areas of old-age dune sand (Pl. 1) the slopes are much less and the soil is thicker and more compact. Within these areas there is much land having soils and slopes such that irrigation could be developed. The depth to water level in all these areas is less than 50 feet. The thickness and coarseness of the water-bearing materials in this area are sufficiently great to permit the development of wells having moderately large yields. The porous soil and the undeveloped drainage in a large part of this area greatly facilitate recharge from precipitation.

Arkansas Valley.—Irrigation in the Arkansas Valley in Pawnee and Edwards Counties has been developed only slightly, owing in part to the character of the soil, which is too sandy or gravelly in some places. It is believed, however, that there is adequate ground water in the alluvium of the Arkansas Valley to permit extensive development of irrigation from wells. Inasmuch as the soil in many parts of the valley is very porous, the recharge from precipitation is rapid. In addition, water added to the ground-water reservoir by recharge in the sand-hills area adjacent to the valley moves into the alluvium in the Arkansas Valley.

If irrigation from wells were developed extensively in the Arkansas Valley and the water table were lowered over a wide area, Arkansas River would become a losing stream and would contribute large quantities of water to the ground-water reservoir in the valley. The amount of water that would be added to the ground-water reservoir by loss of stream flow is not known but it probably would be large. By way of comparison, the loss of water in Arkansas River between Syracuse and Garden City (a distance of about 50 miles) averaged nearly 32,000 acre-feet annually between 1922 and 1942 even though there was a net gain during two of those years

(78,118 acre-feet in 1923-1924 and 6,830 acre-feet in 1928-1929). The greatest loss amounted to nearly 78,000 acre-feet in the water year 1941-1942, at the end of a long drought during which the water table had declined as much as 10 feet largely as a result of heavy withdrawals of water by wells for irrigation. The recharge from rainfall and from stream loss in the water year 1941-1942 was sufficient to restore the water table to its approximate pre-drought position, thus replenishing the ground-water reservoir (McLaughlin, 1943).

The channel of Arkansas River in Pawnee and Edwards Counties is very similar to the channel between Syracuse and Garden City; that is, it is in most places wide and sandy and would permit relatively rapid downward percolation of water. Records of the stream flow at Garden City and Larned and of the loss of stream flow below those stations give some idea of the potential recharge from

TABLE 8.—*Annual discharge of Arkansas River at Garden City and Larned, and loss or gain of stream flow between Garden City and Larned for the 18-year period from Oct. 1, 1922, to Sept. 30, 1940.*[1]

Water year (Oct. 1 through Sept. 30)	Annual discharge at Garden City (acre-feet)	Annual discharge at Larned (acre-feet)	Loss (—) or gain (+) between Garden City and Larned	
			Acre-feet	Percentage of discharge at Garden City
1922-1923	484,000	459,000	—25,000	5.2
1923-1924	562,581	544,757[2]	—17,824	3.0
1924-1925	113,000	85,800	—27,200	24.1
1925-1926	15,600	46,600	+31,000	198.7
1926-1927	204,000	243,000	+39,000	19.1
1927-1928	236,000	247,000	+11,000	4.7
1928-1929	133,000	158,000	+25,000	18.8
1929-1930	42,600	77,500	+34,900	81.9
1930-1931	120,000	187,000	+67,000	55.8
1931-1932	11,700	41,600	+29,900	255.5
1932-1933	50,000	56,200	+6,200	12.4
1933-1934	11,960	22,690	+10,730	89.7
1934-1935	81,720	109,700	+27,980	34.2
1935-1936	199,400	162,900	+36,500	18.3
1936-1937	37,290	45,100	+7,810	20.9
1937-1938	32,940	42,820	+9,880	30.0
1938-1939	21,550	38,340	+16,790	77.9
1939-1940	1,340	54,678	+53,338	3,980.4

1. From records compiled by the Division of Water Resources of the Kansas State Board of Agriculture in coöperation with the Water Resources Branch of the U. S. Geological Survey.
2. Includes estimated flow of 100,000 acre-feet for January and February.

Arkansas River in this area (Table 8). The records show that generally Arkansas River gains in stream flow between Garden City and Larned. Much of this gain probably is derived from groundwater discharge and represents water lost from the ground-water reservoir that could be salvaged largely by a general lowering of the water table. The water thus salvaged would then be available to wells. Part of the gain in stream flow, however, is caused by additions of water from small tributary streams although no large tributaries are confluent with Arkansas River between the two gaging stations.

The records also show that the channel of the river between Garden City and Larned is capable of absorbing relatively large quantities of water. There was a net loss in stream flow during the period from 1922 to 1925, the maximum loss being 27,200 acre-feet during the water year 1924-1925.

Pawnee Valley.—Irrigation from wells has been developed more fully in the Pawnee Valley than in the Arkansas Valley in the Pawnee-Edwards area, owing primarily to the character of the soil, which is more suitable for irrigation. The upper part of the alluvium in the Pawnee Valley consists of clay and silt in most places and the soil derived from these materials generally is more suitable for irrigation than is soil derived from coarser sediments. The records of water levels in the Pawnee Valley show that the pumpage for irrigation between 1940 and 1947 did not materially affect the water level; in fact, the water table was higher in some areas in 1947 than it was in 1940. This period, however, was one of above-normal precipitation and below-normal pumpage.

The records of water-level fluctuations show that the groundwater reservoirs in this area are recharged from precipitation. The recharge from precipitation in the Pawnee Valley is believed to be less than that in the Arkansas Valley and areas south of that valley because the upper part of the alluvium is relatively fine-grained, which naturally reduces the rate of infiltration. The water table fluctuates in the relatively fine-grained material in the upper part of the alluvium; thus a given rise in water level reflects a smaller addition of water than an equal rise in coarser-grained material.

Pawnee River is also a possible source of recharge of the ground-water reservoir in the Pawnee Valley. If pumping for irrigation increases to the extent that the water table adjacent to the stream is lowered below the level of the stream channel, the river will then contribute water to the ground-water reservoir. The loss in stream flow probably would be small compared to that in parts of the Arkansas Valley because the channel is narrow and its bottom and sides generally consist of silt or clay, thus retarding the downward percolation of water.

QUALITY OF WATER

The chemical character of the ground waters in Pawnee and Edwards Counties is indicated by the analyses in Tables 9 and 10. The analyses were made by H. A. Stoltenberg in the Water and Sewage Laboratory of the Kansas State Board of Health. Seventy-one samples of water were collected from representative wells distributed as uniformly as possible within the area and among the water-bearing formations. The constituents listed were determined by 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 U. S. Geological Survey.

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

TABLE 9.—*Analyses of water from typical wells in Pawnee County, Kansas*

Analyzed by H. A. Stoltenberg. Dissolved constituents given in parts per million and in equivalents per million (in italics)

Well or test hole no. on Plate 1 or 2	Location	Depth (feet)	Geologic source	Date of collection	Temperature (°F)	Dissolved solids	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Borate (BO_3)	Hardness as $CaCO_3$		
																	Total	Carbonate	Noncarbonate
	T. 20 S., R. 16 W.																		
1	NE¼ NW¼ sec. 4	......	Terrace deposits	Oct. 12, 1944	58	377	0.30	107 *5.34*	12 *.99*	19 *.82*	339 *5.56*	16 *.33*	33 *.93*	0.2 *.01*	20 *.32*	......	316	278	38
5	NE¼ SW¼ sec. 13	165	Dakota	Oct. 12, 1944	60	374	.74	91 *4.54*	18 *1.48*	20 *.86*	290 *4.76*	85 *1.77*	8.5 *.24*	.5 *.03*	5.3 *.08*	......	301	238	63
8	SE¼ SW¼ sec. 31	43.8	Terrace deposits	Oct. 7, 1944	59	343	1.0	84 *4.19*	11 *.90*	33 *1.45*	295 *4.84*	21 *.44*	43 *1.21*	.4 *.02*	1.7 *.03*	......	254	242	12
	T. 20 S., R. 17 W.																		
11	NW¼ NE¼ sec. 26	40	do	Oct. 7, 1944	59	310	3.3	78 *3.89*	11 *.90*	27 *1.17*	320 *5.25*	19 *.40*	9.0 *.25*	.3 *.02*	2.7 *.04*	......	240	240	0
	T. 20 S., R. 18 W.																		
14	SW¼ SE¼ sec. 10	10	Carlile	Aug. 2, 1944	65	426	.58	48 *2.40*	18 *1.48*	93 *4.06*	373 *6.12*	56 *1.16*	19 *.54*	1.1 *.06*	4.0 *.06*	......	194	194	0
	T. 20 S., R. 19 W.																		
18	SW¼ SE¼ sec. 8	28	do	Oct. 11, 1944	58	473	.25	126 *6.29*	7.2 *.59*	26 *1.13*	282 *4.62*	55 *1.14*	29 *.82*	.1 *.01*	88 *1.42*	......	344	231	113
22	SW¼ SW¼ sec. 26	......	Greenhorn	Aug. 24, 1944	60	354	4.3	49 *2.44*	20 *1.64*	57 *2.46*	284 *4.66*	58 *1.21*	21 *.59*	1.0 *.05*	2.1 *.03*	......	204	204	0
23	NE¼ NE¼ sec. 28	312	Dakota	Oct. 13, 1944	60	1,108	.59	26 *1.30*	16 *1.32*	365 *15.88*	483 *7.92*	324 *6.74*	125 *3.52*	4.6 *.24*	5.3 *.08*	......	131	131	0
24	SE¼ SE¼ sec. 29	44.7	Greenhorn	Aug. 24, 1944	59	409	4.7	116 *5.79*	11 *.90*	14 *.62*	340 *5.58*	14 *.29*	13 *.37*	.2 *.01*	66 *1.06*	......	334	279	55
	T. 20 S., R. 20 W.																		
27	NW¼ SW¼ sec. 11	17.9	Carlile	Oct. 11, 1944	61	620	3.9	164 *8.18*	17 *1.40*	39 *1.70*	433 *7.10*	112 *2.33*	62 *1.75*	.2 *.01*	5.8 *.09*	......	479	355	124

30	SE¼ SW¼ sec. 32	110	Dakota	Oct. 11, 1944	59	972	5.8	45 *2.25*	28 *2.30*	267 *11.60*	379 *6.22*	322 *6.70*	107 *3.02*	2.4 *.13*	5.3 *.08*	......	228	228	0
34	*T. 21 S., R. 15 W.* NE¼ SE¼ sec. 14	23	Meade	Oct. 9, 1944	59	278	.67	60 *2.99*	11 *.90*	27 *1.19*	234 *3.84*	16 *.33*	11 *.31*	.9 *.05*	34 *.55*	......	194	192	2
38	*T. 21 S., R. 16 W.* SE¼ SE¼ sec. 7	38.8	Terrace deposits	Oct. 7, 1944	58	551	2.7	89 *4.44*	14 *1.15*	102 *4.44*	299 *4.90*	27 *.56*	155 *4.37*	.3 *.02*	11 *.18*	......	280	245	35
41	SE¼ SE¼ sec. 12	......	do	Aug. 23, 1944	58	696	.86	132 *6.59*	25 *2.06*	78 *3.39*	216 *3.54*	173 *3.60*	166 *4.68*	.6 *.03*	12 *.19*	1.5	432	177	255
56	SE¼ SW¼ sec. 33	......	Alluvium	Aug. 11, 1945	......	1,480	.0	178 *8.88*	54 *4.44*	201 *8.73*	254 *4.17*	726 *15.10*	94 *2.65*	....	4.9 *.08*	......	666	208	458
62	*T. 21 S., R. 17 W.* SE¼ SE¼ sec. 18	......	Terrace deposits	Oct. 10, 1944	58	295	2.5	76 *3.79*	9.8 *.81*	25 *1.10*	311 *5.10*	7.4 *.15*	10 *.28*	.5 *.03*	8.4 *.14*	......	230	230	0
65	*T. 21 S., R. 18 W.* SE¼ NE¼ sec. 5	100	do	Oct. 13, 1944	59	287	13	75 *3.74*	11 *.90*	19 *.83*	317 *5.20*	.0 *.00*	6.0 *.17*	.9 *.05*	3.2 *.05*	......	232	232	0
T-26	SW cor. sec. 17	120	Alluvium	June 21, 1945	......	272	10	74 *3.69*	14 *1.15*	13 *.56*	288 *4.72*	11 *.23*	12 *.34*	.5 *.03*	5.3 *.08*	......	242	236	6
T-27	NW cor. sec. 29	110	do	June 21, 1945	......	276	9.4	76 *3.79*	14 *1.15*	13 *.57*	300 *4.92*	8.2 *.17*	11 *.31*	.5 *.03*	5.3 *.08*	......	247	246	1
T-28	NW cor. sec. 32	418	Permian	June 22, 1945	......	8,834	6.1	628 *31.34*	284 *23.34*	2,049 *89.10*	116 *1.90*	2,991 *62.21*	2,820 *79.52*	1.8 *.09*	3.5 *.06*	......	2,734	95	2,639
T-28	do	306	Dakota (?)	June 13, 1945	......	423	17	56 *2.79*	17 *1.40*	86 *3.73*	293 *4.80*	37 *.77*	80 *2.26*	1.1 *.06*	2.0 *.03*	......	210	210	0
69	SW¼ SW¼ sec. 32	120	Alluvium	Sept. 25, 1944	......	370	.08	74 *3.69*	15 *1.23*	49 *2.13*	324 *5.31*	32 *.66*	36 *1.02*	.8 *.04*	1.4 *.02*	......	246	246	0
76	*T. 21 S., R. 19 W.* NW¼ SW¼ sec. 27	42	do	Aug. 24, 1944	59	319	.52	80 *3.99*	14 *1.15*	26 *1.15*	340 *5.58*	13 *.27*	13 *.37*	.7 *.04*	2.0 *.03*	2.5	257	257	0
84	*T. 21 S., R. 20 W.* NE¼ SE¼ sec. 15	45	do	Sept. 25, 1944	58	403	.24	122 *6.09*	14 *1.15*	11 *.49*	405 *6.64*	19 *.40*	11 *.31*	.2 *.01*	23 *.37*	......	362	332	30
88	NE¼ NW¼ sec. 20	55	do	Sept. 21, 1944	60	331	.05	80 *3.99*	13 *1.07*	28 *1.21*	299 *4.90*	38 *.79*	17 *.48*	.6 *.03*	4.4 *.07*	......	253	245	8
94	SW¼ SE¼ sec. 28	126	Dakota	Aug. 24, 1944	60	369	1.6	74 *3.69*	25 *2.06*	30 *1.31*	327 *5.36*	56 *1.16*	16 *.45*	1.1 *.06*	2.1 *.03*	2.0	288	268	20

Table 9.—*Analyses of water from typical wells in Pawnee County, Kansas—Continued*

Well or test hole no. on Plate 1 or 2	Location	Depth (feet)	Geologic source	Date of collection	Temperature (°F)	Dissolved solids	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Borate (BO_3)	Hardness as $CaCO_3$ Total	Carbonate	Noncarbonate
	T. 22 S., R. 15 W.																		
99	NE¼ NE¼ sec. 3	30	Meade	Oct. 7, 1944	59	356	0.46	79 *3.94*	9.8 *.80*	45 *1.94*	305 *5.00*	37 *.77*	31 *.87*	0.4 *.02*	1.3 *.02*	......	237	237	0
102	SW¼ SW¼ sec. 24	55	do	Oct. 9, 1944	59	294	.13	66 *3.29*	7.1 *.58*	37 *1.61*	251 *4.12*	21 *.44*	24 *.68*	.5 *.03*	13 *.21*	......	194	194	0
103	SE¼ SE¼ sec. 31	30	do	Oct. 9, 1944	58	281	.11	59 *2.94*	7.8 *.64*	37 *1.60*	242 *3.97*	20 *.42*	16 *.45*	.6 *.03*	19 *.31*	......	179	179	0
	T. 22 S., R. 16 W.																		
109	NE¼ SW¼ sec. 4	12	Alluvium	Oct. 6, 1944	59	1,019	.46	188 *9.38*	40 *3.29*	90 *3.90*	295 *4.84*	501 *10.42*	37 *1.04*	1.0 *.05*	14 *.22*	......	634	242	392
119	NW¼ NE¼ sec. 23	68	Meade	Oct. 6, 1944	60	284	2.7	66 *3.29*	9.3 *.76*	31 *1.34*	271 *4.44*	15 *.31*	20 *.56*	.4 *.02*	3.9 *.06*	......	202	202	0
	T. 22 S., R. 17 W.																		
123	NE¼ SW¼ sec. 5	......	Alluvium	Oct. 10, 1944	59	795	7.0	128 *6.39*	28 *2.30*	128 *5.55*	418 *6.86*	118 *2.45*	171 *4.82*	.5 *.03*	5.3 *.08*	......	434	343	91
125	SE¼ SE¼ sec. 11	......	do	Aug. 23, 1944	58	981	0.72	169 *8.43*	34 *2.79*	102 *4.44*	239 *3.92*	492 *10.23*	38 *1.07*	.7 *.04*	25 *.40*	......	561	196	365
129	NW¼ SW¼ sec. 19	206	Dakota	Aug. 23, 1944	60	1,475	.58	42 *2.10*	26 *2.14*	491 *21.36*	337 *5.53*	129 *2.68*	610 *17.20*	2.0 *.10*	5.8 *.09*	3.5	212	212	0
	T. 22 S., R. 18 W.																		
142	SW¼ SW¼ sec. 9	26	Alluvium	Oct. 11, 1944	58	316	.16	88 *4.39*	12 *.99*	18 *.77*	331 *5.43*	7.0 *.15*	12 *.34*	.3 *.02*	13 *.21*	......	269	269	0
150	SW¼ SW¼ sec. 28	82.5	Terrace deposits	Oct. 10, 1944	59	391	6.7	103 *5.14*	17 *1.40*	16 *.69*	300 *4.92*	12 *.25*	54 *1.52*	.3 *.02*	32 *.52*	......	327	246	81
151	SE¼ SE¼ sec. 35	56 5	do	Oct. 7, 1944	59	455	20	116 *5.79*	18 *1.48*	29 *1.27*	454 *7.44*	15 *.31*	25 *.70*	.4 *.02*	4.2 *.07*	......	364	364	0

152	*T. 22 S., R. 19 W.* SE¼ SE¼ sec. 8	40.5	do	Oct. 9, 1944	60	314	.30	66 *3.29*	13 *1.07*	38 *1.66*	290 *4.76*	18 *.37*	26 *.73*	1.0 *.05*	7.1 *.11*	.....	218	218	
155	SW¼ SW¼ sec. 29	.....	Dakota	Oct. 11, 1944	59	527	34	42 *2.10*	22 *1.81*	118 *5.13*	351 *5.76*	76 *1.58*	54 *1.52*	2.6 *.14*	2.5 *.04*	.....	196	196	0
156	*T. 22 S., R. 20 W.* NW¼ NW¼ sec. 4	210	do	Oct. 9, 1944	60	361	5.5	64 *3.19*	27 *2.22*	32 *1.40*	310 *5.08*	63 *1.31*	11 *.31*	1.4 *.07*	2.3 *.04*	.....	270	254	16
160	NE¼ NW¼ sec. 29	28.2	Terrace deposits	Oct. 9, 1944	58	348	.12	102 *5.09*	7.2 *.59*	15 *.67*	300 *4.92*	14 *.29*	15 *.42*	.2 *.01*	44 *.71*	.....	284	246	38
162	*T. 23 S., R. 15 W.* NW¼ NW¼ sec. 13	25	Meade	Oct. 9, 1944	58	255	.02	62 *3.09*	6.8 *.56*	27 *1.19*	234 *3.84*	14 *.29*	19 *.54*	.3 *.02*	9.3 *.15*	.....	182	182	0
165	SE¼ SE¼ sec. 28	32	do	Oct. 9, 1944	58	296	1.0	70 *3.49*	7.0 *.58*	35 *1.54*	268 *4.40*	24 *.50*	23 *.65*	.5 *.03*	1.7 *.03*	.....	204	204	0
T-71	NW cor. sec. 32	120	do	June 20, 1945	.....	439	1.3	54 *2.69*	14 *1.15*	100 *4.35*	303 *4.97*	30 *.62*	90 *2.54*	.7 *.04*	1.1 *.02*	.....	192	192	0
T-72	NE cor. sec. 36	115	do	June 20, 1945	.....	282	1.1	62 *3.09*	8.0 *.66*	37 *1.61*	249 *4.08*	21 *.44*	26 *.73*	.5 *.03*	4.9 *.08*	.....	188	188	0
166	*T. 23 S., R. 16 W.* SW¼ NW¼ sec. 6	.....	do	Oct. 11, 1944	58	229	.17	57 *2.84*	6.6 *.54*	16 *.68*	181 *2.97*	11 *.23*	7.0 *.20*	.3 *.02*	40 *.64*	.....	169	148	21
169	NE¼ NE¼ sec. 17	44	do	Oct. 6, 1944	58	426	.02	90 *4.49*	14 *1.15*	50 *2.19*	296 *4.85*	63 *1.31*	56 *1.58*	.6 *.03*	3.9 *.06*	.....	282	242	40
171	NW¼ NW¼ sec. 34	30	Meade	Oct. 11, 1944	58	259	.40	60 *2.99*	7.2 *.59*	29 *1.25*	227 *3.72*	17 *.35*	18 *.51*	.7 *.04*	13 *.21*	.....	179	179	0
173	*T. 23 S., R. 17 W.* SW¼ SE¼ sec. 5	25	Alluvium	Aug. 25, 1944	63	307	.03	63 *3.14*	9.5 *.78*	34 *1.46*	188 *3.08*	88 *1.83*	12 *.34*	.5 *.03*	6.2 *.10*	1.5	196	154	42
175	NW¼ NW¼ sec. 20	12.9	Meade	Oct. 11, 1944	58	177	.32	42 *2.10*	5.2 *.43*	14 *.63*	142 *2.33*	7.8 *.16*	6.0 *.17*	.4 *.02*	30 *.48*	.....	126	116	10
176	SE¼ SE¼ sec. 22	25	do	Oct. 10, 1944	58	300	8.3	72 *3.59*	9.6 *.79*	26 *1.14*	276 *4.53*	15 *.31*	12 *.34*	.6 *.03*	19 *.31*	.....	219	219	0

TABLE 9.—*Analyses of water from typical wells in Pawnee County, Kansas—Concluded*

Well or test hole no. on Plate 1 or 2	LOCATION	Depth (feet)	Geologic source	Date of collection	Temperature (°F)	Dissolved solids	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Borate (BO_3)	Hardness as $CaCO_3$		
																	Total	Carbonate	Noncarbonate
	T. 23 S., R. 18 W.																		
178	SE¼ SE¼ sec. 1	25	Alluvium	Aug. 23, 1944	58	1,688	0.08	214 *10.68*	75 *6.16*	240 *10.42*	405 *6.64*	821 *17.08*	109 *3.07*	0.9 *.05*	26 *.42*	......	842	332	510
180	SE¼ SE¼ sec. 6	73	Dakota	Oct. 9, 1944	59	330	.10	83 *4.14*	11 *.90*	29 *1.26*	312 *5.12*	21 *.44*	19 *.54*	.7 *.04*	9.7 *.16*	......	252	252	0
182	SE¼ SE¼ sec. 21	16	Alluvium	Aug. 23, 1944	60	2,250	.06	310 *15.47*	71 *5.84*	314 *13.64*	354 *5.80*	1,140 *23.71*	131 *3.69*	.8 *.04*	106 *1.71*	2.0	1,066	290	776
T-82	SW cor. sec. 29	55	do	June 18, 1945	......	698	5.6	114 *5.69*	25 *2.06*	96 *4.18*	299 *4.90*	233 *4.85*	68 *1.92*	.7 *.04*	14 *.22*	......	388	245	143
184	SW¼ SW¼ sec. 33	......	do	Aug. 23, 1944	59	549	0	101 *5.04*	26 *2.14*	49 *2.13*	264 *4.33*	187 *3.89*	15 *.42*	1.2 *.06*	38 *.61*	......	359	216	143

Table 10.—*Analyses of water from typical wells in Edwards County, Kansas*

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

Well or test hole no. on Plate 1 or 2	Location	Depth (feet)	Geologic source	Date of collection	Temperature (°F)	Dissolved solids	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Hardness as $CaCO_3$ Total	Carbonate	Noncarbonate
186	*T. 23 S., R. 19 W.* SW¼ SW¼ sec. 9	66.9	Dakota	Aug. 18, 1945	58	666	8.3	16	72 *3.59*	40 *3.29*	98 *4.25*	262 *4.30*	294 *6.12*	21 *.59*	1.8 *.09*	1.8 *.03*	344	215	129
199	*T. 23 S., R. 20 W.* SE¼ SE¼ sec. 16	124	do.	Aug. 18, 1945	59	415	9.0	2.2	42 *2.10*	24 *1.97*	79 *3.42*	298 *4.89*	88 *1.83*	22 *.62*	2.4 *.13*	1.5 *.02*	204	204	0
204	*T. 24 S., R. 16 W.* NW¼ NW¼ sec. 2	50.7	Meade	Aug. 28, 1945	59	277	12	.05	67 *3.34*	6.6 *.54*	26 *1.13*	243 *3.98*	18 *.37*	16 *.45*	.6 *.03*	11 *.18*	194	194	0
210	SW¼ NE¼ sec. 20	......	do.	Feb. 27, 1945	......	249	......	0	57 *2.84*	6.4 *.53*	23 *1.02*	210 *3.44*	14 *.29*	14 *.39*	....	15 *.24*	168	168	0
213	*T. 24 S., R. 17 W.* SW¼ NW¼ sec. 16	......	do.	Aug. 28, 1945	59	294	22	1.0	72 *3.59*	7.6 *.62*	20 *.88*	235 *3.85*	19 *.40*	18 *.51*	.5 *.03*	19 *.30*	210	192	18
223	*T. 24 S., R. 18 W.* SE¼ NW¼ sec. 25	......	do.	Sept. 26, 1944	......	237	......	.09	54 *2.69*	7.8 *.64*	20 *.85*	193 *3.17*	15 *.31*	13 *.37*	....	19 *.31*	166	158	8
225	NW¼ NW¼ sec. 28	47.0	do.	Aug. 18, 1945	58	246	16	.11	58 *2.89*	8.2 *.67*	17 *.75*	210 *3.44*	14 *.29*	7.0 *.20*	.5 *.03*	22 *.35*	178	172	6
230	*T. 24 S., R. 19 W.* NW¼ NE¼ sec. 9	377	Alluvium	Aug. 18, 1945	62	493	37	.10	78 *3.89*	26 *2.14*	66 *2.89*	437 *7.17*	33 *.69*	35 *.99*	.6 *.03*	2.4 *.04*	302	302	0
245	*T. 24 S., R. 20 W.* SW¼ SE¼ sec. 11	......	Terrace deposits	Aug. 28, 1945	58	347	21	.29	96 *4.79*	11 *.90*	8.5 *.37*	298 *4.89*	7.4 *.15*	7.0 *.20*	.5 *.03*	49 *.79*	284	244	40
256	*T. 25 S., R. 16 W.* NW¼ SW¼ sec. 27	40	Meade	Aug. 28, 1945	59	272	11	.02	61 *3.04*	7.8 *.64*	26 *1.12*	217 *3.56*	21 *.44*	13 *.37*	.6 *.03*	25 *.40*	184	178	6

TABLE 10.—*Analyses of water from typical wells in Edwards County, Kansas—Concluded*

Well or test hole no. on Plate 1 or 2	LOCATION	Depth (feet)	Geologic source	Date of collection	Temperature (°F)	Dissolved solids	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Hardness as $CaCO_3$		
																	Total	Carbonate	Noncarbonate
	T. 25 S., R. 18 W.																		
265	SW¼ NW¼ sec. 6........	......	Meade...........	Aug. 13, 1945	......	178	......	0.4	42 *2.10*	5 *.41*	6.0 *.26*	142 *2.33*	11 *.23*	4.0 *.11*	....	....	126	116	10
266	SE¼ SE¼ sec. 16.........	40	do...............	Aug. 28, 1945	59	238	16	.05	53 *2.64*	7.4 *.61*	14 *.60*	152 *2.49*	13 *.27*	10 *.28*	.4 *.02*	49 *.79*	162	124	38
	T. 25 S., R. 19 W.																		
279	SW¼ SE¼ sec. 10........	13	Alluvium.........	Aug. 17, 1945	65	246	12	.34	57 *2.84*	8.0 *.66*	15 *.64*	152 *2.49*	40 *.83*	13 *.37*	.5 *.03*	26 *.42*	175	124	51
	T. 25 S., R. 20 W.																		
308	SW¼ SE¼ sec. 16........	74	Terrace deposits...	Aug. 18, 1945	59	428	12	.24	108 *5.39*	14 *1.15*	25 *1.08*	349 *5.72*	19 *.40*	19 *.54*	.5 *.03*	58 *.93*	327	286	41
	T. 26 S., R. 19 W.																		
331	NE¼ NE¼ sec. 21........	47.7	Meade...........	Aug. 18, 1945	59	145	17	.08	30 *1.50*	5.2 *.43*	9.7 *.42*	105 *1.72*	11 *.23*	5.0 *.14*	.3 *.02*	15 *.24*	96	86	10

The dissolved solids in samples of water from Pawnee and Edwards Counties ranged from 145 to 8,834 parts per million. Ten of the samples contained between 500 and 1,000 parts per million and seven samples contained more than 1,000 parts per million (Table 11). More than 75 percent of the samples of water contained less than 500 parts per million and, therefore, are suitable for most ordinary uses.

Hardness.—The hardness of water, which is the property that generally receives the most attention, is most commonly recognized by its effects when soap is used with the water for washing. Calcium and magnesium cause almost all the hardness of ordinary water. These constituents also are the active agents in the formation of most of the scale in steam boilers and in other vessels in which water is heated or evaporated.

TABLE 11.—*Dissolved solids in samples of water from wells in Pawnee and Edwards Counties*

Dissolved solids (parts per million)	Number of samples		
	Pawnee County	Edwards County	Total
101–200	1	2	3
201–300	14	8	22
301–400	17	1	18
401–500	8	3	11
501–600	3	0	3
601–700	3	1	4
701–800	1	0	1
801–900	0	0	0
901–1,000	2	0	2
More than 1,000	7	0	7
Total	56	15	71

In addition to the total hardness, the tables of analyses show 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 caused by sulfates and chlorides of calcium and magnesium, but it cannot be removed by boiling and has been called permanent hardness. With reference to use with soap, 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 generally is rated as soft, and its treatment for the removal of hardness under ordinary circumstances is not necessary. Hardness between 50 and 150 parts per million does not seriously interfere with the use of water for most purposes; however, it does slightly increase the consumption of soap, and softening is profitable for laundries or other industries using large quantities of soap. Waters in the upper part of this range of hardness will cause scale on steam boilers. Hardness of more than 150 parts per million can be noticed by anyone, and if the hardness is 200 or 300 parts per million it is common practice in some parts of the country to soften water for household use or to install cisterns to collect soft rain water. Where municipal water supplies are softened, an attempt generally is made to reduce the hardness to 60 or 80 parts per million. The additional improvements from further softening of a whole public supply is not deemed worth the increase in cost.

Water samples collected in Pawnee and Edwards Counties ranged in hardness from 96 to 2,734 parts per million; hence none of the samples of water would be rated as soft. Only 3 of the 71 samples had a hardness of less than 150 parts per million, whereas 61 of the 71 samples had a hardness between 150 and 400 parts per million (Table 12).

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 though the waters are derived from the same formation. If a water contains much more than 0.1 part per million of iron, the excess may precipitate and settle as a reddish sediment. Iron, which may be present in sufficient quantity to give a disagreeable taste and to stain cooking utensils and porcelain fixtures, may be removed from most waters by simple aeration and filtration, but a few waters require the addition of lime or some other substance.

TABLE 12.—*Hardness of samples of water from wells in Pawnee and Edwards Counties*

Hardness (parts per million)	Number of samples		
	Pawnee County	Edwards County	Total
Less than 100	0	1	1
101–200	13	8	21
201–300	25	3	28
301–400	9	3	12
401–500	3	0	3
501–600	1	0	1
601–700	2	0	2
701–800	0	0	0
801–900	1	0	1
901–1,000	0	0	0
More than 1,000	2	0	2
Total	56	15	71

The iron content of samples of water from wells in Pawnee and Edwards Counties ranged from less than 0.1 part to 34 parts per million, the greatest concentration being in water from the Dakota formation. Forty-six of the samples contained 1 part per million of iron or less and 14 samples contained more than 5 parts per million (Table 13).

TABLE 13.—*Iron content of samples of water from wells in Pawnee and Edwards Counties*

Iron (parts per million)	Number of samples		
	Pawnee County	Edwards County	Total
0.0– 0.10	10	7	17
0.11– 1.0	23	6	29
1.1– 2.0	3	0	3
2.1– 3.0	3	1	4
3.1– 4.0	2	0	2
4.1– 5.0	2	0	2
5.1–10.0	9	0	9
10.1–20.0	3	1	4
20.1–30.0	0	0	0
30.1–40.0	1	0	1
Total	56	15	71

Fluoride.—Although determinable quantities of fluoride are not as common as fairly large quantities of the other constituents of natural water, it is desirable to know the amount of fluoride in water that is likely to be used by children. Fluoride in drinking water has been shown to be associated with the dental defect known as mottled enamel, which may appear on the teeth of children during the period of formation of the permanent teeth. It has been stated that waters containing more than 1.5 parts per million of fluoride are likely to produce mottled enamel on the teeth of children (Dean, 1936). If the water contains as much as 4 parts per million of fluoride, 90 percent of the children drinking the water are likely to have mottled enamel, and 35 percent or more of the children will have moderately or badly mottled enamel. Contents of fluoride up to 1 part per million are believed to be beneficial in inhibiting tooth decay.

Fifteen of the 71 samples of water collected in Pawnee and Edwards Counties contained 1 part per million or more of fluoride, the greatest concentrations being in waters from the Dakota formation. The fluoride content of the waters ranged from 0.1 part to 4.6 parts (Table 14).

TABLE 14.—*Fluoride content of samples of water from wells in Pawnee and Edwards Counties*

Fluoride (parts per million)	Number of samples		
	Pawnee County	Edwards County	Total
Less than 0.5	17	2	19
0.5–0.9	25	8	33
1.0–1.4	8	0	8
1.5–1.9	1	1	2
2.0–2.4	2	1	3
2.5–2.9	1	0	1
More than 2.9	1	0	1
Total	55	12	67

Water for irrigation.—The suitability of water for irrigation is commonly believed to depend mainly on the quantity of soluble salts and on the ratio of the quantity of sodium to the total quantity of sodium, calcium, and magnesium. The quantity of chloride may be large enough to affect the use of the water, and in some areas there may be other constituents, such as boron, 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 concentration of dissolved salts is less than 700 parts per million there is not much probability of harmful effects in irrigation, but that if it exceeds 2,100 parts per million there is a strong probability of damage to the crops, to the land, or to both. Water containing less than 50 percent sodium (the percentage being calculated as 100 times the ratio of the sodium to all the bases, in equivalents) is not likely to be injurious, but if it contains more than 60 percent sodium its use is inadvisable. Similarly, less than about 150 parts per million of chloride is not objectionable, but more than about 350 parts per million of chloride is undesirable. It is recognized that the harmfulness of irrigation water is so dependent upon the type of land and crops, on the manner of use, and on the drainage that no definite limits can be adopted.

Most of the waters of Pawnee and Edwards Counties can be used safely for irrigation. Eight samples of water contained between 700 and 2,100 parts per million of dissolved solids. Five of these samples were from the alluvium of the Arkansas Valley but three

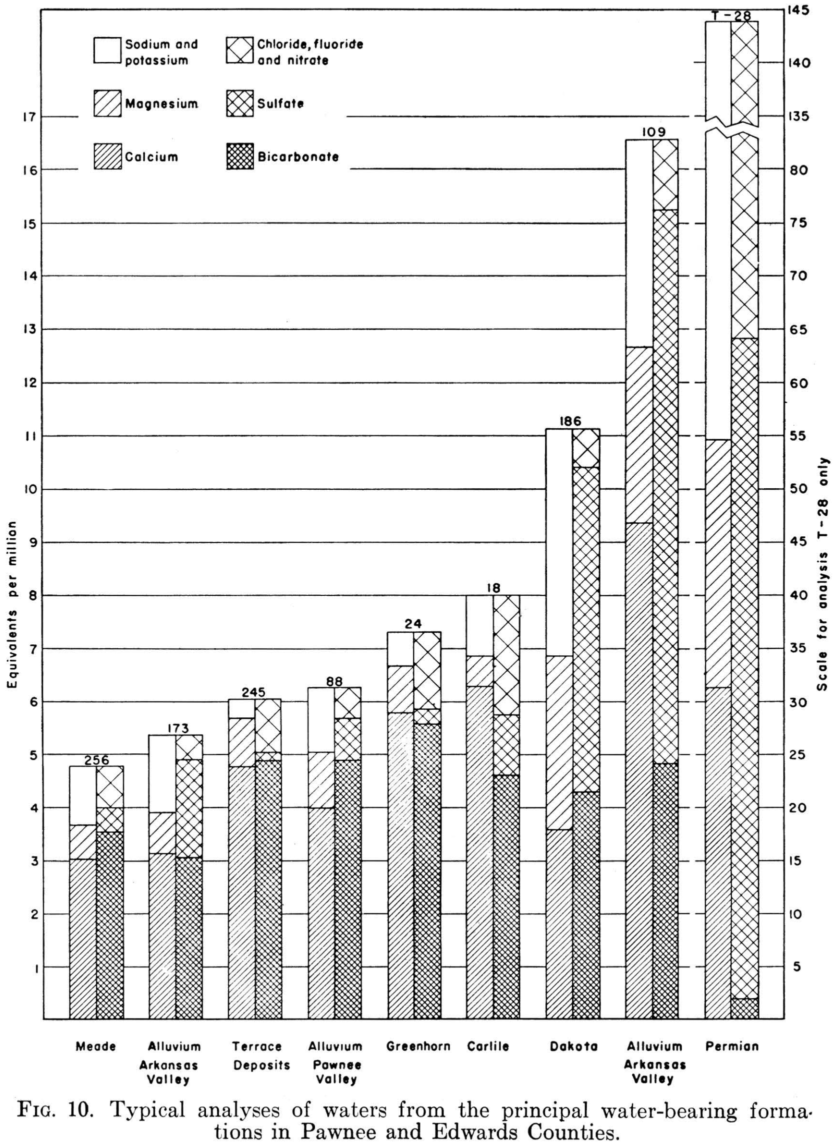

FIG. 10. Typical analyses of waters from the principal water-bearing formations in Pawnee and Edwards Counties.

were from the Dakota formation, which would not yield sufficient water for extensive irrigation. Waters from two wells contained more than 2,100 parts per million of dissolved solids and probably would be harmful to crops. One of these samples was from the alluvium of the Arkansas Valley and the other was from the Permian redbeds.

The sodium content of only four samples of water exceeded the limit set by Scofield. These samples were from the Dakota formation and the Permian redbeds, two formations that do not yield water to irrigation wells in this area. Three samples of water contained between 150 and 350 parts per million of chloride and two samples contained more than 350 parts. Of these samples, only one was from a formation that yields water to irrigation wells in this area. The concentration of borate in six samples of water from wells in Pawnee County was determined but it was not sufficient to be harmful to crops.

Sanitary Considerations

The analyses of water given in Tables 9 and 10 show only the amounts of dissolved mineral matter in the water and do not indicate the sanitary quality of the water. An abnormal amount of certain mineral matter, such as more than a few parts per million of nitrate, however, may indicate pollution of the water.

Most of the population of Pawnee and Edwards Counties is dependent upon water supplies from wells, and every precaution should be taken to protect these supplies from pollution. A well should not be constructed near possible sources of pollution, such as barnyards, privies, and cesspools, and every well should be tightly sealed to a level somewhat below the water table. Dug wells are more likely to be contaminated from surface sources than are drilled wells, chiefly because dug wells generally are not effectively cased or sealed at the top. Drilled wells generally are well protected by the casing, athough many are poorly sealed at the top.

Quality in Relation to Water-bearing Formations

The quality of water from the principal water-bearing formations in Pawnee and Edwards Counties is shown in Figure 10 and is discussed below.

Permian redbeds.—The undifferentiated redbeds of Permian age yield little or no water to wells in this area, but the quality of the water from these beds is important because of the danger of pollution of the overlying beds that contain fresh water. Several deep wells and test holes in this area have encountered salt water under artesian pressure in these deposits. It is essential, therefore, that such wells and test holes be effectively sealed to prevent contamination of other waters. One well, near Frizell, was reported to have had a flow of nearly 700 gallons a minute. Test hole 28 encountered salt water under artesian pressure. The analysis of this water is shown in Figure 10. This hole was cemented to prevent contamination of other waters.

Dakota formation.—Water from the Dakota formation generally

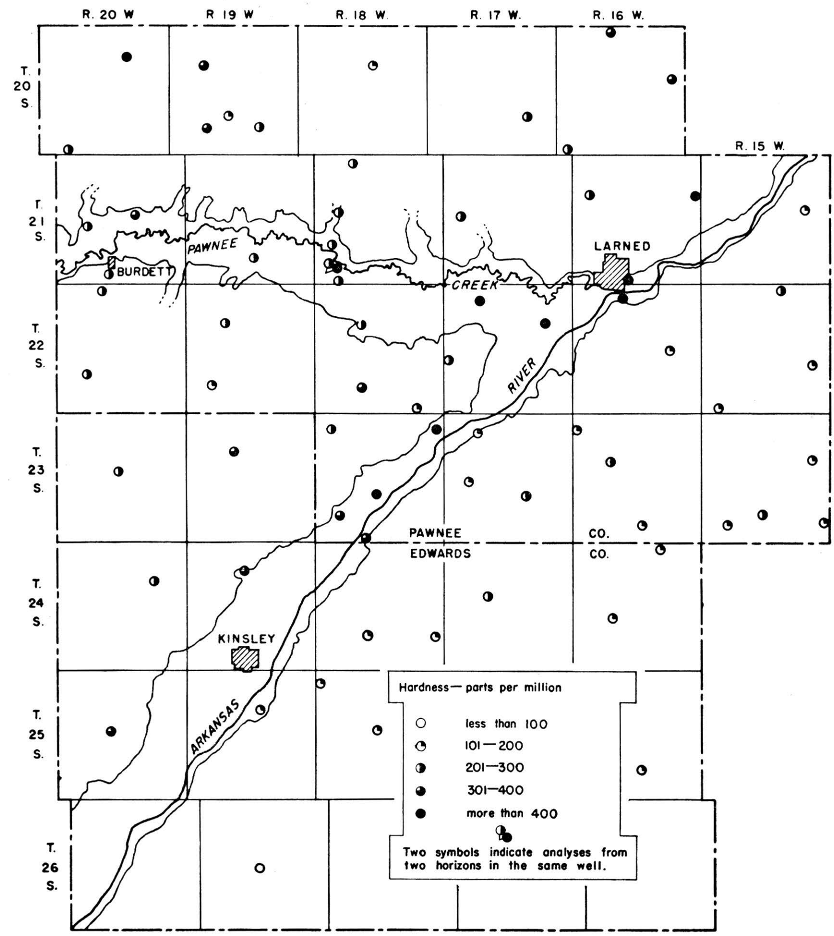

FIG. 11. Map of Pawnee and Edwards Counties showing the hardness of ground waters.

contains a large amount of dissolved solids (the average for 10 samples was 669 parts per million) but is only moderately hard, owing to natural softening (Figs. 10 and 11). The dissolved solids ranged from 361 to 1,475 parts per million, whereas the hardness ranged from 131 to 301 parts per million. Water from the Dakota formation generally contains a relatively high ratio of sodium to the total bases. This ratio exceeded 50 percent in 4 of the 10 samples, the highest being 86 percent. These relatively soft sodium bicarbonate waters may represent calcium bicarbonate waters in which the calcium and magnesium have been exchanged for sodium by reaction with base-exchange silicates in the rocks as the water percolated through the formation. The base-exchange silicates probably are the clay-forming minerals in the Dakota formation. The degree of softening depends upon the amount and softening capacity of base-exchange silicates in the clay and upon the length of time the hard water remains in contact with the silicates.

All but one of the samples of water from the Dakota formation contained sufficient fluoride to be harmful to children's teeth. The fluoride content of these samples ranged from 0.5 part to 4.6 parts per million and averaged 2.0 parts.

Greenhorn limestone.—Two samples of water were collected from wells penetrating the Greenhorn limestone. They were calcium bicarbonate waters containing 354 and 409 parts per million of dissolved solids and having hardnesses of 204 and 334 parts per million, respectively (Fig. 10). The fluoride contents were 0.2 and 1 part per million, respectively.

Carlile shale.—The Fairport chalky shale member of the Carlile shale yields small quantities of water to a few wells in northern Pawnee County. The dissolved solids in samples of water from three of these wells averaged 506 parts per million and the hardness averaged 339 parts per million. The fluoride content ranged from 0.1 part to 1.1 parts per million.

Meade formation.—These deposits, which underlie the dune-sand area south of Arkansas River, contain the softest ground water in Pawnee and Edwards Counties. The amount of dissolved solids in 23 samples of water from these beds ranged from 145 to 439 parts per million and averaged 274. The hardness ranged from 96 to 282 and averaged 184. The fluoride content of these waters generally is low, as indicated by Figure 12. None of the samples contained enough fluoride to be harmful to children's teeth, the average fluoride content being 0.5 part per million.

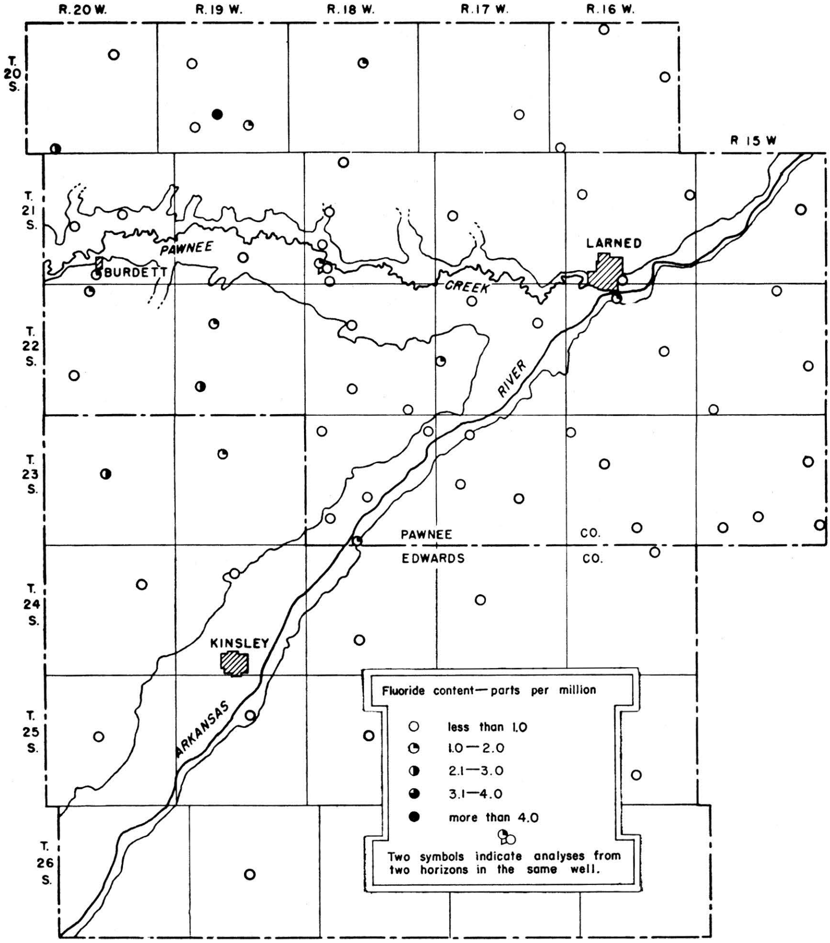

FIG. 12. Map of Pawnee and Edwards Counties showing the fluoride content of ground waters.

Terrace deposits.—Waters from these deposits are moderately uniform in chemical quality. The amount of dissolved solids in 14 samples ranged from 287 to 696 parts per million and averaged 390 parts. The hardness, which ranged from 218 to 432 parts per million, averaged 288 parts per million. The fluoride content of these waters generally is low (average 0.5 parts per million) and only one sample contained as much as 1.0 part per million.

Alluvium.—Eighteen samples of water from the alluvium of the Pawnee and Arkansas Rivers were analyzed. The composition of the waters in the two valleys is not alike (Fig. 10).

Water from the alluvium of the Arkansas Valley generally is very hard but may be much softer on the south side of the valley (Fig. 11) near the sand dunes because of the movement of the softer water from the south into the valley. The amount of dissolved solids in eight samples of water from wells that were not close to the sand dunes ranged from 493 to 2,250 parts per million and averaged 1,176. The hardness, which ranged from 302 to 1,066 parts per million, averaged 612 parts. The amounts of dissolved solids in three samples of water from wells near the edge of the sand dunes were 246, 307, and 543 parts per million. The hardnesses were 175, 196, and 359 parts, respectively. The fluoride content of waters from the alluvium of the Arkansas Valley averaged 0.7 part per million.

Waters from the alluvium of the Pawnee Valley were softer than the average water from the alluvium of the Arkansas Valley (Figs. 10 and 11). The average amount of dissolved solids in these waters was 327 parts per million and the average hardness was 268 parts per million. The average fluoride content of these waters (0.5 part per million) was slightly lower than that of waters from the alluvium of the Arkansas Valley.

GEOLOGIC FORMATIONS AND THEIR WATER-BEARING PROPERTIES

Permian System

UNDIFFERENTIATED REDBEDS

General description.—Undifferentiated redbeds of Permian age underlie the Cretaceous rocks in Pawnee and Edwards Counties. They do not crop out in this area; hence their lithologic character is known only from a few well cuttings. The redbeds consist primarily of red siltstone and sandstone containing gypsum and anhydrite (calcium sulfate with and without water of crystallization, respectively).

Water supply.—Several wells and test holes in this area have encountered salt water under strong artesian pressure. A deep well near Frizell was reported to have a yield of nearly 700 gallons of salt water a minute. Darton (1905) reported that two wells at Larned, drilled to depths of 743 and 756 feet, yielded salt water at the rate of 400 and 250 gallons a minute, respectively. Water from the shallower well had a temperature of 65° F. and rose to a level 50 feet above the land surface. Test hole 28 at the NW cor. sec. 32, T. 21 S., R. 18 W., encountered salt water under artesian pressure at a depth of about 400 feet. An analysis of the water is shown in Table 9 and Figure 10.

Cretaceous System

Cheyenne Sandstone

Character.—The Cheyenne sandstone does not crop out in Pawnee and Edwards Counties, hence little is known of its lithologic character in this area except as determined by the cuttings from five test holes (Pl. 3). The formation has been described in detail by Latta (1946) at the type locality near Belvidere, which is about 20 miles south of the south line of Edwards County. Latta (1946, p. 235) states:

> The Cheyenne consists chiefly of light-colored fine- to medium-grained friable cross-bedded sandstone and lenses of sandy shale and conglomerate. Minor amounts of clay, selenite crystals, iron nodules, and pyrite occur in different parts of the formation. . . . Sandstone is by far the most dominant type of rock in the Cheyenne. The most common colors of the sandstone are white, light gray, and tan, but in some places iron staining has produced beautiful shades of yellow, red, purple, and brown along bedding and lamination planes or in irregular splotches. The brightly colored zones are most common in the upper half of the formation. The texture of the sandstone ranges from flourlike material of silt and clay size to fine gravel, but fine- to medium-grained sandstone is most common. The material in general is well sorted although the degree of assortment varies from one part of the formation to another and from one locality to another.

The materials encountered in test holes drilled by the State and Federal Surveys is primarily fine- to medium-grained sandstone containing gray and gray-green shale and a little siltstone.

Distribution and thickness.—The Cheyenne sandstone probably underlies all or most of Pawnee and Edwards Counties (Pl. 3) as well as large areas of southwestern Kansas, except in some of the counties in the southern tier. The formation crops out in very few places in southwestern Kansas. The principal localities of outcrops are in the Belvidere area in southeastern Kiowa County and in adjacent areas in Comanche and Barber Counties. Sandstone in outcrops in Clark County is of undetermined age but may belong to the Cheyenne sandstone.

The thickness of the Cheyenne sandstone has been reported by Latta (1946) to range from 32.5 to 94 feet in the Belvidere area and to average about 45 feet. The thickness of the formation in Pawnee and Edwards Counties, as determined by test drilling, ranged from about 19 feet in test holes 28 and 88 to 47 feet in test hole 95. The average thickness was about 27 feet.

Age and correlation.—The exact age of the Cheyenne sandstone is not known. Berry (1922, p. 226) reports that the flora is post-Trinity and pre-Woodbine, which would place the Cheyenne in the Fredericksburg or Washita. Bullard (1928, p. 53) states that the Cheyenne is pre-Washita or may represent a part of the most basal Washita. The Cheyenne probably is also equivalent to the lower sandstone member of the Purgatoire formation of eastern Colorado and the Oklahoma Panhandle. During investigations of the geology and ground-water resources of most of the counties in southwestern Kansas, members of the State and Federal Surveys have traced the Cheyenne sandstone and Kiowa shale, by means of extensive test drilling, from the type localities in Kiowa County to the Kansas-Colorado State line in Morton and Stanton Counties. There is little doubt, therefore, that these beds are equivalent to the near-by Purgatoire formation.

Water supply.—The Cheyenne sandstone is an important potential source of ground water but is unexploited in Pawnee and Edwards Counties, owing to its considerable depth and to the availability of larger supplies of potable water in the overlying formations.

KIOWA SHALE

Character.—The Kiowa shale does not crop out in Pawnee and Edwards Counties and its lithologic character is known only from cuttings from test holes and from its exposures in adjacent areas, particularly in the type locality near Belvidere in Kiowa County.

Latta (1946, p. 244) describes the Kiowa shale in the vicinity of the type locality as follows:

> The Kiowa shale consists dominantly of thinly laminated dark-gray to black shale in the lower part grading upward into gray, tan, mottled tan, red, and brown clay and clay shale. The shale in the lower part generally is black and has been called a paper-shale because it is so thinly laminated. A conspicuous feature of the formation, especially of the lower part, is the presence of thin beds of shell limestone. . . .

Latta states that large lenses of sandstone occur at the top of the formation in some places and that thin lenses of sandstone occur throughout the formation.

The material encountered in test drilling through the Kiowa shale in Pawnee and Edwards Counties consisted principally of light- to dark-gray and black clay shale containing thin beds of sandstone. Thin layers of pyrite were encountered in several of the test holes. A hard layer of limestone that may be equivalent to one of the beds of shell limestone was encountered in test hole 28 at a point 78 feet above the base of the formation. Small fragments of limestone were noted in some of the other test holes.

Distribution and thickness.—The Kiowa shale crops out in small areas in Kiowa, Clark, Comanche, and Barber Counties and over a wide area in central Kansas. The formation underlies all of Pawnee and Edwards Counties and much of southwestern Kansas, where it is in most places concealed beneath Cretaceous, Tertiary, or Quaternary rocks.

The maximum reported thickness of the Kiowa shale is 293 feet in the Belvidere area (Latta, 1946). The formation has a maximum thickness of 100 to 125 feet in central Kansas and about 135 feet in southwestern Kansas. The thickness of the formation in Pawnee and Edwards Counties, as determined by test drilling, ranged from 133 feet to 222 feet and averaged about 180 feet.

Age and correlation.—The Kiowa shale is Comanchean, but its position within the Comanchean has been in dispute for many years. Discussions concerning the age of the Kiowa have been summarized by Latta (1946, p. 248), who concluded that:

> The available evidence indicates, therefore, that the Kiowa shale is equivalent in age to the Washita division and possibly in part to the Fredericksburg division of the Texas section.

As stated in the section on the Cheyenne sandstone, the Kiowa shale has been traced by means of test drilling from the type locality to the Kansas-Colorado State line; hence, the formation probably is equivalent to the upper shale member of the Purgatoire formation of southeastern Colorado and the Oklahoma Panhandle.

Water supply.—No wells in Pawnee and Edwards Counties obtain water from the Kiowa shale. Small quantities of water may be available from beds of sandstone within the Kiowa but larger qauntities of potable water are available from overlying formations.

Dakota Formation

Character.—The lithology of the Dakota formation in the Pawnee-Edwards area was determined from the study of a few small outcrops (Pl. 6) and of the cuttings from more than 100 test holes that penetrated the formation. The formation consists principally of buff, yellow-brown, and brown sandstone and varicolored clay and sandy clay. Where the formation is exposed the sandstone may be thin-bedded to massive but generally is strongly ripple-marked and cross-bedded. Where the sandstone is well cemented, as at Larned, it forms steep bluffs. In other areas, however, the beds of the formation are poorly cemented and form low, smooth hills having a thick cover of soil. For this reason the outcrops in many areas are far apart or are absent, and the contacts between the Dakota and younger formations are difficult to map.

In a few places in Pawnee County there are zones of hard ironstone and very hard quartzitic sandstone. These deposits weather to large rounded boulders and hard outcropping ledges (Pl. 7).

Distribution and thickness.—The Dakota formation crops out in several isolated areas in Pawnee County (Pl. 1), particularly in the vicinity of Larned and of Burdett. The Dakota underlies all of Pawnee County except perhaps local areas in the eastern part of the county, and it underlies all but the southeastern part of Edwards County (Pl. 3).

The Dakota is reported to attain a maximum thickness of about 275 feet in north-central Kansas (Plummer and Romary, 1942, p. 330). None of the test holes in Pawnee and Edwards Counties penetrated the entire thickness of the Dakota formation but it is believed that the average thickness of the Dakota in this area is about 200 feet (Pl. 3). Test hole 61, which entered the formation at a point below the base of the Graneros shale, penetrated 183 feet of the Dakota formation before entering the Kiowa shale.

Age and correlation.—The Dakota formation, as defined by the Kansas Geological Survey, includes the Cretaceous strata from the top of the Kiowa shale, below, to the base of the Graneros shale, above. The Dakota of this area is in the lower part of the Upper Cretaceous and is equivalent to the Dakota formation of adjacent areas.

Water supply.—The Dakota formation yields small to moderate quantities of water to many domestic and stock wells in Pawnee and Edwards Counties and to public-supply wells at Larned. Most of the domestic and stock wells have small diameters and yield only small quantities of water from the Dakota, but the large-diameter public-supply wells at Larned yield quantities ranging from 125 to 150 gallons a minute.

The Dakota supplies water to wells primarily in the areas where it is overlain by relatively impermeable materials such as those in the Graneros shale, Greenhorn limestone and Carlile shale. These areas lie north of Arkansas River and include nearly half of Pawnee County and the northwestern part of Edwards County. Where

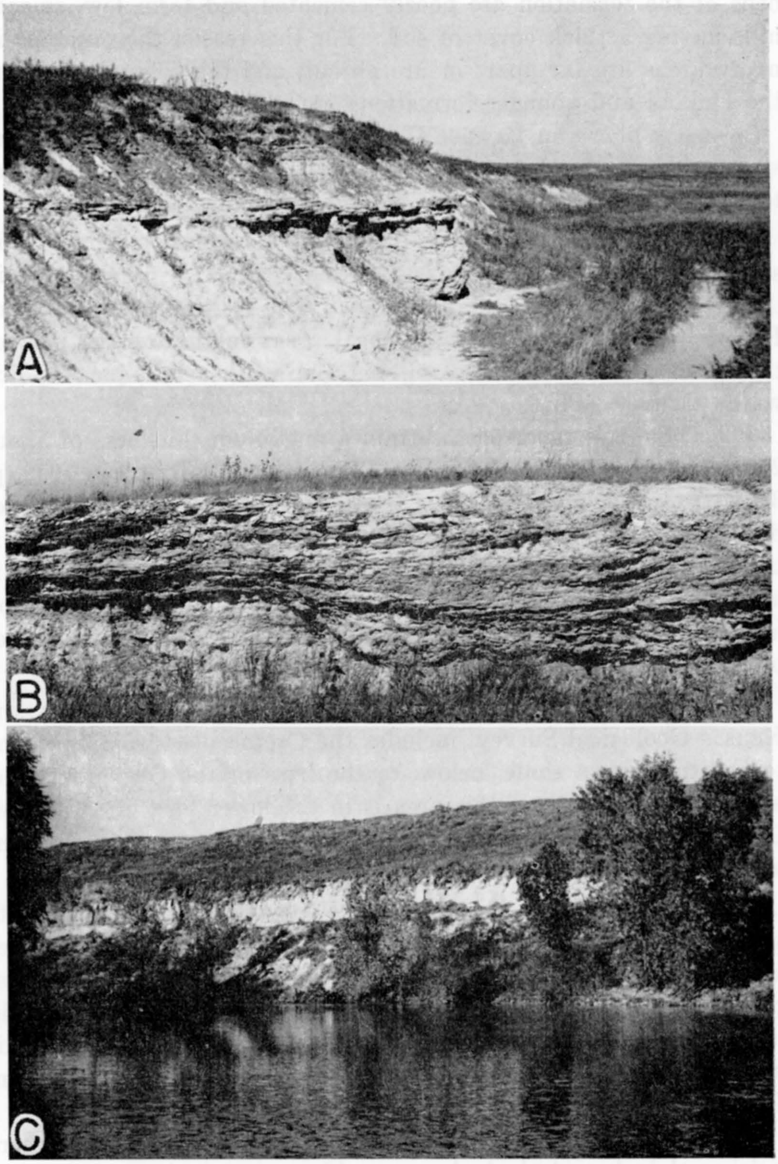

PLATE 6. Outcrops of the Dakota formation. *A,* SW cor. SE¼ sec. 28, T. 22 S., R. 20 W. *B,* Along highway about 1.5 miles west of Burdett. *C,* Along Pawnee River in sec. 2, T. 22 S., R. 17 W.

the Dakota is overlain by coarse water-bearing materials such as in the Pawnee and Arkansas Valleys and in the large dune-sand area south of Arkansas River, wells generally obtain an adequate supply of suitable water in the overlying materials. In the Arkansas Valley, however, where the water in the alluvium is very hard, a few domestic wells have been drilled into the Dakota formation in order to obtain softer water.

Water from the Dakota formation generally contains a large amount of dissolved solids but is comparatively soft, owing to natural softening by the base-exchange silicates within the formation (p. 71 and Fig. 10). As indicated by the analyses in Tables 9 and 10 water from the Dakota formation generally contains fluoride in quantities sufficient to cause slight to severe mottling of the enamel on children's teeth.

Graneros Shale

General description.—The lithology of the Graneros shale is variable. In some places it consists entirely of dark-gray to black fissile argillaceous shale, whereas in other places it consists of shale, sandy shale, and sandstone. The formation is soft in most localities and forms a gentle slope between the Greenhorn limestone and the Dakota formation. Because of the poor and scattered exposures of the Graneros shale in Pawnee and Edwards Counties, it was not possible to map the formation separately; hence, the Greenhorn and Graneros were mapped as a unit. The distribution of the Graneros and Greenhorn formations in this area is shown on Plate 1.

The thickness of the Graneros shale in Pawnee and Edwards Counties is not known but is believed not to exceed about 35 feet. Moss (1932) observed a maximum thickness of 36 feet in Hodgeman County but stated that the thickness in that area was variable and in most places was less than 30 feet.

The Graneros shale yields little or no water to wells in the Pawnee-Edwards area, inasmuch as much larger supplies are available from the underlying Dakota formation.

Greenhorn Limestone

Character.—The Greenhorn limestone consists largely of a succession of thin chalky to crystalline limestones interstratified with thicker beds of gray calcareous shale (Pl. 7). The shales contain thin beds of bentonitic clay. The formation has been divided into four members in this area, including the Pfeifer shale at the top,

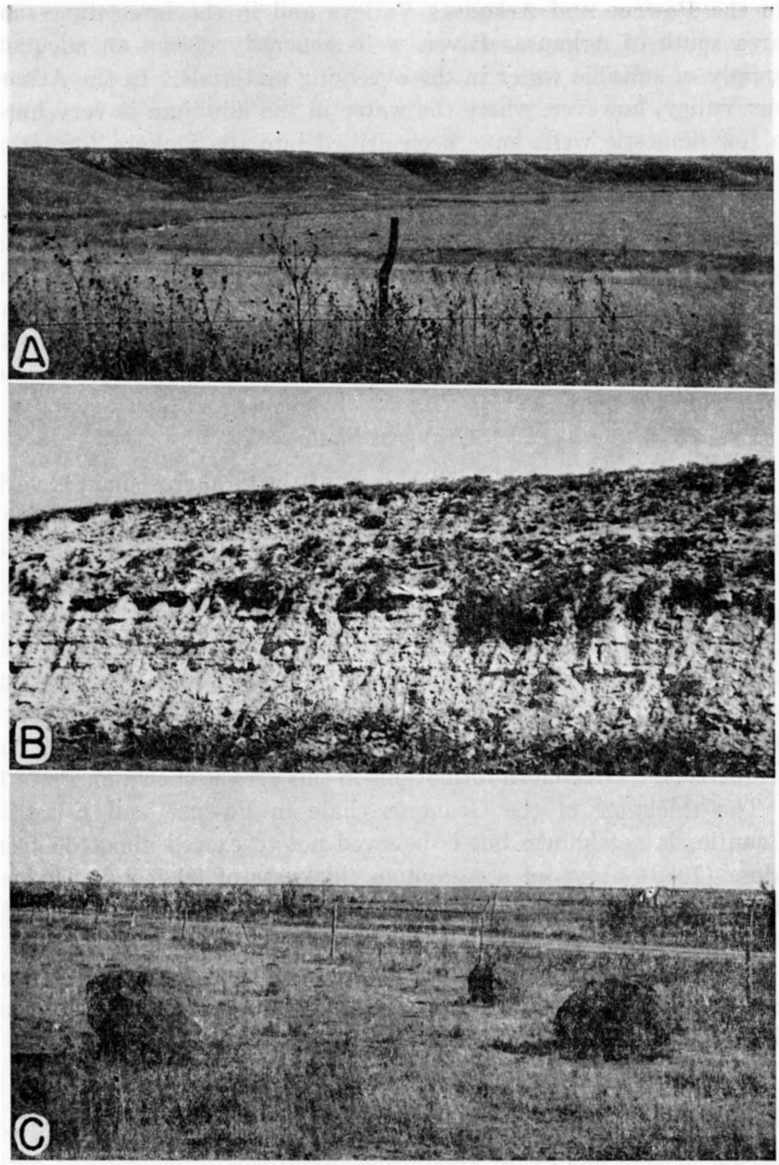

PLATE 7. Outcrops of the Greenhorn limestone and Dakota formation. *A*, Bluffs formed by resistant beds of the Greenhorn limestone in the NE¼ sec. 31, T. 22 S., R. 20 W. *B*, Upper part of the Greenhorn limestone in sec. 10, T. 20 S., R. 18 W. *C*, Residual boulders of ironstone in the Dakota formation in the SW¼ SE¼ sec. 15, T. 21 S., R. 17 W.

the Jetmore chalk, the Hartland shale, and the Lincoln limestone at the base. The base of the formation is marked by an abrupt change from the calcareous beds of the Greenhorn to the noncalcareous shale and sandy shale of the Graneros. The top of the formation is marked by the "Fencepost" limestone, which is a prominent bed of relatively hard chalky limestone that is quarried extensively in north-central Kansas for use as fence posts.

Distribution and thickness.—The Greenhorn limestone is poorly exposed in Pawnee and Edwards Counties. There are a few places in the area where several beds in the formation are exposed, but generally the outcrops are indicated only by occasional fragments of limestone that have been turned up in plowed fields. Accurate mapping of the formation, therefore, was impossible. The distribution of the formation as shown on Plate 1 was based on the few small outcrops, on the small fragments in plowed fields, and on the topographic expression, and is subject to considerable error.

The formation crops out in the upland areas in Pawnee County that lie north of Arkansas River and in small areas in northwestern Edwards County (Pl. 1). It underlies the area of outcrop of the Carlile shale in northern Pawnee County and that of the Tertiary formations in part of northwestern Edwards County (Pl. 3).

The thickness of the Greenhorn limestone in Pawnee and Edwards Counties is not known because a complete section of the formation is not exposed in the area and because none of the test holes penetrated the entire formation. Inasmuch as the thickness of the formation is moderately uniform, it is believed that the thickness in this area is about the same as in adjacent counties to the west, where a thickness of about 125 feet was measured by Moss (1932).

Water supply.—The Greenhorn limestone yields small quantities of water to a few dug domestic and stock wells in northern Pawnee County. The water, which is derived from cracks and fissures in the thin beds of limestone, is replenished by local rainfall; hence, wells in this formation may become dry during long periods of drought. Water from the Greenhorn generally is very hard, as indicated by the analyses in Table 9.

Carlile Shale

Character.—The Carlile shale consists of the Codell sandstone member at the top, the Blue Hill shale member, and the Fairport chalky shale member at the base. The basal Fairport chalky shale member, which is the only part of the Carlile exposed in the Pawnee-Edwards area, consists of thick beds of chalky shale containing flat concretions and a few beds of bentonite and alternating with thin beds of chalky limestone. The thin beds of chalky limestone are harder and more numerous near the base of the member. The lower, more resistant beds form small terraces, whereas the upper beds erode to smooth, rounded, soil-covered hills.

Distribution and thickness.—The Carlile shale, like the Greenhorn limestone, is very poorly exposed in Pawnee County and, hence, accurate mapping is not possible. The formation crops out only in the northern part of Pawnee County, as indicated by Plate 1. Inasmuch as only a part of the formation is exposed in this area, the total thickness of the Carlile in Pawnee County is not known. It is believed that nowhere in the county does it exceed 100 feet.

Water supply.—The Carlile shale yields small quantities of water to a few shallow dug wells in the northern part of Pawnee County. The water is obtained from the joints and bedding planes of the beds of chalky limestone in the lower part of the formation. The upper shaly part of the formation probably would yield little or no water to wells.

Water from the Carlile shale is hard (Fig. 10) but it can be used for domestic and stock purposes. (See analyses in Table 9.)

Tertiary System

PLIOCENE SERIES

Ogallala Formation

General description.—The Ogallala formation consists mainly of silt, sand, and gravel containing caliche (Pl. 8). It crops out principally in northwestern Edwards County but also in a few scattered areas in Pawnee County (Pl. 1). At many places in Pawnee County there are thin patches of algal limestone overlying the Dakota formation which probably are equivalent to the algal limestone that marks the top of the Ogallala formation in parts of western Kansas. The Ogallala is 66 feet thick at test hole 86 but it may be nearly 100 feet thick at the Edwards-Hodgeman county line. Moss (1932) reports a maximum thickness of 100 feet in Hodgeman County, and Waite (1942) stated that its thickness may be as much as 250 feet in Ford County.

The Ogallala formation yields small quantities of water to a few domestic and stock wells in the northwestern part of Edwards County. The formation overlies high areas of Cretaceous rocks and is, therefore, largely drained of water.

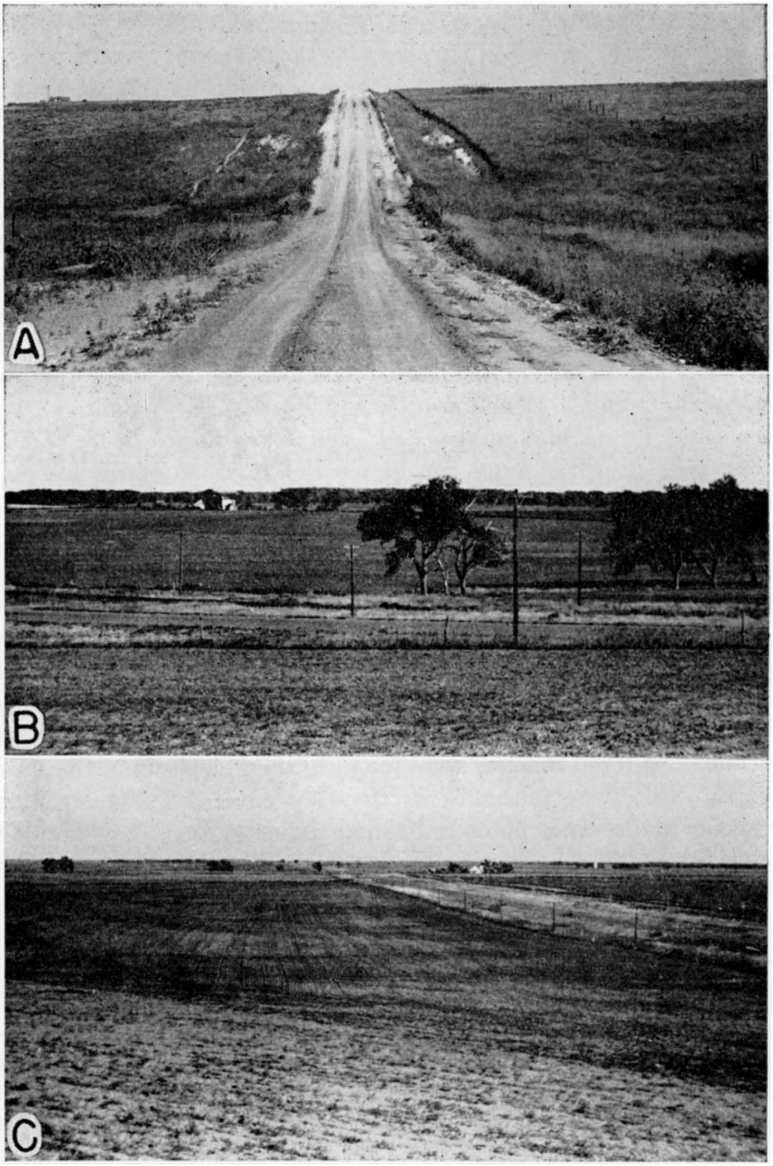

PLATE 8. Views of the Ogallala formation and alluvium. *A,* Outcrop of caliche (Ogallala) in road ditches on Edwards-Hodgeman county line. *B* and *C,* Terrace deposits in the foreground and the flood plain of Arkansas River in the distance (darker areas).

Quaternary System

PLEISTOCENE SERIES

Meade Formation

The Meade formation was recognized and described by Cragin (1896, p. 53) as the *Meade gravels*. The name was proposed for to lowest of three "terranes" in the vicinity of the old Vanhem post office in sec. 13, T. 30 S., R. 23 W., Clark County (Hibbard, 1944, p. 709). In addition, he gave the name *Pearlette ash* to the deposits of volcanic ash in that region. Smith (1940, pp. 100-111) described the Pleistocene *Odee formation, Equus niobrarensis beds,* and *Jones Ranch beds* in Meade County and adjacent areas in 1940. Frye and Hibbard (1941, pp. 411-419) redefined the Meade formation to include Cragin's *Meade gravels* and *Pearlette ash;* Smith's *Odee formation, Equus niobrarensis beds,* and *Jones Ranch beds;* and all other beds of Pleistocene age above the Rexroad formation and below the Kingsdown silt.

Additional geological studies made by members of the State and Federal Geological Surveys have shown that these beds are distributed widely in southwestern Kansas. Latta (1948) recognized these beds in Kiowa and Stafford Counties, which border Edwards County on the south and west. Fossil vertebrates collected from these beds in Kiowa and Stafford Counties were identified by Claude W. Hibbard and indicate that they belong to the Meade. No fossil remains were found in these deposits in the Pawnee-Edwards area, inasmuch as they are covered by younger deposits of dune sand, but test drilling indicates that they are continuous with the Meade formation of Kiowa and Stafford Counties.

Character.—Inasmuch as the Meade formation does not crop out in the Pawnee-Edwards area, its lithologic character is known only from test-hole cuttings. Test holes drilled in this area indicate that the formation consists predominantly of coarse sand and gravel containing beds of fine sand, silt, and clay. The beds generally are poorly consolidated but in some places the sand and gravel is cemented with calcium carbonate to form hard ledges known as "mortar beds."

Distribution and thickness.—The Meade formation is distributed widely throughout southwestern Kansas. It underlies parts of Hamilton, Stanton, Morton, Kearny, Grant, Stevens, Finney, Haskell, Seward, Gray, Ford, Meade, Clark, Kiowa, and Stafford Counties, Kansas, as well as parts of Texas and Beaver Counties, Oklahoma.

In much of this area, however, the formation is overlain by younger beds, such as silt (Kingsdown) and dune sand. In Pawnee and Edwards Counties it underlies only the area south of the Arkansas Valley.

The Meade formation in Pawnee and Edwards Counties ranges in thickness from about 50 feet to more than 300 feet. Test hole 119, south of Trousdale in Edwards County, encountered the base of the formation at a depth of 288 feet. A test hole drilled near the Kiowa-Edwards county line as a part of the ground-water study of Kiowa County (log 132) penetrated more than 300 feet of materials composing the Meade formation. In general, the formation thickens southward from the Arkansas Valley through Pawnee, Edwards, and northern Kiowa Counties and becomes thinner in central and southern Kiowa County.

Age and correlation.—Claude W. Hibbard, of the University of Michigan Museum of Vertebrate Paleontology, has been collecting fossils from the Meade formation of southwestern Kansas since 1936, during which time he has collected the Cudahy, Borchers, and Cragin Quarry faunas (Hibbard, 1938, 1940, 1941, and 1943). These faunas have definitely established the age of the Meade formation as Pleistocene.

The beds in this area that have been assigned to the Meade formation may be equivalent in part to the Pleistocene McPherson formation of south-central Kansas (Williams and Lohman, 1949), but sufficient studies have not been made in the intermediate area to justify correlation with those beds.

Water supply.—The Meade formation yields water to all wells in Pawnee and Edwards Counties south of the Arkansas Valley. The yields of these wells range from a few gallons a minute in most domestic and stock wells to more than 1,000 gallons a minute in some of the irrigation wells. The Meade formation is the most extensive and potentially the most important water-bearing formation in the two-county area.

There is little danger of the overdevelopment of this aquifier by pumping for irrigation, except locally, because of the relatively rapid rate of recharge from precipitation and from undrained depressions, and because of the widespread distribution of areas of dune sand in which the soil and topography generally are unsuitable for the development of irrigation. Large supplies of water could be obtained in this area for industrial use, however.

Water from these beds is moderately hard but is suitable for most uses (Tables 9 and 10, Fig. 10).

Terrace Deposits

Deposits consisting primarily of silt and clay overlie the bedrock in large areas in Pawnee and Edwards Counties. The origin of these deposits is not understood entirely, inasmuch as they do not resemble the coarse-grained terrace deposits of the major streams in southwestern Kansas. They probably were derived primarily from fine-grained sedimentary rocks in areas to the west but their origin may be in part colluvial—that is, by soil creep.

Character.—The terrace deposits consist principally of light-tan to brown clay and silt containing some caliche and interbedded with fine to coarse sand and a little gravel. The silt and clay, which generally are brown or buff, may have a variety of colors ranging from white to bright green and blue. The clay generally is blocky and the silt is poorly consolidated except where it is in part cemented by calcium carbonate. The sand and gravel is poorly sorted and generally occurs at the base of the formation. The sand may consist primarily of grains of quartz or may contain fragments of sandstone and limestone. The gravel pebbles consist principally of limestone, sandstone, and ironstone, which probably were derived from the Greenhorn limestone, Carlile shale, and Dakota formation.

Locally the terrace deposits may consist of coarser material, such as along the lower reaches of Ash Creek on the north side of the Arkansas Valley northeast of Larned. Here the deposits contain sufficient sand and gravel to warrant the development of irrigation from wells.

Distribution and thickness.—Moderately thick soils have been developed on the terrace deposits in this area, making them difficult to map. The area was mapped primarily on the basis of the topographic expression of the deposits and with the aid of the accurate soils map prepared by the Soil Conservation Service. The terrace deposits underlie the areas adjacent to the Pawnee and Arkansas Valleys as well as smaller areas along Ash Creek and Little Walnut Valleys (Pl. 1 and 3).

The topographic expression of these deposits is in places very prominent (Pls. 8 and 9). Two terraces can be observed in many places adjacent to the Pawnee Valley, but in some areas they are difficult to recognize because of dissection by streams tributary to Pawnee and Arkansas Rivers. The lowermost terrace, which is the

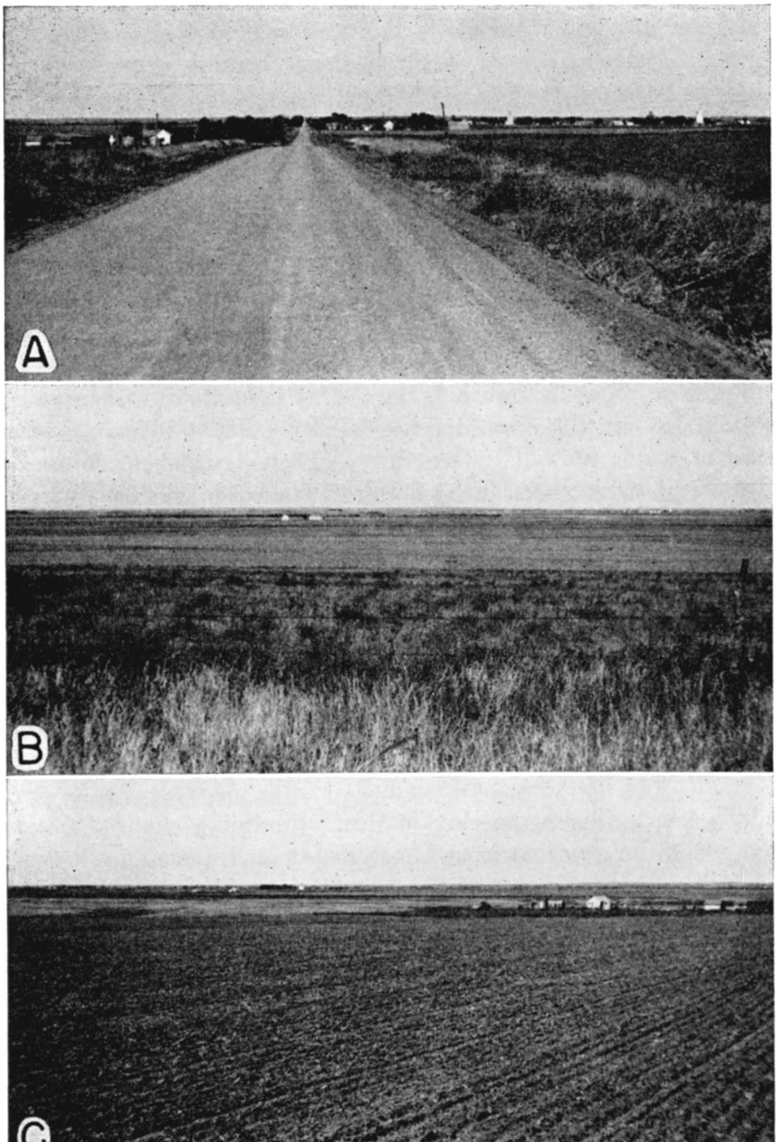

Plate 9. Terrace deposits in Pawnee County. *A,* Low terrace in foreground and Pawnee Valley flood plain in distance. (View north toward Rozel.) *B,* High terrace in foreground (dark area); low terrace and Pawnee Valley in distance. (View north from a point 0.6 mile east of the SW cor. sec. 17, T. 22 S., R. 19 W.) *C,* Low terrace in foreground (darker plowed area) and Pawnee Valley flood plain in distance. (View northwest from a point 0.2 mile north of the SE cor. sec. 33, T. 21 S., R. 19 W.)

most prominent, is about 20 feet above the flood plain of Pawnee River and the upper terrace is about 50 or 60 feet above the flood plain. Latta (in press) observed three terraces along Arkansas River in Barton County, one of which was underlain by coarse sand and gravel. It may be that the coarse materials underlying the low terrace northeast of Larned represent a third terrace equivalent to the third terrace in Barton County.

The thickness of the terrace deposits in Pawnee and Edwards Counties ranges from a featheredge near its contact with the Cretaceous bedrock to 145 feet in Ash Creek Valley north of Larned (Pl. 3). The average thickness of these deposits, as determined by the cuttings from 58 test holes, was slightly more than 60 feet.

Water supply.—Inasmuch as the terrace deposits consist primarily of clay and silt, the formation yields only small to moderate quantities of water to wells. Generally, sufficient water for most domestic and stock uses can be obtained from the thin beds of sand and gravel. In the few places where the formation contains much sand and gravel the beds will yield adequate water for irrigation. In general, however, wells in these beds will not yield enough water for irrigation. In the vicinity of Rozel a farmer drilled several test holes on the lower terrace in an attempt to find a suitable site for an irrigation well, but only silt and clay and a little gravel were encountered. As a last resort the well was drilled in the alluvium of Pawnee Valley and the water was pumped to the first terrace, where it was used for irrigation.

In a few localities the clay in this formation yields more water than would be expected from a material of such seemingly low permeability. Moderate quantities of water have been obtained from these beds in Little Walnut Creek Valley, where they are known locally as "water clay." The joints in the blocky clay seem to remain open when the beds are saturated, thus allowing the relatively free movement of water. One well in these beds yielded more than 50 gallons of water a minute.

Water from the terrace deposits is moderately hard but otherwise is of good quality (Fig. 10 and Tables 9 and 10).

PLEISTOCENE AND RECENT SERIES

Alluvium

Character.—The alluvium of the Pawnee and Arkansas Valleys consists of sand, gravel, silt, and clay. The alluvium of the Pawnee Valley, however, differs in several respects from that in the Arkansas Valley. In the Pawnee Valley the upper part of the alluvium consists predominantly of clay containing some silt and sand. This zone ranges in thickness from about 15 feet to 50 feet and has an average thickness of about 30 feet. The clay makes possible the development of an excellent soil but it retards the recharge of the underlying sand and gravel from local precipitation and from Pawnee River. Beneath the clay there is, in most places, a thick deposit of sand and gravel that yields large quantities of water to wells in the valley.

The alluvium of Arkansas Valley contains no thick deposit of clay or silt in the upper part, although thick beds of these materials may occur within the formation. In Arkansas Valley the sandy soil may be underlain by thick beds of sand and gravel; hence, recharge from precipitation and from streams probably is much greater than in Pawnee Valley.

Distribution and thickness.—Alluvium underlies the bottomland of the Pawnee and Arkansas Valleys and of some of the larger tributaries to these valleys. The southern limit of the alluvium on the south side of Arkansas River is not known because of the overlap of dune sand. Below Larned it may extend several miles south of the alluvium-dune sand contact but its southern limit could not be determined by test drilling, owing to the lithologic similarity of the alluvium and the Pleistocene materials underlying the dune sand in the southern part of the area.

The thickness of the alluvium in the Pawnee Valley as determined by 15 test holes ranged from 65 to 138 feet and averaged 105 feet. In the Arkansas Valley the thickness, as determined by 16 test holes, ranged from 18 to 135 feet and averaged about 61 feet. The thickness of the alluvium in the Pawnee Valley is moderately uniform, whereas in the Arkansas Valley there are areas where the alluvium is very thin and others where there is a deep channel. This condition is well illustrated by test holes 97, 110, and 111 on Plate 3.

Age.—The alluvium in the Pawnee and Arkansas Valleys has been deposited in channels cut into Cretaceous, Tertiary, and Pleistocene sediments. The age of the alluvium, therefore, probably is late Pleistocene and in part Recent. There may be older terraces of Arkansas River beneath the cover of dune sand toward the south, but their presence could not be determined by test drilling.

Water supply.—The alluvium of the Arkansas and Pawnee Valleys yields large quantities of water to wells. Most of the domestic and stock wells and all the irrigation wells in the valleys obtain water from the sand and gravel of this formation. The water in the alluvium is hard but generally is suitable for most domestic, stock, and irrigation uses. In general, the water in the Pawnee Valley alluvium is softer and contains less dissolved solids than the water in the alluvium of the Arkansas Valley. Some of the water in the alluvium of the Arkansas Valley contains enough dissolved solids to be harmful to plants. (See Tables 9 and 10 and Fig. 10.)

Dune Sand

Almost all the area lying south of Arkansas River in Pawnee and Edwards Counties is underlain by dune sand. The dune sand contains uniform-grained, moderately well-rounded fragments of quartz, as well as lesser amounts of silt and clay. Inasmuch as the dune sand overlies the alluvium of Arkansas River in some places, it probably is largely Recent, but it may be in part Pleistocene.

Two types of topography may be recognized in the dune-sand areas south of Arkansas River (Pl. 1) which are reflections of the stage or phase of erosion of the sand dunes. The first type is characterized by typical sand-dune topography wherein the dunes are grass-covered, moderately steep, irregular hills between which are small undrained basins. This type is best exposed in the areas near the Arkansas Valley. The second type of topography comprises broad subdued swells and swales having a thicker, heavier soil which is cultivated extensively.

As a result of his studies of sand dunes, Smith (1940, pp. 159-165) described an ideal dune cycle consisting of two phases: (1) an eolian or active phase during which the dune is built up, and (2) an eluvial or passive phase during which the vegetation prevents further growth and the dune is subdued by weathering and creep. He divides the eluvial phase into stages of youth, maturity, and old age. In the youthful stage the soil zone is formed and the slopes are reduced. The dune becomes mature when its profile is smooth and regular and when its soil becomes thicker and more stable. Old age is reached when the dune form is indistinguishable. He states that the eluvial phase in any stage may be interrupted by rejuvenation.

Most of the sand dunes in Pawnee and Edwards Counties are in the eluvial phase of the dune cycle, although a few dunes are in the eolian or active phase. The types of dune sand mapped in the Pawnee-Edwards area are (1) those that produce a typical sand-dune topography and which are in the youthful and mature stages of the eluvial phase of the dune cycle, together with those that are in the eolian phase of the cycle, and (2) those that produce a relatively flat topography and which are in the old-age stage of the eluvial phase of the dune cycle. The boundaries between the two types of dunes and between the dune sand and other formations are indistinct in many places; hence they are shown on Plate 1 by dashed lines.

The thickness of the dune sand is variable and ranges from a featheredge to about 40 or 50 feet. Where the dunes have reached the old-age stage they are very thin and where they are in the eolian phase and in the youthful stage of the eluvial phase they attain their maximum thickness.

The dune sand lies above the water table and, hence, yields no water to wells, but the areas of dune sand form ideal catchment areas for rainfall and facilitate the relatively rapid recharge of the underlying formations.

WELL RECORDS

Information pertaining to water wells in Pawnee and Edwards Counties is tabulated in Tables 15 and 16. The numbers in the first column correspond to well numbers on the map (Pl. 1) and in the tables of analyses (Tables 9 and 10). The numbers in the first column that are in parentheses indicate wells from which samples of water were taken for analysis (Tables 9 and 10).

TABLE 15.—*Records of wells in Pawnee County, Kansas*

No. on Pl. 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		Method of lift (5)	Use of water (6)	Measuring point			Depth to water level below measuring point (feet) (7)	Date of measurement	Remarks—(Yield given in gallons a minute; drawdown in feet)
							Character of material	Geologic source			Description	Distance above (+) or below (—) land surface (feet)	Height above mean sea level (feet)			
	T. 20 S., R. 16 W.															
(1)	NE¼ NW¼ sec. 4	Wm. Hagerman	Dr	68.5	6	GI	Clay and sand	Ter. deposits	Cy,W	S	Base of pump	....	2,036.6	44.2	2-14-45	
2	NE¼ SE¼ sec. 4	Jas. E. Kay	Dr	30	6	GI	do	do	Cy,G	D,S	do	+0.8	2,011.3	21	....	
3	NW¼ NW¼ sec. 6	....	Dr	32.0	6	GI	do	do	(?)	S	Top of casing, south side	+1.2	2,035.4	18.90	2-14-45	
4	SW¼ NW¼ sec. 7	W. J. Vernon	Dr	150+	6	OW	Sandstone	Dakota	Cy,W	N	Top of casing, southeast side	+ .8	2,134.5	136.29	5-10-45	Abandoned; formerly a domestic and stock well.
(5)	NE¼ SW¼ sec. 13	Stanolind Oil & Gas Co.	Dr	165	(?)	(?)	do	do	Cy,W	D	....	....	....	153	10-12-44	
6	SW¼ NW¼ sec. 24	....	Dr	114.0	6	GI	do	do	Cy,H	N	Top of casing	+ .2	2,031.9	83.25	2-14-45	Do
7	NE¼ SE¼ sec. 28	School district	Dr	96.1	6	GI	do	do	Cy,W	D	Top of casing, north side	0	2,055.2	65.77	5-12-45	
(8)	SE¼ SW¼ sec. 31	F. J. Finger	Dr	40.0	5	GI	Sand	Ter. deposits	Cy,H	D,S	do	—3.8	2,019.6	21.86	7-22-44	
	T. 20 S., R. 17 W.															
9	SE¼ SE¼ sec. 5	F. L. Singer	Dr	158.0	2	GI	Sandstone	Dakota	N	N	Top of 2-inch pipe	— .8	2,119.3	76.50	3-13-45	Abandoned; formerly a mestic well.
10	NW¼ NW¼ sec. 21	....	Dr	61.0	6	GI	Sand	Ter. deposits	N	N	Top of casing, east side	+ .5	2,100.0	45.98	7-18-44	Do
(11)	NW¼ NE¼ sec. 26	School district	Dr	40.0	5	GI	do	do	Cy,H	P	do	+ .1	2,055.3	38.50	7-18-44	
12	SE¼ SE¼ sec. 31	M. Fulton	Dr	83.1	5	GI	Sandstone	Dakota	Cy,W	N	do	+ .2	2,132.9	74.30	7-24-44	Abandoned; formerly a stock well.
	T. 20 S., R. 18 W.															
13	NW¼ NW¼ sec. 4	J. W. Griffith estate	Du	34.0	36	R	Limestone	Carlile	Cy,W	N	Top of concrete curb, west side	+1.8	2,217.9	27.25	2-13-45	Do

(14)	SW¼ SE¼ sec. 10	School district 52	Du	10	(?)	C	do	do	Cy,H	P	Top of 5-inch hole in concrete cover	0	2,200.6	5.50	7-24-44	
15	NE¼ NE¼ sec. 22	School district	Dr	41.2	6	GI	do	Greenhorn	Cy,H	P	Top of casing, north side	+ .3	2,071.0	25.30	5-14-45	
16	SE¼ NE¼ sec. 29	J. W. Fox	Du	22.0	48	R	do	do	Cy,W	S	Top of concrete platform, next to pump	0	2,158.0	15.15	2-13-45	
	T. 20 S., R. 19 W.															
17	NE¼ SE¼ sec. 8	School district	Du	9.8	54	R	do	Carlile	Cy,H	P	Top of 1.4-foot manhole in concrete cover	+ .7	2,234.1	9.23	7-27-44	
(18)	SW¼ SE¼ sec. 8	W. Pfenninger	Du	28	60	R	do	do	Cy,W	S	Top of concrete well curb, east side of pipe	—1.3	2,198.7	24.16	6-11-45	
19	NE¼ NW¼ sec. 11	School district 67	Du	12.6	72	C	do	do	P,H	P	Top inside steel rim of manhole	+0.7	2,222.9	11.51	7-27-44	
20	SE¼ SE¼ sec. 16	....	Dr	242.0	2	GI	Sandstone	Dakota	N	N	Top of 2-inch pipe	— .6	2,240.2	199.04	5-15-45	Abandoned; formerly a domestic and stock well.
21	SW¼ NW¼ sec. 17	E. M. Drake and W. Pfenninger	Dr	465	5	GI	do	Cheyenne (?)	Cy,W	S	Top of casing	+1.5	2,209.6	101.37	3- 3-45	
(22)	SW¼ SW¼ sec. 26	F. M. Stephens	Dr	160	(?)	T	Limestone	Greenhorn	Cy,W	S	Land surface	0	....	100	....	
(23)	NE¼ NE¼ sec. 28	Howard Winkler	Dr	312	5	GI	Sandstone	Dakota	Cy,W	D,S	....	....	2,197.8	160	10-13-44	
(24)	SE¼ SE¼ sec. 29	School district 46	Dr	44.7	5	GI	Limestone	Greenhorn	Cy,H	P	Top of casing, north side	0	2,149.3	16.90	7-27-44	
	T. 20 S., R. 20 W.															
25	SE¼ SE¼ sec. 3	H. Uhland	Dr	390	5	OW	Sandstone	Dakota	Cy,W	S	Top of casing	+1.3	2,224.2	171.18	3-21-45	
26	SE¼ NE¼ sec. 8	C. B. Fox	Dr	12	5	GI	Limestone	Greenhorn	Cy,W	N	Top of casing, east side	+ .7	2,177.9	6.64	7-31-44	Abandoned; formerly a stock well.
(27)	NW¼ SW¼ sec. 11	R. F. Hazelette	Du	17.9	48	R	do	Carlile	Cy,W	S	Top of 2- by 6-inch board over well, south side	+1.8	2,200.6	7.08	7-31-44	
28	SE¼ SE¼ sec. 20	Chas. Keller	B	32.0	6	GI	(?)	Ter. deposits(?)	Cy,W	D,S	Top of board platform under pump	+ .5	2,151.3	12.51	2- 9-45	
29	SE¼ SE¼ sec. 22	N. L. Olsen	Dr	42.0	6	GI	Limestone	Greenhorn	Cy,W	D,S	Top of casing, north side	+1.6	2,161.5	18.47	2- 9-45	
(30)	SE¼ SW¼ sec. 32	J. H. Armstrong	Dr	110	5	I	Sandstone	Dakota	Cy,W	S	do	+ .5	2,177.1	65.34	7-31-44	
31	NE¼ SE¼ sec. 34	Mr. Stokes	Dr	27.0	6	GI	Sand	Ter. deposits	Cy,W	D,S	Top of casing, east side	+ .8	2,137.2	18.28	2- 9-45	
	T. 21 S., R. 15 W.															
32	NW¼ NE¼ sec. 3	H. D. Unruh	Dn	22.0	1¼	GI	do	do	N	N	Top edge of concrete pit over well	0	1,937.7	11.77	2-15-45	Abandoned; formerly a domestic and stock well.
33	SE¼ NE¼ sec. 10	John Kledel	Dn	14.0	1¼	GI	Sand and gravel	Alluvium	P,H	S	Bottom of check valve on pump	+2.4	1,937.2	9.53	2-15-45	
(34)	NE¼ SE¼ sec. 14	W. Phillips	Dn	23	(?)	(?)	do	Meade	Cy,H	D,S	....	....	1,946.7	16	10- 9-44	

TABLE 15.—*Records of wells in Pawnee County, Kansas—Continued*

No. on Pl. 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		Method of lift (5)	Use of water (6)	Measuring point			Depth to water level below measuring point (feet) (7)	Date of measurement	Remarks—(Yield given in gallons a minute; drawdown in feet)
							Character of material	Geologic source			Description	Distance above (+) or below (−) land surface (feet)	Height above mean sea level (feet)			
	T. 21 S., R. 15 W.															
35	SW¼ SE¼ sec. 18	Earl Givens	Dr	52	19	GI	Sand and gravel	Ter. deposits	T,T	I	Top of casing, east side	0	1,965.3	10.78	2-20-45	Reported yield, 1,000; drawdown 16.
36	NW¼ SW¼ sec. 29	B. Unruh	Du,Dn	29.8	48	C	do	Meade	N	N	Top, 16-inch hole in concrete cover, west side	+ .7	1,978.1	18.42	7-21-44	Abandoned; formerly a domestic and stock well.
37	NW¼ SW¼ sec. 30	L. Osmond	Dn	16.1	(?)	(?)	do	Alluvium	P,H	N	Top of 1½-inch pipe	+2.7	1,970.3	8.16	7-21-44	Abandoned; formerly a domestic well.
	T. 21 S., R. 16 W.															
(38)	SE¼ SE¼ sec. 7	School district	Dr	38.8	5	GI	Sand	Ter. deposits	Cy,W	P	Top of casing, northeast side	+ .4	2,003.4	21.69	7-22-44	
39	NE¼ NW¼ sec. 10		Dr	22(?)	4	GI	do	do	Cy,W	S	Bottom of hole in side of pump	+1.3	1,978.8	9.64	2-15-45	
40	SE¼ SE¼ sec. 12		Dn	20.0	1.25	GI	do	do	P,H	S	Top of pump base at check valve	+2.3	1,966.7	11.35	3-16-45	
(41)	SE¼ SE¼ sec. 12	School district	Dn	25	(?)	(?)	do	do	Cy,H	P			1,963.4	11		
42	SW¼ NW¼ sec. 14	Schrope	DD	47	19	GI	Sand and gravel	do	N	N	Top of concrete curb, southeast corner	0	1,975.0	12.60	2-20-45	Abandoned; formerly an irrigation well.
43	NW¼ NE¼ sec. 15	Clyde Glaze	DD	50.0	20	C	do	do	C,G	I	Top of curb	0	1,980.2	17.38	2-20-45	Reported yield, 350.
44	SW¼ SE¼ sec. 20	City of Larned	Dr	167	10	I	Sandstone	Dakota	T,E	P			2,006.5	30		
45	SE¼ NE¼ sec. 21	Wm. Zecha	Dr	130+	6	OW	do	do	Cy,W	D,S	Top concrete platform above opening in casing	+ .2	2,100.3	110.34	5-12-45	
46	SE¼ SW¼ sec. 24	DeLos Carr	Dn	27.0	1.25	GI	Sand and gravel	Alluvium	P,H	D	Top check valve on pitcher pump	+4.7	1,977.3	13.75	2-15-45	
47	SW¼ SW¼ sec. 26	Bell	DD	45	24	GI	do	do	C,G	I	Top of concrete curb	−1.5	1,985.6	13.26	2-20-45	Reported yield, 1,200.
48	NW¼ NE¼ sec. 27	do	DD	36.0	16	GI	do	Ter. deposits	C,E	I	Top of pit	0	1,988.8	16.81	2-20-45	Reported yield, 400.

49	NE¼ NW¼ sec. 27	Dr. C. E. Sheppard	Dr	82	24	C(?)	do.	do.	T,E	I	Base of pump frame	+ .8	1,990.5	19.71	5- 9-45	Reported yield, 1,500; drawdown 5 to 6.
50	NE¼ NE¼ sec. 29	City of Larned	Dr	123	10	I	Sandstone	Dakota	T,E	P			2,006.1	30		
51	NW¼ NE¼ sec. 29	do.	Dr	145	10	I	do.	do.	T,E	P			2,006.5	30		
52	NW¼ NE¼ sec. 29	do.	Dr	123	10	I	do.	do.	T,E	P			2,005.0	30		
53	NE¼ SE¼ sec. 32	do.	Dr	140	10	I	do.	do.	T,E	P			2,004.6	30		Drawdown to within 25 or 30 feet of the bottom of the well.
54	SE¼ SE¼ sec. 32	do.	Dr	150	10	I	do.	do.	T,E	P			1,999.8	30		
55	NE¼ NW¼ sec. 33	Don Burnett	Dr	47	16	GI	do.	Ter. deposits	C,E	I			1,996.3	10		Reported yield, 800.
(56)	SE¼ SW¼ sec. 33	City of Larned	Dr	70	19	GI	do.	Alluvium	T,E	P			1,994.2	10		Reported yield, 1,450; drawdown 11.
57	NW¼ NE¼ sec. 34	Fairchild	DD	45	(?)	(?)	do.	do.	C,T	I	Top of wood cover by discharge pipe	0	1,993.7	17.08	6-17-45	
58	SW¼ NE¼ sec. 34	Warren Phinney	Dr	36	19	GI	do.	do.	T,G	I			1,982.9	6.5		Reported yield, 1,100; drawdown 23.5.
	T. 21 S., R. 17 W.															
59	NE¼ NE¼ sec. 3		Dr	27.0	6	GI	Sand	Ter. deposits	Cy,W	S	Top of casing, northeast side	+1.1	2,033.9	19.37	5- 9-45	
60	SE¼ SE¼ sec. 10	Walter M. Fox	Dr	53.0	6	GI	Sandstone	Dakota	N	N	Top of casing, south side	0	2,048.0	36.55	3-13-45	Abandoned; formerly a domestic well.
61	SW¼ SE¼ sec. 17	School district 40	Dr	45.4	5	GI	Sand	Ter. deposits	Cy,W	P	Top of casing, west side	+ .2	2,054.3	24.87	7-24-44	
(62)	SE¼ SE¼ sec. 18		Dr	42.5	6	GI	do.	do.	Cy,H	P	Top of casing	+ .1	2,062.6	30.94	3-15-45	
63	NE¼ NW¼ sec. 33	C. Sweeny	Du,Dn	41.5	28	C	Sand and gravel	Alluvium	N	N	Top of concrete curb, west side	+1.9	2,030.0	19.63	7-13-44	Abandoned; formerly a domestic and stock well.
	T. 21 S., R. 18 W.															
64	SW¼ SW¼ sec. 4	J. F. Johnson	Dr	87.3	6	GI	Sandstone	Dakota	Cy,W	S	Top of casing, west side	+ .4	2,113.1	45.75	7-24-44	
(65)	SE¼ NE¼ sec. 5	do.	Dr,Dn	100	(?)	N	Sand	Ter. deposits	Cy,W	D,S			2,132.2	55	10-13-44	
66	SW¼ SW¼ sec. 15	O. Mickelson	Dr	186.0	8	OW	Sandstone	Dakota	Cy,H	N	Top of wood platform, north side of pump	0	2,090.8	44.72	5-22-45	Abandoned; formerly an oil-well supply well.
67	SE¼ SE¼ sec. 17	Clara Bukman	DD	53.0	6	GI	Sand	Ter. deposits	Cy,W	D,S	Top of concrete well curb		2,088.8	33.48	5-22-45	
68	NE¼ SW¼ sec. 31	A. H. Hall	DD	90	19	GI	Sand and gravel	Alluvium	C,T	I			2,058.3	15		Reported yield, 1,000; drawdown 30.
(69)	SW¼ SW¼ sec 32	A. B. Thomas estate	Dr	120	20,16	GI	do.	do.	T,G	I	Top of casing, north side	+ .9	2,059.4	18.15	7-22-44	Reported yield, 1,400; drawdown 23 after 150 hours of pumping

TABLE 15.—*Records of wells in Pawnee County, Kansas—Continued*

No. on Pl. 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: Distance above (+) or below (—) land surface (feet)	Measuring point: Height above mean sea level (feet)	Depth to water level below measuring point (feet) (7)	Date of measurement	Remarks— (Yield given in gallons a minute; drawdown in feet)
	T. 21 S., R. 19 W.															
70	NW¼ SW¼ sec. 1	Leo Haberman	Dr	60.0	6	GI	Limestone	Greenhorn	N	N	Top of casing	0	2,148.9	36.90	....	Abandoned; formerly a domestic and stock well.
71	SW¼ SW¼ sec. 3	L. O. Bley	Dr	200	8	OW	Sandstone	Dakota	Cy,W	D,S	Top of concrete well curb	+1.0	2,152.5	65	....	
72	NW¼ NE¼ sec. 7	....	Dr	52.0	6	GI	Sand	Ter. deposits	Cy,W	S	Base of pump, southeast side	+1.5	2,127.9	32.35	2-10-45	
73	SW¼ SE¼ sec. 16	A. F. Bruntzel	Dr	65.0	6	GI	Sand and gravel	Alluvium	Cy,W	S	Top of casing, north side	+ .8	2,089.0	27.15	2-12-45	
74	SW¼ SW¼ sec. 20	D. B. Wiens	Dr	96	19	GI	do	do	T,E	I	....	....	2,086.2	30	....	Reported yield, 1,160; drawdown 29.
75	NW¼ NE¼ sec. 23	H. W. Scott	Du Dn	43	30	B	do	do	Cy,W	D,S	Top of manhole, west side	+ .3	2,077.1	20.09	2-12-45	
(76)	NW¼ SW¼ sec. 27	W. W. Christian	Dn	42	(?)	(?)	do	do	C,E	D	Basement floor	—8.0	2,065.4	25	....	
77	SW¼ SW¼ sec. 27	Frank Elmore	Dr	123	16	GI	do	do	T,G	I	Top of casing, northeast side	+1.6	2,076.7	23.22	7-26-44	Reported yield, 1,485; drawdown 27 after 7 hours of pumping.
78	SW cor. sec. 27	do	DD	56.3	24	GI	do	do	C,E	I	Top of lath strip on wooden cover	+1.0	2,075.7	24.59	8-21-40	Reported yield, 600; drawdown 27.
79	SE¼ SW¼ sec. 29	Ralph W. Cone	DD	60	24	GI	do	do	C,G	I	Top of 3- by 12-inch board, east side	+1.0	2,082.6	37.02	5-23-45	Reported yield, 1,000; drawdown 10.
80	NW¼ NW¼ sec. 33	Cook Brothers	DD	61.0	24	GI	do	do	C,G	I	Top of board platform next to discharge pump	0	2,078.7	23.80	5-23-45	Reported yield, 1,100; drawdown 10.
81	SW¼ NE¼ sec. 36	F. J. Finger	Dr	100	16	GI	do	do	T,G	I	Top of casing, northeast side	+ .2	2,064.3	18.56	7-24-44	Reported yield, 1,300.
82	NW¼ SE¼ sec. 36	Nick Werner	Dr	104	(?)	(?)	do	do	T,E	I	....	....	2,062.3	18	....	Reported yield, 1,900.

	T. 21 S., R. 20 W.															
83	SW¼ NW¼ sec. 9	C. Schwind	Dr	58.8	5	GI	Sand	Ter. deposits	Cy,W	N	Top of casing, east side	+2.2	2,126.4	21.27	7-31-44	Abandoned; formerly a stock well.
(84)	NE¼ SE¼ sec. 15	Nuckolls Brothers	Dr	45	5	I	Sand and gravel	Alluvium	Cy,W	D,S			2,100.1	32		
85	NW¼ SE¼ sec. 15	do	DD	75	24	GI	do	do	C,T	I			2,100.8	32		Reported yield, 1,200; drawdown 25.
86	SE¼ SW¼ sec. 17	Schrater	DD	(?)	24	GI	do	do	C,T	N	Top of concrete curb, northeast side	0	2,109.7	29.61	6- 6-45	Abandoned; formerly an irrigation well.
87	NW¼ NE¼ sec. 20	Fred Brown	DD	87	28,24	GI	do	do	C,G	I	Top of concrete well curb	+ .2	2,106.3	27.32	6- 6-45	Reported yield, 1,000; drawdown 50-55.
(88)	NE¼ NW¼ sec. 20	George Smith	Dn	55	(?)	N	do	do	Cy,W	D,S			2,108.9	29	9-21-44	
89	NE¼ NW¼ sec. 20	do	DD	80	24	GI	do	do	C,G	I	Top of concrete curb, north side	+1.4	2,110.2	30.44	9-16-44	Reported yield, 650
90	NW¼ SW¼ sec. 21	John Maur	Dr	64	19	GI	do	do	C,T	I	Top of concrete curb, east side		2,100.8	24.49	7-25-45	Reported yield, 1,250.
91	NW¼ NE¼ sec. 24	Henry Peak	Dr	70	24	GI	do	do	T,T	I	Top of 6- by 10-inch timber under pump, south side	0	2,093.9	31.57	5-25-45	Reported yield, 800; drawdown 28.
92	NW¼ NE¼ sec. 26	Harold Bell	Dr	90	19	GI	do	do	T,G	I	Top of concrete pump base	0	2,091.5	30.28	5- 7-45	Reported yield, 1,400; drawdown 56.
93	NE¼ SE¼ sec. 26	Lester Preston	DD	90	19	GI	do	do	C,T	I	Top of steel pulley frame	+ .4	2,094.7	33.58	5-23-45	Reported yield, 450; drawdown 20.
(94)	SE¼ SW¼ sec. 28	Whiteway Cafe	Dr	126	6	GI	Sandstone	Dakota	C,E	P				30		
95	SW¼ NW¼ sec. 29	Irving Brownlee	DD	53	19	GI	Sand and gravel	Alluvium	C,G	I	Top of concrete curb	+ .3	2,107.8	27.61	6- 6-45	Battery of three wells; reported yield, 800.
96	SW¼ NW¼ sec. 29	do	Dr	94	19	I	do	do	T,G	I			2,107.6	27.5		Reported yield, 1,200; drawdown 14.
97	SW¼ NW¼ sec. 30	Rex Lee Estate	DD	93	24	GI	do	do	C,G	I			2,115.1	34		Reported yield, 1,000.
	T. 22 S., R. 15 W.															
98	NW¼ NE¼ sec. 2	Mr. Vratil	DD	48.0	4	GI	do	Meade	Cy,E	D,S	Top of casing, south side	—21.5	1,953.9	10.67	7-21-44	
(99)	NE¼ NE¼ sec. 3	School district	Dn	30	(?)	N	do	do	Cy,H	P			1,970.2	19	10- 7-44	
100	NW¼ SW¼ sec. 7	Hartman	Dr	54.0	8	OW	do	do	Cy,G	N	Top of casing	+0.5	1,996.7	22.0	3-23-45	Drilled for oil-well supply
101	SE¼ NW¼ sec. 15	J. R. Vratil	Dr	46.0	6	OW	do	do	N	N	do	+1.3	1,989.2	24.93	2-15-45	Do
(102)	SW¼ SW¼ sec. 24	A. H. Ackerman	Dr	55	5	GI	do	do	Cy,W	D,S			1,997.9	20	10- 9-44	
(103)	SE¼ SE¼ sec. 31	H. B. Bowman	Dn	30	(?)	(?)	do	do	Cy,W	[illegible]			2,015.0	19	10- 9-44	

TABLE 15.—*Records of wells in Pawnee County, Kansas—Continued*

No. on Pl. 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: Distance above (+) or below (−) land surface (feet)	Measuring point: Height above mean sea level (feet)	Depth to water level below measuring point (feet) (7)	Date of measurement	Remarks—(Yield given in gallons a minute; drawdown in feet)
	T. 22 S., R. 16 W.															
104	SW¼ NW¼ sec. 3	Orville Baldwin	DD	65	19	GI	Sand and gravel	Alluvium	C,T	I	Top of concrete foundation at window	+1.0	1,992.0	7.58	6-17-45	Reported yield, 1,000.
105	NW¼ NE¼ sec. 4	Handshaw	Dr	38	30	GI	do	do	T,E	I	Top of pump base	+ .5	1,995.4	10.91	6-17-45	Reported yield, 1,200; drawdown 16 to 18.
106	NE¼ NW¼ sec. 4	Leo Myers	Dr	75	19	GI	do	do	T,E	I	Hole in base of pump	+1.2	1,996.2	9.29	6-17-45	Reported yield, 1,500; drawdown 9+.
107	NW¼ NW¼ sec. 4	Fred W. Freeland	DD	45	18	(?)	do	do	C,G	I	Top of 1-inch plank at discharge pipe.	+ .2	1,998.0	8.98	6-17-45	
108	NE¼ SE¼ sec. 4	James Buster	DD	38	16	GI	do	do	C,E	I			1,996.0	9		Reported yield, 400; drawdown 6.
(109)	NE¼ SW¼ sec. 4		Dn	12	(?)	N	do	do	P,H	D			1,995.7	6	10- 6-44	
110	SE¼ NW¼ sec. 5	City of Larned	Du,Dn	26	240	C	do	do	C,E	P	Top of concrete rim of hole in well floor	−1.7		6.63	7-28-44	Reported yield, 600.
111	NW¼ NW¼ sec. 6	F. B. Reed	Dr	33.5	19	(?)	do	do	C,E	I	Top of round concrete curb, south side	+1.5	2,011.3	19.29	8-28-40	Reported yield, 300; drawdown 10 after several hours of pumping.
112	SE¼ NW¼ sec. 6	A. L. Stockwell	DD	33.0	19	GI	do	do	C,T	I	Top of casing	0	2,010.0	12.53	11-29-45	Reported yield, 700; drawdown 16.
113	SE¼ SW¼ sec. 6	do	DD	31.4	16	GI	do	do	N	N	Top of concrete curb, southwest side	0	2,014.7	14.23	7-13-44	Abandoned; formerly an irrigation well.
114	NW¼ NW¼ sec. 7	F. Hoag	DD	32.9	16	GI	do	do	C,T	N	Base of 2- by 8-inch board over well	+ .5	2,016.1	14.34	7-13-44	Do
115	SW¼ SW¼ sec. 7	M. Christian	DD	35	20	GI	do	do	C,T	I				8		Reported yield, 1,000; drawdown 6. Not in use since 1938.
116	NE¼ NW¼ sec. 8	John Beamer	DD	34	24	GI	do	do	C,G	I			2,008.1	7		Reported yield, 1,000; drawdown 10 to 12.
117	NE¼ NE¼ sec. 18		Dn	12.3	1¼	GI	do	do	P,H	S	Bottom of check calve	+1.8	2,013.1	4.85	2-16-45	

118	NE¼ NE¼ sec. 23	Edgar Clark	Dr	80	19	GI	do	Meade	T,T	I	Top of hole, northeast side of pump	+ .3	2,011.4	24.54	2-20-45	Reported yield, 500.
(119)	NW¼ NE¼ sec. 23	do	Dn	68	(?)	(?)	do	do	Cy,W	D,S			2,026.1	40	10- 6-44	
	T. 22 S., R. 17 W.															
120	NW¼ NW¼ sec. 5	E. E. Frizell	Dr	66	24	GI	Sand and gravel	Alluvium	T,G	I	Top of steel pump support	—0.1	2,036.4	15.74	7-22-44	Reported yield, 700.
121	NW¼ NW¼ sec. 5	do	Dr	66	24	GI	do	do	T,G	I	Base of pump, north side	+1.9	2,037.8	16.93	5-14-45	Do
122	NW¼ NW¼ sec. 5	do	Dr	66	24	GI	do	do	T,G	I	Base of pump	+ .6	2,036.6	15.80	5-14-45	Do
(123)	NE¼ SW¼ sec. 5	School district	Dr	(?)	(?)	(?)	do	do	Cy,H	P	Top of casing, south side	0		12.16	5-14-45	
124	SE¼ SW¼ sec. 9	W. L. Brooks	DD	55	19	GI	do	do	C,G	I			2,046.1	20		Reported yield, 1,000.
(125)	SE¼ SE¼ sec. 11	School district 49	Dn	20	(?)	N	do	do	Cy,H	P			2,020.6	12		
126	SW¼ SW¼ sec. 12	Joe Smith	DD	52	19	GI	do	do	C,G	I			2,021.4	14		Reported yield, 1,000; drawdown 8.
127	SE¼ NE¼ sec. 17	Henry C. Schnack	DD	35	19	GI	do	Ter. deposits	C,E	I			2,052.4	23		Reported yield, 1,000.
128	NE¼ NE¼ sec. 18	Ralph Lupfer	Dr	124	19	GI	do	do	T,E	I	Top of 20-inch casing, southwest side	+ .5	2,056.1	27.13	8- 2-45	Reported yield, 1,000; drawdown 28.
(129)	NW¼ SW¼ sec. 19	Mary Eikmeier	Dr	215.0	5	I	Sandstone	Dakota	Cy,W	S	Top of casing		2,092.9	48.04	11-17-45	
130	NE¼ NW¼ sec. 21	Fagen Brothers	DD	44	16	GI	Sand and gravel	Alluvium	C,G	I			2,056.4	19		Reported yield, 650.
131	SW¼ SW¼ sec. 28	M. Ewing	Du	21.7	48	(?)	do	do	N	I	Top of 1-inch board over well	0	2,060.5	12.92	7-19-44	Abandoned; formerly an irrigation well.
132	NW¼ NW¼ sec. 32	D. B. Welsh	Dr	151.0	(?)	(?)	Sandstone	Dakota	Cy,W	S	Top of board over casing	0	2,080.8	24.10	8- 2-44	
133	NE¼ NE¼ sec. 36		Du,Dn	(?)	1¼	GP	Sand and gravel	Meade	N	S	Top of metal rim around well	0	2,047.2	13.13	2-16-45	
	T. 22 S., R. 18 W.															
134	NE¼ SE¼ sec. 3	Irvin Whitmore	Du	26.0	60	Bs	do	Alluvium	C,G	I	Top of casing	+ .5		13.89	5-14-45	
135	NW¼ SW¼ sec. 4	Dan Fox	Dr	98	19	GI	do	do	T,E	I	Top of pump base, south side	+ .6	2,051.0	14.00	7-13-44	Reported yield, 1,000.
136	NW¼ SE¼ sec. 5	Frank Brownlee	DD	74.5	19	GI	do	do	C,G	I	Top of casing	+ .3	2,053.1	15.85	11-28-45	Do
137	NE¼ NE¼ sec. 6	Webster	Dr	100	19	GI	do	do	T,E	I			2,057.5	15		Do
138	NW¼ NW¼ sec. 6	Lee Meador	Dr	96	24	GI	do	do	T,G	I	Top of oil-gage hole in pump base	+ .9	2,056.9	12.42	7-22-44	Reported yield, 1,000; drawdown 30 to 32.
139	SW¼ NW¼ sec. 8	J. Mackfessel	Dr	69.5	18	GI	do	do	T,G	I	Top of casing	+1.0	2,052.7	12.09	11-28-45	Reported yield, 2,000.
140	NW¼ NW¼ sec. 9	Donald Younkin	Dr	100	19	GI	do	do	T,E	I			2,050.7	14		Reported yield, 1,100; drawdown 15.5.

TABLE 15.—*Records of wells in Pawnee County, Kansas—Continued*

No. on Pl. 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: Distance above (+) or below (—) land surface (feet)	Measuring point: Height above mean sea level (feet)	Depth to water level below measuring point (feet) (7)	Date of measurement	Remarks—(Yield given in gallons a minute; drawdown in feet)
	T. 22 S., R. 18 W.															
141	NW¼ SW¼ sec. 9	Ernest Mackfessel	Dr	102	19	GI	Sand and gravel	Alluvium	T,G	I			2,051.0	16		Reported yield, 1,500; drawdown 20.
(142)	SW¼ SW¼ sec. 9	do	Du	26	60	B	do	do	Cy,W	D,S			2,062.7	23	10-11-44	
143	NW¼ NW¼ sec. 10	Warren Charles	Dr	110	19	GI	do	do	T,E	I			2,048.3	16		
144	NW¼ SW¼ sec. 10	A. L. Stockwell	Dr	100	19	GI	do	do	T,G	I	Top of casing	+0.5	2,047.3	13.63	11-27-45	Reported yield, 1,200; drawdown 38.
145	NW¼ SW¼ sec. 10	do	Dr	100	24	GI	do	do	T,G	I				13		Reported yield, 700; drawdown 68.
146	SE¼ SW¼ sec. 11	Elmer Williams	Dr	96	19	GI	do	do	T,G	I			2,042.5	10		Reported yield, 1,200.
147	NW¼ NE¼ sec. 14	G. L. Eddy	Dr	74+	19,16	GI	do	do	T,G	I	Top of casing, east side	0	2,044.5	12.48	11-27-45	Reported yield, 750; drawdown 40 to 45.
148	SW¼ NE¼ sec. 15	Easley	DD	86	10	GI	do	do	C,T	I			2,047.3	12		Reported yield, 700.
149	NE¼ NE¼ sec. 27	P. O. Palmer	Dr	53.5	5	GI	Sandstone	Dakota	Cy,W	S	Top of ½-inch hole in steel pipe clamp	+1.6	2,070.0	17.27	8- 2-44	
(150)	SW¼ SW¼ sec. 28	T. B. Price	Dr	82.5	5	GI	Sand	Ter. deposits	Cy,W	N	Top of casing, west side	+ .2	2,100.3	25.16	8- 2-44	Abandoned; formerly a domestic and stock well.
(151)	SE¼ SE¼ sec. 35	E. A. Shumway	Dr	56.5	5	(?)	do	do	Cy,W	N	Top of 5-inch hole in concrete	+ .5	2,111.3	46.15	8- 2-44	Do
	T. 22 S., R. 19 W.															
(152)	SE¼ SE¼ sec. 8	I. E. Tebbel	Dr	40.5	5	GI	do	do	Cy,W	S	Top of casing, east side	+ .3	2,097.7	22.96	8- 3-44	
153	SE¼ SE¼ sec. 10		Dr	38.6	6	GI	do	do	Cy,W	D,S	Top of casing	+1.2	2,087.1	24.38	3-20-45	
154	SE¼ SE¼ sec. 26		Du	67.5	28	R	Sandstone	Dakota	N	N	Top of 2- by 12-inch plank over well	+ .4	2,138.9	43.77	3-20-45	Do
(155)	SW¼ SW¼ sec. 29	School district	Dr	100	6	GI	do	do	Cy,W	P			2,162.0	47		

	T. 22 S., R. 20 W.														
(156)	NW¼ NW¼ sec. 4	Burdett Cemetery	Dr	210	4	I	do	do	Cy,W	I	Top of casing, south side	+ .5	2,208.1	117.66	7–31–44	
157	SE¼ NE¼ sec. 9	Norris	Dr	167.0	8	OW	do	do	N	N	Top of casing	+ .3	2,165.2	65.04	3–14–45	Formerly an oil-well supply well.
158	SW¼ SW¼ sec. 13	A. A. Smith	Dr	120	6	OW	do	do	Cy,W	S	Top of casing, south side	+1.3	2,087.1	41.75	3–15–45	
159	NE¼ NW¼ sec. 19	J. E. Mooney	Dr	125.5	5	GI	do	do	Cy,W	N	Top of casing, north side	+ .5	2,239.6	91.60	7–31–44	Abandoned; formerly a domestic and stock well.
(160)	NE¼ NW¼ sec. 29	B. W. Klein	Dr	28.2	8	GI	Sand	Ter. deposits	Cy,W	S	do	+1.4	2,185.1	17.60	7–30–44	
161	SE¼ NE¼ sec. 30		Dr	35.2	6	GI	do	do	Cy,W	N	do	+ .2	2,192.4	18.91	3–20–45	Abandoned; formerly a stock well.
	T. 23 S., R. 15 W.															
(162)	NW¼ NW¼ sec. 13	D. E. Johnson	Dn	25	(?)	(?)	Sand and gravel	Meade	Cy,W	D,S			1,975.7	6	10– 9–44	
163	NW¼ SE¼ sec. 14	C. E. Walker	DD	50	15	GI	do	do	C,G	I	Top of concrete curb, southwest side	+ .4	1,982.6	6.80	2–20–45	Reported yield, 600; drawdown 18.
164	NW¼ SE¼ sec. 26	do	DD	50	15	GI	do	do	C,T	I	Top of concrete curb under engine pulley	+ .4	1,990.0	13.30	2–20–45	Reported yield, 350; drawdown to total depth.
(165)	SE¼ SE¼ sec. 28	School district	Du,Dn	32	(?)	(?)	do	do	Cy,H	P			2,009.4	12	10– 9–44	
	T. 23 S., R. 16 W.															
(166)	SW¼ NW¼ sec. 6	D. W. Martin	Dr	40	6	GI	do	do	Cy,W	S			2,058.2	20		
167	SE¼ NW¼ sec. 12	Walter Zook	Dr	48	19	GI	do	do	T,G	I				20		Reported yield, 850; drawdown 12.
168	NE¼ NW¼ sec. 16	Townsite	Dr	20.4	5	GI	do	do	Cy,H	N	Top of casing, west side	+ .5	2,045.6	10.79	7–19–44	Abandoned; formerly a domestic well.
(169)	NE¼ NE¼ sec. 17		Dn	44	(?)	(?)	do	do	C,E	D			2,043.4	5	10– 6–44	
170	NE¼ NE¼ sec. 24	E. E. Giles	Du,Dn	34.0	1.25	GP	do	do	Cy,W	S			2,032.7	12.3	2–20–45	
(171)	NW¼ NW¼ sec. 34	A. J. Weinkheimer	Dn	30	(?)	(?)	do	do	Cy,W	S			2,063.0	14	10–11–44	
	T. 23 S., R. 17 W.															
172	SW¼ SE¼ sec. 4	C. Anderson	Dn	23.8	(?)	N	do	do	N	N	Top of 1½-inch pipe, south side	+ .3	2,062.3	9.76	8– 1–44	Abandoned; formerly a stock well.
(173)	SW¼ SE¼ sec. 5	Fred J. Hoag	Dn	25	(?)	(?)	do	Alluvium	Cy,W	S			2,057.3	4		
174	NE¼ SE¼ sec. 12		Dr	24.0	6	GI	do	Meade	Cy,W	N	Top of casing	+1.5	2,060.6	9.35	2–16–45	Do
(175)	NW¼ NW¼ sec. 20	Fred J. Hoag	Du	12.9	36	W	do	do	Cy,W	S	Top of 6- by 6-inch tie over well	+ .5	2,097.8	4.45	7–19–44	
(176)	SE¼ SE¼ sec. 22	J. C. Shottenkirk	Dn	25	(?)	(?)	do	do	Cy,H	N				16	10–10–44	Do

TABLE 15.—*Records of wells in Pawnee County, Kansas—Concluded*

No. on Pl. 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: Distance above (+) or below (—) land surface (feet)	Measuring point: Height above mean sea level (feet)	Depth to water level below measuring point (feet) (7)	Date of measurement	Remarks—(Yield given in gallons a minute; drawdown in feet)
	T. 23 S., R. 18 W.															
177	SE¼ SE¼ sec. 1	Albert Mostrum	DD	23.0	8	GI	Sand and gravel	Alluvium	C,E	I	Top of 2″x 4″ board at south side of trap door	+0.4	1,994.0	9.00	7-28-44	
(178)	SE¼ SE¼ sec. 1	Carl Nystrom	Dn,B	25	(?)	(?)	do	do	Cy,E	D	....	....	....	9	....	
179	NE¼ SE¼ sec. 4	Mrs. Fred Eikimier	Dr	74.0	6	GI	Sandstone	Dakota	Cy,W	D,S	Top of casing	+ .3	2,145.8	59.50	3-22-45	
(180)	SE¼ SE¼ sec. 6	R. J. Boyd	Dr	73+	5	(?)	do	do	Cy,W	S	Top of 5-inch hole in concrete base	+ .3	2,165.5	57.70	8- 2-44	
181	NE¼ NE¼ sec. 8	S. M. Rains	Dr	94.0	5	GI	do	do	Cy	N	Top of pump base, east side	+2.5	2,164.4	67.12	8- 2-44	Abandoned; formerly a domestic and stock well.
(182)	SE¼ SE¼ sec. 21	G. O. Mostrum	Dn	16	(?)	(?)	Sand and gravel	Alluvium	P,H	D	....	....	2,101.8	12	....	
183	NE¼ SE¼ sec. 22	W. Porteous	Dn	20.0	1¼	GP	do	do	P,H	D	Bottom of check valve on pump	+5.0	2,091.8	10.50	3-22-45	
(184)	SW¼ SW¼ sec. 33	Blaine Roberts	Dn	25	(?)	(?)	do	do	Cy,W	S	....	....	2,112.4	16	....	
185	SW¼ NW¼ sec. 36	Henry Lutz	Dn	28	1¼	GP	do	Meade	Cy,W	S	....	....	2,110.3	24	....	

1. Well number in parentheses indicates that analysis of water is given in table.
2. B, bored well; DD, dug and drilled well; Dn, driven well; Dr, drilled well; Du, dug well; J, jetted.
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; B, brick.
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; B, bucket and rope. 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.

TABLE 16.—*Records of wells in Edwards County, Kansas*

No. on Pl. 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: Distance above (+) or below (−) land surface (feet)	Measuring point: Height above mean sea level (feet)	Depth to water level below measuring point (feet) (7)	Date of measurement	Remarks— (Yield given in gallons a minute; drawdown in feet)
	T. 23 S., R. 19 W.															
(186)	SW¼ SW¼ sec. 9	A. F. Plager	Dr	66.9	3.5	I	Sandstone	Dakota	Cy,W	S	Top of casing, west side	+1.6	2,184.2	43.6	8-14-45	
187	SE¼ NE¼ sec. 10	School district	Dr	60.1	5	I	do	do	Cy,H	D	Top of casing	+ .2	2,219.5	51.8	8-14-45	
188	SE¼ SE¼ sec. 16	F. J. Anderson	Dr	151.0	5	GI	do	do	Cy,W	S	Top of casing, north side	+ .9	2,248.5	69.60	7-18-45	
189	SW¼ SW¼ sec. 20	R. W. Lippoldt	Du	56.4	34	B	do	do	B,H	D	Top edge of board curb, west side	+2.4	2,232.3	51.53	8-13-45	
190	SW¼ SW¼ sec. 22	E. F. Lippoldt	Du	69.6	54	R	do	do	Cy,W	N	Top of 24-inch hole in concrete cover	+ .6	2,239.0	65.53	7-11-44	Abandoned; formerly a domestic and stock well.
191	NE¼ NW¼ sec. 23	M. L. Duval	Dr	90.4	4.5	I	do	do	Cy,W	N	Top of flanged casing, south side	+1.1	2,230.2	41.19	8-14-45	Abandoned; formerly a stock well.
192	SW¼ SW¼ sec. 31	P. Herman	Dr	78.0	5	I	do	do	Cy,G	N	Top of 5-inch hole in concrete base	+ .5	2,238.6	56.40	7-16-45	Do
193	NE¼ NE¼ sec. 34	School district	Dr	86.8	5	GI	do	do	Cy,W	N	Top of casing, west side	+ .3	2,214.2	74.67	8-14-45	Abandoned; formerly a domestic well.
194	SW¼ SW¼ sec. 34	C. W. Buchanan	Dr	83.8	5	GI	do	do	Cy,W	D	Top of casing	+ .3	2,214.1	53.64	7-18-45	
	T. 23 S., R. 20 W.															
195	NW¼ NE¼ sec. 10	T. V. Donnell	Dr	27.9	4.5	GI	Sand	Ogallala	Cy,W	N	Top of casing, east side	+2.6	2,237.1	19.36	8- 9-45	Abandoned; formerly a stock well.
196	NE¼ NE¼ sec. 12	D. V. Lippoldt	Dr	(?)	5	GI	Sandstone	Dakota	Cy,W	N	Top of 5-inch hole, north side	+1.1	2,286.9	59.38	7-16-45	Do
197	NW¼ NE¼ sec. 16	J. F. Demain	Du	24.0	36	B	Sand	Ogallala	Cy,W	N	Top of casing inside concrete curb	+6.3	2,283.5	20.6	8- 9-45	Do
198	SW¼ SW¼ sec. 16	M. F. Flager	Dr	121.4	5	GI	Sandstone	Dakota	Cy,W	N	Top of rock surrounding casing, south side	+ .6	2,295.5	105.36	8- 9-45	Do

(199)	SE¼ SE¼ sec. 16	J. F. Demain	Dr	124.0	4.5	GI	do	do	Cy	N	Top of concrete curb, south side	+1.5	2,295.9	113.18	8- 9-45	Do
200	SW¼ NE¼ sec. 18	C. M. Lauber	Du	26.4	60	C	Sand	Ogallala	Cy,H	N	Top of concrete curb, east side	+ .2	2,333.0	26.1	8-15-45	Do
201	SE¼ SE¼ sec. 21	V. Vannrahan	Dr	129.3	5	GI	Sandstone	Dakota		N	Bent edge of casing, southeast side	0	2,281.0	89.73	8- 9-45	Do
202	NW¼ NW¼ sec. 31	F. F. Burmeister	Dr	23.0	4	GI	Sand	Ter. deposits	Cy,W	S	Top of casing, north side	+1.0	2,306.0	16.28	8-15-45	
203	NW¼ SE¼ sec. 31	J. R. Crockett	Dr	18.4	5	GI	do	do	Cy,W	S	Top of inner casing, east side	+ .2	2,284.7	13.05	8-11-45	
	T. 24 S., R. 16 W.															
(204)	NW¼ NW¼ sec. 2	A. F. Fertig	Dn	50.6	(?)	(?)	Sand and gravel	Meade	P,H	S	Top of 1¼-inch pipe	+1.5	2,062.0	15.2	7-27-45	
205	SW¼ SE¼ sec. 8	Ira Dutton	Du	40	53	I	do	do	C	N	Edge of casing, north side	+ .2	2,085.6	17.14	7-27-45	Abandoned; formerly an irrigation well.
206	SE¼ SE¼ sec. 9	H. F. Rudd	Dr	66.0	6¾	I	do	do	N	N	Top of casing	+ .4		10.79	7-30-45	Abandoned; formerly drilled for an oil well; but came in dry.
207	SE¼ NE¼ sec. 12	A. W. Howell	Du,Dn	65	(?)	(?)	do	do	C,T	S,I	do	+ .2	2,051.1	13.67	7-30-45	
208	NW¼ NE¼ sec. 18	Wesley Hager	DD	17.2	15	GI,C	do	do	Cy,W	S	Edge of board in platform, west side of pump	+ .4	2,085.0	9.74	8- 4-45	
209	SE¼ SE¼ sec. 18	Bessie Massey	DD	70.0	16	GI,C	do	do	C,G	I	Top of concrete casing	0	2,098.1	20.88	8-31-45	
(210)	SW¼ NE¼ sec. 20	City of Belpre	Du	(?)	144	C	do	do	C,E	P				17	8-18-45	
211	SW¼ SE¼ sec. 24	H. C. Embry	Dr	99.0	6	GI	do	do	C,E	S	Top of casing	+2.0	2,061.8	13.00	7-30-45	
	T. 24 S., R. 17 W.															
212	NE¼ NW¼ sec. 2	H. Massey	DD	60	16	GI,C	do	do	C,G	N	Edge of casing, northeast side	0	2,091.7	13.5	7-28-45	Abandoned; formerly an irrigation well.
(213)	SW¼ NW¼ sec. 16	W. Winters	DD	20.4	8	GI	do	do	Cy,W	S	Top edge of board over well, west side	+ .5	2,114.0	17.1	8-18-45	
214	SW¼ SW¼ sec. 16	D. Britton	DD	68	24	GI	do	do	C,G	I	Top of concrete curb, west side	0	2,117.9	17.76	7-27-45	
215	SW¼ NW¼ sec. 17	A. R. Lovette	DD	37.2	(?)	C	do	do	C,E	I	High point at bend of concrete casing	+1.7	2,124.2	23.61	8- 2-45	
216	SW¼ SE¼ sec. 18	E. Cross	Dr	74.0	22	I	do	do	T,T	I	Edge of base of turbine	0	2,130.2	23.9	7-27-45	
217	NW¼ NW¼ sec. 29	J. L. Cross	DD	55.0	(?)	C	do	do	C,E	I	Top edge of opening in curb	+ .3	2,127.5	21.01	7-27-45	
218	NW¼ NE¼ sec. 31	L. F. Tallman	Dr	37.3	18	GI	do	do	Cy,W		Top of casing, south side	+ .5	2,137.5	23.12	7-20-45	Do

TABLE 16.—*Records of wells in Edwards County, Kansas—Continued*

No. on Pl. 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: Distance above (+) or below (—) land surface (feet)	Measuring point: Height above mean sea level (feet)	Depth to water level below measuring point (feet) (7)	Date of measurement	Remarks—(Yield given in gallons a minute; drawdown in feet)
	T. 24 S., R. 18 W.															
219	SE¼ NW¼ sec. 4	J. F. Eberhardt	Dn	16.5	(?)	(?)	Sand and gravel	Alluvium	P,H	D	Top of 1¼-inch pipe	+3.8	2,119.2	7.43	9- 1-45	
220	NW¼ NW¼ sec. 7	R. G. Bowman	Dn	14.0	1.5	(?)	do.	do.	N	N	Top of 1½-inch pipe, north side	+2.5	2,126.5	5.67	7- 7-44	Abandoned; formerly a domestic well. Observation well.
221	SW¼ SW¼ sec. 8	A. J. Obleness	Dn	15.8	(?)	(?)	do.	do.	P,H	D	Top of 1¼-inch pipe	+4.2	2,131.7	13.5	9- 1-45	
222	NW¼ NW¼ sec. 13	H. Wolfe	DD	44.0	12	GI	do.	Meade	C,T	I	Top of concrete casing	+ .7	2,136.9	26.63	8- 2-45	
(223)	SE¼ NW¼ sec. 25	City of Lewis	Dr	150	(?)	(?)	do.	do.	C,G	P				32	8- 6-45	
224	SE¼ NW¼ sec. 25	do.	Dr	150	(?)	(?)	do.	do.	T,E	P				32	8- 6-45	
(225)	NW¼ NW¼ sec. 28	Thomas White	Dr	47.0	5.5	GI	do.	do.	N	D	Top of casing	— .5	2,156.7	23.43	8- 1-45	Not completed for use on Aug. 1, 1945.
226	NW¼ NE¼ sec. 32	L. Malin	DD	31.2	(?)	(?)	do.	do.	Cy,W	N	Top edge of iron beam across well	0	2,163.3	23.05	8- 2-45	Abandoned; formerly a domestic well.
227	NW¼ NE¼ sec. 35	Geo. C. Fox	DD	36.4	(?)	(?)	do.	do.	Cy,G	I	Top of steel cross-piece, south side	0	2,151.8	29.70	7-20-45	
	T. 24 S., R. 19 W.															
228	SW¼ SE¼ sec. 2	E. D. Delander	DD	25.0	30,34	IC	do.	Alluvium	C,T	I	Lower edge of board across well	+ .2	2,140.9	13.09	8-14-45	
229	SW¼ SW¼ sec. 2	do.	DD	21.4	16	GI	do.	do.	C,G	I	Top edge of board over well	+ .6	2,140.7	13.05	8-14-45	
(230)	NW¼ NE¼ sec. 9	Robert Burcher	Dr	37.7	8	GI	do.	do.	Cy,W	S	Top of 8-inch casing, east side	+1.3	2,163.8	9.84	7-18-45	
231	NE¼ SE¼ sec. 9	School district	Dr	27.0	5	I	do.	do.	Cy,W	D	Top of casing, north side	0	2,160.4	15.30	7-19-45	
232	NE¼ NE¼ sec. 17	E. H. Smith	Dr	60.6	6	GI	Sand	Ter. deposits	Cy,W	D,S	do.	+ .8	2,201.3	43.55	7-18-45	

233	SW¼ SE¼ sec. 21	H. M. Montgomery	Du	23.2	(?)	(?)	Sand and gravel	Alluvium	C,G	I	Top of board covering casing	—9.0	2,164.3	1.5	7-17-45	
234	SW¼ SE¼ sec. 21	do	Dr	18.0	5	GI	do	do	P,H	S	Top of casing	+2.4	2,164.7	12.1	7-17-45	
235	NW¼ SE¼ sec. 22	Washburn College	DD	29	16	GI	do	do	C,G	I	Top of steel curb, northeast side	+ .3	2,154.8	8.01	7-19-45	
236	SW¼ SE¼ sec. 24	J. Rehmert	Dn	15.3	(?)	(?)	do	do	P,H	D	Top of 1¼-inch pipe	+5.6	2,151.3	12.45	8- 1-45	
237	SE¼ NW¼ sec. 26	M. Shouse	Dr	13.6	5	GI	do	do	Cy,W	S	Top of wood pipe clamp	+ .5	2,156.1	9.29	7-17-45	
238	NW¼ SW¼ sec. 27	H. G. Ropp	Du	9.6	6	GI	do	do	N	N	Top of 2-inch plank on concrete	+ .4	2,159.4	8.32	7-17-45	Abandoned; formerly a stock well.
239	SW¼ SW¼ sec. 28	N. Kindsvater-Eslinger	DD	23.7	60,16	C,I	do	do	N	N	Top of concrete curb, south side	— .1	2,173.3	10.9	8-15-45	Abandoned; formerly an irrigation well.
240	SW¼ SW¼ sec. 28	do	DD	24.5	22,16	GI,I	do	do	C,G	I	Top of iron casing	+ .4	2,173.0	10.76	8-15-45	
241	SE¼ SE¼ sec. 29	G. E. Eslinger	DD	23.8	24	I	do	do	C,G	I	Top edge of board covering	+ .2	2,172.7	12.25	8-13-45	
242	NW¼ SE¼ sec. 34	J. Lacy	B	22	14	GI	do	do	C,T	I	Top of pipe flange	—5.5	....	1.77	7-25-45	Reported yield, 500; drawdown 21 after 3 minutes of pumping.
243	SW¼ NW¼ Sec. 35	M. Shouse	DD	28.0	16	GI	do	do	C,T	N	Top of concrete curb, north side	+ .1	2,162.3	6.38	7- 7-44	Irrigation well, not used since 1943.
	T. 24 S., R. 20 W.															
244	SW¼ NW¼ sec. 9	School district	Dr	67.0	5	GI	Sand	Ter. deposits	Cy,H	D	Top of casing, east side	+ .3	2,273.7	58.32	8-15-45	
(245)	SW¼ SE¼ sec. 11	B. B. Souster	Dr	33.0	5	GI	do	do	Cy,W	S	Top of pipe clamp, north side	+ .1	2,223.1	28.88	7-16-45	
246	NE¼ NE¼ sec. 16	J. Schnastock	Dr	52.8	4.5	GI	do	do	Cy,W	S	Top of casing, northeast side	+4.1	2,243.8	34.05	8- 9-44	
247	SW¼ NW¼ sec. 21	Emma Kuhn	Dr	46.0	(?)	(?)	do	do	Cy,W	S	Top of wood clamp, west side	+ .6	2,251.9	37.1	8- 8-45	
248	SW¼ SW¼ sec. 30	Oliphant	Dr	19.4	12	GI	do	do	Cy,W	S	Top of tin covering casing, northeast side	+1.1	2,255.6	17.76	8-13-45	
249	SE¼ SE¼ sec. 31	G. M. Boehm	Dr	30.2	5	GI	do	do	Cy,W	N	Top of casing	+2.1	2,243.7	13.1	12- 7-45	Abandoned; formerly a stock well.
250	SW¼ SE¼ sec. 32	M. A. Rapp and E. B. Hoops	Dr	29.5	5.5	GI	do	do	Cy,W	S	do	+3.7	2,242.7	19.85	8- 8-45	
251	NE¼ NE¼ sec. 34	....	DD	47.0	5	GI	do	do	Cy,W	N	Top of concrete cover, west side	+ .2	2,221.2	25.4	12- 7-45	Do
252	SE¼ NW¼ sec. 36	C. R. Piburn	Dr	23.3	5	GI	Sand and gravel	Alluvium	Cy,W	N	Top of casing, north side	+1.4	2,196.6	13.11	7-17-45	Do
	T. 25 S., R. 16 W.															
253	NW¼ SW¼ sec. 4	L. P. Wilson	Dr	63.0	6	GI	do	Meade	N	N	Top of casing, west side	+ .5	2,081.5	7.10	7-20-45	Abandoned; formerly used for test oil drilling.
254	NW¼ NW¼ sec. 20	A. A. Mayhew	Du	15	60	I	do	do	C,T	N	Top of casing, southeast side	+ .5	2,083.6	6.73	7-30-45	Abandoned; formerly an irrigation well.

TABLE 16.—*Records of wells in Edwards County, Kansas*—Continued

No. on Pl. 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: Distance above (+) or below (—) land surface (feet)	Measuring point: Height above mean sea level (feet)	Depth to water level below measuring point (feet) (7)	Date of measurement	Remarks— (Yield given in gallons a minute; drawdown in feet)
	T. 25 S., R. 16 W.															
255	SW¼ NE¼ sec. 24	Elmer Pratt	Dn	34.7	(?)	(?)	Sand and gra el	Meade	Cy,H	S	Edge of board in platform, south side of pump	+0.4	2,061.1	10.27	8- 3-45	
(256)	NW¼ SW¼ sec. 27	F. M. Cudney	Dr	40	(?)	(?)	do	do	Cy,W	D		0	2,084.0	18	8-28-45	
257	NE¼ SE¼ sec. 31	F. B. Mayhew	Dr	70	15	GI	do	do	C,T	I	Top of steel casing, east side	0	2,089.5	15.81	8- 3-45	Estimated yield, 1,000; drawdown 14. Last used in 1942.
258	NW¼ NW¼ sec. 36	Tom Hamilton	Dn	11.0	(?)	(?)	do	do	P,H	N	Top of 1¼-inch pipe	+2.8	2,057.1	9.55	8- 4-45	Abandoned; formerly a stock well.
	T. 25 S., R. 17 W.															
259	NE¼ SE¼ sec. 1	Charley Johnson	DD	72	102	C	do	do	T,T	I	Edge of space in board covering east side	+ .6	2,101.6	11.65	7-30-45	Reported yield, 1,800; drawdown 15 after 24 hours of pumping.
260	SW¼ NW¼ sec. 19	J. P. Caroll	Dr	37.9	10	C	do	do	Cy,W	N	Top of casing, west side	0	2,160.3	34.17	7-20-45	Abandoned; formerly a domestic well.
261	SW¼ SW¼ sec. 22	L. McCarty	Dn	20.4	(?)	N	do	do	N	N	Top of 2-inch pipe	+2.2	2,116.2	6.66	7-28-45	Abandoned; formerly a stock well.
262	SE¼ NW¼ sec. 28	C. A. Milhon	DD	64.0	(?)	(?)	do	do	C,G	I	Top of concrete curb	+ .3	2,123.4	9.02	7-28-45	Reported yield, 1,000; drawdown 5 after 24 hours of pumping.
263	SW¼ SE¼ sec. 34	C. W. Fisher	DD	79.0	16	GI	do	do	C,G	I	Top of concrete curb, west side	0	2,116.6	16.69	7-31-45	Estimated yield, 350; drawdown 20 after 24 hours of pumping.
	T. 25 S., R. 18 W.															
264	SW¼ NW¼ sec. 6	City of Kinsley	Dr	86	18	I	do	do	T,E	P				41		Reported yield, 600; drawdown 15.
(265)	SW¼ NW¼ sec. 6	do	Dr	72	18	I	do	do	T,E	P				32		Do
(266)	SE¼ SE¼ sec. 16	H. Schaller	Dn	40	(?)	(?)	do	do	Cy,W	D		0	2,175.1	32	8-28-45	

267	SW cor. NW sec. 19		Dr	37.2	3	I	do	do	N	In	Top of casing, south side	+ .3	2,190.1	19.66	7-8-44	Well, formerly shot for seismograph observations. Water level is questionable.
268	NW¼ NW¼ sec. 27	Federal Land Bank	Dr	60	7	I	do	do	Cy,G	In	Top of pipe clamp, north side	+1.0	2,169.1	22.91	7-19-45	Well was drilled for oil test.
269	NW cor. sec. 30		Dr	44.9	3	I	do	do	N	In	Top of casing, north side	+1.2	2,194.1	29.06	7-11-44	Well was formerly shot for seismograph observations.
270	SW¼ NW¼ sec. 34	E. J. Huff	DD	29.3	(?)	(?)	do	do	C,T	I	Top of steel casing, east side	0	2,168.9	21.5	7-31-45	
	T. 25 S., R. 19 W.															
271	NE¼ NE¼ sec. 4	G. E. Smith	DD	29.0	(?)	GI,C	do	Alluvium	C,G	I	Lower edge of board across well, north side	+ .8	2,170.4	6.54	8-11-45	Battery of 4 wells, connected in series. Reported yield, 1,500.
272	SW¼ NE¼ sec. 5	E. F. Lippoldt	DD	25.0	16,44	GI,C	do	do	C,E	I	Top of concrete curb, west side	—6.0	2,178.5	9.68	8-11-45	Battery of 3 wells. Reported yield, 1,100; drawdown 12 after 24 hours of pumping.
273	SW¼ NE¼ sec. 5	do	Du	17	16	GI	do	do	C,E	I	Top edge of flange on pump pipe, southwest side	— .5	2,172.7	1.6	8-11-45	Battery of 3 wells, not used in the last 6 years. Reported yield, 850; drawdown 17 after 24 hours of pumping. Well filled with mud, questionable depth measurement.
274	NW¼ NE¼ sec. 6	Rose Welsh	Dr	22.9	5	GI	do	do	Cy,W	S	Top of casing, south side	+1.6	2,187.6	11.45	7-18-45	
275	SE¼ SE¼ sec. 6	R. Schmidt	Dr	18.3	5	GI	do	do	P,H	N	Hole in outer rim of pump base	+2.2	2,184.3	11.63	7-19-45	Abandoned; formerly a domestic well.
276	SW¼ NE¼ sec. 8	Mrs. E. M. Lockwood	DD	39.0	18	GI	do	do	C,G	I	Top of casing, northeast side	—9.2	2,177.2	0.14	8-11-45	Reported yield, 1,100; drawdown 8 after 24 hours of pumping.
277	NE¼ NE¼ sec. 9	J. J. Tubbs	Dn	9.0	(?)	(?)	do	do	P,H	S	Top of 1¼-inch pipe	+2.0	2,174.2	5.79	7-16-45	
278	NW¼ SW¼ sec. 10	E. F. Eslinger	Dn	11.2	(?)	(?)	do	do	P,H	S	do	+2.1	2,177.8	8.36	7-25-45	
(279)	SW¼ SE¼ sec. 10	Kinsley Golf Club	Dn	13.0	(?)	(?)	do	do	P,H	D	do	+2.3	2,181.2	9.64	7-16-45	
280	SE¼ NW¼ sec. 11	E. F. Eslinger	B	11.7	8	GI	do	Meade	Cy,W	S	Top of tin cover, south side	0	2,170.8	6.29	7-25-45	
281	SW¼ SW¼ sec. 14	D. C. Bearman	Du	24.6	48	C	do	do	Cy,G	I	Top of concrete curb, west side	0	2,193.1	19.37	7-25-45	
282	SE¼ NE¼ sec. 16	G. J. Smith	Dn	13.4	(?)	(?)	do	Alluvium	P,H	N	Top of 1¼-inch pipe	+2.0	2,181.2	6.04	7-19-45	Abandoned; formerly a domestic well.
283	NE¼ NW¼ sec. 17	T. Miller	Dn	13.0	(?)	(?)	do	do	P,H	N	do	+2.8	2,185.1	7.35	7-19-45	Abandoned; formerly a stock well.

TABLE 16.—*Records of wells in Edwards County, Kansas—Continued*

No. on Pl. 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: Distance above (+) or below (—) land surface (feet)	Measuring point: Height above mean sea level (feet)	Depth to water level below measuring point (feet) (7)	Date of measurement	Remarks— (Yield given in gallons a minute; drawdown in feet)
	T. 25 S., R. 19 W.															
284	NE¼ NW¼ sec. 17	T. Miller	DD	50.0	22	GI	Sand and gravel	Alluvium	T,T	N	Top of casing, north side	0	2,188.1	9.06	8-10-45	Abandoned irrigation well; not in use for the last 4 years.
285	SE¼ NE¼ sec. 18	S. W. Kallaus	Du	23.4	22	I	do	do	C,T	N	Top of casing, west side	0	2,188.3	6.37	8-10-45	Abandoned; formerly an irrigation well.
286	SW¼ SE¼ sec. 19	W. Charlet	B	8.9	8	I	do	do	Cy,W	S	Top of outer casing, northwest side	— .6	2,197.4	5.21	7-21-45	
287	SE¼ SE¼ sec. 19	Wm. Charlet	B	14.8	8	GI	do	do	Cy,T	S,I	Top of casing, south side	+ .5	2,201.0	10.07	7-21-45	
288	NW¼ SW¼ sec. 20	do	Dr	11.0	8	GI	do	do	Cy,W	N	Top of casing	+ .6	2,193.2	5.61	7-16-45	Abandoned; formerly a stock well.
289	SW¼ SW¼ sec. 20	Mrs. L. Prichard	Dr	12.6	5	GI	do	do	N	N	Top of casing, west side	+1.0	2,198.2	8.13	7-21-45	Do
290	NE cor. sec. 23		Dr	42.8	3	I	do	Meade	N	N	Top of casing, north side	+1.0	2,198.2	30.87	7- 8-44	Abandoned; well was formerly shot for seismograph observations.
291	SW¼ NW¼ sec. 23		J	27.4	(?)	(?)	do	do	N	N	Top of 3-inch pipe	+2.2	2,199.1	23.69	7-25-45	Abandoned; formerly an oil test well.
292	Cent. W. line SW sec. 23		Dr	38.5	3	I	do	do	N	N	Top of casing, south side	+ .5	2,194.7	20.22	7-19-44	Abandoned; well was formerly shot for seismograph observations.
293	SE¼ SW¼ sec. 23		Dr	50	3	I	do	do	N	N	Top of casing, north side	+1.8	2,210.5	37.22	7-11-44	Do
294	SE¼ SW¼ sec. 23		J	47.2	3	I	do	do	N	N	Top of 3-inch pipe	+3.3	2,213.1	39.08	7-25-45	Abandoned; formerly an oil test well.
295	Cent. N. Line sec. 24		Dr	50	3	I	do	do	N	N	Top of casing, north side	+ .9	2,197.7	34.34	7- 8-44	Abandoned; well was formerly shot for seismograph observations.

296	SW¼ NW¼ sec. 24		J	30.2	3	I	do	do	N	N	Top of 3-inch pipe	+ .2	2,196.8	28.02	7–25–45	Abandoned; formerly an oil test well.
297	NE cor. SE sec. 24		Dr	40.8	3	I	do	do	N	N	Top of casing, north side	+1.4	2,188.8	39.23	7– 8–44	Abandoned, well was formerly shot for seismograph observations.
298	SW¼ SW¼ sec. 24		Dr	50	3	I	do	do	N	N	Top of casing, south side	+ .1	2,198.9	28.29	7–11–44	Do
299	NE¼ NW¼ sec. 31	W. Charlet	B	13.8	6	GI	do	do	Cy,W	S	Top of barrel casing, east side.	+ .4	2,213.2	10.37	7–21–45	
300	SW¼ NW¼ sec. 32	do	B	14.8	8	I	do	do	Cy,W	N	Top of inside casing, north side	— .5	2,209.0	9.8	7–21–45	Abandoned; formerly a stock well.
	T. 25 S., R. 20 W.															
301	SW¼ NW¼ sec. 1	C. Wartman	Dr	23.9	5	GI	do	Alluvium	Cy,W	N	Top of pipe, east side	+1.0	2,202.2	14.31	7–19–45	Do
302	SW¼ NW¼ sec. 2	J. Wartman, Sr	Dr	28.8	5	GI	Sand	Ter. deposits	Cy,W	N	Top of ½-inch hole in iron platform, northeast side	+ .5	2,222.8	25.6	7–19–45	Do
303	SE¼ SW¼ sec. 2	do	Dr	30.3	5	GI	do	do	Cy,W	N	Top of casing, south side	+1.1	2,215.4	21.6	8–18–45	Do
304	SE¼ SE¼ sec. 10	N. C. Wartman	Dr	34.0	5	GI	do	do	Cy,W	S	do	+ .3	2,224.3	18.45	7–18–45	
305	SW¼ NW¼ sec. 11	School district	Dr	40.2	5	GI	do	do	Cy,H	D	Top of casing, east side	+ .8	2,225.0	24.7	7–18–45	
306	NW¼ NE¼ sec. 12	O. Brehm	Du	16.8	(?)	(?)	Sand and gravel	Alluvium	N	N	Edge of platform, east side	+ .6	2,201.7	15.3	7–18–45	Abandoned; formerly a stock well.
307	SE¼ NE¼ sec. 13	Henry Tasset	DD	23	24	GI,I	do	do	T,G	N	Top of casing, east side	+1.4	....	9.86	8– 9–45	Abandoned; formerly an irrigation well. Reported yield, 800; drawdown 8 after 10 minutes of pumping.
(308)	SW¼ SE¼ sec. 16	J. Bosgell	Dr	74.0	5	GI	Sand	Ter. deposits	Cy,W	S	Top of casing, west side	+ .6	2,251.0	31.5	7–19–45	
309	SW¼ NE¼ sec. 17	Emma Hedges	Dr	28.4	5.5	GI	do	do	Cy,W	S	Top of pipe, east side	+1.4	2,240.8	12.32	8– 7–45	
310	SE¼ NE¼ sec. 20	D. O. Brown	Dr	111.5	5.5	GI	do	do	N	N	Top of casing	+1.2	2,294.5	66.37	8– 7–45	Abandoned; formerly a stock well.
311	SE¼ NE¼ sec. 26	N. Schaller	DD	28.2	16	GI	Sand and gravel	Alluvium	C,G	I	Hole in cover below pipe, northeast side	—7.2	2,207.8	2.65	7–10–45	Reported yield, 1,500; drawdown 8 after 24 hours of pumping.
312	SW¼ SE¼ sec. 29	E. Craig	Dr	22.1	6	GI	Sand	Ter. deposits	Cy,W	N	Top of casing, west side	+2.2	2,230.7	13.05	8– 7–45	Abandoned; formerly a stock well.
313	NE¼ NE¼ sec. 34	A. Froetschner	Du	22.4	22	I	Sand and gravel	Alluvium	C,T	N	Top edge of bar supporting pump, north side	+2.0	2,214.2	10.4	8–10–45	Abandoned; formerly an irrigation well.
314	SW¼ SW¼ sec. 34	M. Shouse	Du	25.6	22	I	do	do	T,G	I	Top of casing	+1.4	2,220.7	7.78	8– 6–45	Reported yield, 600; drawdown total depth after 8 hours of pumping.

TABLE 16.—*Records of wells in Edwards County, Kansas—Continued*

No. on Pl. 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: Distance above (+) or below (—) land surface (feet)	Measuring point: Height above mean sea level (feet)	Depth to water level below measuring point (feet) (7)	Date of measurement	Remarks—(Yield given in gallons a minute; drawdown in feet)
	T. 26 S., R. 16 W.															
315	NW¼ NE¼ sec. 4	H. L. Cudney	Du,Dn	32+	(?)	(?)	Sand and gravel	Meade	N	I	Edge of hole in board cover	0	2,083.1	18.00	8- 4-45	
316	SW¼ SW¼ sec. 17	H. W. Ellis	Dn	39.0	(?)	(?)	do	do	P,H	D	Top of pump, east side	+3.1	2,083.4	11.37	7-30-45	
	T. 26 S., R. 17 W.															
317	SE¼ SW¼ sec. 3	Fellsburg Cemetery	Du,Dn	58	(?)	(?)	do	do	Cy,W	I	....	....	2,124.4	19	7-30-45	
318	NW¼ NW¼ sec. 4	E. E. Randall	Du	24.2	96	I	do	do	N	I	Top of casing, north side	+ .2	2,130.6	19.98	8- 3-45	Irrigation well, not finished at time of measurement.
319	NE¼ SW¼ sec. 21	E. M. Johnson	Dr	26+	12	I	do	do	N	N	Top of ½-inch iron plate, east side	+1.0	2,131.8	23.26	8- 1-45	Formerly an oil test well. Depth of well was not reached because of obstacle in the pipe.
320	NE¼ NW¼ sec. 27	Ethel Watson	Dr	19.2	(?)	(?)	do	do	N	N	Land surface	0	2,123.3	19.6	8- 1-45	Abandoned; well was formerly a seismograph observation hole.
	T. 26 S., R. 18 W.															
321	NW¼ SE¼ sec. 1	I. T. Newson	Dr	57.6	6.5	I	do	do	N	N	Top of casing, east side	+ .3	2,142.0	14.40	7-31-45	Abandoned; formerly an oil test well.
322	NW¼ SW¼ sec. 2	Louis Nehrt	Dr	25.9	6	GI	do	do	Cy,W	D	Top of board platform	+ .4	2,154.5	20.48	7-31-45	
323	NE¼ NW¼ sec. 5	Mrs. S. R. Woods	......	55.0	(?)	(?)	do	do	T,T	N	Edge of hole in base of turbine, west side	+1.0	2,193.4	37.26	7-27-45	Abandoned; formerly an irrigation well.
324	NW¼ NE¼ sec. 12	A. J. Sewing	Dr	76.0	18	GI	do	do	T,G	I	Top of casing, west side	+ .8	2,214.2	46.28	8- 2-45	Reported yield, 1,000; drawdown 28.
325	SW¼ SW¼ sec. 13	B. Bordewick	Dr	32.3	3	I	do	do	N	N	Top of 3-inch pipe	0	2,154.3	24.65	8- 3-45	Abandoned; well was formerly shot for seismograph observations.

326	SW¼ SW¼ sec. 35	Glen Cooper	Dr	76.0	18	GI	do	do	T,G	I	Top of base flange, west side	0	2,170.5	33.21	8- 1-45	Reported yield, 1,400; drawdown 9.
	T. 26 S., R. 19 W.															
327	SE¼ NW¼ sec. 6	D. V. Lewis	B	21.0	8	I	do	do	Cy,W	S	Top of casing, west side	+2.8	2,216.6	13.55	7-23-45	
328	NE¼ NE¼ sec. 15	Leo R. Craft	Dr	40.3	6	GI	do	do	Cy,H	S	do	+ .5	2,220.9	36.90	8- 2-45	
329	NE¼ NE¼ sec. 16	Emma Peters	Dr	52.0	6	GI	do	do	Cy,T	N	Top of pipe clamp, west side	+ .8	2,228.5	37.70	7-19-45	Abandoned; formerly a stock well.
330	SW¼ SE¼ sec. 18	G. C. McLean	B	51.3	5	I	do	do	Cy,W	S	do	+4.6	2,248.8	39.37	7-24-45	
(331)	NE¼ NE¼ sec. 21	J. W. Peterie	Dr	47.7	6	GI	do	do	Cy,W	D,S	Top of board platform, east side	+1.0	2,225.1	34.2	8- 2-45	
332	SW¼ SW¼ sec. 28	School district	Dn	45	5	GI	do	do	Cy,H	D	....	....	2,241.1	40	....	
333	NE¼ SW¼ sec. 29	R. W. Scott	Dn	44.6	(?)	(?)	do	do	N	N	Top of 2-inch pipe	+1.8	2,246.0	40	7-23-45	Do
334	SW¼ SW¼ sec. 30	C. Barlow	Dn	54.1	(?)	(?)	do	do	N	N	do	+5.9	2,261.4	23.05	7-23-45	Do
335	SW¼ SW¼ sec. 33	Bethel Cemetery	Dr	59.2	6	I	do	do	Cy,W	I	Top of casing, southwest side	+ .8	2,245.9	49.37	7-26-45	
	T. 26 S., R. 20 W.															
336	SW¼ SE¼ sec. 3	M. Shouse	Du	25.8	30	C	do	Alluvium	T,T	I	Top of casing, west side	+1.0	2,222.2	8.41	8- 6-45	Reported yield, 1,200; drawdown total depth after 10 hours of pumping. Not in use. Struck pump cylinder when measuring depth.
337	SW¼ SW¼ sec. 4	L. Erickson	DD	31.4	22	C,I	do	do	T,T	I	Top of curb, north side	+1.2	2,228.8	9.57	8- 9-45	Reported yield, 1,200; drawdown 12 after 24 hours of pumping. Not in use.
338	NW¼ NE¼ sec. 5	Carl Froetschner	DD	31.6	22	I	do	do	C,T	I	Top of casing, south side	+1.8	2,226.5	9.05	8-17-45	Estimated yield, 800.
339	NW¼ NW¼ sec. 5	A. Libhart	DD	31.5	24	GI	do	do	C,T	N	Top of curb, west side	0	2,231.5	11.4	8- 6-45	Abandoned since 1938; formerly an irrigation well.
340	NE¼ SE¼ sec. 7	L. H. Lightcap	DD	20.0	22	I	do	do	T,T	I	Top of casing, south side	+1.0	2,237.8	10.6	8-17-45	Reported yield, 450; drawdown 6 after 3 hours of pumping.
341	SW¼ SE¼ sec. 12	Susie Ware	Dr	23.4	8	GI	do	Meade	Cy,W	S	Top of casing, west side	+1.5	....	20.13	7-24-45	
342	NE¼ NW¼ sec. 13	Jennie M. Blank	Dr	21.9	8	GI	do	do	Cy,W	S	Top of casing, north side	+ .4	....	17.75	7-24-45	

TABLE 16.—*Records of wells in Edwards County, Kansas—Concluded*

No. on Pl. 1	LOCATION	Owner or tenant	Type of well (2)	Depth of well (feet) (3)	Diameter of well (in.) (4)	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: Distance above (+) or below (—) land surface (feet)	Measuring point: Height mean above sea level (feet)	Depth to water level below measuring point (feet) (7)	Date of measurement	Remarks— (Yield given in gallons a minute; drawdown in feet)
	T. 26 S., R. 20 W.															
343	NE¼ SE¼ sec. 18	H. Wetzel	DD	47.5	22	I	Sand and gravel	Alluvium	T,T	I	Top of casing, west side	+0.9	2,241.2	7.42	8- 6-45	Reported yield, 1,200; drawdown 14 after 24 hours of pumping.
344	SE¼ SE¼ sec. 18	do	Du	29.8	22	I	do	do	T,G	I	Top of casing, east side	+ .2	2,243.1	8.42	8- 7-45	
345	SE¼ SE¼ sec. 18	do	Du	46.4	24	GI	do	do	C,T	I	Top of casing, south side	+1.2	2,246.0	10.9	8- 8-45	Reported yield, 1,500; drawdown 18 after 2 hours of pumping.
346	NE¼ NE¼ sec. 19	E. H. Wetzel	DD	22.0	15	GI,I T	do	do	T,T	I	Edge of board laid across pit	+ .4	2,244.3	8.39	8- 8-45	Reported yield, 450; drawdown 12.
347	NE¼ NE¼ sec. 19	do	DD	16.4	15	I,C	do	do	T,T	I	Top of board or curb, north side	+ .6	2,244.1	7.84	8- 8-45	
348	NE¼ NW¼ sec. 19	Mrs. S. Israel	Du	23.0	20	I	do	do	C,G	I	Top of casing, north side	—5.5	2,245.7	4.78	8- 7-45	
349	NE¼ NW¼ sec. 19	do	Du	21.2	22	I	do	do	C,T	I	do	+ .4	2,246.3	8.33	8- 7-45	
350	SE¼ NE¼ sec. 19	E. H. Wetzel	Du	26.0	22	I	do	do	T,T	I	Top of casing, south side	+1.2	2,247.2	9.53	8- 7-45	Reported yield, 1,000; immediate drawdown 12.
351	SE¼ SW¼ sec. 19	R. Speck	Dr	20	20	GI	do	do	C,G	I	Top of casing, east side	—4.0	2,261.5	8.38	10-28-38	Reported yield, 500.
352	NW¼ NW¼ sec. 20	Herbert Wetzel	DD	29.6	19	GI	do	do	T,T	I	do	+1.6	2,244.6	8.16	8-17-45	Reported yield, 800; drawdown 5 after 10 hours of pumping.
353	SE¼ SW¼ sec. 21	M. Muletor	Dn	18.2	(?)	(?)	do	do	Cy,H	N	Top of concrete curb	+1.2	2,253.9	10.04	7-21-45	Abandoned; formerly a domestic well.
354	SW¼ SE¼ sec. 28	R. W. Robbins	Dr	40	5	I	do	Meade	Cy,W	S	Top of casing, east side	+ .6	2,249.9	12.85	7-23-45	

355	SW¼ NE¼ sec. 29	W. E. Broadie	Du	30.0	30	C	do	Alluvium	T,T	I	Top of concrete curb, west side	+1.5	2,251.7	11.62	8- 6-45	Reported yield, 1,000; drawdown 8 after 3 minutes of pumping.
356	NW¼ SE¼ sec. 30	G. O. Spiers	Du	27.7	22	GI	do	do	C,T	I	Edge of iron plate, south side	0	2,252.3	6.35	8- 8-45	
357	NW¼ SE¼ sec. 30	do	Du	30.0	26	GI	do	do	T,T	I	Top of casing, north side	+1.7	2,251.6	7.59	8- 6-45	Drawdown 18 after 6 hours of pumping.
358	NW¼ NW¼ sec. 34	R. W. Robbins	Dr	31.6	6	GI	do	do	Cy,W	S	Top of concrete, east side	+1.7	2,231.6	27.60	7-26-45	
359	NW¼ NW¼ sec. 36	do	Dr	22.5	5	I	do	do	Cy,W	S	Top of casing, south side	+1.4	2,265.0	30.88	7-23-45	
360	SE¼ SE¼ sec. 36	Edward R. Miller	Dr	51.5	6	I	do	do	Cy,W	D	do	+ .5	2,257.9	40.97	7-26-45	

1. Well number in parentheses indicates that analysis of water is given in table.
2. B, bored well; DD, dug and drilled well; Dn, driven well; Dr, drilled well; Du, dug well; J, jetted.
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; B, Brick.
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; B, bucket and rope. 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

Listed in the following pages are the logs of 144 wells and test holes in Pawnee and Edwards Counties, including 133 test holes drilled by the State Geological Survey of Kansas. The numbers of the logs correspond to the numbers used in the diagrammatic cross section (Pl. 3).

Logs entitled "sample log" are those for which the well cuttings were collected and studied. A "driller's log" is a written log obtained from a driller or from some other source.

1. *Sample log of test hole at the NW cor. sec. 3, T. 20 S., R. 16 W. Surface altitude, 2,021.4 feet.*

	Thickness, feet	Depth, feet
Road fill	2.5	2.5
QUATERNARY—Pleistocene		
Terrace deposits		
Silt, brown, dense	3.5	6
Clay, silty, tan and buff; contains white caliche	54	60
Clay, silty, tan; contains white caliche and fine to medium sand	6	66
Gravel, fine to medium, tan	2	68
CRETACEOUS—Gulfian		
Dakota formation		
Clay, silty, tan and yellow	4	72

2. *Sample log of test hole at the SW cor. NW¼ sec. 3, T. 20 S., R. 16 W. Surface altitude, 2,009.7 feet.*

	Thickness, feet	Depth, feet
Road fill	3	3
QUATERNARY—Pleistocene		
Terrace deposits		
Silt, compact, brown	3	6
Clay, silty, tan, contains white caliche	51	57
Clay, silty, buff and tan; contains white caliche	4	61
Clay, silty, buff and tan; contains fine to medium sand and white caliche	4	65
Gravel, fine to coarse, contains tan silty clay	3	68
Clay, silty, buff and tan; contains fine to medium sand and white caliche	10	78
Clay, silty, tan and buff; contains fragments of brown ironstone	7	85
CRETACEOUS—Gulfian		
Dakota formation		
Clay, silty, light gray and tan; contains fragments of brown to tan sandstone	5	90

3. *Sample log of test hole at the SW cor. sec. 3, T. 20 S., R. 16 W. Surface altitude, 2,026.9 feet.*

	Thickness, feet	Depth, feet
Road fill	3	3
QUATERNARY—Pleistocene		
Terrace deposits		
Silt, brown	3	6
Clay, silty, dark tan	4	10
Clay, silty, tan and light brown; contains white and tan caliche	30	40
Clay, silty, buff; contains fragments of white caliche	35	75
Clay, silty, dark tan and dark gray	13	88
Clay, silty, brown and tan with dark red and yellow stains, and white gypsum	8	96
CRETACEOUS—Gulfian		
Dakota formation		
Clay, silty, gray; contains red and yellow sandstone	4	100

4. *Sample log of test hole at the NW cor. sec. 18, T. 20 S., R. 16 W. Surface altitude, 2,078.2 feet.*

	Thickness, feet	Depth, feet
Road fill	3	3
QUATERNARY—Pleistocene		
Terrace deposits		
Silt, tan and gray	3.5	6.5
Clay, silty, brown	5.5	12
Clay, silty, buff and tan; contains fragments of caliche,	6	18
CRETACEOUS—Gulfian		
Graneros shale		
Shale, tan and gray, having red stains	2	20
Shale, gray and tan	5	25

5. *Sample log of test hole at the SE cor. SW¼ sec. 28, T. 20 S., R. 16 W. Surface altitude, 2,030.5 feet.*

	Thickness, feet	Depth, feet
Road fill and soil, gray-brown	3	3
QUATERNARY—Pleistocene		
Terrace deposits		
Silt, gray brown to yellow gray	5	8
Silt, blocky, light brown	5	13
Silt, tan to light buff; contains nodular caliche	95	108
Gravel, coarse to fine; contains sand and silt; buff and tan	3	111
CRETACEOUS—Gulfian		
Dakota formation		
Clay, micaceous, light blue gray	5	116

6. *Sample log of test hole at the NW cor. sec. 24, T. 20 S., R. 17 W. Surface altitude, 2,053.2 feet.*

	Thickness, feet	*Depth, feet*
Soil, dark gray	4	4
QUATERNARY—Pleistocene		
Terrace deposits		
Clay, silty, tan and gray	5	9
Clay, silty, brown	2	11
Clay, silty, tan and buff; contains caliche	62	73
CRETACEOUS—Gulfian		
Dakota formation		
Clay, silty, buff with faint red stains	5	78

7. *Sample log of test hole at the NE cor. sec. 27, T. 20 S., R. 17 W. Surface altitude, 2,057.5 feet.*

	Thickness, feet	*Depth, feet*
Road fill	2	2
QUATERNARY—Pleistocene		
Terrace deposits		
Clay, silty, gray to brown	3	5
Clay, silty, tan	4	9
Clay, silty, brown	3	12
Clay, silty, tan; contains white caliche and very fine sand	48	60
Silt, buff; contains fine to coarse sand and white caliche,	21	81
Clay, silty, tan and gray; contains fine to medium sand,	8	89
CRETACEOUS—Gulfian		
Dakota formation		
Clay, silty, tan and yellow; contains fragments of ironstone	5	94

8. *Sample log of test hole at the NE cor. sec. 33, T. 20 S., R. 17 W. Surface altitude, 2,069.3 feet.*

	Thickness, feet	*Depth, feet*
Road fill	2	2
QUATERNARY—Pleistocene		
Terrace deposits		
Clay, silty, dark gray	5	7
Clay, silty, tan and buff	7	14
Clay, silty, tan and brown; contains fine sand	2	16
Clay, silty, tan and brown; contains white caliche	9	25
Clay, silty, tan and buff; contains white caliche	53	78
CRETACEOUS—Gulfian		
Dakota formation		
Clay, tan and light gray, mottled red	2	80

9. *Sample log of test hole at the SW cor. SE¼ sec. 29, T. 20 S, R. 18 W. Surface altitude, 2,140.0 feet.*

	Thickness, feet	Depth, feet
Road fill	2	2
QUATERNARY—Pleistocene		
Terrace deposits		
Clay, silty, brown and gray	3	5
Clay, silty, brown and tan	2	7
Clay, silty, buff; contains lime-cemented zones	1	8
CRETACEOUS—Gulfian		
Greenhorn limestone		
Limestone, coarsely crystalline, cream to light tan, having red stains	2	10

10. *Sample log of test hole at the SE cor. SW¼ sec. 34, T. 20 S., R. 20 W. Surface altitude, 2,132.1 feet.*

	Thickness, feet	Depth, feet
Soil, silty, brown	3	3
QUARTERNARY—Pleistocene		
Terrace deposits		
Clay, silty, tan	5	8
Clay, silty, light yellowish tan	1.5	9.5
CRETACEOUS—Gufian		
Greenhorn limestone		
Shale; contains a few fragments of limestone and yellow limonite stains	5.5	15

11. *Sample log of test hole at the NE cor. sec. 5, T. 21 S., R. 16 W. Surface altitude, 2,025.6 feet.*

	Thickness, feet	Depth, feet
Soil, dark gray	2	2
QUATERNARY—Pleistocene		
Terrace deposits		
Silt, gray to yellow gray	6	8
Silt, blocky, brown	5	13
Silt, tan to light buff; contains a little nodular caliche,	25	25
Gravel, very coarse to fine; contains sand and buff silt,	2	27
CRETACEOUS—Gulfian		
Dakota formation		
Sandstone, medium-grained, yellow to brown; contains a little light blue-gray clay	8	35

12. *Sample log of test hole at the NE cor. sec. 8, T. 21 S., R. 16 W. Surface altitude, 2,005.1 feet.*

	Thickness, feet	Depth, feet
Road fill and soil, gray brown	4	4
QUATERNARY—Pleistocene		
Terrace deposits		
Silt, light gray to light brown	10	14
Silt, blocky, buff; contains nodular caliche	18	22
Silt, greenish gray to buff	8	40
Silt, light gray and buff. Blocky and slightly cemented between the depths of 60 and 65 feet	31	71
Silt, buff; contains much fine to medium sand and caliche	2	73
CRETACEOUS—Gulfian		
Dakota formation		
Sandstone, medium to fine-grained, brown	7	80

13. *Sample log of test hole at the NE cor. sec. 17, T. 21 S., R. 16 W. Surface altitude, 1,998.6 feet.*

	Thickness, feet	Depth, feet
Road fill and soil, gray brown	2	2
QUATERNARY—Pleistocene		
Terrace deposits		
Silt, yellow gray	3	5
Silt, light brown to buff, and fine sand	6	11
Silt, light buff; contains a few nodules of caliche	26	37
Silt, gray white; contains fine sand	6	43
Silt, green and dark gray; contains much fine to medium sand	15	58
Silt, light gray to buff, and fine to medium sand; contains a little caliche. Silt is in part slightly cemented,	66	124
Gravel, fine, and sand	4	128
Silt, light gray, and fine to medium sand	8	136
Gravel, fine to coarse, and sand; contains much buff and light-gray silt	4	140
Gravel, fine to medium, sand, and light-gray to buff silt,	5	145
CRETACEOUS—Gulfian		
Dakota formation		
Sandstone, medium- to fine-grained, white, yellow, and brown; contains yellow and light-gray clay	15	160

14. *Sample log of test hole at the NE cor. sec. 20, T. 21 S, R. 16 W. Surface altitude, 1,997.6 feet.*

	Thickness, feet	*Depth, feet*
Road fill and soil, dark gray brown	1	1
QUATERNARY—Pleistocene		
Terrace deposits		
Silt, buff gray	3	4
Silt, tan, and fine to very fine sand; contains nodular caliche	14	18
Silt, light gray, and caliche	7	25
Silt, light buff; contains very fine to fine sand and a few streaks of greenish and yellowish silt and clay	25	50
Silt, blue gray and buff, and fine sand	10	60
Silt, gray to buff, and very fine to fine sand	10	70
Silt, dark gray and green, and fine sand	5	75
Silt, buff; contains fine sand and caliche	25	100
Silt, brown and greenish gray, and fine sand; in part cemented by caliche; contains a little gravel	10	110
Sand, very fine to fine, and brown silt, friable	10	120
Silt, buff and light gray, and fine to medium sand; contains gravel	12	132
Sand, coarse to fine, and yellow-buff silt; contains fine to coarse gravel	4	136
CRETACEOUS—Gulfian		
Dakota formation		
Sandstone, medium-grained, white	14	150

15. *Sample log of test hole at the NE cor. sec. 29, T. 21 S., R. 16 W. Surface altitude, 2,007.5 feet.*

	Thickness, feet	*Depth, feet*
Road fill	2	2
QUATERNARY—Pleistocene		
Terrace deposits		
Silt, gray brown	5	7
Sand, medium to fine, and buff silt	3	10
Silt, buff, tan, and light gray	10	20
Silt, buff; contains a little caliche and some Cretaceous-derived pebbles	59	79
Gravel, coarse to fine, and sand; contains buff silt	3	82
CRETACEOUS—Gulfian		
Dakota formation		
Clay, light blue gray and mottled yellow and red	4	86

16. *Sample log of test hole at the SW cor. sec. 6, T. 21 S., R. 17 W. Surface altitude, 2,106.5 feet.*

	Thickness, feet	Depth, feet
Road fill	2	2
QUATERNARY—Pleistocene		
Terrace deposits		
Clay, silty, tan and gray	3	5
Clay, silty, brown	2	7
Clay, silty, tan and buff	9	16
Clay, silty, tan; contains black ironstone	1	17
No sample recovered	2	19
CRETACEOUS—Gulfian		
Dakota formation		
Sandstone, very fine, red and tan; contains tan silty clay and black ironstone	3	22
Clay, silty, light gray and tan; contains gray shale	6	28

17. *Sample log of test hole at the NW cor. sec. 18, T. 21 S., R. 17 W. Surface altitude, 2,098.6 feet.*

	Thickness, feet	Depth, feet
Soil, gray	4	4
QUATERNARY—Pleistocene		
Terrace deposits		
Silt, light grayish tan	3	7
Silt, tan and gray	4	11
Silt, tan and buff	9	20
CRETACEOUS—Gulfian		
Dakota formation		
Clay, silty, yellow and tan	5	25

18. *Sample log of test hole at the NW cor. sec. 19, T. 21 S., R. 17 W. Surface altitude, 2,095.7 feet.*

	Thickness, feet	Depth, feet
Road fill	3	3
QUATERNARY—Pleistocene		
Terrace deposits		
Silt, tan and gray	5	8
Silt, brown	3	11
Silt, tan and brown	5	16
Silt, tan, contains white caliche	8	24
CRETACEOUS—Gulfian		
Dakota formation		
Sandstone, fine to medium, brown and white	4	28

19. *Sample log of test hole at the SW cor. sec. 19, T. 21 S., R. 17 W. Surface altitude, 2,070.8 feet.*

	Thickness, feet	*Depth, feet*
Road fill	3	3
QUATERNARY—Pleistocene		
Terrace deposits		
Silt, tan and light gray	4	7
Clay, silty, tan and brown	2	9
Clay, silty, brownish tan	4	13
Clay, silty, tan	13	26
Caliche, soft, light tan to white; contains silt and fine sand	1	27
CRETACEOUS—Gulfian		
Dakota formation		
Sandstone, fine to coarse, tan and brown	2	29

20. *Sample log of test hole at the SW cor. sec. 4, T. 21 S., R. 18 W. Surface altitude, 2,111.0 feet.*

	Thickness, feet	*Depth, feet*
Road fill	4.5	4.5
QUATERNARY—Pleistocene		
Terrace deposits		
Clay, silty, light gray	2.5	7
Clay, silty, tan to brown	3	10
Clay, silty, buff; contains fragments of white caliche	26	36
Clay, silty, yellowish tan; contains fine to medium sand,	5	41
No samples recovered below a depth of 41 feet. Driller believes the test hole penetrated coarse sand and gravel between the depths of 41 and 46 feet and shale or clay between the depths of 46 and 50 feet. The clay may be a part of the Dakota formation.		

21. *Sample log of test hole at the NW cor. sec. 5, T. 21 S., R. 18 W. Surface altitude, 2,114.8 feet.*

	Thickness, feet	*Depth, feet*
Road fill	4	4
QUATERNARY—Pleistocene		
Terrace deposits		
Silt, brown and tan	3	7
Clay, silty, brown	4	11
Clay, silty, gray and tan	2.5	13.5
Clay, silty, brown	6.5	20
Clay, silty, tan to brown	18	38
Clay, silty, buff and tan; contains fine sand	20	58
CRETACEOUS—Gulfian		
Dakota formation		
Clay, silty, tan, buff, and yellow	2	60

22. *Sample log of test hole at the NE cor. sec. 7, T. 21 S., R. 18 W. Surface altitude, 2,095.2 feet.*

	Thickness, feet	*Depth, feet*
Road fill	3	3
QUATERNARY—Pleistocene		
Terrace deposits		
Silt, gray and tan	5	8
Clay, silty, brown and tan	12	20
Clay, silty, contains fine sand and caliche; brown to tan	8	28
Clay, silty; contains fine to medium gravel; tan	5	33
Clay, silty, tan	17	50
Clay, silty, buff	12	62
Clay, silty, buff to light gray; contains fine to medium tan gravel and caliche	6	68
Gravel, fine to medium; contains silt and caliche; tan	5.5	73.5
Clay, silty; contains fine to medium gravel; tan	7.5	81
Gravel, fine to coarse; contains silt; tan	10.5	91.5
Silt, tan to buff	3.5	95
Gravel, fine to coarse, tan; contains tan silt and fragments of brown ironstone	8	103
CRETACEOUS—Gulfian		
Dakota formation		
Sandstone, fine- to medium-grained, tan to brown	7	110

23. *Sample log of test hole at the SE cor. sec. 7, T. 21 S., R. 18 W. Surface altitude, 2,086.0 feet.*

	Thickness, feet	*Depth, feet*
Road fill	2.5	2.5
QUATERNARY—Pleistocene		
Terrace deposits		
Clay, silty, tan and brown; contains white caliche	2.5	5
Clay, silty, brown; contains white caliche	2	7
Clay, silty, tan and brown; contains white caliche	66	73
Gravel, fine to medium, tan and gray; contains fine to medium tan sand	10	83
CRETACEOUS—Gulfian		
Dakota formation		
Sandstone, fine, tan	5	88

24. *Sample log of test hole at the NE cor. sec. 10, T. 21 S., R. 18 W. Surface altitude, 2,092.0 feet.*

	Thickness, feet	*Depth, feet*
Road fill	4	4
QUATERNARY—Pleistocene		
Terrace deposits		
Clay, silty, tan and gray	3	7
Clay, silty, brown	3	10
Clay, silty, tan and buff; contains fragments of caliche,	19	29
CRETACEOUS—Gulfian		
Dakota formation		
Clay, silty, tan and yellow	7	36

25. *Sample log of test hole at the NW cor. sec. 12, T. 21 S., R. 18 W. Surface altitude, 2,096.8 feet.*

	Thickness, feet	*Depth, feet*
Road fill	5	5
QUATERNARY—Pleistocene		
Terrace deposits		
Clay, silty, grayish tan and brown	3	8
Clay, silty, brown	3	11
Clay, silty, buff; contains fragments of white caliche,	40	51
Gravel, fine to coarse, tan and buff; contains white and tan caliche and fragments of tan limestone	1	52
CRETACEOUS—Gulfian		
Dakota formation		
Sandstone, fine to medium, tan to brown	4	56

26. *Sample log of test hole at the SW cor. sec. 17, T. 21 S., R. 18 W. Surface altitude, 2,075.4 feet.*

	Thickness, feet	*Depth, feet*
Road fill and dark gray silty soil	7	7
QUATERNARY—Pleistocene and Recent		
Alluvium		
Silt, dark gray to brown	2	9
Clay, silty, dark gray and tan	3	12
Clay, silty, tan	7	19
Gravel, fine to coarse, brown and tan; contains white caliche and tan silt	1	20
Clay, silty, contains fine to coarse sand; brown	6.5	26.5
Gravel, fine to coarse; contains silt and fine sand; tan,	0.5	27
Clay, silty, tan and gray; contains white caliche	33	60
Gravel, fine to medium, tan and gray; contains tan silt and white and tan caliche	5	65
Clay, silty, tan; contains white caliche	12	77

	Thickness, feet	Depth, feet
Gravel, fine to coarse, tan and gray; contains tan silt and white and tan caliche	37.5	114.5
CRETACEOUS—Gulfian		
Dakota formation		
Clay, silty, tan and yellow, mottled red	5.5	120

27. *Sample log of test hole at the NW cor. sec. 29, T. 21 S., R. 18 W. Surface altitude, 2,063.6 feet.*

	Thickness, feet	Depth, feet
Soil, silty, containing fine sand; brown	3.5	3.5
QUATERNARY—Pleistocene and Recent		
Alluvium		
Clay, silty, gray and brown; contains white caliche	11.5	15
Clay, silty, gray and tan; contains fragments of white shells and fine tan sand	11	26
Clay, silty, tan with orange stains	9	35
Sand, fine to medium, tan	5	40
Gravel, fine to coarse; contains coarse sand; tan	6	46
Clay, silty, buff to tan	24	70
Clay, silty; contains fine to medium sand and fine gravel; buff to tan	10	80
Gravel, fine to medium; contains fine to coarse sand and fragments of ironstone; buff to tan	10	90
Gravel, fine to coarse; contains silt, fine to coarse sand, and caliche; buff and gray	11	101
CRETACEOUS—Gulfian		
Dakota formation		
Clay, silty, yellow; contains fine tan sand and brown fine-grained sandstone	4	105
Clay, silty, bluish gray with faint red mottle	5	110

28. *Sample log of test hole at the NW cor. sec. 32, T. 21 S., R. 18 W. Surface altitude, 2,059.6 feet.*

	Thickness, feet	Depth, feet
Soil, dark gray	3	3
QUATERNARY—Pleistocene and Recent		
Alluvium		
Clay, silty, dark gray; contains coarse brown sand and white caliche	25	28
Sand, fine to coarse, tan; contains white caliche	2	30
Sand, fine to coarse, tan and gray; contains fine to coarse, tannish-gray gravel; and fragments of white shells	16	46
Silt, buff to tan	7	53
Sand, fine to coarse, tan	9	62
Silt, buff	3	65

	Thickness, feet	Depth, feet
Gravel, fine to medium; contains fine to coarse sand; tan and gray	3	68
Silt, tan; contains fine to medium buff gravel	12	80
Clay, silty, tan with yellow limonitic stains	10	90
Gravel, fine to medium; contains fine to coarse sand and silt	15	105
Silt, tan to buff; contains tan caliche having yellow stains, and fine to coarse sand and gravel	5	110
Gravel, fine to coarse; contains caliche; tan	2	112
CRETACEOUS—Gulfian and Comanchean		
Dakota formation (Gulfian)		
Sandstone, fine to medium, tan and brown	3	115
Clay, gray, mottled red	13	128
Sandstone, fine to medium, yellow and tan	9	137
Sandstone, fine to coarse; contains fine gravel; tan with yellow limonitic stains	13	150
Sandstone, fine to coarse, tan with yellow stains	9	159
Clay, silty, light gray; contains coarse sand	11	170
Kiowa shale (Comanchean)		
Clay, silty, bluish gray; contains light-gray to white sandstone	38	208
Clay, silty, light gray; contains fragments of brown carbonaceous material	7	215
Clay, silty, gray; contains fragments of gray sandstone and white lime	23.5	238.5
Pyrite and gray silty clay	1	239.5
Shale, gray; contains fragments of white shells and fragments of brown and black carbonaceous material	66.5	306
Limestone, hard, white	0.5	306.5
Shale, gray; contains fragments of white shells	77.5	384
Cheyenne sandstone (Comanchean)		
Shale, light to medium gray; contains very fine to fine sand	19	403
PERMIAN Redbeds (Undifferentiated)		
Shale, brown; contains fine sandstone. Encountered artesian water	15	418

29. *Sample log of test hole at the NE cor. sec. 36, T. 21 S., R. 18 W. Surface altitude, 2,040.3 feet.*

	Thickness, feet	Depth, feet
Road fill	3	3
QUATERNARY—Pleistocene and Recent		
Alluvium		
Silt, gray and tan	15	18
Silt, light gray	4	22
Clay, silty; contains fine sand; tan	5	27

	Thickness, feet	Depth, feet
Clay, silty, tan and gray; contains very fine to fine sand	6	33
Sand, fine to coarse, tan; contains fragments of white shells	13	46
Clay, silty, tan and gray; contains fine to medium sand,	2	48
Clay, silty, tan and gray; contains fine sand	8	56
Gravel, fine to coarse, tan; contains silt and fine to medium sand	1	57
Silt, tan; contains fine to coarse gravel, fine to medium sand, and white caliche	6	63
Gravel, fine to coarse, tan; contains silt, fine to medium sand, and caliche	2	65
CRETACEOUS—Gulfian		
Dakota formation		
Clay, silty, tan mottled yellow	5	70
Clay, silty, light gray to dark gray	8	78

30. *Sample log of test hole at the SE cor. sec. 17, T. 21 S., R. 19 W. Surface altitude, 2,085.6 feet.*

	Thickness, feet	Depth, feet
Road fill	1	1
QUATERNARY—Pleistocene		
Terrace deposits		
Clay, silty, brown	4	5
Clay, silty; contains fine to medium sand; tan and brown	5	10
Clay, silty; contains fine sand; tan	10	20
Clay, silty; contains fine sand; light brown	7	27
Clay, silty; contains fine sand; tan to light brown	3	30
Clay, silty, light brown	2	32
Clay, silty; contains medium sand and small fragments of ironstone; brown to tan	4	36
CRETACEOUS—Gulfian		
Dakota formation		
Clay, silty; contains fine sandstone; yellow and light gray	4	40

31. *Sample log of test hole 31 at the SE cor. sec. 18, T. 21 S., R. 19 W. Surface altitude, 2,095.6 feet.*

	Thickness, feet	Depth, feet
Road fill	3	3
QUATERNARY—Pleistocene		
Terrace deposits		
Clay, silty, buff	34	37
Gravel, fine to coarse, buff; contains silt, sand, and white caliche	3	40
CRETACEOUS—Gulfian		
Dakota formation		
Clay, silty, tan and yellow; contains sand	2	42

32. *Sample log of test hole at the NW cor. sec. 28, T. 21 S., R. 19 W. Surface altitude, 2,079.5 feet.*

	Thickness, feet	*Depth, feet*
Road fill	2	2
QUATERNARY—Pleistocene and Recent		
Alluvium		
Silt, tan	3	5
Clay, silty, gray	1	6
Clay, silty, brown	7	13
Clay, silty, tan to gray	4	17
Clay, silty, brown and gray	10	27
Clay, silty; contains fine to medium sand; tan and light gray	5	32
Clay, silty; contains very fine sand; tan and light gray,	4	36
Gravel, fine to coarse; contains silt; tan	14	50
Gravel, fine to coarse, tan; contains tan silt, and white caliche	15	65
Clay, silty, gray; contains fine to medium tan gravel	9	74
Gravel, fine to medium, tan and gray; contains tan caliche	6	80
Gravel, fine to coarse, tan and gray; contains tan silt and lime-cemented zones	10	90
Sand, medium to coarse; contains fine gravel and silt; tan	10	100
Gravel, fine to medium; contains coarse sand and tan and gray silt	16	116
Gravel, fine to coarse; contains fine to coarse sand and silt; tan to gray	13	129
CRETACEOUS—Gulfian		
Dakota formation		
Sandstone, fine to coarse, brown	6	135

33. *Sample log of test hole at the NE cor. sec. 32, T. 21 S., R. 19 W. Surface altitude, 2,077.2 feet.*

	Thickness, feet	*Depth, feet*
Soil, sandy, dark	3	3
QUATERNARY—Pleistocene and Recent		
Alluvium		
Silt and sand, very fine to fine, gray to tan	7	10
Silt and fine sand, tan	10	20
Silt and sand, very fine, tan; contains brown to yellow limonitic stains	12	32
Silt and sand, very fine; contains brown to yellow limonitic stains, limy concentrations and a few medium-grained fragments of quartz; tan to gray	4	36
Gravel, fine to medium; contains a few limy zones; tan,	4	40

	Thickness, feet	Depth, feet
Gravel, fine to coarse; contains caliche, fossil bone, and fragments of shells; tan	10	50
Gravel, fine to coarse; contains tan caliche	10	60
Gravel, fine to medium; contains tan caliche	10	70
Gravel, fine to medium; contains caliche and fragments of fossil bone; tan	8	78
Clay, silty, gray and tan	7	85
Clay, silty; contains fine-grained gravel and caliche; gray to tan	7	92
Gravel, fine to coarse; contains caliche and minor amounts of fine tan sand; gray to tan	8	100
Silt and sand; fine to coarse; contains fine to medium gravel; brown	10	110
Clay, silty; contains medium gravel; tan	10	120
Gravel; fine to coarse; contains numerous fragments of ironstone; tan	6	126
CRETACEOUS—Gulfian		
Dakota formation		
Sandstone, fine- to medium-grained, tan to brown	4	130

34. *Sample log of test hole at the SE cor. sec. 32, T. 21 S., R. 19 W. Surface altitude, 2,079.0 feet.*

	Thickness, feet	Depth, feet
Soil, dark gray	3	3
QUATERNARY—Pleistocene and Recent		
Alluvium		
Clay, silty, brown to gray; contains fragments of gastropods	6	9
Clay, silty, brown	4	13
Clay, silty, tan	5	18
Clay, silty, buff	2	20
Clay, silty; contains medium gravel; tan	10	30
Sand, medium, and silt; contains caliche; tan	10	40
Sand, medium to coarse, tan	8	48
Clay, silty; contains fine-grained sand; tan	2	50
Silt and sand, medium to coarse; tan	10	60
Sand, medium to coarse; contains gravel; tan	7	67
Clay, silty, tan to yellowish tan	7	74
Clay, silty; contains medium-grained sand; buff	6	80
Gravel, fine to medium; contains fragments of ironstone,	10	90
Gravel, fine to coarse, tan	12	102
CRETACEOUS—Gulfian		
Dakota formation		
Clay, silty, bluish gray; contains yellow limonitic stains,	8	110

35. *Sample log of test hole at the NE cor. sec. 9, T. 21 S., R. 20 W. Surface altitude, 2,132.8 feet.*

	Thickness, feet	Depth, feet
Soil, silty, brown	2	2
QUATERNARY—Pleistocene		
Terrace deposits		
Clay, silty, tan to buff	8	10
Clay, silty, tan	10	20
Clay, silty; contains a few lime concretions; tan	10	30
Clay, silty; contains a few small fragments of ironstone; tan	8	38
Gravel, fine to medium; contains silt; tan	9	47
Silt, buff	17	64
Silt; contains a few lime-cemented zones; yellow to light tan	5	69
Gravel, fine to coarse; contains silt; tan	21	90
Gravel, fine to coarse; contains silt and caliche; tan	10	100
CRETACEOUS—Gulfian		
Dakota formation		
Clay, silty, mottled red and tan; contains limonitic concretions	3	103

36. *Sample log of test hole at the SE cor. sec. 9, T. 21 S., R. 20 W. Surface altitude, 2,111.4 feet.*

	Thickness, feet	Depth, feet
Road fill	2	2
QUATERNARY—Pleistocene		
Terrace deposits		
Clay, silty, tan	8	10
Clay, silty; contains hard white particles (bentonite?); tan	10	20
Clay, silty, tan	30	50
Clay, silty; contains caliche; tan to gray	10	60
Clay, silty, dark gray and tan giving unit a mottled appearance	5	65
Clay, silty, dark gray and tan	7	72
Gravel, fine to coarse, tan to gray; contains tan silt	8	80
Gravel, fine to medium; contains tan silt and caliche,	6	86
Clay, silty; contains fine to coarse gravel; buff	9	95
Clay, silty; contains fine to medium gravel; buff	5	100
Gravel, fine to medium; contains silt; buff	8	108
CRETACEOUS—Gulfian		
Dakota formation		
Sandstone, medium, white	7	115

37. *Sample log of test hole at the SW cor. sec. 15, T. 21 S., R. 20 W. Surface altitude, 2,097.1 feet.*

	Thickness, feet	*Depth, feet*
Soil, silty, brown	3	3
QUATERNARY—Pleistocene and Recent		
Alluvium		
Clay, silty, brown	13	16
Clay, silty, tan	4	20
Clay, silty; contains fine sand; tan	8	28
Clay, silty; contains fine sand and fragments of fossil shells; tan	4	32
Sand, medium to coarse; contains silt and fine gravel,	12	44
Gravel, fine to coarse; contains silt, sand, and caliche; tan	6	50
Gravel, fine to coarse; contains coarse sand, silt, and caliche; tan	13	63
Clay, silty; contains fine gravel; tan to gray	4	67
Clay, silty; contains fine sand; light tan	4	71
Clay, silty; contains caliche; light tan	3	74
Gravel, fine to medium; contains silt; tan	6	80
Gravel, fine to coarse; contains caliche and silt; tan	10	90
Clay, silty; contains lime-cemented zones; light tan	12	102
Clay, silty, tan to yellowish tan	5	107
Gravel, fine to coarse; contains silt; tan to gray	12.5	119.5
CRETACEOUS—Gulfian		
Dakota formation		
Clay, silty, mottled tan and rose	5.5	125

38. *Sample log of test hole at the SE cor. sec. 17, T. 21 S., R. 20 W. Surface altitude, 2,103.7 feet.*

	Thickness, feet	*Depth, feet*
Road fill	3	3
QUATERNARY—Pleistocene and Recent		
Alluvium		
Clay, silty, tan and brown	23	26
Clay, silty, tan and brown; contains fine to coarse sand,	4	30
Sand, fine to coarse, tan; contains tan silt and fragments of white shells	17	47
Clay, silty, tan and buff	10	57
Clay, silty, bluish gray	12	69
Gravel, fine to medium, tan; contains tan caliche	10	79
CRETACEOUS—Gulfian		
Dakota formation		
Sandstone, fine, tan and white	14	93

39. *Sample log of test hole at the SW cor. sec. 18, T. 21 S., R. 20 W. Surface altitude, 2,121.8 feet.*

	Thickness, feet	*Depth, feet*
Soil, dark gray	7	7
QUATERNARY—Pleistocene and Recent		
Alluvium		
Clay, silty, light gray	2	9
Clay, silty, light tan; contains fine to medium sand and white nodular caliche	6	15
Clay, silty, buff	18	33
Clay, silty, tan to buff; contains fine to coarse sand and white caliche	15	48
Clay, silty, dark gray	2	50
Clay, silty, tan; contains fine to medium sand	8	58
Gravel, fine to medium; contains fine to coarse sand, silt, and tan caliche	8	66
Clay, silty, dark gray; contains fine to medium sand and fragments of snail shells	4	70
Gravel, fine to coarse, tan; contains fine to coarse sand and tan caliche	3	73
Clay, silty, light gray; contains fine sand	8	81
Clay, silty, tan with yellow stains; contains fine to coarse sand	3	84
Gravel, fine to coarse, tan; contains fine to coarse sand and tan caliche	9	93
Gravel, fine to coarse; contains tan and gray silt and white caliche	2	95
Gravel, fine to coarse; contains fine to coarse sand and silt	7	102
Sand, fine to coarse; contains tan silt	10	112
Gravel, fine to coarse; contains medium to coarse sand, and tan and white caliche	26	138
CRETACEOUS—Gulfian		
Dakota formation		
Clay, silty, gray, mottled red	2	140

40. *Sample log of test hole at the SE cor. sec. 18, T. 21 S., R. 20 W. Surface altitude, 2,113.1 feet.*

	Thickness, feet	*Depth, feet*
QUATERNARY—Pleistocene and Recent		
Alluvium		
Silt, dark tan	20	20
Clay, silty, tan and buff	10	30
Clay, silty, grayish tan with small red concretions	10	40
Clay, silty, light gray to dark gray	8	48
Silt, dark tan and gray; contains fine to medium sand and fragments of white shells	3	51

	Thickness, feet	*Depth, feet*
Gravel, fine to coarse, tan; contains fine to coarse sand and fragments of white shells	9	60
Sand, fine to coarse, tan; contains fine to coarse gravel and white to tan caliche	10	70
Gravel, fine to coarse, tan; contains medium to coarse sand and tan and white caliche	27	97
Clay, silty, tan; contains fine to coarse sand and white and tan caliche	14	111
Gravel, fine to coarse, tan; contains fine to medium sand and white and tan caliche	5	116
CRETACEOUS—Gulfian		
Dakota formation		
Clay, silty, light gray to tan, mottled red	4	120

41. *Sample log of test hole at the NW cor. sec. 23, T. 21 S., R. 20 W. Surface altitude, 2,094.8 feet.*

	Thickness, feet	*Depth, feet*
Road fill	2	2
QUATERNARY—Pleistocene and Recent		
Alluvium		
Clay, silty, tan gray	21	23
Clay, silty; contains fine sand; tan and light yellowish tan	3	26
Silt, tan; contains fine to coarse sand	4	30
Gravel, fine to medium; contains medium to coarse sand and tan silt	31	61
Clay, silty, buff; contains white caliche	22	83
CRETACEOUS—Gulfian		
Dakota formation		
Clay, silty, tan, mottled red	3	86

42. *Sample log of test hole in the NE cor. sec. 24, T. 21 S., R. 20 W. Surface altitude, 2,094.9 feet.*

	Thickness, feet	*Depth, feet*
Road fill	3	3
QUATERNARY—Pleistocene and Recent		
Alluvium		
Clay, silty, buff; contains caliche	7	10
Clay, silty, tan and yellow; contains fine sand	19	29
CRETACEOUS—Gulfian		
Dakota formation		
Clay, silty, tan and yellow	2	31

43. *Sample log of test hole at the NW cor. sec. 24, T. 21 S., R. 20 W. Surface altitude, 2,093.0 feet.*

	Thickness, feet	Depth, feet
Soil, dark gray	1.5	1.5
QUATERNARY—Pleistocene and Recent		
Alluvium		
Clay, silty, tan to gray	23.5	25
Clay, silty, buff; contains fragments of shells	7	32
Sand, fine to coarse, tan; contains fragments of caliche and tan silt	8	40
Gravel, fine to coarse, tan; contains fine to coarse sand, silt, and tan and white caliche	25	65
Clay, silty, tan and gray; contains nodular caliche	11	76
Sand, fine to coarse, yellowish tan; contains fine to coarse gravel, and tan silt	2	78
CRETACEOUS—Gulfian		
Dakota formation		
Clay, silty, yellow; contains fragments of brown ironstone and fine sand	2	80

44. *Sample log of test hole at the NE cor. sec. 28, T. 21 S., R. 20 W. Surface altitude, 2,096.4 feet.*

	Thickness, feet	Depth, feet
Road fill	3	3
QUATERNARY—Pleistocene and Recent		
Alluvium		
Clay, silty, tan and gray	7	10
Clay, silty, brown and gray	15	25
Sand, medium to coarse; contains a few lime-cemented zones; tan	5	30
Sand, coarse; contains fine gravel; tan	10	40
Gravel, fine to coarse; contains coarse sand; tan to gray,	5	45
Clay, silty, contains coarse sand and fine gravel; tan,	2	47
Gravel, fine to coarse, tan to gray	13	60
Sand, coarse; contains fine to medium gravel; tan	10	70
Gravel, fine to coarse, tan	10	80
Gravel, fine to coarse, tan to gray	13	93
CRETACEOUS—Gulfian		
Dakota formation		
Clay, silty; contains sandstone and purple and tan fragments of ironstone	7	100

45. *Sample log of test hole at the SW cor. sec. 27, T. 21 S., R. 20 W. Surface altitude, 2,123.8 feet.*

	Thickness, feet	Depth, feet
Road fill	2	2
QUATERNARY—Pleistocene		
Terrace deposits		
Clay, silty, tan to brown	3	5
Clay, silty, brown	2	7
Clay, silty, tan to brown	12	19
Clay, silty, tan	11	30
Clay, silty, buff; contains a few lime-cemented zones	11	41
Clay, silty; contains coarse sand; tan	3	44
CRETACEOUS—Gulfian		
Dakota formation		
Sandstone, fine to medium, tan to brown	4	48

46. *Sample log of test hole at the SW cor. sec. 4, T. 22 S., R. 16 W. Surface altitude, 2,000.3 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene and Recent		
Dune sand (Pleistocene and Recent)		
Sand, fine to medium; contains silt; tan to gray	2	2
Meade formation (Pleistocene)		
Gravel, fine to coarse, tan; contains medium to coarse sand and silt	18	20
Gravel, fine to coarse, tan; contains fine to coarse sand, silt, and tan and white caliche	30	50
Sand, fine to coarse, tan; contains fine to medium gravel,	14	64
Clay, silty, tan; contains fine to coarse sand and gravel, with fragments of tan and white caliche	9	73
Clay, silty, tan and gray; contains gray and tan caliche with limonitic stains	12	85
Gravel, fine to coarse, tan; contains sand and silty clay; gray to tan	16	101
CRETACEOUS—Gulfian		
Dakota formation		
Sandstone, fine to medium, brown with yellow stains	19	120

47. *Sample log of test hole in the NE¼ NE¼ sec. 5, T. 22 S., R. 16 W. Surface altitude, 1,999.6 feet.*

	Thickness, feet	Depth, feet
Soil, dark gray	3	3
QUATERNARY—Pleistocene and Recent		
Alluvium		
Silt, tan and gray; contains fine to medium sand	3	6
Sand, fine to coarse; contains fine gravel	4	10
Gravel, fine to coarse; contains coarse sand	15	25
CRETACEOUS—Gulfian		
Dakota formation		
Clay, silty, gray, mottled red	10	35

48. *Sample log of test hole at the SW cor. sec. 9, T. 22 S., R. 16 W. Surface altitude, 2,010.4 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Meade formation		
Sand, fine to coarse, tan; contains fine to coarse gravel and white caliche	19	19
Gravel, fine to coarse, tan; contains fine to coarse sand and tan silt	11	30
Sand, fine to coarse, tan; contains fine to medium gravel,	19	49
CRETACEOUS—Gulfian		
Dakota formation		
Clay, silty, tan and buff, mottled red	8	57

49. *Sample log of test hole at the NW cor. sec. 21, T. 22 S., R. 16 W. Surface altitude, 2,031.9 feet.*

	Thickness, feet	Depth, feet
Soil, dark gray	3	3
QUATERNARY—Pleistocene		
Meade formation		
Clay, silty, light gray; contains very fine sand	5	8
Sand, very fine to coarse; contains tan silt	14	22
Silt, tan; contains fine to coarse sand and white caliche,	4	26
Sand, fine to coarse, tan; contains fine gravel	4	30
Gravel, fine to coarse, tan; contains fine to coarse gravel and white and tan caliche	31	61
Sand, fine to coarse, tan; contains fine gravel	6	67
Clay, silty, tan and gray; contains fine to coarse sand	13	80
Clay, silty, tan and gray	8	88
Clay, silty, tan; contains fine to coarse sand and white caliche	2	90
CRETACEOUS—Gulfian		
Dakota formation		
Sandstone, fine to medium, tan and brown, with yellow stains	10	100

50. *Sample log of test hole at the NW cor. sec. 33, T. 22 S., R. 16 W. Surface altitude, 2,041.2 feet.*

	Thickness, feet	Depth feet
QUATERNARY—Pleistocene		
Meade formation		
Sand, fine to coarse; contains tan silt	2	2
Clay, silty, tan and gray; contains fine to medium sand,	6	8
Silt, greenish gray; contains fine to medium sand	5	13
Silt, tan with yellow stains; contains fine sand	8	21
Gravel, fine to medium; contains fine to coarse sand; tan	5	26
Sand, very fine to fine; contains tan silt	2	28
Sand, fine to coarse; contains fine gravel and tan and white caliche	12	40

	Thickness, feet	Depth, feet
Sand, fine to coarse, yellow tan; contains limonitic cemented zones	12	52
Sand, fine to coarse, tan; contains fine to coarse gravel and tan and white caliche	38	90
Clay, silty, gray and tan with yellow limonitic stains; contains fine to medium sand and white caliche	23	113
Sand, fine to coarse, tan; contains fine to medium gravel,	17	130
Sand, fine to coarse, tan and gray; contains fine to coarse gravel, tan and white caliche, and gray silt	20	150
Sand, very fine to coarse, tan; contains tan and white caliche and fine gravel	20	170
Gravel, fine to coarse, tan; contains fine to coarse sand, tan caliche, and silt	17	187
CRETACEOUS—Gulfian		
Dakota formation		
Clay, silty, bluish gray; contains blue shale, fine to medium sand, black carbonaceous material, and pyrite,	13	200

51. *Sample log of test hole at the NW cor. sec. 7, T. 22 S., R. 17 W. Surface altitude, 2,039.6 feet.*

	Thickness, feet	Depth, feet
Road fill	2.5	2.5
QUATERNARY—Pleistocene and Recent		
Alluvium		
Clay, silty, tan and gray; contains fine to medium sand,	15.5	18
Sand, fine to coarse, tan; contains silt and clay	22	40
Sand, fine to coarse, tan; contains fine to medium gravel, white caliche, and fragments of white shells	14	54
Clay, silty, tan and gray; contains fine to coarse sand and fine gravel	12	66
Clay, silty, brown and gray	1	67
Clay, silty, tan and gray; contains fine to medium sand,	3	70
Sand, fine to medium, tan; contains silt	8	78
Gravel, fine to coarse; contains fine to coarse sand, caliche, and silt; tan and gray	18	96
Clay, silty, buff; contains fine to medium sand, and coarse gravel	12	108
Gravel, fine to coarse, tan; contains fine to coarse sand, caliche, and silt	19	127
CRETACEOUS—Gulfian		
Dakota formation		
Sandstone, fine to coarse, brown and tan; contains yellow and tan silty clay	13	140

52. *Sample log of test hole at the SW cor. sec. 7, T. 22 S., R. 17 W. Surface altitude, 2,040.0 feet.*

	Thickness, feet	Depth, feet
Road fill	2	2
QUATERNARY—Pleistocene and Recent		
Alluvium		
Clay, silty, tan; contains fine sand	12	14
Clay, silty, light gray and dark gray	2	16
Clay, silty, tan; contains fine to medium sand	2	18
Sand, fine to coarse, tan, interbedded with tan silty clay,	7	25
Sand, fine to coarse, tan; contains silt	5	30
Sand, fine to coarse; contains fine gravel; tan and gray,	9	39
Silt, brown; contains fine to medium sand	5	44
Silt, grayish tan; contains fine to medium sand	3	47
Sand, fine to coarse, tan; contains tan and gray fine gravel	14	61
Silt, tan; contains fine to medium sand, caliche, and fragments of shells	9	70
Gravel, fine to coarse, tan and gray; contains fine to coarse sand and caliche	11	81
CRETACEOUS—Gulfian		
Dakota formation		
Clay, silty, light gray with red stains	9	90

53. *Sample log of test hole at the NW cor. sec. 19, T. 22 S., R. 17 W. Surface altitude, 2,069.4 feet.*

	Thickness, feet	Depth, feet
Road fill	2	2
QUATERNARY—Pleistocene		
Terrace deposits		
Silt, tan and brown	6	8
Silt, tan and buff; contains clay and nodular white caliche	42	50
Silt, tan; contains white caliche and fine to medium sand	7	57
CRETACEOUS—Gulfian		
Dakota formation		
Clay, silty, tan and gray, mottled red	3	60

54. *Sample log of test hole at the NW cor. sec. 30, T. 22 S., R. 17 W. Surface altitude, 2,097.0 feet.*

	Thickness, feet	Depth, feet
Road fill	3	3
QUATERNARY—Pleistocene		
Terrace deposits		
Clay, silty, brown and tan	6	9
Clay, silty, brown, tan, and white, contains caliche and fragments of brown ironstone	3	12

	Thickness, feet	Depth, feet
CRETACEOUS—Gulfian		
Dakota formation		
Clay, silty, tan, white, and yellow; contains very fine-grained sandstone	3	15

55. *Sample log of test hole at the SW cor. sec. 31, T. 22 S., R. 17 W. Surface altitude, 2,074.8 feet.*

	Thickness, feet	Depth, feet
Road fill	2	2
QUATERNARY—Pleistocene and Recent		
Alluvium		
Clay, silty, tan and gray; contains fine to medium sand,	6	8
Gravel, fine to coarse, tan and gray; contains coarse tan sand	12	20
No sample recovered. Drilling speed indicated coarse sand and gravel	5	25
CRETACEOUS—Gulfian		
Dakota formation		
Sandstone, fine, yellow and tan, interbedded with tan and yellow clay	5	30

56. *Sample log of test hole at the NE cor. sec. 7, T. 22 S., R. 18 W. Surface altitude, 2,053.4 feet.*

	Thickness, feet	Depth, feet
Road fill	4	4
QUATERNARY—Pleistocene and Recent		
Alluvium		
Clay, silty, dark gray to tan	7	11
Clay, silty, tan to brown; contains tan fine to medium sand	19	30
Clay, silty; contains very fine-grained sand; buff and tan,	7	37
Gravel, fine to coarse; contains fine to coarse sand, and tan and gray silt	16	53
Clay, silty, buff; contains fine to coarse sand, and white caliche	7	60
Sand, fine to coarse; contains fine gravel and silt; tan,	4	64
Clay, silty, dark gray	6	70
Sand, fine to coarse, tan to brown	6	76
Clay, silty, light gray to dark gray; contains fine to medium sand	6	82
Sand, fine to coarse; contains fine to medium gravel; tan	11	93
Gravel, fine to coarse, tan and brown; contains fine to coarse sand and fragments of limonitic-stained ironstone and white caliche	16	109
CRETACEOUS—Gulfian		
Dakota formation		
Clay, silty, yellow tan, light gray, and buff	4	113

57. *Sample log of test hole at the SE cor. sec. 7, T. 22 S., R. 18 W. Surface altitude, 2,068.0 feet.*

	Thickness, feet	*Depth, feet*
Road fill	2	2
QUATERNARY—Pleistocene		
Terrace deposits		
Silt, light brown	3	5
Clay, silty, tan and buff	15	20
Clay, silty, brown and tan	12	32
Clay, silty, tan and buff	31	63
Gravel, fine to coarse; contains coarse sand and silt; tan and gray	8	71
Clay, silty, light brown	11	82
Clay, silty, tan; contains fine to coarse fragments of ironstone and white caliche	8	90
Clay, silty, mottled red and tan	6	96
CRETACEOUS—Gulfian		
Dakota formation		
Clay, silty, light gray, tan, and yellow	4	100

58. *Sample log of test hole at the SE cor. sec. 18, T. 22 S., R. 18 W. Surface altitude, 2,086.4 feet.*

	Thickness, feet	*Depth, feet*
Soil, silty, brown	2.5	2.5
QUATERNARY—Pleistocene		
Terrace deposits		
Clay, silty; contains fine sand; brown	7.5	10
Clay, silty; contains caliche; buff	36	46
CRETACEOUS—Gulfian		
Dakota formation		
Sandstone, fine to medium, brown and tan; contains fragments of yellow and brown silty clay	4	50

59. *Sample log of test hole at the SE cor. sec. 19, T. 22 S., R. 18 W. Surface altitude, 2,098.2 feet.*

	Thickness, feet	*Depth, feet*
Soil, silty, gray	2	2
QUATERNARY—Pleistocene		
Terrace deposits		
Silt, brown	2	4
Clay, silty, brown to tan; contains white caliche	6	10
Clay, silty, buff	10	20
Clay, silty, buff to tan; contains small fragments of caliche	10	30
Clay, silty, tan to buff; contains medium to coarse tan and gray gravel	5	35
Gravel, fine to coarse; contains silt; tan	1	36

	Thickness, feet	*Depth, feet*
CRETACEOUS—Gulfian		
Dakota formation		
Clay, silty, tan and yellow	2	38

60. *Sample log of test hole at the SE cor. sec. 25, T. 22 S., R. 18 W. Surface altitude, 2,090.9 feet.*

	Thickness, feet	*Depth, feet*
Road fill	2	2
QUATERNARY—Pleistocene		
Terrace deposits		
Clay, silty, gray	7	9
Clay, silty, tan to buff; contains white caliche	19	28
Clay, silty, tan to buff; contains white caliche and fine to coarse sand	13	41
Clay, silty, pale yellow and white; contains soft lime-cemented zones	1	42
Gravel, fine to medium; contains fine to coarse sand and fragments of brown ironstone	1.5	43.5
CRETACEOUS—Gulfian		
Dakota formation		
Clay, silty, mottled yellow and tan	6.5	50

61. *Sample log of test hole at the SE cor. sec. 31, T. 22 S., R. 18 W. Surface altitude, 2,147.3 feet.*

	Thickness, feet	*Depth, feet*
Road fill	2	2
QUATERNARY—Pleistocene		
Terrace deposits		
Clay, silty, buff to tan; contains white and tan caliche,	11	13
CRETACEOUS—Gulfian and Comanchean		
Dakota formation (Gulfian)		
Sandstone, fine to medium, yellow and tan	6	19
Clay, silty, mottled tan and yellow	10	29
Sandstone, fine, calcareous, tan and yellow	0.5	29.5
Clay, silty, mottled tan and reddish brown	15.5	45
Clay, silty, mottled red and tan	15	60
Clay, silty, gray, purple, and tan	7	67
Clay, silty, gray; contains fragments of coal	8	75
Clay, silty, yellow and gray	2	77
Sandstone, fine, brown; contains yellow and gray silty clay and fragments of ironstone	8	85
Clay, silty, gray, buff, and red	5	90
Clay, silty, gray and buff	6.5	96.5
Sandstone, fine, gray	11.5	108
Clay, silty, gray, yellow, and red	14.5	122.5
Clay, silty, gray, yellow, and orange	2.5	125
Clay, silty, gray, tan, and red	17	142
Clay, silty, gray, tan, yellow, and red; contains fragments of ironstone	15	157

	Thickness, feet	Depth, feet
Clay, silty, gray, tan, and yellow	0.5	157.5
Clay, silty, gray and yellow; contains fragments of fine brown sandstone	11.5	169
Clay, gray; contains fragments of brown and white fine sandstone having limonitic stains	7	176
Clay, silty, gray, tan, and orange; contains fragments of coal	8	184
Clay, gray, tan, and orange	5	189
Clay, white, gray, and mottled red and tan	7	196
Kiowa shale (Comanchean)		
Shale, dark gray	3.5	199.5
Clay, mottled yellow and gray	6.5	206
Clay, gray and tan	8	214
Sandstone, fine, tan and gray, having red stains	5	219
Clay and shale; gray with red stains	9	228
Sandstone, fine, tan, and gray; contains red oxidized fragments of ironstone and fragments of brown carbonaceous material	8	236
Sandstone, fine, tan and gray; contains interbedded tan clay	14	250
Sandstone, fine, buff and gray; contains fragments of carbon	16	266
Sandstone, fine, dark gray; contains buff clay	9	275
Clay, gray	7	282
Clay, gray to bluish gray	2.5	284.5
Shale and clay, tan and gray	5.5	290
Shale, gray; contains interbedded tan clay	6	296
Shale, gray and tan	2	298
Shale, tan and gray; contains fragments of carbon	6	304
Shale, gray; contains interbedded tan clay having red stains	16	320
Shale, gray; contains interbedded fine tan sandstone,	10	330
Shale, gray; contains fragments of carbon	16	346
Shale, bluish gray	10	356
Shale, gray; contains interbedded tan clay and sandstone having red stains	15	371
Shale, dark gray	3	374
Shale, dark gray; contains interbedded tan sandstone and fragments of pyrite	31	405
Cheyenne sandstone (Comanchean)		
Shale, gray; contains interbedded tan sandstone	14	419
Shale, gray to grayish green; contains interbedded tan and white sandstone	10	429
PERMIAN Redbeds (Undifferentiated)		
Shale, gray and tan; contains interbedded sandstone	6	435
Shale, gray; contains interbedded brown sandstone	15	450
Shale, reddish tan, sandy	5	455

62. *Sample log of test hole at the SW cor. sec. 4, T. 22 S., R. 19 W. Surface altitude, 2,094.0 feet.*

	Thickness, feet	Depth, feet
Soil, silty, brown	3	3
QUATERNARY—Pleistocene		
Terrace deposits		
Clay, silty, brown to tan	4	7
Clay, silty, brown	6	13
Clay, silty, tan	17	30
Clay, silty; contains tan caliche	10	40
Clay, silty, buff	10	[illegible]
Clay, silty; contains limonitic oxidized fragments of ironstone; buff	8	58
Clay, silty, brown to tan	15	73
CRETACEOUS—Gulfian		
Dakota formation		
Clay, silty, bluish gray to tan, having red limonitic stains	4	77

63. *Sample log of test hole at the SE cor. sec. 8, T. 22 S., R. 19 W. Surface altitude, 2,098.2 feet.*

	Thickness, feet	Depth, feet
Soil, silty, brown	4	4
QUATERNARY—Pleistocene		
Terrace deposits		
Clay, silty; contains a few small fragments of shells; tan,	4	8
Clay, silty; tan	22	30
Clay, silty, light brown to tan	10	40
Clay, silty, tan, mottled red	7	47
CRETACEOUS—Gulfian		
Dakota formation		
Clay, light greenish gray, mottled red and yellow	3	50

64. *Sample log of test hole at the SE cor. sec. 20, T. 22 S., R. 19 W. Surface altitude, 2,119.6 feet.*

	Thickness, feet	Depth, feet
Soil, silty, brown to dark tan	3	3
QUATERNARY—Pleistocene		
Terrace deposits		
Clay, silty, tan; contains numerous fossil shells	4	7
Clay, silty, tan and gray	3	10
Clay, silty, tan	10	20
Clay, silty; contains minor fine grains of quartz; light brown to tan	10	30
Clay, silty, tan	14	44
Clay, silty; contains minor yellow limonitic stains and fine grains of quartz; tan	6	50
CRETACEOUS—Gulfian		
Dakota formation		
Clay, silty; contains yellow limonitic stains giving the unit a mottled appearance	3	53

65. *Sample log of test hole at the SE cor. sec. 32, T. 22 S., R. 19 W. Surface altitude, 2,154.3 feet.*

	Thickness, feet	Depth, feet
Soil, silty, brown	2	2
QUATERNARY—Pleistocene		
Terrace deposits		
Clay, silty, tan	5	7
Clay, silty, brown	4	11
Clay, silty; contains a few fragments of mica and particles of caliche; tan	9	20
Clay, silty, tan	10	30
Clay, silty, buff	20	50
Clay, silty; contains medium-grained sand and minor fragments of caliche; tan	7	57
Silt and gravel, fine to coarse; contains caliche and many fragments of ironstone having the appearance of limonite; tan	3	60
Silt and sand, medium to coarse, tan; contains a few fragments of fossil shells	5	65
Clay, silty, and medium to coarse sand; contains yellow limonitic stains throughout; tan and yellow	5	70
CRETACEOUS—Gulfian		
Dakota formation		
Clay, silty. Red oxidized areas give unit a mottled red and tan appearance	3	73

66. *Sample log of test hole at the SW cor. sec. 3, T. 22 S., R. 20 W. Surface altitude, 2,164.7 feet.*

	Thickness, feet	Depth, feet
Road fill and soil, silty, gray to dark brown	4	4
QUATERNARY—Pleistocene		
Terrace deposits		
Clay, silty, tan gray	2	6
Clay, silty; contains some fine-grained sand; brown	4	10
Clay, silty, buff	15	25
Clay, silty; contains some fine-grained sand; tan gray,	3.5	28.5
CRETACEOUS—Gulfian		
Dakota formation		
Clay, silty, tan and yellow, with some red oxidized coloring	2.5	31

67. *Sample log of test hole at the NE cor. sec. 4, T. 22, S, R. 20 W. Surface altitude, 2,143.0 feet.*

	Thickness, feet	Depth, feet
Road fill	1	1
QUATERNARY—Pleistocene		
Terrace deposits		
Clay, silty, tan and gray	3	4
Clay, silty, brown and tan	6	10

	Thickness, feet	Depth, feet
Clay, silty, tan	15	25
Clay, silty; contains fine-grained sand and fine ironstone gravel; tan and rust red	1	26
CRETACEOUS—Gulfian		
Dakota formation		
Sandstone, fine-grained; contains silt and fine fragments of reddish-brown to tan ironstone	2	28

68. *Sample log of test hole at the NW cor sec. 15, T. 22 S., R. 20 W. Surface altitude, 2,183.0 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Terrace deposits		
Clay, silty, tan and light gray	5	5
Clay, silty, brown	1	6
Clay, silty; contains tan caliche	6	12
CRETACEOUS—Gulfian		
Dakota formation		
Clay, silty, yellow and tan	2	14

69. *Sample log of test hole at the NE cor. sec. 28, T. 22 S., R. 20 W. Surface altitude, 2,163.1 feet.*

	Thickness, feet	Depth, feet
Road fill and brown soil	4	4
QUATERNARY—Pleistocene		
Terrace deposits		
Clay, silty, tan to gray	6	10
Clay, silty, tan	20	30
Clay, silty; contains medium sand; tan	15	45
Clay, silty, buff	9	54
Clay, silty; contains fine to medium sand and caliche; tan	7	61
Gravel, fine to coarse; contains silt and fine to medium sand; tan	6	67
CRETACEOUS—Gulfian		
Dakota formation		
Clay, silty, mottled tan and red	3	70

70. *Sample log of test hole at the SE cor. sec. 28, T. 22 S., R. 20 W. Surface altitude, 2,198.1 feet.*

	Thickness, feet	Depth, feet
Road fill	3	3
QUATERNARY—Pleistocene		
Terrace deposits		
Clay, silty, brown	3	6
Clay, silty, gray to brown	2	8
Clay, silty, brown	2	10
Clay, silty; contains fine sand; buff	10	20
Clay, silty, buff	7	27

	Thickness, feet	Depth, feet
Clay, silty; contains fine to medium sand; buff	9	36
Clay, silty; contains fine to medium sand; buff to tan,	2	38
Clay, silty; contains fine to medium sand; tan	15	53
Clay, silty; contains fine to medium sand; yellow to buff	4	57
Gravel, fine to medium; contains silt and fine to medium sand; tan	4	61
CRETACEOUS—Gulfian		
Dakota formation		
Clay, silty, mottled red and tan	2	63

71. *Sample log of test hole at the NW cor. sec. 32, T. 23 S., R. 15 W. Surface altitude, 2,044.5 feet.*

	Thickness, feet	Depth, feet
Road fill	3	3
QUATERNARY—Pleistocene		
Meade formation		
Silt, tan and brown; contains fine to medium sand	7	10
Clay, silty; contains fine to medium sand; tan	13	23
Sand, fine to medium; contains tan and yellow silt	13	36
Clay, silty, tan; contains white caliche	9	45
Clay, silty, buff and tan; contains caliche	2	47
Gravel, fine to coarse; contains silt and caliche; tan	36	83
Clay, silty, yellowish tan	3	86
Clay, silty, compact, tan; contains white caliche	14	100
Clay, silty; contains fine to medium sand, and caliche; tan and buff	11	111
Gravel, fine to coarse, tan and gray; contains fine to coarse sand, silt, and caliche	3	114
CRETACEOUS—Gulfian		
Dakota formation		
Clay, silty, tan and yellow	6	120

72. *Sample log of test hole at the NE cor. sec. 36, T. 23 S., R. 15 W. Surface altitude, 1,984.1 feet.*

	Thickness, feet	Depth, feet
Road fill	2.5	2.5
QUATERNARY—Pleistocene		
Meade formation		
Silt, brown; contains fine to medium sand	10.5	13
Silt; contains fine to coarse sand and fragments of caliche; tan	7	20
Gravel, fine to coarse; contains fine to coarse sand and silt; tan	17	37
Clay, silty; contains fine to medium sand; buff	3	40
Gravel, fine to medium; contains tan and buff silt	28	68
Clay, silty; contains fine sand; tan	32	100
Clay, silty, tan; contains fragments of red ironstone	10.5	110.5

	Thickness, feet	Depth, feet
CRETACEOUS—Gulfian		
Dakota formation		
Clay, silty, light green and tan; contains fine brown sandstone	4.5	115

73. *Sample log of test hole at the NW cor. sec. 9, T. 23 S., R. 16 W. Surface altitude, 2,045.1 feet.*

	Thickness, feet	Depth, feet
Road fill	3	3
QUATERNARY—Pleistocene		
Meade formation		
Clay, silty, gray and brown	3	6
Clay, silty, greenish gray	2	8
Clay, silty, tan gray; contains fine to coarse sand	2	10
Clay, silty, buff; contains fragments of white caliche and fine sand	11	21
Sand, fine to coarse, tan; contains silt and fragments of white and tan caliche	9	30
Sand, fine to coarse, buff; contains silt and white caliche	14	44
Gravel, fine to coarse, tan; contains coarse sand and white caliche	32	76
Clay, silty, buff; contains fine to coarse sand	44	120
Clay, silty, buff and tan; contains fine to coarse sand and white caliche	5	125
CRETACEOUS—Gulfian		
Dakota formation		
Clay, silty, light gray with red stains; contains fine to coarse sand	5	130

74. *Sample log of test hole at the NW cor. sec. 21, T. 23 S., R. 16 W. Surface altitude, 2,055.3 feet.*

	Thickness, feet	Depth, feet
Road fill	3	3
QUATERNARY—Pleistocene		
Meade formation		
Clay, silty, brown; contains fine to medium sand and white caliche	5	8
Clay, silty, tan; contains fine to medium sand	14	22
Gravel, fine to coarse, tan; contains medium to coarse sand with silt and zones of cemented sand	35	57
Clay, silty, buff with yellow tint; contains fine to medium sand	11	68
Clay, silty, tan; contains fine to medium sand	9	77
Gravel, fine to coarse; contains medium to coarse sand and tan caliche	9	86
Clay, silty, buff; contains fine to coarse sand and fragments of ironstone	7	93
CRETACEOUS—Gulfian		
Dakota formation		
Clay, silty, tan mottled red	7	100

75. *Sample log of test hole at the NW cor. sec. 33, T. 23 S., R. 16 W. Surface altitude, 2,063.4 feet.*

	Thickness, feet	Depth, feet
Road fill	2	2
QUATERNARY—Pleistocene		
Meade formation		
Sand, fine to coarse, brown	3	5
Sand, fine to medium, brown; contains white caliche and brown silt	2	7
Sand, fine to coarse; contains fine gravel; yellowish tan,	13	20
Gravel, fine to coarse; contains fine to coarse sand and silt; tan	51	71
Clay, silty, compact, grayish tan with yellow stains	9	80
Clay, silty, gray, yellow, and red	9	89
CRETACEOUS—Gulfian		
Dakota formation		
Clay, silty, bluish gray with faint red and yellow stains,	11	100

76. *Sample log of test hole at the SW cor. sec. 6, T. 23 S., R. 17 W. Surface altitude, 2,062.3 feet.*

	Thickness, feet	Depth, feet
Road fill	2	2
QUATERNARY—Pleistocene and Recent		
Alluvium		
Clay, silty, grayish tan	2	4
Gravel, fine to coarse; contains fine to coarse sand, and silt; tan and gray	14	18
Clay, silty, tan and buff; contains white caliche	22	40
Silt, buff; contains white caliche and fine to coarse sand,	8	48
Gravel, fine; contains fine to coarse sand; tan and buff,	4	52
CRETACEOUS—Gulfian		
Dakota formation		
Clay, tan, gray, and yellow, mottled red	2	54

77. *Sample log of test hole at the NW cor. NE¼ sec. 18, T. 23 S., R. 17 W. Surface altitude, 2,075.4 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene and Recent		
Alluvium		
Gravel, fine to medium; contains fine to coarse sand; tan and gray	7.5	7.5
Silt, tan and buff; contains fine to coarse sand	7.5	15
Gravel, fine to coarse, contains fine to coarse sand; tan and gray	9	24
Gravel, fine to medium, tan and gray; contains fine to coarse tan sand and silt	36	60
Clay, silty, tan and buff; contains coarse sand and fine gravel	19	79
CRETACEOUS—Gulfian		
Dakota formation		
Clay, silty, bluish gray, interbedded with tan fine-grained sandstone	9	88

78. *Sample log of test hole in the SW¼ SE¼ sec. 18, T. 23 S., R. 17 W. Surface altitude, 2,092.6 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene and Recent		
Dune sand (Pleistocene and Recent)		
Sand, fine to coarse, contains silt; tan	7	7
Meade formation (Pleistocene)		
Silt, tan with red stains; contains fine to coarse sand	9	16
Sand, fine to coarse; contains fine gravel and silt; tan with red stains	4	20
Gravel, fine to coarse; contains medium to coarse sand; buff and tan	10	30
Sand, fine to coarse; contains fine to coarse gravel; buff and tan	11	41
Clay, silty; contains fine to coarse sand; tan	9	50
Clay, silty, tan and buff; contains fine to coarse sand and white caliche	10	60
Silt, tan and buff; contains white caliche	38	98
Clay, silty, tan; contains fragments of brown ironstone,	1	99
CRETACEOUS—Gulfian		
Dakota formation		
Clay, silty, tan and yellow	4	103

79. *Sample log of test hole at the SE cor. sec. 30, T. 23 S., R. 17 W. Surface altitude, 2,107.3 feet.*

	Thickness, feet	Depth, feet
Road fill	5	5
QUATERNARY—Pleistocene		
Meade formation		
Clay, silty, gray and tan	2	7
Clay, silty, tan with orange stains	3	10
Sand, fine to coarse; contains silt; tan	9	19
Clay, silty, tan and gray; contains fine to medium sand,	3	22
Gravel, fine to medium; contains fine to medium sand and silt; tan	8	30
Gravel, fine to coarse; contains fine to coarse sand; tan,	36.5	66.5
Clay, silty, tan and buff	5.5	72
CRETACEOUS—Gulfian		
Dakota formation		
Sandstone, silty; contains silty clay; tan and yellow	3	75

80. *Sample log of test hole at the SE cor. sec. 7, T. 23 S., R. 18 W. Surface altitude, 2,196.7 feet.*

	Thickness, feet	Depth, feet
Road fill	1.5	1.5
QUATERNARY—Pleistocene		
Terrace deposits		
Clay, silty, gray and tan	4.5	6
Silt, brown	3	9
Silt, tan to buff; contains white caliche	58	67
Limestone, buff to tan	0.5	67.5

	Thickness, feet	Depth, feet
CRETACEOUS—Gulfian		
Dakota formation		
Clay, silty, gray, tan, and yellow; contains fragments of brown fine sandstone	2.5	70

81. *Sample log of test hole at the SE cor. sec. 19, T. 23 S., R. 18 W. Surface altitude, 2,151.1 feet.*

	Thickness, feet	Depth, feet
Road fill	2	2
QUATERNARY—Pleistocene		
Terrace deposits		
Silt, tan	7	9
Silt, brown	17	26
Silt, tan and buff; contains fine to medium sand, and fragments of white caliche	14	40
Clay, silty, tan and buff; contains fragments of brown ironstone and white caliche	7.5	47.5
CRETACEOUS—Gulfian		
Dakota formation		
Sandstone, fine- to medium-grained; contains clay; yellow and tan	2.5	50

82. *Sample log of test hole at the SW cor. sec. 29, T. 23 S., R. 18 W. Surface altitude, 2,114.7 feet.*

	Thickness, feet	Depth, feet
Road fill and soil, dark gray	2.5	2.5
QUATERNARY—Pleistocene		
Alluvium		
Silt, brown and tan	1	3.5
Clay, silty, brown, tan, and gray; contains fine to medium sand	2.5	6
Gravel, fine to coarse, gray and tan; contains medium and coarse sand and white caliche	14	20
Clay, silty, tan	8	28
Clay, silty, tan and gray; contains fine to medium sand,	7	35
Clay, silty, tan and brown; contains white caliche	14	49
CRETACEOUS—Gulfian		
Dakota formation		
Clay, silty, tan, mottled red; contains fragments of tan and yellow fine sandstone	6	55

83. *Sample log of test hole at the SE cor. sec. 31, T. 23 S., R. 18 W. Surface altitude, 2,121.2 feet.*

	Thickness, feet	Depth, feet
Road fill and soil	3	3
QUATERNARY—Pleistocene		
Alluvium		
Sand, fine to medium, brown and tan, contains silt	1.5	4.5
Clay, silty, tan and gray	4.5	9

	Thickness, feet	Depth, feet
Gravel, fine to coarse, tan and gray	13	22
Clay, silty, tan and buff; contains white and tan caliche,	11	33
Clay, silty, buff; contains fine to medium sand	13	46
Silt, tan; contains very fine to fine sand	4	50
Silt, tan and white; contains very fine to fine sand	10	60
Sand, very fine to fine, tan and white; contains silt	7	67
Cretaceous—Gulfian		
Dakota formation		
Clay, silty, tan, mottled red and yellow	11	78

84. *Sample log of test hole at the SE cor. sec. 20, T. 23 S., R. 19 W. Surface altitude, 2,211.0 feet.*

	Thickness, feet	Depth, feet
Road fill	3	3
Quaternary—Pleistocene		
Terrace deposits		
Silt, light gray green to gray	4	7
Silt and clay, buff to tan; contains fine sand, gravel, and nodules of caliche	18	25
Cretaceous—Gulfian		
Dakota formation		
Clay, blue gray and yellow, interbedded with fine-grained brown sandstone	5	30

85. *Sample log of test hole at the SW cor. sec. 33, T. 23 S., R. 19 W. Surface altitude, 2,197.7 feet.*

	Thickness, feet	Depth, feet
Road fill	2	2
Quaternary—Pleistocene		
Terrace deposits		
Silt, yellow gray	4	6
Silt, brown	2	8
Silt, buff; contains fine sand, gravel, and nodules of caliche	57	65
Silt and clay, white and yellow, in part cemented; contains fragments of ironstone	3	68
Sand and gravel, fine to coarse; contains gray and buff silt	6	74
Silt and clay, yellow brown and light gray; contains fine to medium sand	6	80
Cretaceous—Gulfian		
Dakota formation		
Sandstone, medium-grained, yellow brown	7	87

86. *Sample log of test hole at the NW cor. sec. 15, T. 23 S., R. 20 W. Surface altitude, 2,319.3 feet.*

	Thickness, feet	Depth, feet
TERTIARY—Pliocene		
Ogallala formation		
Silt, blocky, dark brown; contains fine gravel	9	9
Silt, light brown to tan; contains fine gravel and nodules of caliche	5	14
Silt, white, in part consolidated; contains fine sand to fine gravel	17	31
Sand, gray to white, cemented with calcium carbonate,	11	42
Sand, fine to coarse, and white to tan silt	24	66
CRETACEOUS—Gulfian		
Graneros shale		
Clay, yellow to light gray	5	71
Shale, fissile, black, contains fragments of bentonite	14	85
Shale, black; contains bentonite and fine-grained very hard gray sandstone	5	90
Dakota formation		
Clay, blue gray; contains hard gray fine-grained sandstone	23	113
Shale, light gray to dark gray, and gray to white sandstone; contains fragments of pyrite and charcoal	19	132
Clay, light gray; contains fragments of charcoal, pyrite, and gray sandstone	15	147
Siltstone, light gray; contains fragments of charcoal, pyrite, and hard brown sandstone	28	175
Clay, varicolored; contains streaks of fine brown sandstone and fragments of charcoal and pyrite	52	227
Clay, silty, gray	15	242
Clay, silty, brown; contains charcoal and pyrite	38	280

87. *Sample log of test hole at the SW cor. sec. 22, T. 23 S., R. 20 W. Surface altitude, 2,273.7 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Terrace deposits		
Silt, gray brown	5	5
Silt, buff; contains fine to coarse sand and nodules of caliche	17	22
Silt, buff; contains fine to coarse sand	7	29
CRETACEOUS—Gulfian		
Greenhorn limestone (?)		
Shale, calcareous, white to orange	1	30

88. *Sample log of test hole at the SE cor. sec. 5, T. 24 S., R. 16 W. Surface altitude, 2,076.2 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Meade formation		
Silt, brown; contains fine sand	2	2
Silt, gray; contains fine to coarse sand	3	5
Silt, brown; contains fine to coarse sand	3	8
Silt, gray to brown; contains fine to coarse sand	5	13
Sand, very fine to coarse	18	31
Gravel, fine; contains fine to coarse sand	9	40
Gravel, fine; contains gray silt and fine to coarse sand,	10	50
Gravel, fine to medium, and fine to coarse sand	23	73
Gravel, fine to medium; contains fine sand and gray-green silt	20	93
Silt, dark gray to tan; contains very coarse gravel	7	100
Silt, dark gray to light gray	8	108
Silt, tan; contains a litttle gravel	16	124
CRETACEOUS—Gulfian and Comanchean		
Dakota formation (Gulfian)		
Clay, buff, yellow, and light gray; contains red clay and ironstone	24	148
Clay, gray	15	163
Shale, blocky, gray to buff; contains ironstone and fine yellow sandstone	37	200
Kiowa Shale (Comanchean)		
Shale, dark gray; contains hard gray sandstone and a few fragments of pyrite	17	217
Shale, dark gray; contains hard gray sandstone, pyrite, and fragments of fossil shells	38	255
Shale, dark gray; contains thin beds of dark-gray to black fissile shale and fragments of ironstone	29	284
Shale, dark gray; contains hard gray sandstone, pyrite, and fragments of fossil shells	31	315
Shale, fissile, gray and black; contains pyrite and charcoal	13	328
Shale, fissile, gray to black; contains many fragments of fossil shells and lesser amounts of charcoal, pyrite, and hard white sandstone	5	333
Cheyenne sandstone (Comanchean)		
Sandstone, fine-grained to very fine-grained light gray,	8	341
Sandstone, fine-grained to very fine-grained light greenish gray	11	352
PERMIAN		
Redbeds (Undifferentiated)		
Siltstone, brick red	8	360

89. *Sample log of test hole at the NW cor. sec. 21, T. 24 S., R. 16 W. Surface altitude, 2,092.9 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Meade formation		
Silt, brown, and fine sand	4	4
Silt, compact, dark gray to black	4	8
Silt, compact, light gray	3	11
Silt, brown; contains fine sand	3	14
Sand, very fine to fine	4	18
Silt, light brown; contains fine sand	10	28
Sand, very fine to fine, and light gray to buff silt	10	38
Silt, compact, white and buff; contains fragments of caliche	8	46
Silt, buff and gray; contains fine to coarse sand and fine gravel	5	51
Gravel, fine to coarse; contains fine to coarse sand	23	74
Gravel, fine to coarse; contains ironstone and buff clay,	7	81
Gravel, fine to coarse; contains sand and gray to buff silt	9	90
Silt, buff; contains fine sand	3	93
Gravel, fine to coarse; contains fine to coarse sand and gray to buff silt	12	105
Silt, gray and tan; contains a little gravel	40	145
Silt, light blue gray	16	161
Silt, light gray to tan, and fine to coarse sand	23	184
Gravel, fine to medium, and fine to coarse sand	6	190
CRETACEOUS—Gulfian		
Dakota formation		
Clay, blue gray to tan; contains brown sandstone and fragments of ironstone	10	200

90. *Sample log of test hole at the SE cor. sec. 29, T. 24 S., R. 16 W. Surface altitude, 2,079.8 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Meade formation		
Silt, brown, and fine sand	3	3
Silt, compact, light gray to dark gray	4	7
Silt, brown to tan, and very fine to fine sand; contains fragments of caliche	7	14
Silt, buff to gray; contains fine sand and fragments of caliche	11	25
Sand, fine to coarse; contains fine gravel and buff silt,	8	33
Silt, compact, light gray to white	5	38
Silt, buff and gray; contains fine to coarse sand and a little gravel	5	43
Silt, light gray; contains caliche, fine to coarse sand, and fine to medium gravel	7	50

	Thickness, feet	Depth, feet
Gravel, fine to coarse, and fine to coarse sand; contains a small amount of buff silt	74	124
Gravel, fine, to sand, fine; contains light-gray silt	4	128
Gravel, fine, to sand, coarse; contains blue-gray silt	5	133
Silt, light gray, and fine gravel; contains fine to coarse sand	29	162
Gravel, medium, to sand, fine	5	167
CRETACEOUS—Gulfian		
Dakota formation		
Clay, varicolored, and ironstone	23	190

91. *Sample log of test hole at the SW cor. sec. 6, T. 24 S., R. 17 W. Surface altitude, 2,123.3 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Meade formation		
Silt, compact, dark gray to black	4	4
Silt, light gray; contains fine gravel	4	8
Silt, soft, brown and gray; contains fine to coarse sand,	3	11
Silt, light gray to buff; contains fine gravel	4	15
Sand, fine to coarse; contains fine gravel and gray silt,	23	38
Gravel and sand, fine to coarse	5	43
Silt, light gray and buff	4	47
Gravel, fine to medium, and fine to coarse sand; contains buff silt	12	59
Gravel and sand, fine to coarse; contains a small amount of gray and buff silt	11	70
Silt, compact, tan to gray	13	83
Silt, light gray to white; contains fine to medium gravel and fragments of caliche	18	101
CRETACEOUS—Gulfian		
Dakota formation		
Sandstone, fine-grained, brown and white, and light-gray clay; contains fragments of ironstone	9	110

92. *Sample log of test hole at the NE cor. sec. 18, T. 24 S., R. 18 W. Surface altitude, 2,128.4 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene and Recent		
Alluvium		
Silt, compact, and fine sand	3	3
Sand, fine to coarse	11	14
Gravel, fine to coarse	4	18
Silt, soft, tan and gray	19	37
Silt, gray, and fine sand	12	49
Silt, blocky, brown; contains caliche	1	50
Silt, brown	6	56

	Thickness, feet	Depth, feet
Sand, fine, white; contains silt	9	65
Clay, light gray to buff	3	68
CRETACEOUS—Gulfian		
Dakota formation		
Clay, varicolored; contains ironstone and brown sandstone	3	71

93. *Sample log of test hole at the SW cor. sec. 20, T. 24 S., R. 18 W. Surface altitude, 2,193.7 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene and Recent		
Dune sand (Pleistocene and Recent)		
Sand, fine, and brown silt	3	3
Sand, fine; contains silt and very fine sand	25	28
Meade formation (Pleistocene)		
Silt, dark brown	6	34
Sand, fine to very fine	4	38
Sand, fine to very fine, and silt; brown	18	56
Gravel, medium, to sand, fine	49	105
CRETACEOUS—Gulfian		
Dakota formation		
Clay, gray and buff	5	110

94. *Sample log of test hole at the NE cor. sec. 24, T. 24 S., R. 18 W. Surface altitude, 2,134.2 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Meade formation		
Silt, compact, dark gray	4	4
Silt, light gray and brown; contains a small amount of fine gravel	11	15
Sand, very fine to medium, brown	7	23
Sand, very fine to medium; contains a small amount of fine gravel	9	32
Gravel and sand; fine to coarse	18	50
Gravel and sand, fine to coarse; contains a small amount of gray and buff silt	20	70
Gravel and sand, fine to coarse	15	85
Silt, gray to tan; contains gravel	38	123
Silt, gray and white; contains fine gravel and fragments of caliche	8	131
CRETACEOUS—Gulfian		
Dakota formation		
Sandstone, fine-grained, hard; contains yellow clay	9	140

95. *Sample log of test hole at the NE cor. sec. 36, T. 24 S., R. 18 W. Surface altitude, 2,141.3 feet.*

	Thickness, feet	*Depth, feet*
QUATERNARY—Pleistocene		
Meade formation		
Silt, soft, brown	3	3
Silt, compact, light gray to brown	4	7
Sand, fine, and red and brown silt	6	13
Silt, soft, gray and brown	4	17
Sand, fine to coarse; contains fine gravel	12	29
Gravel and sand, fine to coarse; contains a small amount of tan clay	32	61
Gravel and sand, fine to coarse; contains buff to yellow silt	9	70
Gravel and sand; fine to coarse	9	79
Silt, compact, light gray to white; contains fine to coarse gravel	31	110
Silt, white and tan; contains caliche	5	115
Gravel, medium, to sand, fine; contains white to tan silt,	3	118
CRETACEOUS—Gulfian and Comanchean		
Dakota formation (Gulfian)		
Clay, varicolored	14	132
Clay, varicolored; contains ironstone	44	176
Sandstone, fine-grained, very hard, gray; contains a small amount of pyrite	2	178
Siltstone, compact, gray; contains fine sand and tan blocky clay	18	196
Sandstone, fine-grained, gray	22	218
Kiowa shale (Comanchean)		
Clay, silty, gray; contains a few fragments of charcoal,	32	250
Clay, silty, gray; contains gray sandstone and many fragments of pyrite	16	266
Shale, dark gray to black; contains gray fine-grained sandstone and fragments of fossil shells	21	287
Shale, dark gray to black; contains a few fragments of pyrite	23	310
Shale, dark gray to black, and black fissile shale	30	340
Shale, dark gray to black; contains fragments of charcoal and pyrite	38	378
Shale, soft, light gray	4	382
Shale, dark gray	18	395
Cheyenne sandstone (Comanchean)		
Sandstone, fine-grained, white	20	415
Shale, light greenish gray	6	421
Shale, light greenish gray; contains gray medium-grained sandstone	21	442
PERMIAN		
Redbeds (Undifferentiated)		
Siltstone and shale; brick red	8	450

96. *Sample log of test hole at the SW cor. sec. 9, T. 24 S., R. 19 W. Surface altitude, 2,184.9 feet.*

	Thickness, feet	*Depth, feet*
Road fill	2	2
QUATERNARY—Pleistocene		
Terrace deposits		
Silt, yellow gray, contains a few nodules of caliche	1	3
Silt, light brown	2	5
Silt, buff; contains fine to coarse sand and nodules of caliche	44	49
CRETACEOUS—Gulfian		
Dakota formation		
Sandstone, white; contains light blue-gray clay	11	60
Sandstone, brown	3	63

97. *Sample log of test hole at the NW cor. sec. 28, T. 24 S., R. 19 W. Surface altitude, 2,165.4 feet.*

	Thickness, feet	*Depth, feet*
Soil, silty, dark gray to black	3	3
QUATERNARY—Pleistocene and Recent		
Alluvium		
Silt, dark brown; contains fine sand	4	7
Gravel and sand, fine to coarse	11	18
CRETACEOUS—Gulfian		
Dakota formation		
Clay, buff and light blue gray	2	20

98. *Sample log of test hole at the NW cor. sec. 3, T. 24 S., R. 20 W. Surface altitude, 2,289.4 feet.*

	Thickness, feet	*Depth, feet*
Road fill	2	2
QUATERNARY—Pleistocene		
Terrace deposits		
Silt, gray brown	2	4
Silt, greenish gray	3	7
Silt, blocky, brown	5	12
Silt and clay, tan to buff; contains caliche and fine to coarse sand	20	32
Silt and clay, gray white; contains sand and many fragments of limestone	1	33
CRETACEOUS—Gulfian		
Greenhorn and Graneros formations (?)		
Shale, calcareous, yellow to gray; contains blue-white bentonite. Thin beds of limestone at depths of 33.5 and 39 feet	8	41
Shale, noncalcareous, light blue gray; contains fine brown sandstone and white bentonite	9	50

99. *Sample log of test hole at the NW cor. sec. 15, T. 24 S., R. 20 W. Surface altitude, 2,260.4 feet.*

	Thickness, feet	Depth, feet
Road fill	1.5	1.5
QUATERNARY—Pleistocene		
Terrace deposits		
Silt, light brown, and blocky brown silt	3.5	5
Silt and clay, buff; contains nodules of caliche, fine gravel, and fine sand	54	59
CRETACEOUS—Gulfian		
Dakota formation		
Clay, yellow, and ironstone	1	60
Clay, light blue gray	7	67
Clay, varicolored	3	70
Clay, varicolored; contains fine-grained sandstone	15	85

100. *Sample log of test hole at the NW cor. sec. 34, T. 24 S., R. 20 W. Surface altitude, 2,245.6 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Terrace deposits		
Silt, gray brown	4	4
Silt, greenish gray to yellow gray	4	8
Silt, blocky, brown	3	11
Silt and clay, light brown to buff; contains a few nodules of caliche	64	75
Silt, light brown; contains fine to coarse sand	8	83
Sand and gravel; hard, cemented with calcium carbonate	3	86
Clay, light gray to light brown; contains fine to coarse sand	4	90
Silt and clay, in part cemented, light brown and white; contains fine sand to medium gravel	12	102
Sand, fine, to gravel, medium	8	110
Silt, light brown; contains caliche	9	119
Gravel, medium, to sand, fine	4	123
Silt, light buff	3	126
Gravel, medium, to sand, medium	8	134
CRETACEOUS—Gulfian		
Dakota formation		
Clay, micaceous, light gray and yellow, interbedded with white fine-grained sandstone	4	138

101. *Sample log of test hole at the SW cor. sec. 4, T. 25 S., R. 16 W. Surface altitude, 2,080.4 feet.*

	Thickness, feet	*Depth, feet*
QUATERNARY—Pleistocene		
Meade formation		
Silt, brown; contains fine to very fine sand	3	3
Silt, compact, light gray; contains fragments of caliche,	3	6
Silt, brown and gray; contains caliche	4	10
Silt, compact, tan to gray	14	24
Sand, very fine to fine	4	28
Silt, white	2	30
Sand, very fine to fine	11	41
Sand, fine, to gravel, fine; contains a small amount of gray silt	4	45
Gravel and sand; fine to coarse	5	50
Sand, very fine to medium	10	60
Sand and gravel, fine to coarse; contains gray and buff silt	20	80
Silt, dark blue gray; contains fine to coarse gravel	8	88
No sample recovered (probably sand)	10	98
Silt, tan and white; contains fine sand, fine gravel, and caliche	38	136
Gravel, fine; contains light gray-green clay	5	141
Silt, compact, dark tan	17	158
Gravel, coarse. Consists of materials derived from the Dakota formation	8	166
CRETACEOUS—Gulfian		
Dakota formation		
Clay, light gray and buff	4	170

102. *Sample log of test hole at the NE cor. sec. 20, T. 25 S., R. 16 W. Surface altitude, 2,074.2 feet.*

	Thickness, feet	*Depth, feet*
QUATERNARY—Pleistocene		
Meade formation		
Silt, compact, gray, and fine sand	3	3
Silt, brown, and fine sand	3	6
Silt, gray to white and tan; contains a few nodules of caliche	16	22
Silt, gray and tan; contains very fine to fine sand	4	27
Silt, light gray to buff; contains caliche	4	31
Gravel and sand; fine to coarse	29	60
Silt, gray, tan, and yellow; contains caliche	20	80
Gravel, medium, to sand, fine	33	113
Silt, compact, varicolored	5	118
Gravel, medium, to sand, fine	14	132
Silt, compact, dark tan	12	144

	Thickness, feet	Depth, feet
Gravel, fine to coarse. Pebbles consist of caliche and of materials from the Dakota formation	7	151
CRETACEOUS—Gulfian		
Dakota formation		
Clay, varicolored	9	160

103. *Sample log of test hole at the SE cor. sec. 29, T. 25 S., R. 16 W. Surface altitude, 2,073.8 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Meade formation		
Silt, brown, and very fine to fine sand	5	5
Sand, very fine to coarse	18	23
Sand, very fine to medium; contains a small amount of brown silt	17	40
Gravel, medium, to sand, fine	22	62
Silt, tan and gray; contains caliche	11	73
Gravel, fine, to sand, fine	20	93
Silt, gray; contains caliche	12	105
Sand, fine to coarse	10	115
Gravel, and sand, fine to coarse	57	172
CRETACEOUS—Comanchean		
Kiowa shale		
Clay, light gray	9	181
Clay, light gray to dark gray, and fine-grained sandstone; contains fragments of fossil shells	9	190

104. *Sample log of test hole at the NW cor. sec. 5, T. 25 S., R. 18 W. Surface altitude, 2,171.1 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Meade formation		
Silt, brown, and fine sand	5	5
Silt, gray; contains fine gravel	4	9
Silt, gray; contains fine sand and fine gravel	15	24
Gravel, fine, to sand, fine	8	32
Gravel, coarse, to sand, medium	18	50
Gravel, medium, to sand, fine; in part cemented; contains a small amount of yellow and buff silt	23	73
Silt, gray and tan; contains caliche	25	98
CRETACEOUS—Gulfian		
Dakota formation		
Sandstone, fine-grained, hard, brown, and ironstone	2	100
Clay, yellow and light gray, and ironstone	20	120

105. *Sample log of test hole at the NE cor. sec. 12, T. 25 S., R. 18 W. Surface altitude, 2,144.2 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Meade formation		
Silt, drak gray	3	3
Silt, blocky, hard, light gray	3	6
Sand, fine to coarse	5	11
Sand, very fine to medium, brown	14	25
Sand, fine to coarse; contains tan and gray silt	6	31
Gravel and sand; fine to coarse	24	55
Gravel, coarse to fine; contains thin layers of yellow and gray clay and cemented sand	38	93
Gravel, medium, to sand, fine; in part cemented; contains gray silt	6	99
CRETACEOUS—Gulfian		
Dakota formation		
Clay, varicolored; contains fine-grained hard yellow and white sandstone	11	110

106. *Sample log of test hole at the SE cor. sec. 13, T. 25 S., R. 18 W. Surface altitude, 2,166.8 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Meade formation		
Sand, fine to very fine, and brown silt	11	11
Silt, soft, brown	14	25
Sand, very fine to medium, light brown	7	32
Sand, very fine to medium, light brown; contains brown silt	13	45
Silt, gray; contains fragments of caliche and a small amount of fine gravel	3	48
Sand, fine, to gravel, fine	17	65
Gravel and sand, fine to coarse	7	72
Sand, fine to coarse; contains a small amount of fine to coarse gravel and gray silt	18	90
Gravel, coarse to fine, and coarse sand	10	100
Sand, fine, to gravel, fine	36	136
Gravel and sand, fine to coarse	6	142
Sand and gravel, fine to coarse; contains fragments of caliche, gray silt, and ironstone	22	164
Silt, tan and gray	21	185
CRETACEOUS—Gulfian		
Dakota formation		
Clay, varicolored; contains fragments of buff fine-grained sandstone and ironstone	5	190

107. *Sample log of test hole at the NW cor. sec. 17, T. 25 S., R. 18 W. Surface altitude, 2,187.7 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Meade formation		
Silt, brown, and fine sand	5	5
Silt, compact, brown	8	13
Silt, red brown and gray; contains fine sand	4	17
Sand, fine to very fine	18	35
Gravel and sand, fine to coarse	35	70
Gravel, fine to coarse; contains a little sand	24	94
Silt, white and light gray; contains caliche	21	115
Gravel, fine to coarse; contains a little sand	9	124
Silt, gray and tan; contains a small amount of fine gravel	16	140
Gravel, fine to coarse. Pebbles consist of sandstone and ironstone derived from the Dakota formation	13	153
CRETACEOUS—Gulfian		
Dakota formation		
Clay, varicolored	7	160

108. *Sample log of test hole at the SE cor. sec. 25, T. 25 S., R. 18 W. Surface altitude, 2,142.5 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Meade formation		
Silt, brown, and fine sand	5	5
Silt, gray, contains fine to coarse gravel, and fine sand,	4	9
Silt, light gray; contains caliche and medium gravel	6	15
Gravel and sand, fine to coarse	30	45
Gravel and sand, fine to coarse; contains a little buff silt	32	77
Silt, light gray to white; contains caliche	21	98
Gravel, fine, to sand, fine	5	103
Silt, gray and tan, contains caliche and fine to coarse gravel	20	123
Gravel, fine, to sand, fine	5	128
Silt, gray; contains caliche	9	137
Sand, fine to coarse	14	151
Silt, gray; contains fragments of caliche and a small amount of fine gravel	11	162
Silt, tan and buff; contains fine gravel	3	165
CRETACEOUS—Gulfian		
Dakota formation		
Clay, varicolored; contains ironstone	5	170

109. *Sample log of test hole at the NE cor. sec. 30, T. 25 S., R. 18 W. Surface altitude, 2,180.0 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Meade formation		
Silt, dark brown	6	6
Silt, gray to light gray	9.5	15.5
Sand and gravel, fine to coarse	32.5	48
Silt, gray and buff	3	51
Gravel and sand, fine to coarse	17	68
Silt, gray and tan, and fine sand	5	73
Gravel, medium, to sand, fine	31	104
Silt, sandy, tan	11	115
Gravel, fine to coarse; contains caliche and gray and white silt	21	136
CRETACEOUS—Gulfian		
Dakota formation		
Clay, buff and gray; contains fine-grained buff to white sandstone	4	140

110. *Sample log of test hole in the NW¼ NE¼ sec. 4, T. 25 S., R. 19 W. Surface altitude, 2,169.5 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene and Recent		
Alluvium		
Silt, dark brown, and fine sand	1	1
Sand, fine, brown	3	4
Gravel, fine to coarse; contains a small amount of sand,	18	22
Gravel, fine to medium; contains much sand	6	28
CRETACEOUS—Gulfian		
Dakota formation		
Sandstone, fine-grained, tan, white, and brown	4	32
Sandstone, fine-grained, soft, light gray	3	35
Sandstone, fine-grained, brownish yellow to gray; contains ironstone and yellow clay	3	38

111. *Sample log of test hole in the SW¼ SW¼ sec. 10, T. 25 S., R. 19 W. Surface altitude, 2,181.7 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene and Recent		
Alluvium		
Sand, fine to coarse, brown; contains silt	2	2
Gravel, medium; contains much sand	11	13
Gravel, coarse to fine; contains a little sand	6	19
Gravel, coarse; contains yellow-brown clay	3	22
Gravel, medium, to sand, fine	20	42
Gravel, medium to fine; contains gray to brown clay	4	46
Sand, fine, light gray	4	50
Silt, clayey, brown to gray; contains medium to coarse gravel	11	61
Silt, clayey, gray	33	94

	Thickness, feet	Depth, feet
Sand, fine to coarse; contains a small amount of gray-green silty clay	21	115
Gravel, medium, to sand, fine	20	135
CRETACEOUS—Gulfian		
Dakota formation		
Clay, dark gray; contains fragments of charcoal and ironstone	10	145

112. *Sample log of test hole in the NW¼ NW¼ sec. 26, T. 25 S., R. 19 W. Surface altitude, 2,198.6 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene and Recent		
Dune sand		
Sand, fine to coarse, and brown silt	7	7
Sand, fine to coarse; contains fine gravel	15	22
Gravel, fine to coarse; contains a little sand	6	28
Silt, yellow brown and gray	3	31
Gravel, fine to coarse; contains a little sand	5	36
Gravel, fine to coarse; contains buff to white silt	7	43
Silt, gray and buff	5	48
Gravel, fine to coarse	27	75
Gravel, fine to coarse; contains fine sand and buff to gray silt	20	95
Silt, gray and buff; contains fine to coarse sand	8	103
CRETACEOUS—Gulfian		
Dakota formation		
Sandstone, brown and yellow, and ironstone	3	106
Clay, blue gray and yellow	4	110

113. *Sample log of test hole in the SW¼ SW¼ sec. 35, T. 25 S., R. 19 W. Surface altitude, 2,214.3 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Meade formation		
Silt, brown, and fine sand	2	2
Silt, dark gray	5	7
Silt, gray; contains a small amount of coarse gravel,	6	13
Silt, dark brown, and fine sand; in part consolidated	10	23
Gravel, fine to coarse, and yellow and buff silt	8	31
Gravel, coarse, to sand, medium; contains thin layers of buff silt	36	67
Gravel, fine to coarse	24	91
Gravel, fine to coarse; contains a little sand	15	106
Gravel, fine to coarse; contains gray and buff silt	27	133
Gravel, fine; contains a small amount of silt	2	135
CRETACEOUS—Gulfian		
Dakota formation		
Siltstone, tan and white; contains a small amount of brown sandstone	6	141
Clay, varicolored; contains ironstone and brown sandstone	4	145

114. *Sample log of test hole at the SW cor. sec. 3, T. 25 S., R. 20 W. Surface altitude, 2,236.4 feet.*

	Thickness, feet	*Depth, feet*
Soil, dark brown to gray	2.5	2.5
QUATERNARY—Pleistocene		
Terrace deposits		
Silt, dull greenish gray	3.5	6
Silt, blocky, brown	2	8
Silt and clay, light brown to buff; contains a few nodules of caliche	67	75
Sand, medium to fine; contains light-gray to buff silt	5	80
Sand, coarse to fine; contains fine gravel	10	90
Gravel, medium, to sand, fine; contains caliche and gray-green to light-buff silt and clay	10	100
Gravel, fine to medium; contains sand	8	108
CRETACEOUS—Gulfian		
Dakota formation		
Sandstone, medium-grained, white to yellow brown	6	114

115. *Sample log of test hole at the NE cor. sec. 21, T. 25 S., R. 20 W. Surface altitude, 2,254.1 feet.*

	Thickness, feet	*Depth, feet*
Soil, gray	1	1
QUATERNARY—Pleistocene		
Terrace deposits		
Silt, dull greenish gray	3	4
Silt, blocky, brown	3	7
Silt and clay, buff; contains nodules of caliche	31	38
Gravel, fine to coarse; contains sand and gray silt	1	39
Sand, fine to coarse, light buff; cemented with calcium carbonate	1	40
Caliche, yellow to white; contains fine to coarse sand	1	41
CRETACEOUS—Gulfian		
Dakota formation		
Clay, light blue gray and yellow	4	45

116. *Sample log of test hole at the SE cor. sec. 28, T. 25 S., R. 20 W. Surface altitude, 2,222.5 feet.*

	Thickness, feet	*Depth, feet*
Road fill	2	2
QUATERNARY—Pleistocene and Recent		
Alluvium		
Silt, yellow gray, and fine to medium sand	5	7
Silt, buff; contains fine to coarse sand	4	11
Sand, fine to coarse, and dark gray silt; contains fine to coarse gravel	9	20
Silt, dark gray, and sand, fine to medium	3	23

	Thickness, feet	Depth, feet
Gravel, fine to coarse; contains a small amount of sand,	5.5	28.5
CRETACEOUS—Gulfian		
Dakota formation		
Clay, light gray and yellow, interbedded with fine- to medium-grained, yellow-brown sandstone	1.5	30

117. *Sample log of test hole at the NW cor. sec. 8, T. 26 S., R. 16 W. Surface altitude, 2,091.1 feet.*

QUATERNARY—Pleistocene	Thickness, feet	Depth, feet
Meade formation		
Sand, very fine to fine, brown, and silt	3	3
Silt, reddish brown, and fine sand	3	6
Gravel and sand, fine to coarse; contains a small amount of gray silt	4	10
Gravel and sand, fine to coarse	15	25
Sand, fine to coarse	13	38
Gravel, coarse to fine; contains a small amount of sand,	43	81
Silt, buff to gray; contains fine sand and a little caliche	5	86
Gravel, fine to coarse; contains a little sand	31	117
Gravel, fine to coarse; contains sand and gray to white silt	21	138
Gravel and sand, fine to coarse	68	206
CRETACEOUS—Comanchean		
Kiowa shale		
Clay, light gray to buff; contains hard brown to tan fine-grained sandstone and fragments of fossil shells	14	220

118. *Sample log of test hole at the NE cor. sec. 19, T. 26 S., R. 16 W. Surface altitude, 2,077.8 feet.*

QUATERNARY—Pleistocene and Recent	Thickness, feet	Depth, feet
Dune sand (Pleistocene and Recent)		
Sand, very fine to fine, and brown silt	2	2
Sand, fine to medium; contains coarse sand; tan	8	10
Meade formation (Pleistocene)		
Sand, fine to coarse; contains gray silt and fine gravel,	9	19
Silt, gray and buff; contains a little sand and gravel,	7	26
Gravel and sand, fine to coarse	14	40
Gravel and sand, fine to coarse; contains buff silt	20	60
Gravel and sand, fine to coarse	20	80
Gravel and sand, fine to coarse; contains a small amount of buff silt	26	106
Silt, tan and gray; contains caliche	8	114
Gravel, medium, to sand, fine	9	123
Silt, tan and gray; contains caliche	6	129
Gravel, medium, to sand, fine; contains a small amount of gray silt	56	185
Gravel, coarse; contains fine sand, fine to medium gravel, and gray silt	25	210

	Thickness, feet	Depth, feet
Gravel and sand, fine to coarse. Pebbles consist of ironstone and sandstone derived from the Dakota formation	12	222
CRETACEOUS—Comanchean		
Kiowa shale		
Shale, blue gray, and fissile, black shale; contains ironstone and fragments of fossil shells	8	230

119. *Sample log of test hole at the NE cor. sec. 31, T. 26 S., R. 16 W. Surface altitude, 2,091.0 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene and Recent		
Dune sand (Pleistocene and Recent)		
Sand, very fine to medium; contains silt	11	11
Sand, fine to coarse; contains gray silt	8	19
Meade formation (Pleistocene)		
Silt, white	2	21
Sand, fine; contains gray silt	7	28
Sand, fine to coarse; contains fine gravel	27	55
Gravel, fine, to sand, fine	5	60
Gravel and sand, fine to coarse; contains a little yellow silt	32	92
Silt, gray and buff; contains caliche and fine to coarse sand	13	105
Gravel, medium, to sand, fine	40	145
Sand, very fine, to gravel, coarse	95	240
Sand, coarse to fine; contains a small amount of fine gravel	20	260
Gravel, fine to coarse. Many fragments consist of sandstone and shale	28	288
CRETACEOUS—Comanchean		
Kiowa shale		
Clay, silty, buff; contains buff hard fine-grained sandstone and fragments of fossil shells	6	294
Shale, compact, gray; contains fragments of fossil shells	9	303
Sandstone, fine-grained, hard, gray; contains a little pyrite and shale	7	310
Shale, fissile, blue gray; contains fragments of fossil shells	31	341
Sandstone, fine-grained, hard, gray to light gray; contains a little pyrite and shale	7	348
Cheyenne sandstone		
Sandstone, fine- to medium-grained, white and light-gray; contains a few fragments of charcoal	28	376
PERMIAN		
Redbeds (Undifferentiated)		
Shale, silty, compact, greenish gray	9	385
Shale, brick red and greenish gray	5	390

120. *Sample log of test hole at the NW cor. sec. 19, T. 26 S., R. 17 W. Surface altitude, 2,146.7 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Meade formation		
Silt, brown, and fine sand	3	3
Silt, compact, dark gray to light gray	6	9
Silt, gray and buff	7	16
Gravel, coarse, to sand, fine	5	21
Gravel, fine to coarse, and buff and gray silt	26	47
Gravel, fine to coarse; contains fine sand	20	67
Silt, light gray to white; contains fine sand	8	75
Gravel, fine, to sand, fine	34	109
Silt, white to gray; contains fine to coarse sand	11	120
Sand, fine to coarse	9	129
Gravel, fine, to sand, fine	31	160
Gravel, fine to coarse, and gray silt	18	178
Sand, fine to coarse; contains fine gravel	14	192
Silt, gray and buff; contains caliche	23	215
CRETACEOUS—Comanchean		
Kiowa shale		
Shale, dark blue gray; contains a few fragments of charcoal and hard fine-grained sandstone	5	220

121. *Sample log of test hole at the NW cor. sec. 31, T. 26 S., R. 17 W. Surface altitude, 2,153.9 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene and Recent		
Dune sand (Pleistocene and Recent)		
Sand, fine, brown; contains a little silt	2	2
Sand, fine, and dark brown silt	3	5
Meade formation (Pleistocene)		
Silt, compact, gray	9	14
Silt, sandy, light gray	4	18
Silt, tan and buff	9	27
Sand, fine to very fine; contains gray-green silt and fine gravel	18	45
Gravel, coarse, to sand, fine	4	49
Gravel, medium to fine; contains gray silt	4	53
Gravel, coarse, to sand, fine	5	58
Sand, coarse to very fine; contains fine gravel	17	75
Gravel, fine to coarse; contains fine sand and gray and tan silt	35	110
Gravel, fine to coarse; contains caliche and white silt,	4	114
Gravel, fine to coarse; contains fine sand and a little white and gray silt	58	172
Silt, sandy, buff and gray	5	177
Gravel, coarse, to sand, fine	15	192
Silt, gray	12	204
Gravel, fine to coarse; contains a little caliche	4	208

CRETACEOUS—Comanchean		
Kiowa shale	*Thickness, feet*	*Depth, feet*
Sandstone, fine-grained, hard, buff and reddish brown; contains varicolored clay	10	218
Clay, dark gray; contains gray and reddish-brown fine-grained sandstone	12	230

122. *Sample log of test hole at the SE cor. sec. 1, T. 26 S., R. 18 W. Surface altitude, 2,144.2 feet.*

QUATERNARY—Pleistocene		
Meade formation	*Thickness, feet*	*Depth, feet*
Silt, brown, and fine sand	4	4
Silt, compact, gray; contains fine gravel	4	8
Silt, yellow brown	4	12
Gravel and sand, fine to coarse; contains a little buff silt	15	27
Silt, buff; contains a little fine sand and gravel	7	34
Silt, white and gray; contains a little fine sand and gravel	4	38
Gravel and sand, fine to coarse	4	42
Gravel and sand, fine to coarse; contains a little buff and gray silt	25	67
Silt, buff; contains fine to coarse gravel	21	88
Silt, light gray to buff; contains caliche and fine sand,	9	97
Gravel and sand, fine to coarse	15	112
Silt, gray and white; contains fine gravel	3	115
Gravel, fine, to sand, fine	25	140
Silt, gray and buff; contains a little caliche and fine gravel	11	151
Gravel, fine, to sand, fine; contains gray silt	19	170
Gravel, fine, and fine to coarse sand. Many fragments consist of materials derived from the Dakota formation	17	187
Silt, gray to white; contains caliche	19	206
Sand, fine to coarse, and fine gravel	14	220
Gravel and sand, fine to coarse. Pebbles consist principally of materials derived from the Dakota formation	6	226
CRETACEOUS—Comanchean		
Kiowa shale		
Clay, dark blue gray to light gray; contains hard gray fine-grained sandstone and fragments of fossil shells,	9	235

123. *Sample log of test hole at the NW cor. sec. 5, T. 26 S., R. 18 W. Surface altitude, 2,188.1 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Meade formation		
Silt, brown, and fine sand	6	6
Silt, compact, dark gray	6	12
Silt, light gray and reddish brown	7	19
Silt, light gray and brown	6	25
Sand, fine to coarse; contains fine gravel near the base,	20	45
Gravel and sand; fine to coarse	34	79
Caliche, moderately hard, white	1	80
Sand and gravel; fine to coarse	14	94
Silt, tan and white; contains caliche	29	123
Sand, fine, to gravel, fine; contains caliche	6	129
Silt, tan and gray	16	145
Sand, fine, to gravel, fine	11	156
Silt, tan; contains a little sand and gravel	7	163
Silt, tan to white and buff; contains fine gravel and caliche	9	172
CRETACEOUS—Gulfian		
Dakota formation		
Sandstone, fine-grained, buff, and varicolored clay; contains ironstone	9	181

124. *Sample log of test hole at the NW cor. sec. 17, T. 26 S., R. 18 W. Surface altitude, 2,193.6 feet.*

	Thickness, feet	Depth. feet
Road fill	3	3
QUATERNARY—Pleistocene		
Meade formation		
Silt, brown and gray	5	8
Silt, gray and light gray	4	12
Silt, brown; contains a little sand	2	14
Sand, fine, to gravel, fine	6	20
Gravel and sand, fine to coarse; contains a little buff clayey silt	30	50
Gravel and sand, fine to coarse	10	60
Gravel, fine to coarse; contains light-gray and tan silt,	17	77
Silt, tan	4	81
Silt, white to light gray and tan; contains caliche	30	111
Sand, fine, to gravel, fine; contains a small amount of buff clay	8	119
Silt, tan, and fine to medium sand	7	126
Sand, fine, to gravel, fine	14	140
Silt, gray	3	143
Sand, fine to coarse	7	150

	Thickness feet	Depth, feet
Silt, gray green	3	153
Sand, fine, to gravel, fine	7	160
Silt, tan to brown	11	171
CRETACEOUS—Gulfian		
Dakota formation		
Clay, light gray and yellow; contains a few fragments of ironstone and white medium-grained sandstone	4	175

125. *Sample log of test hole at the NW cor. sec. 29, T. 26 S., R. 18 W. Surface altitude, 2,194.4 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Meade formation		
Silt, dark gray to black	3	3
Silt, gray to light gray	2	5
Silt, gray and brown, and fine sand	2	7
Silt, brown, and fine sand	2	9
Gravel, medium, to sand, fine	11	20
Gravel, fine to coarse; contains a little sand and buff silt	11	31
Gravel, fine to coarse; contains a little sand, buff and white silt, and nodules of caliche	8	39
Gravel and sand, fine to coarse	11	50
Gravel and sand, fine to coarse; contains a little buff silt,	19	69
Silt, gray and white	6	75
Silt, brown, gray and white	18	93
Sand, fine, to gravel, fine; contains a little buff silt	12.5	105.5
Silt, brown and gray	8.5	114
Sand, fine, to gravel, fine; contains reddish-brown silt,	8	122
Gravel, coarse; contains a little silt	4	126
Silt, gray and brown	6	132
Silt, gray and white, and caliche	14	146
Sand, fine, to gravel, fine	11	157
Silt, gray and tan	18	175
Silt, tan	16	191
Silt, tan, and fine to medium sand	14	205
Sand, fine to coarse, and fine gravel	11	216
Gravel, fine to coarse. Pebbles consist mainly of materials derived from the Dakota formation	4	220
CRETACEOUS—Gulfian		
Dakota formation		
Clay, dark blue gray; contains ironstone	7	227

126. *Sample log of test hole at the NE cor. NW¼ sec. 15, T. 26 S., R. 19 W. Surface altitude, 2,218.2 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Meade formation		
Silt, brown	4	4
Silt, dark gray	3	7
Silt, brown, and medium sand	5	12
Silt, light brown, and fine to coarse sand	13	25
Gravel, fine to coarse; contains sand	27	52
Gravel, coarse to medium; contains gray and buff silt,	10	62
Gravel, fine to coarse; contains a little buff silt	21	83
Sand, fine to coarse, in part cemented	8	91
Gravel, fine to coarse; contains a little sand and buff silt	14	105
Silt, gray and white	13	118
Silt, gray and white; contains several thin layers of caliche	14	132
Silt, gray and white	7	139
Sand, very fine, to gravel, fine	22	161
Silt, tan and gray; contains a little caliche	18	179
CRETACEOUS—Gulfian		
Dakota formation		
Clay, varicolored, and ironstone	3	182
Clay, gray and buff; contains ironstone and soft white fine-grained sandstone	8	190

127. *Sample log of test hole at the SW cor. sec. 16, T. 26 S., R. 19 W. Surface altitude, 2,237.7 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Meade formation		
Sand, fine, and brown silt	5	5
Silt, brown	3	8
Silt, dark gray	7	15
Silt, gray	3	18
Silt, light gray to brown and red	4	22
Gravel, fine to coarse; contains a little sand	30	52
Silt, yellowish buff	2	54
Silt, gray and buff	4	58
Gravel, fine, to sand, fine	27	85
Gravel, fine to coarse	15	100
Gravel, coarse, to sand, fine; contains gray silt	15	115
Silt, gray and white; contains a few fragments of caliche,	14	129
Sand, fine to medium	16	145
Silt, gray and white; contains a few fragments of caliche,	13	158
Gravel, fine; contains sand and gray silt	10	168
CRETACEOUS—Gulfian		
Dakota formation		
Clay, varicolored	7	175

128. *Sample log of test hole at the SE cor. sec. 29, T. 26 S., R. 19 W. Surface altitude, 2,239.9 feet.*

QUATERNARY—Pleistocene

Meade formation	*Thickness, feet*	*Depth, feet*
Silt, brown, and fine sand	3	3
Silt, dark gray	4	7
Sand, fine, dark brown and gray, in part consolidated	4	11
Silt, dark brown to gray	7	18
Gravel, fine to coarse; contains sand	12	30
Gravel, fine to coarse; contains a little sand and buff to gray silt	10	40
Gravel, fine to coarse; contains a little sand	50	90
Gravel, fine to coarse; contains a little gray and white silt	12	102
Silt, tan and white	45	147
Silt, tan and buff; contains coarse gravel	5	152
Silt, gray and tan	33	185

CRETACEOUS—Gulfian

Dakota formation		
Clay, light gray to dark gray and yellow	5	190

129. *Sample log of test hole at the SW cor. sec. 5, T. 26 S., R. 20 W. Surface altitude, 2,230.0 feet.*

	Thickness, feet	*Depth, feet*
Road fill, and gray-brown soil	2	2

QUATERNARY—Pleistocene and Recent

Alluvium		
Gravel, coarse, to sand, fine	28	30
Silt, yellow buff	10	40
Silt, light gray; contains fine sand	10	50
Silt, light greenish gray; contains fine to medium sand,	7	57
Silt, light greenish gray; contains fine to medium gravel and fine to coarse sand	2	59
Silt and clay; light gray and light green	13	72
Silt and clay; blue gray	12	84
Silt, buff; contains gravel, fine sand, and caliche	3	87
Gravel, fine to coarse; contains sand and buff silt	3	90
Gravel, fine to medium; contains sand, buff silt, and caliche	7	97
Gravel, fine to medium; contains caliche. Pebbles consist of material derived from the Dakota formation,	8	105

CRETACEOUS—Gulfian

Dakota formation		
Clay, gray white, mottled red	5	110

130. *Sample log of test hole at the NE cor. sec. 19, T. 26 S., R. 20 W. Surface altitude, 2,243.1 feet.*

	Thickness, feet	Depth, feet
Road fill, and dark-gray silt, contains medium sand..	3	3
QUATERNARY—Pleistocene and Recent		
Alluvium		
Gravel, fine to coarse; contains sand..................	17	20
Gravel, coarse to fine; contains sand and yellow buff silt,	9	29
Silt, yellow buff; contains fine to coarse sand and gravel,	7	36
Gravel and sand, fine to coarse......................	9	45
Silt, buff to gray white; contains caliche and fine to coarse sand	5	50
Silt, gray white to light greenish gray; contains caliche and fine to coarse sand...........................	16	66
Silt and clay, buff; contains fine to medium sand......	7	73
Caliche, pink and white, concentrically banded........	.5	73.5
Silt and clay; white to light buff; in part cemented with lime	3.5	77
CRETACEOUS—Gulfian		
Dakota formation		
Clay, varicolored	5	82
Sandstone, fine-grained, white......................	1	83
Clay, varicolored	2	85

131. *Sample log of test hole at the SE cor. sec. 30, T. 26 S., R. 20 W. Surface altitude, 2,251.4 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene and Recent		
Alluvium		
Silt, light brown, and fine sand......................	5	5
Sand and gravel, fine to coarse......................	20	25
Sand and gravel, fine to coarse; contains a little tan silt,	6.5	31.5
Silt, tan; contains a little sand and gravel............	8.5	40
Silt, tan; contains sand and gravel, white silt, and a few nodules of caliche...........................	15	55
Silt, compact, white; contains a little sand and gravel,	19	74
CRETACEOUS—Gulfian and Comanchean		
Dakota formation (Gulfian)		
Clay, varicolored; contains a few fragments of yellow compact fine-grained sandstone	3	77
Clay, gray and black................................	3	80
Clay, varicolored; contains brown fine-grained sandstone and a few fragments of ironstone.................	23	103
Shale, silty, dark gray; contains white sandstone, yellow clay, and a little pyrite...........................	21	124
Sandstone, fine-grained, brown; contains ironstone and gray clay	3	127
Clay, varicolored	4	131

	Thickness, feet	Depth, feet
Clay, varicolored; contains sandstone and ironstone....	4	135
Sandstone, brown to white; contains ironstone and varicolored clay	33	168
Shale, gray and yellow; contains brown sandstone and ironstone	20	188
Clay, varicolored; contains a little ironstone..........	22	210
Shale, silty to fine sandy, compact; contains a few fragments of charcoal and pyrite	17	227
Shale, in part silty, light gray; contains a small amount of white fine-grained sandstone	26	253
Kiowa shale (Comanchean)		
Shale, blocky, dark gray to black	5	258
Shale, silty, dark gray; contains dark-gray fine-grained sandstone	17	275
Sandstone, fine-grained, hard, dark gray to white; contains pyrite	13	288
Shale, fissile, gray to black; contains a little maroon, red, and white shale	62	350
Shale, fissile, gray to black; contains a little fine-grained gray sandstone, and a few fragments of fossil shells,	40	390

132. *Sample log of test hole at the NW cor. sec. 4, T. 27 S., R. 16 W. Kiowa County. Surface altitude, 2,094.2 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene and Recent		
Dune sand (Pleistocene and Recent)		
Sand, fine to medium, gray and brown	4	4
Meade formation (Pleistocene)		
Sand, fine to medium, gray and brown; contains some fine gravel	7	11
Silt, sandy, gray; contains orange-brown streaks	8	19
Sand, fine, silty, greenish gray	20	39
Gravel, fine to coarse, tan; contains some sand	24	63
Silt and fine sand, yellow tan to light gray; in part cemented with lime	7	70
Gravel, fine to very coarse, silty	5	75
Silt, sandy, limy, tan, greenish gray to light gray, and white	22.5	97.5
Silt and fine sand, limy, tan and light gray to white,	28.5	126
Gravel, fine to coarse, tan; contains some sand and tan sandy silt	24	150
Sand, fine to coarse, brown; contains some gravel	7	157
Gravel, fine to coarse, and some medium to coarse sand; tan	18	175
Silt, sandy, limy, light gray	5	180
Gravel, fine to very coarse, tan; contains some sand, silt, and pebbles of brown ironstone	84	264

	Thickness, feet	Depth, feet
Silt and fine sand, tan, gray and orange brown	13	277
Gravel, fine to medium, tan and brown; contains some sand and pebbles of ironstone	16	293
CRETACEOUS—Comanchean		
Kiowa shale		
Shale, dark gray to black; contains gypsum, pyrite, and thin beds of shell-limestone between 310 and 317 feet,	24	317
Cheyenne sandstone		
Sandstone, fine- to medium-grained, hard, gray, and hard sandy shale	3	320
Shale, sandy, hard, blue gray, and fine-grained sandstone; contains gypsum, pyrite, and charcoal	13	333
Sandstone, fine- to medium-grained, gray; contains abundant small grains of pyrite and charcoal	7	340
Siltstone, light gray; contains charcoal	9	349
PERMIAN		
Redbeds (Undifferentiated)		
Shale, silty, dull red	11	360

133. *Sample log of test hole at the NW cor. sec. 5, T. 27 S., R. 18 W., Kiowa County. Surface altitude, 2,205.5 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene and Recent		
Dune sand (Pleistocene and Recent)		
Sand, fine to medium, gray tan and brown	9	9
Meade formation (?) (Pleistocene)		
Silt, sandy, tan brown	7	16
Sand, coarse, to gravel, coarse; consists predominantly of medium gravel and contains a few balls of yellow-tan silt	14	30
Silt and fine sand; gray tan	9	39
Sand, fine, to gravel, coarse; consists predominantly of medium and coarse gravel. A few pebbles in lower part are 1 inch in diameter	39.5	78.5
Sand, fine, silty, tan to light gray; contains lime-cemented zones and a few large pebbles of "mortar bed"	11.5	90
Gravel, fine to coarse, tan; contains a little sand	14	104
Caliche, soft, sandy, light gray to white	2	106
Silt and sand, fine, tan brown	4	110
Silt and clay, sandy, tan and yellow gray	4	114
Gravel, fine to coarse, tan; consists predominantly of medium gravel and contains some sand	7	121
Silt and fine sand, lime-cemented, light gray to white,	8	129
Silt, sandy, tan and yellow tan; contains some silty clay,	11	140
Gravel, fine to coarse, tan; contains some sand and a few pebbles of abraded sandy caliche	35	175

CRETACEOUS—Comanchean

Kiowa shale	Thickness, feet	Depth, feet
Clay shale, silty, sandy, gray tan. Poor sample	9	184
Shale, sandy, light gray, and fine-grained, hard, gray sandstone	16	200
Shale, silty, yellow tan; contains thin beds or concretions of ironstone	10	210
Shale, silty, light gray; contains brown streaks	16	226
Shale, sandy, blue gray	6	232

134. *Driller's log of well 50 of the City of Larned in the NE¼ NE¼ sec. 29, T. 21 S., R. 16 W. Surface altitude, 2,006 feet.*

	Thickness, feet	Depth, feet
Soil, black	3	3
Gumbo	7	10
Clay, yellow	6	16
Clay, light	12	28
Clay, soft, light	14	42
Clay, light yellow	12	54
Clay, soft	16	70
Clay, hard, tough	4	74
Clay, soft	11	85
Clay, tough, and rocks	4	89
Clay, red	2	91
Sand and clay, blue	2	93
Clay, green	3	96
Clay, blue	2	98
Clay, blue, and rocks	2	100
Sandstone, light	10	110
Clay, yellow	2	112
Rocks, green and red, and clay	2	114
Rainbow clay (probably varicolored clay)	4	118
Shale, blue	5	123

135. *Driller's log of well 51 of the City of Larned in the NW¼ NE¼ sec. 29, T. 21 S., R. 16 W. Surface altitude, 2,006 feet.*

	Thickness, feet	Depth, feet
Soil, black	4	4
Clay, sand, and caliche	16	20
Clay, yellow	10	30
Clay and sand	5	35
Clay, yellow	40	75
Clay, soft, and sand	5	80
Clay, yellow	14	94
Clay, soft, and sand	4	98
Clay, sand, and rock	3	101
Clay, soft, and sand	4	105
Sandstone, coarse, dark	2	107

	Thickness, feet	*Depth, feet*
Sandstone, light	20	127
Shale, black	1	128
Sandstone, coarse	2	130
Sandstone, light	6	136
Shale, blue	4	140

136. *Driller's log of well 52 of the City of Larned in the NW¼ NE¼ sec. 29, T. 21 S., R. 16 W. Surface altitude, 2,005 feet.*

	Thickness, feet	*Depth, feet*
Soil, black	3	3
Caliche and blue clay	5	8
Clay, light, and sand	7	15
Clay, yellow	10	25
Clay, yellow, and sand	7	32
Clay, soft, yellow	8	40
Clay, yellow	10	50
Clay, light	8	58
Clay, soft, yellow, and caliche	10	68
Clay, yellow	5	73
Clay, brown	9	82
Clay, yellow	8	90
Rainbow clay (probably varicolored clay)	2	92
Rock, red	1	93
Rainbow clay (probably varicolored clay)	2	95
Clay, light, and coarse sand	4	99
Sandstone	18	117
Rainbow clay (probably varicolored clay)	11	128
Shale, black	4	132

137. *Driller's log of well 53 of the City of Larned in the NE¼ SE¼ sec. 32, T. 21 S., R. 16 W. Surface altitude, 2,004.6 feet.*

	Thickness, feet	*Depth, feet*
Soil	4	4
QUATERNARY—Pleistocene and Recent		
Alluvium		
Sand	4	8
Sand, coarse	7	15
Sand and gravel (static water level 15 feet)	13	28
CRETACEOUS—Gulfian		
Dakota formation		
Clay, blue (Dakota water level, 40 feet)	19	47
Clay, yellow	6	53
Clay, blue	3	56
Clay, yellow	4	60
Clay, blue	6	66
Clay, yellow, and brown rock	4	70

	Thickness, feet	Depth, feet
Clay, yellow, and white rock	4	74
Sandstone, rusty	4	78
Clay, bright yellow	3	81
Rainbow clay (probably varicolored clay)	2	83
Clay, light gray, and rocks	6	89
Shale, blue	12	101
Clay, yellow	8	109
Shale, blue	7	116
Clay, light	6	122
Sandstone	1.5	123.5
Clay, yellow	4.5	128
Shale, blue	3	131
Sandstone	10	141
Shale, blue	24	165

138. *Driller's log of well 54 of the City of Larned in the SE¼ SE¼ sec. 32, T. 21 S., R. 16 W. Surface altitude, 1,999.8 feet.*

	Thickness, feet	Depth, feet
Soil, black	2	2
QUATERNARY—Pleistocene and Recent		
Alluvium		
Gumbo	3	5
Clay and sand	3	8
Sand (static water level, 13 feet)	15	23
Gravel	4.5	27.5
Clay, yellow (Dakota water level 30 feet)	8.5	36
Clay, yellow, and brown rocks	1	37
Sand and gravel	3	40
CRETACEOUS—Gulfian		
Dakota formation		
Clay, yellow, and brown rocks	3	43
Clay, yellow	4	47
Clay, gray	2	49
Clay, yellow	6	55
Clay, gray	2	57
Clay, yellow	22	79
Rainbow clay (probably varicolored clay)	2	81
Shale, blue	10	91
Sandstone	37	128
Sand, coarse, and brown rocks	2	130
Sandstone	8	138
Shale, blue	5	143

139. *Driller's log of well 55 in the NE¼ NW¼ sec. 33, T. 21 S., R. 16 W.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene and Recent		
Alluvium		
Earth	10	10
Sand	6	16
Gravel, coarse	9	25
Sand	10	35
Sand, fine	9	44
CRETACEOUS—Gulfian		
Dakota formation (?)		
Rock, hard	2	46
Clay, yellow	10	56

140. *Driller's log of well 74 in the SW¼ SW¼ sec. 20, T. 21 S., R. 19 W. Surface altitude, 2,086.2 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene and Recent		
Alluvium		
Soil and clay	30	30
Sand, dry	1	31
Sand, fine and coarse	33	64
Sand and clay	4	68
Clay	11	79
Gravel, coarse	14	93
CRETACEOUS—Gulfian		
Dakota formation (?)		
Clay, sandy	3	96

141. *Driller's log of well 77 in the SW cor. sec. 27, T. 21 S., R. 19 W. Drilled by Otis Shuck, 1944.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene and Recent		
Alluvium		
Earth	15	15
Clay, yellow	13	28
Sand, fine	7	35
Sand, coarse,	5	40
Sand, coarse, white	5	45
Sand and gravel	19	64
Clay	1	65
Sand, brown	1	66
Sand, white	2	68
Clay, blue	12	80
Sand, fine	6	86
Clay, white	4	90
Sand, fine	15	105
Sand, coarse	1	106
Sand	4	110
Sand and gravel, coarse	5	115
Clay, yellow	1	116
Gravel, coarse	9	125

142. *Driller's log of well 105 in the NW¼ NE¼ sec. 4, T. 22 S., R. 16 W.*

	Thickness, feet	*Depth, feet*
QUATERNARY—Pleistocene and Recent		
Alluvium		
Soil and fine sand	4	4
Sand	4	8
Gravel	3	11
Sand	10	21
Clay	5	26
Sand, fine	4	30
Sand and gravel, coarse	6	36

143. *Driller's log of test hole in the NE¼ NW¼ sec. 12, T. 22 S., R. 19 W. Drilled by Otis Shuck, 1940.*

	Thickness, feet	*Depth, feet*
Soil	2	2
QUATERNARY—Pleistocene and Recent		
Alluvium		
Clay, yellow	28	30
Sand	4	34
Clay, gray	1	35
Sand	5	40
Clay, sandy, gray to black	1	41
Silt, fine, sandy, gray to black	9	50
Sand, fine to medium, gray	15	65
Clay, gray to buff	10	75
Sand, medium	5	80
Gravel, coarse. Contains water-worn fragments of sandstone and limestone	28	108
CRETACEOUS—Gulfian		
Dakota formation		
Fire clay, streaked (probably varicolored clay)	1	109
Sandstone, fine-grained, reddish brown	1	110

144. *Driller's log of well 137 in the NE¼ NE¼ sec. 6, T. 22 S., R. 18 W. Drilled by Otis Shuck, 1944.*

	Thickness, feet	*Depth, feet*
QUATERNARY—Pleistocene and Recent		
Alluvium		
Clay	30	30
Sand	5	35
Sand, coarse	13	48
Clay	7	55
Sand	3	58
Clay	14	72
Sand, coarse, yellow	4	76
Sand, fine	4	80
Sand, coarse, yellow	30	110
CRETACEOUS—Gulfian		
Dakota formation (?)		
Clay	10	120

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MAP OF PAWNEE AND EDWARDS COUNTIES, KANSAS

Showing Geology and Water-table Contours, 1944-1945

State Geological Survey of Kansas

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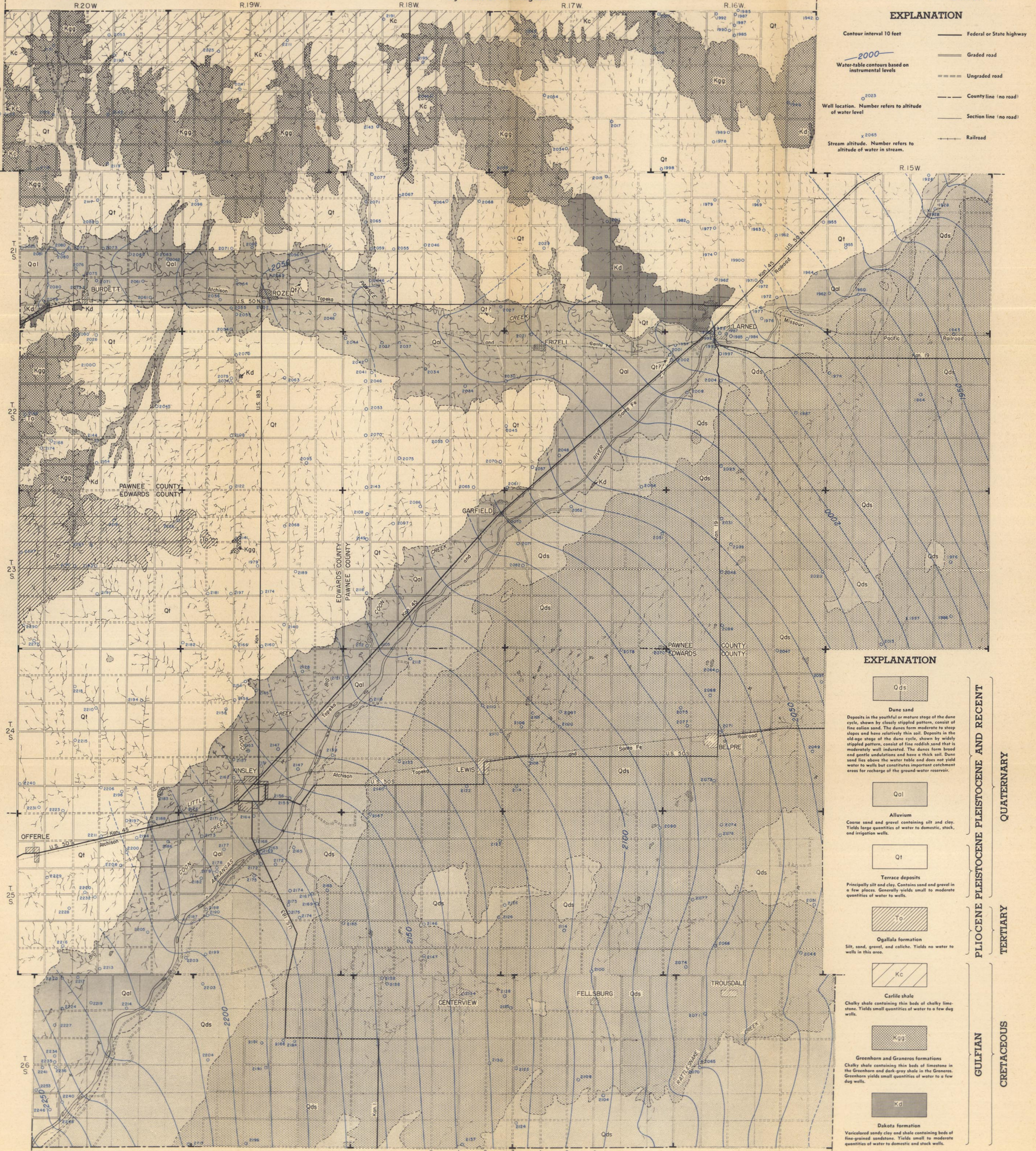
Plate 1

By Thad G. McLaughlin



Base compiled from maps prepared by the Soil Conservation Service

Drainage from aerial photographs of the U. S. Dept. of Agriculture

MAP OF PAWNEE AND EDWARDS COUNTIES, KANSAS

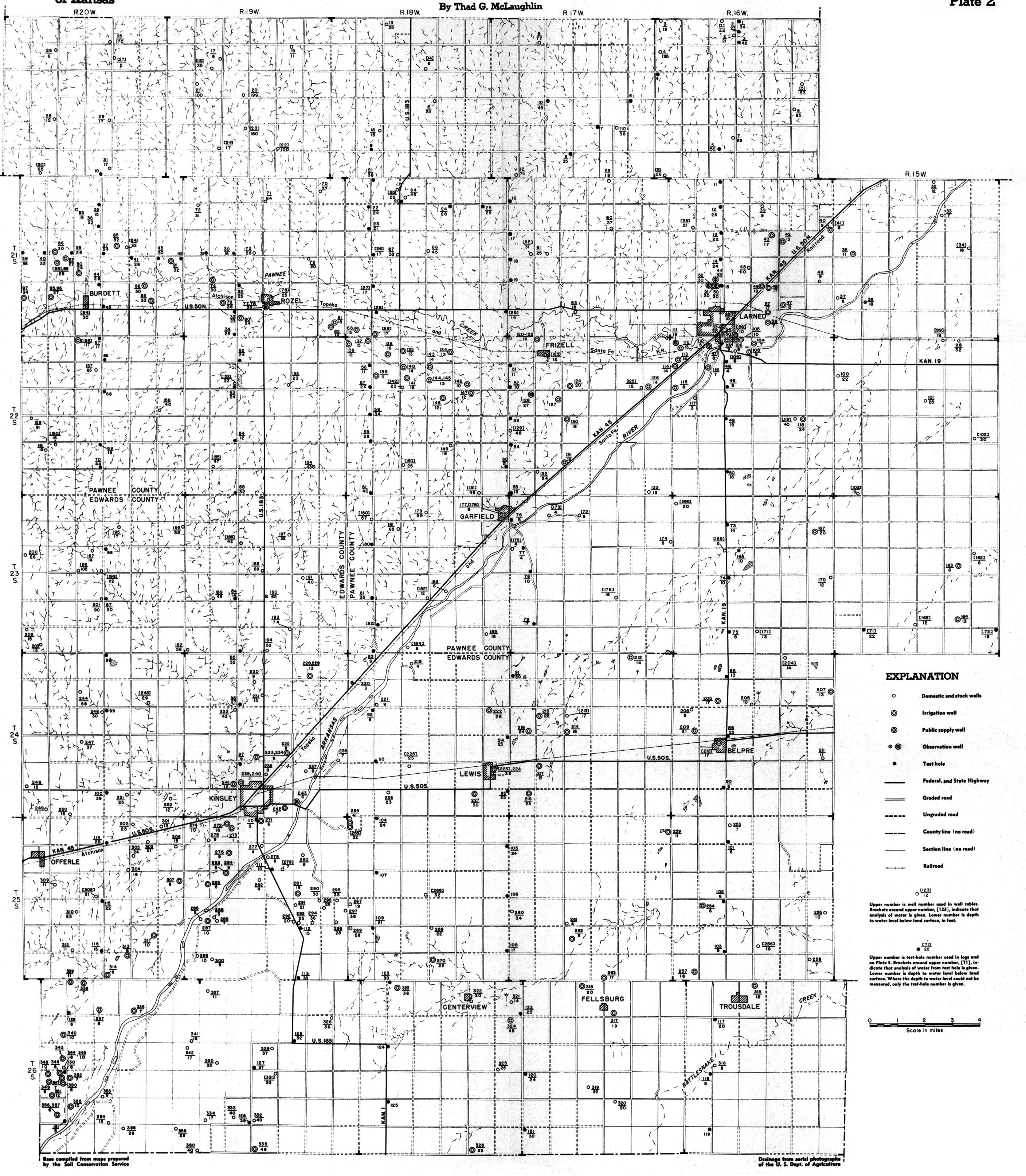
Showing the depths to Water Level and the Location of Wells and Test Holes for which Records are given

1944-1945

State Geological Survey of Kansas

Bulletin 80
Plate 2

By Thad G. McLaughlin



State Geological Survey of Kansas

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DIAGRAMMATIC CROSS SECTION OF PAWNEE AND EDWARDS COUNTIES, KANSAS

By Thad G. McLaughlin